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enabling new Demand REsponse Advanced, Market oriented and secure technologies, solutions and business models

DELIVERABLE: D7.6 Validation Plan V2

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Executive Summary

The deliverable D7.6, related to the Task 7.1 entitled "Methodology for Validation and Preparation of use cases", describes the consolidated version of the validation plan updated at the completion of most of the platform development activities. In particular, the aim of this deliverable, that relies on the **definition of methods, techniques and tools to be used for the eDREAM solution validation**, is to take a step forward for the effective project validation as it is the main objective of the WP7 "eDREAM validation and reliability analysis".

To do this, it is important not to overlook that the project must achieve the objectives, meeting the needs and requirements of the main stakeholders, with particular reference to the actor's categories directly involved in the project use cases.

Therefore, this document updates the validation plan already defined in the D7.1 and defines the future validation actions. In particular, the different expectations of the stakeholders have been taken into consideration in defining validation scenarios, the relative test/unit cases and procedures.

Moreover, the tools for technical validation and user engagement (e.g. questionnaires and observations) already identified in the D7.1, are briefly described. Furthermore, in order to support the evaluation of eDREAM framework and its viability, this document describes the corresponding evaluation methodology which is based on different techniques and KPIs. The KPIs consist of different measures that will have to be collected during the test site trials to evaluate the ability of the platform to provide to the end-user the services and functionalities already defined in WP2 and to evaluate in this context the functioning of every single component. Hence, also the monitoring requirements for each pilot site will be defined to prepare the validation of the three project scenarios defined in WP2. Indeed, the eDREAM use cases are mainly associated with the trial sites, and also the infrastructures available for the UCs validation phase will be reported in this deliverable.

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List of Acronyms and Abbreviations

A	Attitude towards usage
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
ASAI	Average Service Availability Index
ASUI	Average Service Unavailability Index
BAU	Business As Usual
BI	Behavioural Intention to use
BoEU	Block of Energy Unit
CCF	Central Control Facility
CEMI	Customer Experiencing Multiple Interruptions
CIS	Copper (C), Indium (I), and Selenium (S)
CTAIDI	Customer Total Average Interruption Duration Index
DB	Data Base
DC	Direct Current
DERMS	Distributed energy resources management system
DNO	Distribution Network Operators
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand side response
DSS	Decision Support System
eDREAM	enabling new Demand Response Advanced, Market oriented and secure technologies, solutions and business models
EMRS	Electricity Market Reform Settlement
ESCo	Energy Service Company
EV	Electric Vehicle
HL-UCs	High Level Use Cases
HMI	Human Machine Interface
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning

IHD	In-Home Displays
IoT	Internet of Things
KOMP	KiWi Power's Operations Management Platform
KPIs	Key Performance Indicators
LV	Low Voltage
MAIFI	Momentary Average Interruption Frequency Index
MAPE	Mean Absolute Percentage Error
MBL	Maximum Base Load
mCHP	micro Combined Heat and Power
MV	Medium Voltage
MPPT	Maximum Power Point Tracker
PEOU	Perceived Ease of Use
PLC	Power Line Communication
PLT	Perception of flicker Long Term
PoD	Point of Delivery
PST	Perception of flicker Short Term
PU	Perceived Usefulness
PV	PhotoVoltaic
RES	Renewable Energy Source
RoCoF	Rate of Change of Frequency
RRI	Responsible Research and Innovation
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAT	Site Acceptance Testing
SCADA	Supervisory Control And Data Acquisition
SMX	Smart Meter Extension
SoA	State of the Art
SSH	Social Sciences and Humanities
STOR	Short Term Operating Reserve
TAM	Technology Acceptance Model
ToU	Time-of-Use

TRA	Theory of Reasoned Action
UCs	Use Cases
VPN	Virtual Private Network
VPP	Virtual Power Plant

1 Introduction

This deliverable defines a detailed technology validation plan taking into account project requirements, use cases and integration process. Starting from the general methodologies for system evaluation and technical validation, the deliverable describes the steps and actions to be done to perform the validation of eDREAM system through end-user engagement processes. The willingness to comprehend the end user's perspective and important role the eDREAM system can play in their everyday life motivated the inclusion of the processes for user engagement into the project validation process. Key Performance Indicators (KPIs) for validation and for impact measurement across various use cases and application domains have been defined, promoting the importance of quantitative indicators for continuous monitoring of project achievements and for the final evaluation of the project results. The outcomes of this deliverable and the related Task (T7.1) can be considered as a key input for the technology validation and assessment of the eDREAM solution and, in general, for the upcoming tasks in WP7.

1.1 Scope and objectives of the deliverable and relevance in the eDREAM framework

The eDREAM development activities have been aimed at the development of several components of the platform which will provide new approaches for DR management and for balancing energy resources. It leverages on exploiting new technologies such as deep learning and big data analytics for energy demand and production forecasts; blockchain secure distributed control for peer-to-peer energy trading and flexibility services provisioning; self-enforcing smart-contracts and consensus based validation to track energy as a digital asset in a tamper-proof manner and determining financial settlement in a near real time fashion.

These components has been integrated through a scalable Cross-functional Backbone Platform on the base of the business, user and system requirements defined in WP2 and in consideration also of the characteristics of three different environments (ASM Terni living lab, CERTH demo laboratory and Kiwi Power real site) in which the eDREAM solution will be deployed. This platform can be seen as a complex system in which users, different by typology and purposes, can use the available tools, models and mechanisms in support of the distribution energy management services.

In this perspective arises the concept of **eDREAM ecosystem**, conceived as the union of internal and external stakeholders of the project in conjunction with its core technology platform. Understanding the expectations of eDREAM stakeholders and how these will be satisfied by the eDREAM system, is of utmost importance as it will offer the valuable and concrete dimension on how the goals and objectives will be achieved by the project. For that, a study on project case studies has been conducted to prepare specific tests for validating the solution also in consideration of the user feedback that will be retrieved through the use of specific tools and instruments to facilitate user engagement. This deliverable focuses on the *"planning of the eDREAM system validation",* preparing the use cases as well as defining the tools for the analysis of results.

Thus, this deliverable proposes, a comprehensive set of actions for validation of the system that will be followed in the other tasks of WP7, T7.2 and T7.3 above all. To this end, the deliverable also reports a list of preliminary KPIs that must be used to measure the success and impact of the project results at the use cases level and also at the platform components level.

This is the second deliverable of T7.1 and is based on the preliminary validation plan already defined in detail in D7.1 as presented in Table 1.

Deliverable	Objectives
D 7.1: Validation Plan V1 [month 17]	1. Definition of a methodology for system evaluation and technical validation 2. Preliminary analysis of use cases to plan verification and validation of the eDREAM components 3. Identification of tools and instruments for User Engagement in validation to facilitate user acceptance 4. Definition of the first version of the technology validation plan and relative timing
D7.6: Validation Plan V2 [month 30]	1. Refinement of methodology for system evaluation and technical validation 2. Use cases prepared for the verification and validation of the eDREAM components 3. Selection of appropriate tools and instruments for User Engagement during the validation 4. Consolidated technology validation plan and timing

Table 1 Main objectives of the two T7.1 deliverables for Validation Plan Definition

1.2 Structure of the deliverable

D7.6 "Validation Plan V2" consists of five chapters, in which the methodology and tools to be used for the eDREAM system evaluation and technical validation have been described:

- General description of the scope and objective of the deliverable [Chapter 1];
- General methodologies for the systems evaluation and technical validation [Chapter 2];
- Methodology and approaches to be adopted for the eDREAM system evaluation and technical validation [Chapter 3];
- Use case analyses and preparation for the system validation through user engagement using specific user acceptance techniques [Chapter 4];
- Consolidated technology validation plan and timing [Chapter 4];
- Conclusions [Chapter 5].

2 General Techniques for systems evaluation and technical validation

In order to ensure the safe and secure operation of the eDREAM system, it is necessary to perform validation of the various technological components. However, integration of all the components is still one of the most important issues. Correct functionality of all the components does not guarantee that the entire system will behave as expected. System-level validation of actual behaviour is required to demonstrate that the entire eDREAM system is functioning properly.

Software verification and validation represents an analytical approach used to evaluate software products throughout the software development life cycle. The software verification checks that the system satisfies the expected requirements, while the validation aims to ensure the quality of software functionalities guaranteeing compliance of the system with the functional requirements.

During the software validation and verification phase, different techniques are then used for analysis, review, testing and verification of the user acceptability to determine whether a software product complies with requirements in terms of both functional capabilities and quality attributes. To do this, a validation plan must be defined. The validation plan is designed to prescribe the scope, approach, timing and resources of all validation activities. The plan must identify the components to be validated, the characteristics to be verified, the types of the validation tests to be performed, validation test scheduling and the resources necessary to complete the validation.

In general, the validation of technologies for managing demand response programmes is a task that requires holistic treatment of the overall process since the entire domain of the solution has to be considered including technical components, customers, markets, ICT, regulation, governance and so on. The activities defined in the validation plan must aim to: (1) validate the final eDREAM system verifying its compliance to the defined requirements, find defects and determine if the required functions are integrated into the software, (2) verify that the eDREAM system satisfies the standards, policies, practices, procedures, and conventions.

Another important aspect is the verification of system acceptance by the end-user which implies the system's capacity to ensure that the application meets the expectations of the customer according to different aspects such as response time, availability, portability and scalability. Through the assessment of end-user acceptance, it is possible to determine whether the software meets the criteria that allow the customer to determine whether or not to accept the software. Acceptance tests ensure that the objectives of customer requirements are met and that all components are correctly included in the final version.

Furthermore, the whole range of aspects that are of interest and relevant for stable, safe and efficient demand response solutions should be considered. Therefore, the stability of small signals needs to be analysed along with large-scale scenarios, short-term impacts and long-term sustainability, economic feasibility/profitability and IT security. In fact, since all these arguments are dependent on each other, they must be analysed in an integrated way.

In particular, the security of power supply is a crucial element of energy system planning and policy. Decentralised generation through renewables may help minimise the costs of interruptions by reducing the number of affected consumers. Decentralised storage options, Demand Response (DR), and prioritisations of loads play a central role in this context. Network security refers to the ability of a power system to continuously supply electricity to customers and can be measured in terms of frequency of interruptions in a given period or the average duration of interruptions. In order to prevent widespread load loss, different supply security arrangements must be adopted to different load groups according to their size. The following sub-sections will describe the general principles to be followed for the system validation, ensuring compliance with the requirements in terms of security, regulations, and user needs.

2.1 General Principles of System Validation

To ensure that a technology component is fulfilling its purpose, in line with the regulatory guidelines and the stakeholder requirements, the validation process is fundamental. It is especially crucial in energy industries since the activities of this sector impact directly customers.

A validation procedure can be defined as a group of *validation actions* to be performed together in a given configuration (test scenario) using specific tools (benchmarks, simulators, stubs, etc.), proving the satisfaction of system and stakeholder requirements.

A validation action [1] applied to an engineering element includes the following:

- Identification of the component on which the validation action will be performed;
- Identification of the reference that defines the expected result of the validation action.

Performing the validation action includes the following processes:

- Obtaining a result by performing the validation action onto the submitted component;
- Comparing the obtained result with the expected result;
- Deducing the degree of compliance of the component;
- Deciding on the acceptability of this compliance, because sometimes the result of the comparison may require a value judgment to decide whether or not to accept the obtained result as compared to the relevance of the context of use.

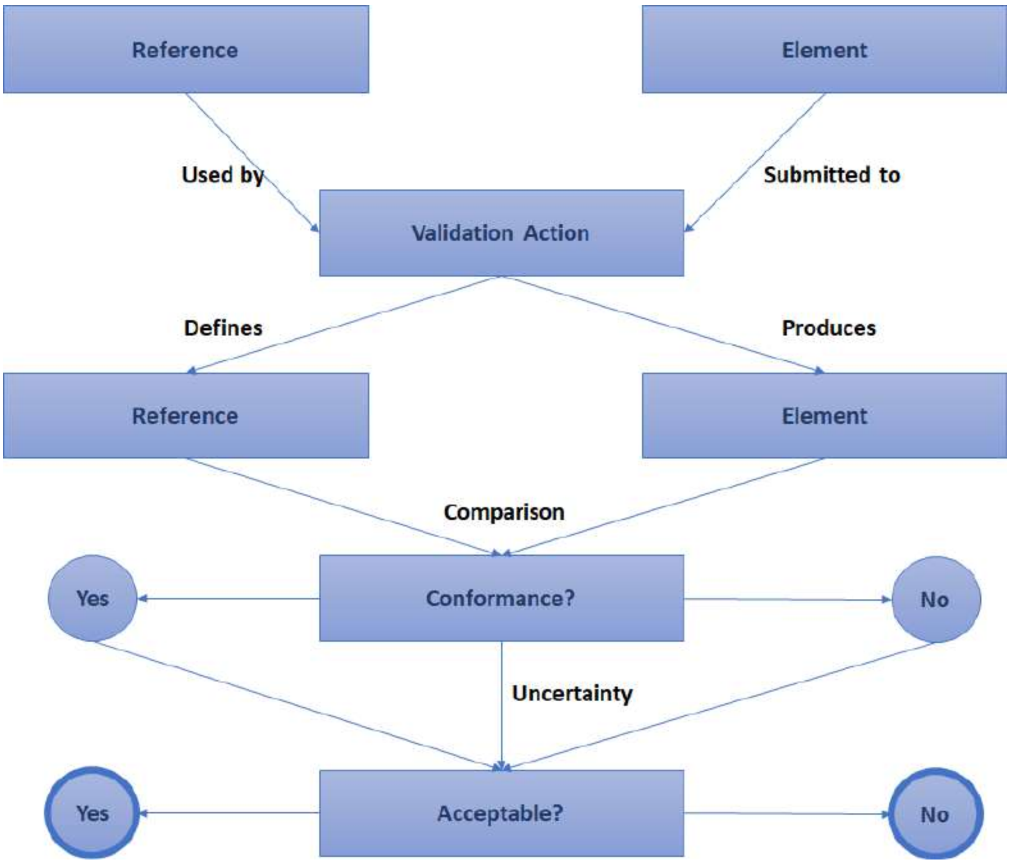

Figure 1 Definition and Usage of a Validation Action [1]

The schema (presented in Figure 1) shows how a validation action describes *what* must be validated (reference) on which element, comparing the obtained result against the expected one.

While hardware technology has been developed with considerable speed, software technology historically suffers from delay in the elaboration and availability of a technological and scientific background. Software engineering identifies one of the main reasons for this situation in the little importance given to the maintenance process from all the affected communities (company managers, information systems managers, computer engineers, users and auditors), even if maintenance costs have a very important weight in the total costs of the complete life-cycle of a software product [2]. For this reason, is important that the audit of information systems gives the necessary attention to the validation phase of the software life-cycle [3].

In computer science, the accuracy of any output depends on the accuracy of the input, making data one of the more valuable assets. Special attention should ensure that the inserted data is correct: *Data validation* is defined as the process of comparing inserted data with a set of rules to check the validity and reduce data entry errors. Examples of typical checks include alphabetic and numeric checks or range checks. If the inserted data fails the validity check, it should be refused and the user should be informed with a specific error message. *Data integrity*, on the other hand, is defined as the overall completeness and consistency of data during the lifecycle, meaning that between two updates or readings of a record there is no alteration. One of the advantages provided by the eDREAM platform, is the usage of a blockchain based data storage solution, providing by design improvement of data security and quality. This can be validated through the adoption of a user acceptance system, asking for answers to the following questions:

- What are the requirements of blockchain-based systems?
- How should blockchain-based systems be designed to meet requirements?
- What evidence is sufficient to justify that a blockchain-based system will meet its requirements?

The key non-functional requirements to be considered in this context, usually include:

- Interoperability
- Security
- Latency
- Integrity
- Confidentiality

Different trade-offs should be evaluated, for example confidentiality can be increased encrypting data before storing it, reducing performance and transparency; the usage of a private blockchain grants greater control over the admittance of processing nodes but will increase the entry barrier for third parties and so on [4].

2.2 Overview of methodologies for validation of Demand Response solutions

The energy transition from fossil fuel to renewable sources is transforming the traditional power supply system that today faces different challenges. The transition means that generation is increasingly dependent on weather conditions, due to the growing contribution of renewable energies; consequently, the volatility of electricity prices is increasing. Furthermore, an increase in load peaks is expected due to the electrification of residential energy demand for heating and transport. This requires both generation and network capacity: the electrification of energy demand is driven by the need to increase energy efficiency and reduce environmental impact; the use of heat pumps and electric vehicles reduces the overall energy demand but increases the demand for electricity.

At the same time, electrification represents both a challenge and an opportunity, since it is expected to increase flexibility from the demand point of view; flexibility refers to the ability to increase or decrease the load on a given time interval. By applying Demand Response (DR) the flexibility can be used to move the load in time; for example, DR can combine flexible demand with generation or reduce peak loads. Energy transition policies, together with technological progress, drive the growing integration of information and communication technologies of the network and therefore the transformation towards the so-called "smart grid". To support the decision-making process for implementing the DR, it is essential to deepen the perspectives and associated value creation with it.

Different categories of benefits and beneficiaries have been identified in the validation frameworks developed by EPRI [5], DOE [6] and JRC [7] on the impact assessment of smart meters and smart grid. The benefits are mainly divided into value of the energy market and value of the network. In a liberalized power supply system these benefits can generally be assigned to the two main electric utilities, the energy supplier and the local Distribution System Operator (DSO).

The disparity of benefits between these different stakeholders is caused both by the complexity of the modelling and by the fact that these two categories have been studied so far separately. According to individual studies, DR can create significant value for both the energy market and the network; however, it can be expected that the different DR strategies can sometimes conflict: for example, the use of flexibility in residential areas to profit from low energy prices can create higher peaks in the networks of local distribution [8]. It is clear, therefore, that there are more methods to validate DR campaigns, which have been designed with the aim of providing information about the benefits of DR campaigns depending on the subject concerned; therefore, we will have methodologies for DSOs, which will focus on the benefits related to the electricity grid, and methodologies for Energy retailers, which will focus on the benefits related to the energy market. In both cases, to evaluate the benefits of the DR from the point of view of the system, a modelling structure is used to represent a national power system.

The design of a method for assessing the performance of the DR program starts with basic criteria:

- Accuracy: the method should provide an accurate estimate of the load so that the demand response resources are credited only for the load reductions associated with the event and the baseline manipulation is minimized;
- Flexibility: the method should provide an accurate estimation of the load for all types of demand response resources that are expected and consider extraordinary circumstances such as excessively high load on the days of events and exclusions that could reduce the accuracy of the estimate;
- Simplicity: the method should be able to be transmitted in simple language so that the requirements and calculations are easily understood;
- Reproducibility: the calculation of the performance evaluation should be reproducible.

To assess the impact of DR on the network it is necessary to distinguish between load and generation by network voltage level: low voltage (LV), medium voltage (MV) and high voltage (HV); furthermore, to evaluate the DR performance it is necessary to estimate a target value obtainable thanks to simulation models. For this purpose, a simplified grid model is used. Within this model, typical user groups and generation groups are distinguished at each grid level. For each of the typical user groups and generation groups, the model simulates the load or the hourly generation for a long-time horizon. Each year the load and generation profiles depend on weather conditions and scenario inputs. To take into account the effects of weather conditions on load and generation, a reference year is used. This reference year consists of a sample of hourly data representing the annual meteorological conditions, including representative time limits. When simulating load and generation over several years, the reference year is used in an iterative way. The load depending on weather condition and the time necessary for the generation to adapting to weather condition.

Moreover, renewable generation from photovoltaic systems and wind turbines is modelled on the basis of global radiation data and wind speed, respectively.

These scenarios represent different directions in which the energy transition could evolve. Different trends are translated into key figures that influence the loading and generation of typical user groups and generation groups. For example, scenarios can vary in terms of number and scale of the prosumers, energy management services to be evaluated, installed wind capacity, penetration of photovoltaic panels and electric vehicles, etc. Scenario-dependent penetration of mCHPs (micro Combined Heat and Power) units, heat pumps and electric vehicles, mainly affects the load of residential user groups. Furthermore, the potential flexibility of these individual devices can be used for DR.

Therefore, a bottom-up approach is applied to model the load of residential user groups; the aggregate residential load is constructed using the number of houses and the penetration of the appliances [9]. Once the hourly load and the mandatory generation profiles of typical user groups and generation groups have been defined, the effects for the grid are quantified.

Nevertheless, NAESB [10] identifies four programs or services for responding to the wholesale demand: energy, capacity, reserve and regulation. Energy programs require resources to supply a quantity of electricity measured in MWh, capacity programs require that resources contribute to balancing the network by controlling the electricity demand in a specific period of time measured in MW, the reserve programs require that the resources are available for implementation by the balancing authority based on reserve capacity requirements and regulatory programs require that resources increase and reduce the load in response to real-time signals from the balancing authority. Within each of these types of programs there are different performance evaluation methodologies: Maximum Base Load, Meter Before/Meter After, Baseline Type I, Baseline Type II and Metering Generator Output.

Maximum Base Load refers to the ability of a resource to operate at an electrical load level equal to or less than a specified level during a DR event. The maximum base load (MBL) is a static technique that uses data, often from the previous year, to trace a line at a given power level below which the customer must maintain the request when it is called. This level of demand is often not representative of current loading conditions due to changes within the customer's structure. This technique often bases the MBL on the peaks of the previous year or coinciding or not coinciding with the peaks of the system.

Meter Before/Meter After refers to the performance measured against a baseline defined by the meter readings before distribution and similar readings during the sustained response period. Baseline Type I refers to a baseline created using the historical interval meter, meteorological and calendar data and Baseline Type II uses statistical sampling to generate a baseline. Meter Before/Meter After is usually used only for rapid response programs and reflects actual load changes in real time, reading the meter before and after the response, to measure the change in demand.

Metering Generator Output is applicable to the on-site generation behind the meter and determines the reduction of the demand based on the output data of the generator, assuming that all the load taken from the generator would otherwise have been in the system.

Baseline Type I methods are widely used and can provide simple and accurate M&V for DR programs. At the same time, these methods can lead to inaccurate results if the type I method variables are not accurately matched to the requirements of the DR program and to the client's energy use characteristics. An example could be the search window. If the search window is too long, unrepresentative and outdated data may be used in the baseline calculation. The overestimation of performance penalizes the operator of the system, while the underestimation of performance penalizes the customer.

Baseline Type II methods are often used in scenarios where aggregate meters are available, but the meters of individual sites are not. Historical data of aggregated counters are used to create a baseline allocated to individual sites or unmeasured loads. This method is generally more appropriate for residential DR than for commercial and industrial facilities which can measure energy consumption economically. Type II methods are often more complex, require more data than meters and may not produce timely results due to lack of real-time visibility.

The Table 2 presents the four NAESB service types and applicable performance evaluation methodologies.

Performance Evaluation Methodology	Valid for Service Type			
	Energy	Capacity	Reserves	Regulation
a) Maximum Base Load	✓	✓	✓	
b) Meter Before/Meter After	✓	✓	✓	✓
c) Baseline Type-I Interval Metering	✓	✓	✓	
d) Baseline Type-II Non-Interval Metering	✓	✓	✓	
e) Metering Generator Output	✓	✓	✓	✓

Table 2 NAESB service types and applicable performance evaluation methodologies [11]

3 eDREAM approach for evaluation and technical validation

We had defined, a methodology for the validation of the whole eDREAM system taking into account the SoA available methods, the specific components to be developed in relation to the use cases and the appropriate tools for end-user involvement in validation phase. The procedural schema to be followed for all platform validation activities is defined in Figure 2.

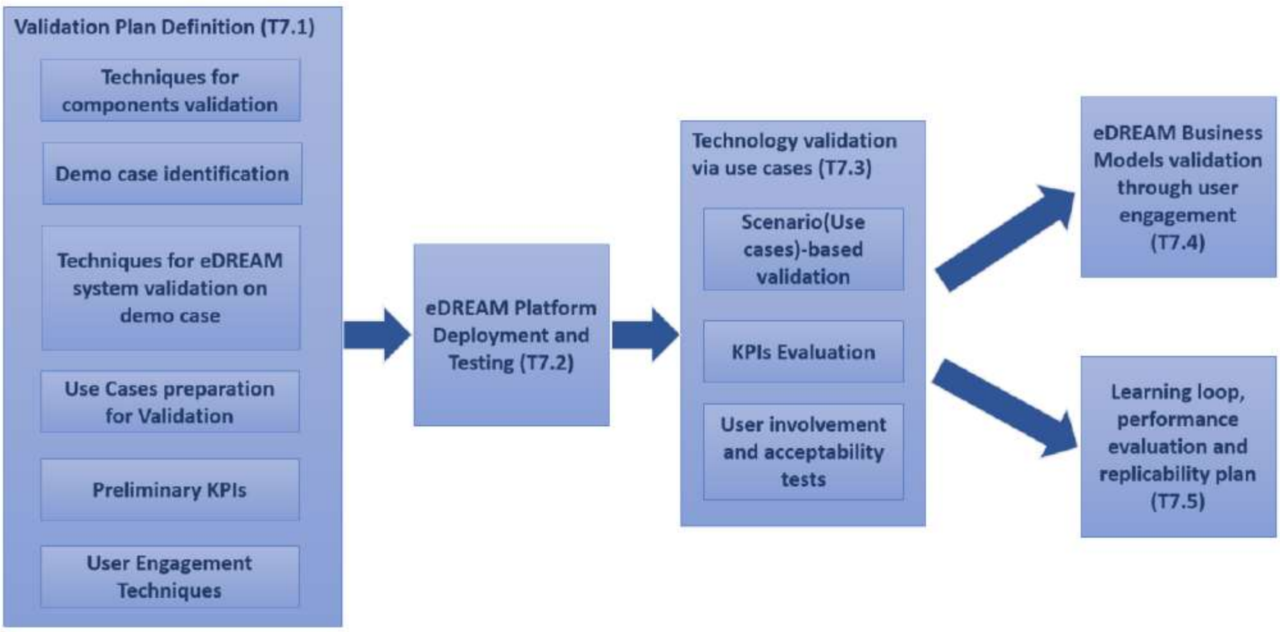

Figure 2 Procedural schema: From the Validation Plan definition (T7.1) to the other WP7 Activities

In this chapter, we have updated the techniques for the validation of the eDREAM platform components already defined in D7.1, in consideration also of the updating of the use cases defined in D2.9. The preliminary set of KPIs for the validation of each component of the platform and for the validation of the whole platform on the base of the use cases will be defined. A specific paragraph will be dedicated to the definition of the techniques that must be adopted for verifying acceptability of the solution by the user.

Starting from this, in Chapter 4 the trial sites for the verification of the solution already defined in D7.1 will be updated on the base of the progress in the development and integration of the eDREAM solution to implement the use cases on pilot sites and in the laboratory. Furthermore, the validation plan will be updated also in consideration of the activities already done and the impact of the spread of COVID19 in Europe on the rest of the validation activities. This also entailed the definition of alternative and/or parallel instruments and tools to those already defined in D7.1 for the user involvement and the collection of feedback.

3.1 Techniques for verification of components on demo cases

This section is related to the techniques that we are using for testing and validation of the eDREAM platform components according to the requirements of the defined eDREAM use cases. The information presented here is a very high-level version of what will be done mainly in the activities related to Task 7.2 as already detailed in the first relative deliverable "D7.2: Technology Verification Report v1". The steps to be considered during the implementation and deployment of each component and the whole system are presented in a high level in Figure 3.

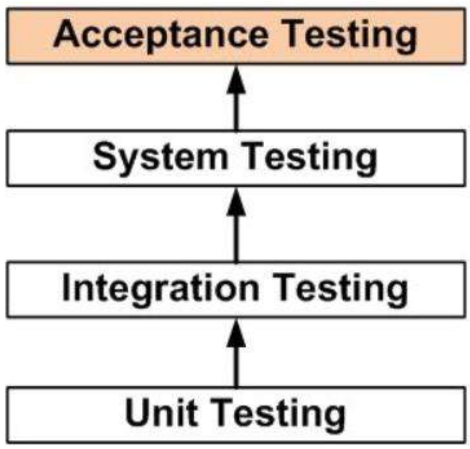

Figure 3 Testing steps during implementation

The software acceptance tests are at the top of the preparatory testing phase for the integration of the various eDREAM components that starts from the tests of a single software unit to get to the system tests through the integration (WP6) and testing of all the components. The purpose of these tests is to evaluate the system's compliance with the business requirements and assess whether the system is acceptable for delivery. More specifically, formal testing with respect to user needs, requirements, and business processes is conducted to determine whether or not a system satisfies the acceptance criteria and to enable the user, customers or other authorized entity to determine whether or not to accept the system.

3.1.1 Planning of Implementation

In order to ensure the implementation and integration of the eDREAM components according to the defined requirements and specifications, an implementation plan has been defined and followed during the first 30 months of the project. The aspects considered are the following:

i. The functional description;
ii. The connectivity with the other eDREAM components (e.g. interfaces, if they exist);
iii. The data flow;
iv. The development status;
v. The integration status;
vi. The problems identified (if any) during development and integration of the components.

The above parameters have been checked separately for all the eDREAM components. For understanding the concept of the plan and the required level of information, an indicative example is presented below for the component *"Electricity consumption/production forecasting"*:

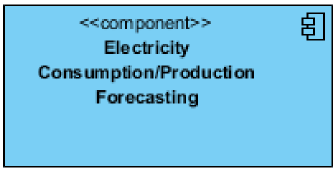

Figure 4 Electricity Consumption/Production Forecasting component

Functional Description

The main functionality of this component is to detect prosumer's energy consumption/production patterns and produce accurate predictions of energy supply and demand at different levels of granularities (scale/time). The component address three different time frames (one hour-ahead, intra-day, day-ahead) and is able to manage big data streams of data derived from IoT smart meters together with weather data. The component also provides the capability of combining different prediction techniques through a hybrid model, in order to extract the most accurate results. The main functionalities of this component can be summarized as follows:

- Enable creation of various prediction models based on large volumes of historical data;
- Provide predictions results in different granularities (scale/time);
- Provide efficient connectivity and communication through RESTful interfaces.

Connections with other components and interfaces

Table 3 presents the necessary information that should be checked during implementation and integration, so as to achieve adequate connection and communication.

Component	*Connection Type*	*API Protocol*	*Data Type*	*Comments*
Input/output components connections	TCP/IP, HTTP, etc.	RESTful Services, MQTT, etc.	JSON/ XML	Receive data from smart meters, results from other components etc. Send prediction results

Table 3 Component Connection Requirements

Data Flow

The Electricity Consumption/Production Forecasting module receives historical data of prosumers' consumption/production from the Cassandra DB, weather data from weather APIs and the baseline load for each prosumer from the Baseline Flexibility Estimation component. The produced results of consumption/production predictions are sent to other components of the platform, which are the Virtual Power Plants Generation Modelling and Forecasting, the Load Profiling, the PV/RES Degradation and Trend Analysis, the VPP & DR Services Optimization engine, the Forecasting Tool, the DSS & DR Strategies Optimization, the Blockchain-driven control for LV networks and the Secured Blockchain-driven energy Market.

Integration Status

The information related to integration process are mentioned in Table 4 in a high-level format without many details.

Integration Status	Under development/Final
Format for Integration	Linux application/Windows application/Web service application
Progress up to date	e.g. Communication with Cassandra DB and Weather APIs has been developed
Pending Integration Actions	e.g. Interfaces to be tested in real-case

Table 4 Integration process Information

Development Status

Table 5 depicts the relevant information with the development process.

Development Status	Under development/Final
Programming Language	Python/C++/JAVA etc.
Progress up to date	e.g. The main standalone functionalities of the component have been implemented
Pending Development Actions	e.g. The functionalities related to other components have to developed

Table 5 Development process information

Software Problems Identified

The characteristics of the software problems encountered are summarized in Table 6.

Failure Type	Failure Description	Failure Cause	Countermeasure
e.g. Slow Response Time	e.g. The system takes timeout	e.g. Slow network	e.g. Parse data incrementally

Table 6 Software problems characteristics

Once the implementation of each component is completed, to deploy the components either in lab and in the real use cases, some necessary activities have to be conducted for compliance with the energy-grade specifications for using new Demand Response and Blockchain technologies. The technology providing partners execute and document the pre-functional checklists and perform start-up and local or remote configuration.

3.1.2 Methodology for Testing and Validation of Components and Platform

The purpose of this section is to provide the methodology and the intermediate steps for the validation and acceptance testing of each eDREAM component, so as to ensure the proper delivery of each module and the eDREAM platform as a whole into operation initially at CERTH/Smart Home laboratory (mainly for the components involved in the second High Level Use Case) and afterwards at the real cases of pilot sites (ASM Terni and Kiwi).

The individual components will be validated against their requirements, while the overall eDREAM solution will be evaluated for its acceptance by its intended users, and for its impact on the involved Demand Response processes.

3.1.2.1 Components Testing and Validation

For each of the eDREAM platform components, test and validation activities to be done, have been defined on the base of the needs of end-users, the data availability and the ongoing activities for the preparation of trial sites. In particular, for the preparation of the trial site, it will be important to deepen and verify the relationships between the components defined by the final use cases in the deliverable D2.9.

Below, from Table 7 to Table 23, the main details for each single component are shown:

Electricity Consumption/Production Forecasting, T3.1, TUC & CERTH	
Validation Pilot Sites	ASM Terni living lab, CERTH demo laboratory, Kiwi real site
Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	MAPE (<18%)

Table 7 Electricity Consumption/Production Forecasting component validation information

Baseline Flexibility Estimation, T3.2, TU	
Validation Pilot Sites	ASM Terni living lab, Kiwi real site
Validation Data	Customer Historical consumption data Estimated Baseline
Validation KPI and/or Metrics	MAPE

Table 8 Baseline Flexibility Estimation component validation information

Virtual Power Plants Generation Modelling & Forecasting, T3.3, TUC	
Validation Pilot Sites	Kiwi real site
Validation Data	Energy Datasets of prosumers monitored

Validation KPI and/or Metrics	VPPs created with success from available prosumers to match specific goals

Table 9 Virtual Power Plants Generation Modelling & Forecasting component validation information

DR Aerial Survey Toolkit, (T3.4 & T6.2), TU & CERTH	
Validation Pilot Sites	CERTH demo laboratory, Kiwi real site
Validation Data	Drone Aerial Survey datasets used in conjunction with historical energy consumption data ROI detection methods will be applied to the gathered material
Validation KPI and/or Metrics	Possibility to take into consideration for DR estimation the Thermal/Visual imagery/detected assets

Table 10 DR Aerial Survey Toolkit component validation information

Multi-building DR characterization through thermal, optical and LIDAR information fusion, T3.4, TU & CERTH	
Validation Pilot Sites	CERTH demo laboratory, Kiwi real site
Validation Data	Energy Datasets of prosumers monitored Drone Aerial Survey datasets used in conjunction with historical energy consumption data
Validation KPI and/or Metrics	Characterization of building analysed for application in a DR program

Table 11 Multi-building DR characterization through thermal, optical and LIDAR information fusion component validation information

PV/RES Degradation & Trend Analysis, T4.1, TU & CERTH	
Validation Pilot Sites	ASM Terni living lab, Kiwi real site
Validation Data	Energy Datasets of prosumers monitored Network Data Available historical datasets of the PV power generation
Validation KPI and/or Metrics	MAPE (<20%)

Table 12 PV/RES Degradation & Trend Analysis component validation information

VPP and DR Services Optimization engine, T4.1, TU & CERTH	
Validation Pilot Sites	ASM Terni living lab, Kiwi real site
Validation Data	Energy Datasets of prosumers monitored

	Network Data Data from other eDREAM component
Validation KPI and/or Metrics	VPP Generation Capacity VPP Generation Flexibility

Table 13 VPP and DR Services Optimization engine component validation information

DSS (Decision Support System) & DR Strategies Optimization, (T4.1, T4.3, T4.4 & T6.2), TU & CERTH	
Validation Pilot Sites	ASM Terni living lab, Kiwi real site
Validation Data	Energy Datasets of prosumers monitored Network Data Near real time data (Terni Pilot site)
Validation KPI and/or Metrics	**For ASM Terni living lab:** Congestion Congestion Cost Flexibility (Demand/Generation) Peak Shaving CO_2 emissions reduction Pollutant emissions reduction DR campaign management **For Kiwi real site:** Electricity savings Economic gain Demand Flexibility CO_2 emissions

Table 14 DSS (Decision Support System) & DR Strategies Optimization component validation information

Load Profiling, T4.2, ATOS & CERTH	
Validation Pilot Sites	ASM Terni living lab
Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	Load Factor

Table 15 Load Profiling component validation information

Big Data Clustering at Multiple Scales, T4.2, ATOS & CERTH	
Validation Pilot Sites	ASM Terni living lab

Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	Flexibility Electricity Savings

Table 16 Big Data Clustering at Multiple Scales component validation information

Customer Segmentation, T4.2, ATOS & CERTH	
Validation Pilot Sites	ASM Terni living lab
Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	Flexibility Electricity Savings

Table 17 Customer Segmentation component validation information

HMIs, (T4.3, T4.4 & T6.2), CERTH	
Validation Pilot Sites	ASM Terni living lab, CERTH demo laboratory
Validation Data	Energy Datasets of prosumers monitored Network Data
Validation KPI and/or Metrics	**For ASM Terni living lab:** Congestion Congestion Cost Flexibility (Demand/Generation) Peak Shaving CO_2 emissions reduction Pollutant emissions reduction **For CERTH demo laboratory:** Electricity savings Peak power reduction Economic gain

Table 18 HMIs validation information

Graph-based Analytics, (T4.3 & T4.4), CERTH	
Validation Pilot Sites	Kiwi real site
Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	Electricity savings Economic gain

	Demand Flexibility CO2 emissions

Table 19 Graph-based Analytics component validation information

Distributed Ledger, T5.1, ENG	
Validation Pilot Sites	ASM Terni living lab, CERTH demo laboratory
Validation Data	Energy Datasets of prosumers monitored
Validation KPI and/or Metrics	No transactions per block (> 25) Queue system throughput (<10.000 Tx)

Table 20 Distributed Ledger component validation information

Secured Blockchain-driven Energy Market, T5.2, TUC	
Validation Pilot Sites	ASM Terni living lab, CERTH demo laboratory
Validation Data	Energy Datasets of prosumers monitored Near real time data (Terni Pilot site)
Validation KPI and/or Metrics	Smart contract implementation (Terni Pilot site) Lab smart house can buy and/or sell energy leveraging on smart contracts (CERTH demo laboratory)

Table 21 Secured Blockchain-driven Energy Market component validation information

Closed loop DR Verification Engine, T5.3, ENG	
Validation Pilot Sites	ASM Terni living lab, CERTH demo laboratory
Validation Data	Energy Datasets of prosumers monitored Near real time data (Terni Pilot site)
Validation KPI and/or Metrics	Financial settlement is operational and prosumers' tokens and wallets are settled

Table 22 Closed loop DR Verification Engine component validation information

Blockchain-driven control for LV networks, T5.2, TUC	
Validation Pilot Sites	ASM Terni living lab
Validation Data	Energy Datasets of prosumers monitored Near real time data
Validation KPI and/or Metrics	The decentralized flexibility control is operational Flexibility delivery over 95% of the request

Table 23 Blockchain-driven control for LV networks component validation information

3.1.2.2 Site Acceptance Testing

The eDREAM project highly values end users, as solutions provided will be adapted to their needs, based on appropriate user requirements and evaluation procedures. Therefore, within eDREAM project, the testing methodology that will be realized in order to identify potential leaks and bugs of the prototype system prior to its deployment and evaluation in realistic conditions to ensure a high level of user acceptance, is the ***Site Acceptance Testing*** (**SAT**). The SAT involves the execution tests, the recording of findings and the addressing of identified shortcomings.

The procedure of SAT should be treated with a high level of formality and be supervised by the project manager with a formal record of any inconsistencies and non-conformities and methods for handling such inconsistencies. On the other hand, the lack of Acceptance Test Plan causes some negative consequences making difficult to correct anomalies and malfunctions without subjecting the project schedule. Sometimes, it may even be too late and the flexibility that comes with offering technical solutions could already be overtaken by events. Normally, the customer or an inspection agency conducts a SAT to ensure that products meet specified requirements.

SAT is not a legal requirement, but it is recommended to be carried out to reduce the occurrences discussed above, if the proposed integrated solution is fairly complex. It is really difficult to predict the correct operation of the integrated system or consequences due to failures in some parts of the integrated solutions. For that reason, the SAT is a valuable check of the correct and nominal operation of the platform's components, as well as for the overall platform.

SAT is a way to ensure that equipment / systems being purchased meet the agreed upon design specifications. Site Acceptance Tests allow any issues to be corrected before production – leveraging the technical expertise and resources of the constructor, preventing any potential cross-contamination with the end user's facilities and improving the general quality of the product delivered to the end user. While there are some general guidelines for SATs, each SAT is a customized procedure. The complexity of the SAT performed is generally determined by factors such as the degree of customization, familiarity with equipment and degree of integration.

To ensure a successful Site Acceptance Test it is important to communicate effectively throughout the process, setting clear expectations and clarifying roles long before the SAT is to be performed. The high-level process for a Site Acceptance Test involves:

- **Planning** determines and documents the tests to be carried out, test criteria, protocols, tools needed and what to look for, along with specifics for variances and acceptability. The timeline and the personnel who should be involved along with their responsibilities should also be determined;
- **Performing Test Activities**: Coordination and performing of tests according to requirements, specifications and agreements as planned;
- **Gathering Test Results**: The specified results and outcomes are collected and measured according to the plan. It is determined whether objectives and criteria of tests have been met or not;
- **Identifying and Correcting Issues** (if necessary): Faults, failures, errors and hazards are identified according to pre-determined criteria. Issues needing resolution are corrected for user acceptance and then re-testing process followed until all errors are addressed at the level of individual components and integrated components;
- **Sign-off**: User acceptance of equipment/ integrated system.

The above steps are presented in a coherent way in Figure 5. The planning presents a set of appropriate tests to be carried out and identifies the person responsible for developing the test cases. Appropriate levels of competence and independence of assessors are required. The realization of tests shall be described as well as the personnel responsible to carry out the test.

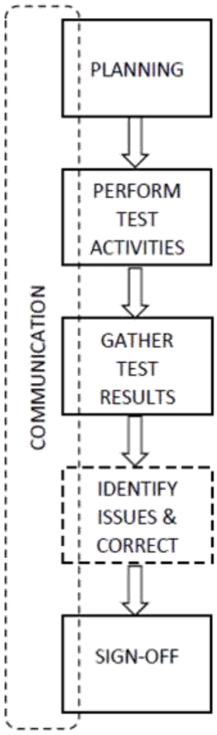

Figure 5 High-level process for a Site Acceptance Test

Each test procedure shall be described in a logical sequence. The needed competence for involved test personnel is described during the planning. It is recommended that personnel with experience suitable for the intended process deal with the SAT planning. Experience from different areas such as process design, hardware design, and software design will contribute to the SAT planning with relevant test cases. The planning includes procedures for corrective action in case of discovered failure during execution of the tests. The test planning shall also include the test criteria on which the completion of the tests shall be judged.

3.2 Validation Cases Design Techniques

As already mentioned, the eDREAM solution will be tested considering the application scenarios and the use cases defined in the Deliverable 2.9 “Use Case Analysis and application scenarios description V3”. Following the output of the related T2.2 task, a list of the main actors directly involved in the procedure were selected:

1. Energy Retailer
2. DSO
3. DNO
4. Distributed Generation Provider
5. Centralized Generation Provider
6. Aggregator
7. ESCo
8. System Operators

9. EV fleet manager
10. Prosumer/Producer
11. Consumer
12. VPP Energy Manager

This section addresses the development of Key Performance Indicators (KPIs) for validation and for success and impact measurement across the different eDREAM use cases and application domains. Considering the metrics described in D2.3 “Standardization Report and Regulatory Roadmap” it is possible to consider those KPIs which can effectively be used for the overall validation of the eDREAM platform.

The preliminary set of KPIs defined in this deliverable on the base of the platform functionalities, the needs of the actors involved and performance requirements, will be evaluated, consolidated and quantified in the activities envisaged by Task 7.3. The main goal of the KPIs is to quantify and evaluate the expected benefits (technical, economic or sociological). For each KPI, calculation methods will be provided in order to evaluate the performance on the base of objectives defined also through a comparison with the State of the Art.

The preliminary set of KPIs has been defined in consideration of the three High Level Use Cases defined as follows:

- HL-UC 01 Prosumer DR flexibility aggregation via smart contracts
- HL-UC 02 Peer-to-peer local energy trading market
- HL-UC 03 VPP in Energy Community

In order to determine the KPIs to evaluate the performance, specific characteristics of the related real site environment in which each of components will be deployed have to be taken into account together with the literature study and the experience of eDREAM technology provider partners, to determine the KPIs for validation and evaluation.

On this basis, a validation on each trial site will be conducted to obtain the quantification of the KPIs and to involve the user through the mechanisms for the user acceptance. These results will be evaluated and combined with user feedback obtained through the use of tools for user acceptance with the aims to test and validate the specific business model and evaluate the performance analysis, while also assessing the solution over the pilot sites.

Figure 6 presents the overall eDREAM use case evaluation process in which evaluation of the output has been considered as the key activity.

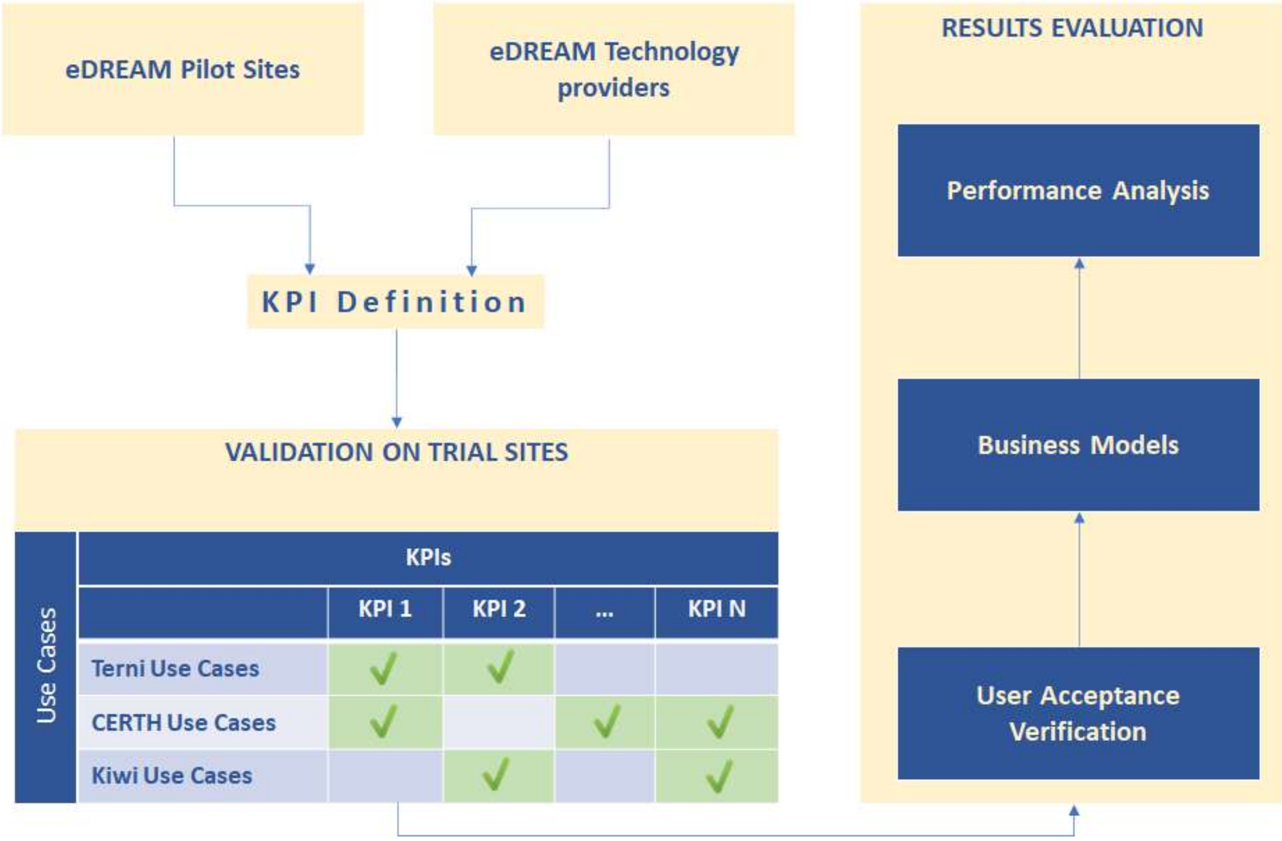

Figure 6 Overall eDREAM use case evaluation approach

Starting from the KPIs defined in D2.3 and other KPIs defined in the literature [12], a methodology was applied for the selection, definition and updating of the KPIs most relevant to the eDREAM project on the base of the defined use cases. In particular, a process has been defined, consisting of the following steps:

1. KPIs selection from D2.3 / Definition of a new set of general KPIs,
2. Verification of relevance for the defined use cases,
3. Definition of specific KPIs.

In particular, after the selection of KPIs from those already defined and/or the definition of the potential new KPIs, a review has been undertaken in consideration of the final use cases and the involvement of the partners' representatives of the pilot sites and the partner responsible for the activities related to the deployment of the solutions on the relative trial sites.

These metrics are categorized into the following 7 categories:

- Electricity, power, economy and social impact of Demand Response;
- Power Supply and Distribution System Evaluation Metrics;
- Flexibility and Balancing System Evaluation Metrics;
- Transmission System Evaluation Metrics;
- Renewable Energy Usage Evaluation Metrics;
- Emissions Evaluation Metrics;
- Digitalization Evaluation Metrics.

Template presented in Table 24 has been created for definition of the KPIs:

KPI ID	<Unique ID > (i.e. KPI-01)
KPI name	<Title of the Requirement>
Description	<Description of Requirement, also with some reference to general KPI identification method>
Type of Impact	<Indicate the categorization of the KPI impact>
Related UCs	<List the UCs for which the KPI have to be measured>
Actors Involved	<List the actors involved>
Priority	Low/Mid/High

Table 24 KPIs Template

For which:

- **KPI ID:** Unique identifier of the KPI that help in traceability of KPI;
- **KPI name:** Short sentence describing the KPI;
- **Description:** Few lines of text describing the KPI.
- **Type of Impact:** Indication of the fields on which KPI affect;
- **Related UCs:** Indication of eDREAM use cases for which will be important to evaluate the KPI;
- **Actors Involved:** Indication of the actors directly interested in the KPI;
- **Priority:** Identification of the priority of the KPI, established through a consensus process among internal stakeholders and based on simple evaluation scheme which provides for the indication of High, Medium (Mid), or Low priority.

Other KPI characteristics, such as the specific method to be applied for the KPI quantification and the relative target value will be defined and evaluated in the Deliverable 7.3. The KPIs description are reported in the following subsections.

3.2.1 Electricity, power, economy and social impact of Demand Response

KPI ID	KPI-01
KPI name	Electricity savings
Description	Reduction of final user's electricity consumption due to DR (including both shedding and shift periods).
Type of Impact	Energy Saving
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	ESCo, Prosumer/Producer, Consumer
Priority	High

Table 25 KPI-01 Electricity savings

KPI ID	KPI-02
KPI name	Peak power reduction

Description	This indicator corresponds to the reduction of the maximum electricity power demand. It refers to the application of DR to the end user. The general identification method, to be considered for the specific DR event, is reported below: $$D_{elec,peakreduction}(\Delta t)=max_{t\in\Delta t}(D_{elec,baseline})-max_{t\in\Delta t}(D_{elec,DR})$$ $$D_{elec,peakreduction}[\%]=100*D_{elec,peakreduction}[kW]/max_{t\in\Delta t}(D_{elec,baseline}[kW])$$ The needed measures are: • $D_{elec,}(t)$: asset real electricity demand during DR event, in kW. • $D_{elec,baseline}(t)$: asset baseline electricity demand without DR event. The calculated data will be: • $D_{elec,peakreduction}(\Delta t)$: average peak power reduction. • In kW of final energy. The percentage will be calculated for all considered time and space perimeters
Type of Impact	Power and demand flexibility
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	ESCo, Prosumer/Producer, Consumer
Priority	High

Table 26 KPI-02 Peak power reduction

KPI ID	KPI-03
KPI name	Avoided Electricity import
Description	The avoided electricity import corresponds to the reduction of electricity demand to the grid in kWh during a fixed amount of time (shedding, DR event, etc.). This indicator reflects the global flexibility obtained from avoided consumptions and local use of electricity increase, including renewables. The general identification method is reported below: $$E_{savings,elec}(\Delta t)\approx\Sigma(\bar{P}_{baseline,elec}(t)-\bar{P}_{DR,elec}(t))\cdot\delta_{shed+shift}(t)_{t\in\Delta t}$$ $$E_{gen,autoconsumed,increase}(\Delta t)\approx\Sigma(\bar{G}_{DR,autoconsumed}(t)-\bar{G}_{baseline,autoconsumed}(t))\cdot\delta_{shed+shift}(t)$$ $$E_{import,avoided,elec}[\%]= =100*E_{import,avoided,elec}[kWh]/E_{import,baseline}[kWh]$$ With: $E_{import,baseline}(\Delta t)=\int D_{elec,baseline}(t).dt_{\Delta t}\approx\Sigma\bar{D}_{elec,baseline}(t)$ The data required for the calculation: • $\delta_{shed+shift}$: DR event trigger ($\delta_{shed+shift}$= 1 during shedding and shift periods, and 0, elsewhere) • $P_{DR,ec}(t)$: asset real electricity consumption during DR event, in kW.

	• $P_{baseline,ec}(t)$: asset baseline electricity consumptions without DR event, in kW. • $G_{DR,toconsumed}(t)$: auto-consumed electricity generation during DR event, in kW. • $G_{baseline,toconsumed}(t)$: auto-consumed electricity generation without DR event, in kW. • $D_{elec,seline}(t)$: whole site baseline electricity import (or demand). The calculated data will be: • $E_{import,avoided,elec}$: Avoided electricity import (or demand). • In kWh of primary energy. In % for all considered time and space perimeters.
Type of Impact	Electricity Saving
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, Prosumer/Producer, VPP Energy Manager
Priority	High

Table 27 KPI-03 Avoided Electricity import

KPI ID	KPI-04
KPI name	Economic gain
Description	The economic gain corresponds to the overall benefit in national currency (£, €, RON) due to the DR implementation. The general identification method, to be considered for the specific DR event, is reported below: $$EG(\Delta t)=\Delta FR(\Delta t)+\Sigma\Delta Ex(t)\ _{t\in\Delta t}$$ ΔEx corresponds to the energy expenses variations (electricity, fuels and district heating): $$\Delta Ex(t)=(D_{baseline,distr\ heating}(t)-D_{DR,distr\ heating}(t))*Pr_{distr\ heating}+(D_{baseline,elec}(t)-D_{DR,elec}(t))*Pr_{elec}(t)$$ The needed measures and information are: • $D_{DR}(t)$: asset real energy demand during DR event, in kW. • $D_{baseline}(t)$: asset baseline energy demand without DR event, in kW. • $S_{DR,ec}(t)$: electricity selling during DR event, in kW. • $S_{baseline,ec}(t)$: electricity selling baseline without DR event, in kW. • $Pr_{ele}(t)$: electricity sales tariff (bought from the grid), in national currency per kWh. • $Pr_{elec,feedin}(t)$: electricity feed-in tariff (sold to the grid), in national currency per kWh. • $FR_{DR,il}$: Utilization payment of related DR program, in national currency or national currency per kWh. • $FR_{DR,ail}$: Availability payment of related DR program. The only output data will be: $E(\Delta t)$: Economic gain from DR scenario, in national currency.

Type of Impact	Electricity saving, Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, Prosumer/Producer, VPP Energy Manager
Priority	High

Table 28 KPI-04 Economic gain

3.2.2 Power Supply and Distribution System Evaluation Metrics

KPI ID	KPI-05
KPI name	Distribution Operation costs
Description	This KPI will evaluate the difference between the cost of the activities related to distribution operation in a reporting period.
Type of Impact	Economic
Related UCs	HL-UC 01, HL-UC 03
Actors Involved	DSO, Aggregator, ESCo
Priority	Mid

Table 29 KPI-05 Distribution Operation costs

KPI ID	KPI-06
KPI name	Distribution Losses
Description	Sum of all the real power generated in the network and transferred through the substation transformers and then subtracting all real power consumed by the loads in the network, in the evaluated period of time. The Distribution losses will be calculated by subtracting power consumed from power produced (P_{prod}-P_{load}).
Type of Impact	Power Network reliability
Related UCs	HL-UC 01, HL-UC 03
Actors Involved	DSO, DNO
Priority	High

Table 30 KPI-06 Distribution Losses

KPI ID	KPI-07
KPI name	SAIFI (System Average Interruption Frequency Index)
Description	Measure the number of service interruptions suffered by an average user. In particular, this KPI will estimate the average number of service interruptions detected by a typical end user in the network during a defined time t (typically one year). SAIFI is measured according to IEEE 1366-2003[13]:

	$$\mathrm{SAIFI} = \frac{\sum N_i}{N_t}$$ Where: • N_i Number of interrupted customers for each interruption event during reporting period; • N_t Total number of customers served for the area being indexed.
Type of Impact	Power Network reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	High

Table 31 KPI-07 SAIFI (System Average Interruption Frequency Index)

KPI ID	KPI-08
KPI name	SAIDI (System Average Interruption Duration Index)
Description	This KPI will estimate the average interruption duration, which leads to disturbance for network users and maintenance costs. It can be calculated using the outage time for every track and the total number of users on it (or averaged number of users per track). SAIFI is measured according to IEEE 1366-2003[13]: $$\mathrm{SAIDI} = \frac{\sum r_i N_i}{N_t}$$ Where: • r_i Restoration time for each interruption event • N_i Number of interrupted customers for each interruption event during reporting period; • N_t Total number of customers served for the area being indexed.
Type of Impact	Power Network reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	High

Table 32 KPI-08 SAIDI (System Average Interruption Duration Index)

KPI ID	KPI-09
KPI name	MAIFI (Momentary Average Interruption Frequency Index)
Description	MAIFI represents the total number of customer interruptions per customer lasting less than five minutes for a particular electric. MAIFI is measured according to IEEE 1366-2003[13]: $$\mathrm{MAIFI} = \frac{\sum ID_i N_i}{N_t}$$ Where:

	• ID_i Number of interrupting device operations; • N_i Number of interrupted customers for each interruption event during reporting period; • N_t Total number of customers served for the area being indexed.
Type of Impact	Power Network reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	Mid

Table 33 KPI-09 MAIFI (Momentary Average Interruption Frequency Index)

KPI ID	KPI-10
KPI name	CTAIDI (Customer Total Average Interruption Duration Index)
Description	This KPI represents the average amount of time consumers have suffered an interruption. CTAIDI is measured according to IEEE 1366-2003[13]: $$\text{CTAIDI} = \frac{Total\ Duration\ of\ Customer\ Interruptions}{Total\ Number\ of\ Custumer\ Interraption}$$
Type of Impact	Power Network reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	Low

Table 34 KPI-10 CTAIDI (Customer Total Average Interruption Duration Index)

KPI ID	KPI-11
KPI name	ASAI (Average Service Availability Index)
Description	This KPI represents the ratio of the total number of hours that the service is available to consumers on the total hours required to be provided to consumers during a specific time period. It is usually calculated on monthly basis or yearly basis. ASAI is measured according to IEEE 1366-2003[13] as: $\text{ASAI} = \left(\frac{1-\sum r_i N_i}{N_t * T}\right) * 100 = \frac{SAIDI}{SAIFI}$ Where: • r_i Restoration time for each interruption event • N_i Number of interrupted customers for each interruption event during reporting period; • N_t Total number of customers served for the area being indexed; • T Time period under study (hours)
Type of Impact	Power Network reliability

Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	Low

Table 35 KPI-11 ASAI (Average Service Availability Index)

KPI ID	KPI-12
KPI name	ASUI (Average Service Unavailability Index)
Description	This KPI is complementary respect to ASAI. In particular, this KPI represents the ratio of the total number of hours that the service is unavailable to consumers on the total hours required to be provided to consumers during a specific time period. ASUI is measured according to IEEE 1366-2003[13]: ASUI=1-ASAI
Type of Impact	Power Network reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	Low

Table 36 KPI-12 ASUI (Average Service Unavailability Index)

KPI ID	KPI-13
KPI name	$CEMI_n$ (Customer Experiencing Multiple Interruptions)
Description	This KPI allows tracking customers with particular levels of reliability. The subscript n is the key threshold that allows the utilities to track multiple values. It thus represents in particular, the fraction or percentage of the customers experiencing more than n interruptions. $CEMI_n$ is measured according to IEEE 1366-2003[13]: $\mathrm{CEMI}_n = \frac{Total\ Number\ of\ Customers\ experienced\ n\ or\ more\ sustained\ interruption}{Total\ Number\ of\ Customers\ Served}$
Type of Impact	Power Network reliability
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	DSO, DNO, Aggregator
Priority	High

Table 37 KPI-13 $CEMI_n$ (Customer Experiencing Multiple Interruptions)

KPI ID	KPI-14
KPI name	Outage Response Time

Description	This KPI indicates the elapsed time between the outage event and the first initiated action. To calculate this KPI the monitored values by the meters are used to detect and report.
Type of Impact	Power Network reliability
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	DSO, DNO, Aggregator
Priority	Low

Table 38 KPI-14 Outage Response Time

3.2.3 Flexibility and Balancing System Evaluation Metrics

KPI ID	KPI-15
KPI name	Demand Flexibility
Description	This KPI will indicate the ability of the sub system to respond and shift their demand to periods when the electricity is cheap and abundant. This KPI will be calculated for each eDREAM demo as the sum of the amount of load capacity participating in demand side management. $$P_{DSM}(\%) = \frac{(P_{DSM})_{eDREAM} - (P_{DSM})_{BAU}}{P_{peak}}$$ Where: • P_{DSM} – represents the sum of the amount of load capacity that can be shifted thanks to DSM in the BAU (business as usual) and eDREAM scenarios • P_{peak} – represents the max. electricity demand in the area under evaluation
Type of Impact	Environmental, Power Network Reliability, Economical
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Energy Retailer, DSO, DNO, Distributed Generation Provider, Centralized Generation Provider, Aggregator, ESCo, System Operators, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Priority	High

Table 39 KPI-15 Demand Flexibility

KPI ID	KPI-16
KPI name	Distributed Generation Capacity
Description	This KPI will indicate the total installed units implicated in demand management programs and the energy delivered and it is calculated taking into account the total capacity of the units.

Type of Impact	Environmental
Related UCs	HL-UC 01, HL-UC 03
Actors Involved	DSO, DNO, ESCo, EV fleet manager
Priority	High

Table 40 KPI-16 Distributed Generation Capacity

KPI ID	KPI-17
KPI name	Forecasting reliability of demand/generation
Description	This KPI will evaluate the accuracy of the forecasting techniques used with regard to electricity demand and generation. This KPI is calculated through the division between predicted capacity and the actual capacity on a reporting period.
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	DSO, DNO, Aggregator, ESCo, VPP Energy Manager
Priority	High

Table 41 KPI-17 Forecasting reliability of demand/generation

KPI ID	KPI-18
KPI name	Fulfilment of voltage limits
Description	This KPI will indicate the power quality in distribution networks through the evaluation of the fulfilment of regulatory voltage limits in distribution networks and it will be calculated using the following formula: $$V(\%) = \frac{V_{BAU} - V_{eDREAM}}{V_{BAU}}$$ Where: • V_{BAU} – Percentage of time that the voltage is out of limits (undervoltage and overvoltage) in BAU scenario (mean value per customer) • V_{eDREAM} – Percentage of time that the voltage is out of limits (undervoltage and overvoltage) in eDREAM scenario (mean value per customer)
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	Mid

Table 42 KPI-18 Fulfilment of voltage limits

KPI ID	KPI-19
KPI name	Generation flexibility
Description	Generation flexibility is mainly measured through generation response capabilities. This KPI will be calculated for eDREAM demo as the sum of the amount of generation capacity managed by the distribution network operator in LV and MV. $$P_{DER}(\%) = \frac{(P_{DER})_{eDREAM}}{\sum(P_R)_{eDREAM}} - \frac{(P_{DER})_{BAU}}{\sum(P_R)_{BAU}}$$ Where: • P_{DER} - Represents the sum of the amount of flexible generation capabilities that the distribution network operator can shift in the BAU and eDREAM scenarios • P_R - Represents the sum of the generation installed capacity on the system in the BAU and R&I scenarios
Type of Impact	Power Network Reliability, Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, EV fleet manager, Prosumer/Producer, VPP Energy Manager
Priority	High

Table 43 KPI-19 Generation flexibility

KPI ID	KPI-20
KPI name	Hosting Capacity of Electric Vehicles
Description	This KPI intends to measure the contribution of the eDREAM project in increasing the capacity of the distribution network to host EVs. A direct contribution to this KPI could improve the capacity of the network (lines and transformers) or even the allocation of new charging points in the demo area. An indirect contribution can be the management or analysis of information on the use of existing recharge points to characterize the user's behaviour and host more recharging points with the same network capacity. Hosting capacity of electric vehicles will be calculated using the following formula: $$HC_{EV}(\%) = \frac{(HC_{EV})_{eDREAM} - (HC_{EV})_{BAU}}{P_{EV}}$$ Where: • HC_{EV} – represents the sum of the power consumed by the characterized EV charging points in the BAU and eDREAM scenarios • P_{EV} – represents the sum of the installed charging points power
Type of Impact	Power Network Reliability

Related UCs	HL-UC 01
Actors Involved	DSO, DNO, EV fleet manager
Priority	High

Table 44 KPI-20 Hosting Capacity of Electric Vehicles

KPI ID	KPI-21
KPI name	Load Factor
Description	This KPI will estimate whether the grid utilization is at a constant level during the day. Load Factor will be calculated using the following formula: $$LF_{day} = \frac{P_{average}}{P_{max}}$$
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	High

Table 45 KPI-21 Load Factor

KPI ID	KPI-22
KPI name	Price Volatility
Description	This KPI will evaluate the volatility of the prices applied for the consumers.
Type of Impact	Economic
Related UCs	Aggregator, ESCo, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Actors Involved	HL-UC 01, HL-UC 02, HL-UC 03
Priority	Mid

Table 46 KPI-22 Price Volatility

KPI ID	KPI-23
KPI name	Ancillary Services Price
Description	This KPI will evaluate the Ancillary Service Price in order to identify the minimum price acceptable for the Aggregator by using eDREAM solution.
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01, HL-UC 03
Actors Involved	DSO, DNO, Aggregator, ESCo, Prosumer/Producer, Consumer, VPP Energy Manager

Priority	High

Table 47 KPI-23 Ancillary Services Price

KPI ID	KPI-24
KPI name	PHEVs
Description	This KPI will evaluate the percentage of the vehicle's capacity versus the total capacity of the grid.
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01
Actors Involved	EV fleet manager
Priority	High

Table 48 KPI-24 PHEVs

KPI ID	KPI-25
KPI name	Flexibility
Description	This KPI will evaluate the flexibility that aggregators can offer to other market players.
Type of Impact	Power Network Reliability
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	DSO, DNO, Aggregator
Priority	High

Table 49 KPI-25 Flexibility

KPI ID	KPI-26
KPI name	Price Elasticity
Description	This KPI will evaluate the demand reduction due to the energy price variation in a time interval.
Type of Impact	Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, ESCo, Prosumer/Producer, Consumer
Priority	High

Table 50 KPI-26 Price Elasticity

KPI ID	KPI-27
KPI name	Net Economic Benefit
Description	This KPI will evaluate the difference of profits after and before the DR program.

Type of Impact	Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Energy Retailer, DSO, DNO, Distributed Generation Provider, Centralized Generation Provider, Aggregator, ESCo, System Operators, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Priority	High

Table 51 KPI-27 Net Economic Benefit

KPI ID	KPI-28
KPI name	Delay responsiveness of demand shed
Description	This KPI will evaluate the time delay of a 1 or more prosumers to shed is demand/generation during 1 or more DR event.
Type of Impact	Flexibility
Related UCs	HL-UC 01, HL-UC 02
Actors Involved	Aggregator, ESCo, Prosumer/Producer, Consumer
Priority	High

Table 52 KPI-28 Delay responsiveness of demand shed

KPI ID	KPI-29
KPI name	Reducing time of Responsiveness
Description	This KPI will evaluate the average reduction of time responsiveness after a DR signal through smart contracts.
Type of Impact	Digitalization
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, ESCo, Prosumer/Producer, Consumer, VPP Manager
Priority	High

Table 53 KPI-29 Reducing time of Responsiveness

3.2.4 Transmission System Evaluation Metrics

KPI ID	KPI-30
KPI name	Congestion
Description	This KPI will evaluate the congestion occurred in the grid in a given period with the aims to provide useful information to improve the grid sustainability to peaks.
Type of Impact	Power Network Reliability

Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	High

Table 54 KPI-30 Congestion

KPI ID	KPI-31
KPI name	Congestion Cost
Description	This KPI will evaluate the cost of the congestions occurred in the grid in a given period.
Type of Impact	Power Network Reliability, Economic
Related UCs	HL-UC 01
Actors Involved	DSO, DNO
Priority	High

Table 55 KPI-31 Congestion Cost

3.2.5 Renewable Energy Usage Evaluation Metrics

KPI ID	KPI-32
KPI name	Share of electrical energy produced by RES/local generation/ CHP
Description	The use of this KPI will allow to evaluate the shared energy produced by RES. The KPI calculation will take into account the eDREAM scenario and a set of boundary conditions to evaluate the percentage of energy production by RES respect to total energy used/generated. The general identification method is: $$\Delta\lambda = \lambda_{SG} - \lambda_{BL}$$ Where: • λ_{SG} is the share of RES energy in smart-grid situation evaluated in a defined period. • λ_{BL} is the share of RES energy in the baseline scenario over the same period. RES energy shares (%) are calculated as: $$\lambda = 100 (E_{RES}/E_{LOAD})$$ Where: • E_{RES} is the energy generated by RES stations in the defined period; • E_{LOAD} is the total load demand in the same period. KPI expressed in %.
Type of Impact	Environmental
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03

Actors Involved	Aggregator, Prosumer/Producer, VPP Energy Manager, V fleet manager
Priority	High

Table 56 KPI-32 Share of electrical energy produced by RES/local generation/ CHP

KPI ID	KPI-33
KPI name	Residential power sales
Description	This KPI will evaluate the residential sales with respect to total sales with the aims to calculate the increase in the energy injected into the grid by residential prosumers.
Type of Impact	Environmental, Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	DSO, DNO, Aggregator
Priority	Mid

Table 57 KPI-33 Residential power sales

3.2.6 Emissions Evaluation Metrics

KPI ID	KPI-34
KPI name	Reduction of green-house gases emissions
Description	This KPI will evaluate the reduction of equivalent CO_2 due to the DR implementation. $$I_{CO2,reduction}(\Delta t)= \Sigma \Delta I_{CO2}(t)_{\ t\in\Delta t}$$ With: $\Delta I_{CO2}(t)= \Sigma(D_{DR,elec}(t)-D_{baseline,elec}(t))_{\ source\in\{sources\}} * MIX_{source}(t) EF_{source}$ The needed measures and information: • $D_{DR}(t)$: asset real energy demand during DR event, in kW. • $D_{baseline}(t)$: asset baseline energy demand without DR event, in kW. • $MIX_{source}(t)$: proportions of the national electricity mix (index source corresponding to the production sources, as diesel, gas, coal, nuclear, hydropower, wind, solar, etc.) • EF_{source}: emission factors of national production sources and district heating supplier, in kgCO2eq/kWh. The only output data will be: $I_{CO2,eduction}$: Reduction of greenhouse gases emission (negative in case of emission increase), $kgCO_2$.
Type of Impact	Environmental, GHG reduction
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03

Actors Involved	Energy Retailer, DSO, DNO, Distributed Generation Provider, Centralized Generation Provider, Aggregator, ESCo, System Operators, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Priority	High

Table 58 KPI-34 Reduction of green-house gases emissions

KPI ID	KPI-35
KPI name	Reduction of pollutant (NOx, SOx, PM-10) air emissions
Description	This KPI will evaluate the reduction of pollutant due to the DR implementation.
Type of Impact	Environmental
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Energy Retailer, DSO, DNO, Distributed Generation Provider, Centralized Generation Provider, Aggregator, ESCo, System Operators, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Priority	High

Table 59 KPI-35 Reduction of pollutant (NOx, SOx, PM-10) air emissions

3.2.7 Digitalization Evaluation Metrics

KPI ID	KPI-36
KPI name	Automation and control
Description	This KPI will evaluate the improvement in automation and control capabilities able to guarantee a reduction of both the human intervention and the cost of manual operations.
Type of Impact	Economic, Network Operations
Related UCs	HL-UC 01, HL-UC 03
Actors Involved	DSO, DNO, Aggregator, VPP Energy Manager
Priority	Mid

Table 60 KPI-36 Automation and control

KPI ID	KPI-37
KPI name	Demand Response service costs
Description	This indicator evaluates the cost of eDREAM DR service per Prosumer respect the previous situation (Different DR program or not presence of DR program). In this case, the indicator is the following: $\Delta C = C_{\mathrm{eDREAM}} - C_{\mathrm{BAU}}$ $\Delta C\% = ((C_{\mathrm{eDREAM}} - C_{\mathrm{BAU}}) / C_{\mathrm{BAU}}) \times 100$ [%]

	Where: • C is the Cost (OPEX and/or CAPEX) • BAU indicate the Business As Usual Scenario.
Type of Impact	Economic
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, ESCo, Prosumer/Producer, Consumer,
Priority	High

Table 61 KPI-37 Demand Response service costs

KPI ID	KPI-38
KPI name	Increasing of Customers Responsiveness
Description	This KPI will evaluate the difference of number of customers that have responded to a DR program following a DR signal through smart contracts.
Type of Impact	Digitalization
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Aggregator, ESCo, Prosumer/Producer, Consumer, VPP Manager
Priority	High

Table 62 KPI-38 Increasing of Customers Responsiveness

KPI ID	KPI-39
KPI name	Service Acceptance
Description	For each eDREAM platform service, this KPI will evaluate the percentage of service acceptance through the user acceptance test and the calculation of the rate of participation.
Type of Impact	Digitalization
Related UCs	HL-UC 01, HL-UC 02, HL-UC 03
Actors Involved	Energy Retailer, DSO, DNO, Distributed Generation Provider, Centralized Generation Provider, Aggregator, ESCo, System Operators, EV fleet manager, Prosumer/Producer, Consumer, VPP Energy Manager
Priority	High

Table 63 KPI-39 Service Acceptance

3.3 User acceptance evaluation Models and Techniques

One of the most cited models for the evaluation of user satisfaction and user acceptance is the Technology Acceptance Model (TAM) [14]. The TAM was effectively developed by Davis in the 1993 [15] to explain computer-usage behaviour and is based on the Theory of Reasoned Action (TRA) [16] defined by Fishbein and Ajzen.

The TAM model defines how users come to accept and use a specific technology. The model aims to define a number of factors that influence the users' decision about how and when they will use a new particular software.

A key objective of TAM model is to act as a basis for tracing the impact of external variables on internal beliefs, attitudes and intentions. The model suggests that perceived usefulness (PU) and perceived ease of use (PEOU) are the two most important factors in explaining system use, defining them as follows:

- Perceived Usefulness (PU): the degree to which a person believes that using a particular system would enhance his or her job performance;
- Perceived ease-of-use (PEOU): the degree to which a person believes that using a particular system would be free from effort.

The PU can be measured by using tools to measure different aspects on which the application can affect, such as: (1) increase in productivity, (2) increase in job performance, (3) enhancement of the effectiveness on the job and (4) overall usefulness of the application for the job. Also, the PEOU can be measured by using tools to measure different aspects such as: (1) ease in learning to use the application, (2) ease of use of the application to do what I would like to do, (3) flexibility in using the application and (4) overall ease of use of the application.

PU and PEOU contribute to the definition of the Attitude towards usage (henceforth indicated with A) by the users. According to Davis [15], A is defined as "the degree to which an individual evaluates and associated the target system with his or her job".

As can be seen from the original TAM model reported in Figure 7, A will have a significant influence on users' Behavioural Intention (BI) to use a system, for example the eDREAM system, which is defined as the degree to which a person has formulated conscious plans to perform or not perform some specified future behaviour.

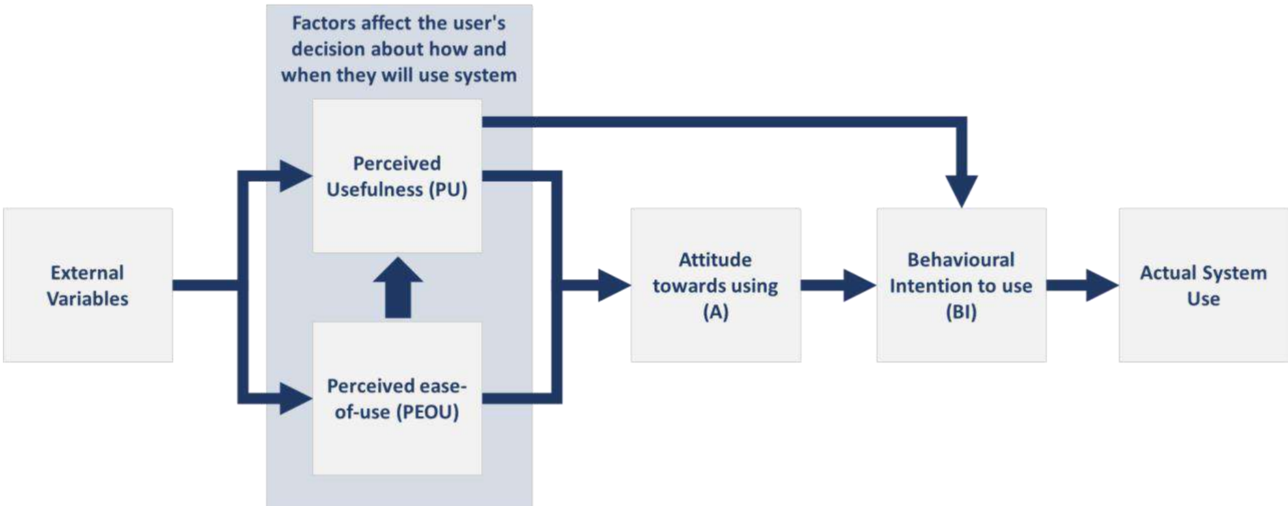

Figure 7 Original Technology Acceptance Model [17]

The PEOU affects perceived usefulness and both variables are significant predictive factors of A. The more positive are the perceived ease of use and perceived usefulness of the system, the greater the probability of actually using the system.

PEOU has a small significant effect on behaviour, which will later fade over time. The influence of the perceived ease of use is less profound towards behaviour than perceived usefulness.

PU has a direct effect on behavioural intentions beyond its effect on attitude. Usefulness is far more important than ease of use in predicting the use of the system. Usefulness is responsible for maximum influence on people's intention. Furthermore, a user can adopt a technology if such adoption is considered convenient, useful and socially desirable, even if the user does not like to use technology. Thus, there may be a possibility of a direct relationship between beliefs and intentions.

The A is defined as the positive or negative feeling of an individual on performing the target behaviour. The A-BI relationship represented in the TAM theory implies that, all else being equal, people form the intentions to perform a behaviour toward which they have a positive effect. The A-BI relationship is adopted by the theory of reasoned action according to which attitudes develop in a reasonable manner from the belief that people hold onto the object of attitude and belief connects behaviour to a certain result or to other attributes such as the cost incurred by the execution of the behaviour. A has been identified as a factor that drives future behaviour or the cause of intention that eventually leads to a particular behaviour influencing the actual use or acceptance of the technology.

In application contexts that involve stakeholders such as the actors involved in the eDREAM project use cases, a system can be considered accepted only if both individuals and organizations have accepted the new technologies also continuing to use the system over time. This is why it is important to acquire data on convictions, intentions, strategies, management policies and opinions both at the managerial or organizational level and at an individual level.

In general, the adoption of the system depends on how much the variables PU and PEOU affect the A, considering all the levels of the company in case of business contexts, as presented in Figure 8.

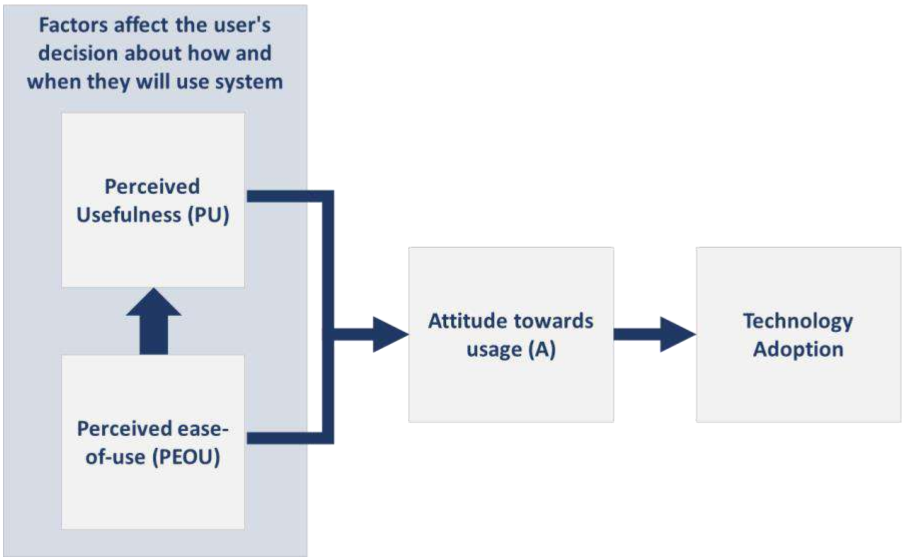

Figure 8 Technology Acceptance Model for technology adoption [17]

In a context of the eDREAM project linked directly to DR management and Smart Grids whose awareness is still not widely diffused today, it is crucial to validate the solution through significant actions aimed at increasing user acceptance. Different barriers affect the user acceptance of this type of solution delaying the diffusion of the relative products and services essentially due to the expensiveness of the solutions and the perception that the real energy savings achieved would be small. It follows that one of the factors to be taken into greater consideration is the ability to create in the user the perception of a real economic advantage due to the use of the solution.

Perceived perception, ease-of-use and intention to use have strong interrelations and it is important to increase the end-user's perception of the utility and ease-of-use of the solution in relation to intelligent network to improve end-user participation. The availability of an effective and easy-to-use technology able to guarantee convenient incentive for consumers improving the perceived energy and cost savings, the environmental compatibility of the solution and its capacity to ensure the security of the exchanged information, are some of the most important factors to motivate the end users to adopt the new technologies. They will be taken into consideration for the construction of specific questionnaires based on TAM model to validate the eDREAM solution through the participation of the end user.

4 Planification for use cases validation

4.1 Use cases preparation for validation

In order to validate the three scenarios and the associated use cases identified within the final version of the deliverable related to the activities of T2.2 (deliverable D2.9), some preparatory activities have been started and are foreseen in the next months. At the beginning of the following sub-paragraph each scenario will be summarized; consequently, the preparation for test and validation of each Use Case (UC) will be presented. The Use Cases will be prepared and validated as follow:

1. UCs related the “Prosumer DR flexibility aggregation via smart contracts” scenario will be validated in the ASM Terni living lab;
2. UCs related the “Peer-to-peer local energy trading market” will be validated in the CERTH demo laboratory;
3. UCs related the “VPP in Energy Community” scenario will be validated in the Kiwi real site.

Finally, in the last sub-paragraph of this section, the preliminary availability of the existing infrastructures will be illustrated with particular reference to the specific equipment or components which will be used.

4.1.1 Brief Overview of eDREAM Scenarios

The main goal of the eDREAM project context is to change the traditional energy processes into a decentralized ecosystem. Even if in a decentralized condition the DSO will maintain a balance of supply, it will achieve the target of reducing the overloading and it will reach power network stability by means of the flexibility provided by active microgrids.

The local DSO in Terni (ASM Terni) will be the Italian field pilot to test and validate the first scenario: “Prosumer DR flexibility aggregation via smart contracts” (HL-UC 01). Concerning this scenario, all the prosumers, within an active microgrid, are able to offer their energy flexibility, through the use of self-enforcing smart contracts and direct injection of DR signal curves. They can be involved directly or via enabling aggregators. In addition, Emotion (EVs and charging stations manager), acting as aggregator of prosumers owning EVs, will be involved in DR campaigns, providing energy flexibility via EV charging.

The CERTH/ITI Smart House will be the testing ground for the second scenario Peer-to-peer local energy trading market” (HL-UC 02). As a prosumer, the CERTH/ITI Smart House will be considered as one of the peers that will exchange/trade energy in the peer-to-peer fashion with other simulated prosumers.

At Kiwi Power real site, the third scenario, "VPP in Energy Community" (HL-UC 03), will be tested and validated. In this scenario, a large set of customers, prosumers and producers are gathered and connected in an Energy Community in order to achieve self-sufficiency and potentially export power surplus or ancillaries to the grid. An aggregator coordinates the active and passive users participating in this community. In such a scenario, an internal under-generation from RES – due to sudden weather changes – will force controllable community's generators to overproduce in order to cover RES drop. On the other hand, passive users may reduce their loads if necessary. In particular, the aggregator or VPP energy manager assesses the potential of the managed resources, analysing prosumers' profiles, enabling the participants to use reserve and/or frequency services. After the assignment of different prosumers in VPP to a specific profile pattern, export capacity forecast is applied to a trading strategy which maintains a day-ahead schedule, as well as offers capacity to the imbalance market.

4.1.2 Trial Site Setup for Validation

4.1.2.1 HL-UC 01 Prosumer DR flexibility aggregation via smart contracts

The trial site is a part of the distribution power network of the city of Terni, which is owned and managed by ASM Terni. It is considered as an active decentralized microgrid in which the power network is connected to the HV grid through three substations. There are also six MV/MV substations and more than six hundred MV/LV substations, supplying about sixty-five thousand energy customers. The DSO in Terni is responsible for the distribution network planning and development. Up to now, it guarantees the safe and secure operation and management of the distribution system; moreover, the DSO is the entity responsible for data management associated with the use of distribution system and procurement of flexibility services. In other words, the DSO will be able to guarantee stable and secure smart grid and quality of the services provided. In order to prepare the trial preparation and validation, eDREAM project will be carried out at the ASM headquarters. The headquarters comprise of five blocks of energy units connected to the Low Voltage (LV) network and different units, notably:

- Two PV arrays (180 kWp and 60 kWp);
- 72 kWh 2nd life Li-ion battery energy storage. An innovative unit, able to be charged and discharged depending on the excess of local energy production. The Battery storage is the Block of Energy Unit (BoEU) providing the service of electric power storage and supply. This BoEU plays an important role since it provides the flexibility necessary to the district for implementation of the different services, especially ancillary services like Primary reserve, Dynamic reactive Power control and Reactive Power Compensation. From one side, this block can be seen as an energy generation unit and as a flexible load during the charging phase with the possibility to control the demand profile;
- ASM Terni buildings comprising i) a 4,050 m^2 three-storey office building; ii) a 2,790 m^2 single-storey building consisting of technical offices, a computer centre and an operation control centre and iii) a 1,350 m^2 warehouse. Usually the base load of these buildings varies between 50 kW and 90 kW and peak load is between 120 kW and 170 kW, depending on seasonal factors. The main building has an HVAC system that can be remotely controlled by automatically setting set points of different zones of the offices;
- Three smart charging stations, developed, monitored and managed by Emotion, and six EVs (two Nissan Leaf and four Renault Zoe), deployed and monitored by Emotion.

Italian pilot site infrastructure is depicted in Figure 9:

Figure 9 Italy, Terni trial site (current situation): Electric Vehicle Supply Equipment; Storage System; PV Array 60 kWp; PV Array 180 kWp; ASM Terni buildings

4.1.2.2 HL-UC 02 Peer-to-peer local energy trading market

For the second scenario, the physical infrastructure that will act as a real player to the energy peer-to-peer energy trading is the CERTH/ITI Smart House at CERTH premises at Thessaloniki, Greece. Consisting of a ~320m^2 building that can emulate real household loads and conditions as an actual prosumer. Providing services that can offer increase/decrease in both consumption and generation, including storage, it can support multiple scenarios for the peer-to-peer energy trading use cases.

The CERTH/ITI Smart House comprises of i) around 70kW nominal installed load, from which regular use is around 8-9kW and includes HVAC, Lighting, Home and Office Appliances, ii) 9,57 kWp thin film CIS PV installation which is divided in 9 DC strings, combined in two MPPT inputs on a 10kW inverter, and iii) a 5kWh Li-on battery, creating a fully functional microgrid.

Figure 10 CERTH/ITI Smart House

4.1.2.3 HL-UC 03 VPP in Energy Community

For the trial site of HL-UC 03 Kiwi will make use of its active portfolio of clients to create the equivalent of a VPP. A virtual portfolio will be created based on anonymized data sets with real data from commercial and industrial users and up to 100 residential users. The residential properties are taking part on a trial that Kiwi Power is running in partnership with the Greenwich Council, to explore the potential of residential DSR through user engagement via a mobile app. With this purpose, more than 60 smart electricity meters were installed across the Greenwich borough of London. However, at the moment only 20 of these properties are providing data to Kiwi's centralized infrastructure. Re-engagement activities have been planned and will start as soon as it is possible to try increasing this participation.

The data collection infrastructure and integration with Kiwi Power's Operations Management Platform (KOMP)s, for the residential users taking part is depicted in Figure 11:

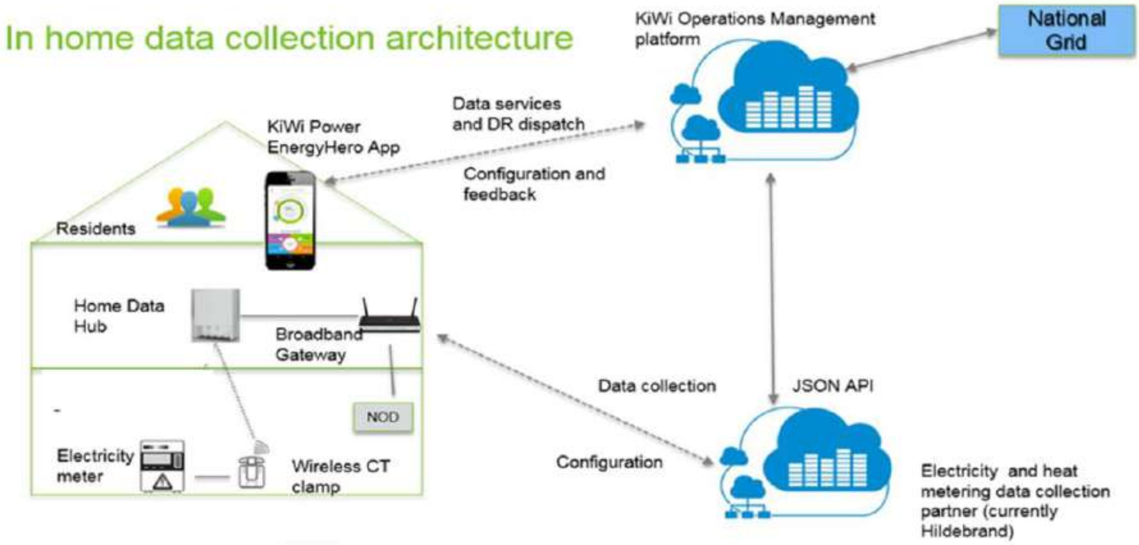

Figure 11 Kiwi Power's data collection infrastructure and operations management platform

Currently, the users are involved via a mobile app co-designed with the residents. The Greenwich Energy Hero App [36] provides residents with near real time data about their energy consumption, historical charts, peer comparison with similar groups and a mean to participate to DSR events triggered via personalized notifications. By accepting the events and taking actions to reduce energy consumption from short periods, participants can earn points which they can either transfer into money for their own personal benefits or can be donated to a short list of local charities, in which case the funds are matched by the local council. These tools enable Kiwi to explore consumers' attitudes towards peak loads reduction and potentially helping the eDREAM team to us understand how to structure DSR programs and rewards aimed at this market segment.

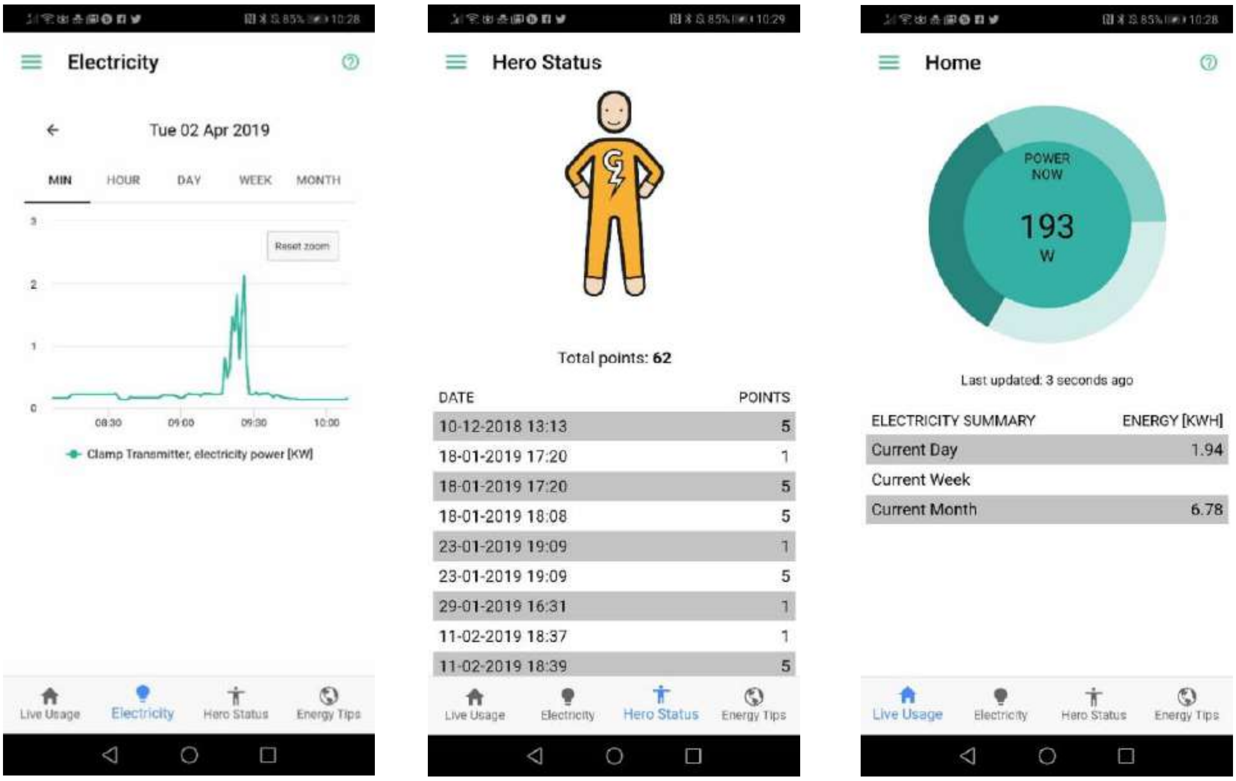

Figure 12 Greenwich Energy Hero App GUI

The commercial and industrial sites providing anonymized data for the Energy Community portfolio are all fitted with Kiwi's edge equipment (named Fruit) capable of providing second by second power, frequency and energy metering and control over the assets.

4.1.3 Description of Existing technologies / infrastructures and additional components / equipment

4.1.3.1 HL-UC 01 Prosumer DR flexibility aggregation via smart contracts

As to the DSO's infrastructures and equipment, at the moment almost all the electricity customers have installed smart meters in their premises, which generate data every 15 minutes. Based on the installed power capacity, different models of Landis+Gyr SMs have been chosen by ASM, as follows:

- Smart meter with PLC (Power Line Communication): for LV users with an installed power capacity ≤30kW;
- GME for LV (GSM/GPRS communication) ≥ 30kW;
- GME for MV customers (GSM/GPRS communication);
- Smart Meter Extension (SMX) devices, 200 units deployed over the Nobel GRID project [18].

Moreover, in some critical points of the power network ASM TERNI has installed a certain number of new generation Smart Meters able to get real-time measurements and support real-time operations in a Smart Grid (class A power quality analyzer - a 3-phase high-precision analyzer and recorder, power quality, power meter, fault recorder and energy meter). It is a three-phase high-precision power quality analyzer compliant to Class A, according to IEC61000-4-30 [37], and Class 0.2S for energy metering. It is capable of measuring the following parameters: voltages and currents; active, reactive and apparent power; active and reactive (4 quadrants) energy; power factor; frequency, flicker (Perception of flicker short term - PST and Perception of flicker long term - PLT); voltage and current harmonics and interharmonics (up to 50° order); voltage unbalance; voltage dips and swells; voltage interruptions (short and long); rapid voltage changes and waveforms (window records with programmable pre and post-triggers).

Nowadays, the ASM network shows relevant features of the “smart grid” since 99% of customers have a smart meter which is managed remotely by an Advanced Metering Infrastructure (AMI). Terni will use an advanced metering infrastructure for near real time monitoring for power network optimisation.

In order to manage time-based data from smart meters, an Advanced Metering Infrastructure (AMI) has been put in place, allowing to turn power on or off to a customer remotely, read usage information from a meter, detect a service outage, change the maximum amount of electricity that a customer may demand at any time, detect "unauthorized" use of electricity and shut it off remotely, and change the meter billing plan remotely. ASM is currently using two different channels for the collection of data from the installed meters; one is exclusively used for the Point of Delivery (PoD) for customers with power installation up to 30 kW and the other for power consumption greater than 30 kW. Data related to the first channel are addressed via PLC; these are temporarily stored in an Electric energy meter concentrator (about one for each 400 meters), extracted and transmitted via GPRS network towards dedicated servers. Data related to the second channel are extracted and transmitted via GSM/GPRS; these are transmitted to a meter data management software and analyzed with the aim to verify any problem in data transmission and finally temporarily stored in the ASM’s server for at least five years.

On the other hand, the whole Medium Voltage (MV) network is under the control of a SCADA system able to:

- Communicate with the calculation platform which hosts all algorithms for status analysis, power flow calculation and voltage regulation;
- Receive and send information from/to the Main Station equipment;
- Receive and send information from/to the Substation equipment;
- Carry out the anti-islanding function and, when needed, send disconnection requests to the Main Station equipment.

Remote Control System staff is using the Operator Terminals to display the grid (status and measurements), interact with it (controls and commands) and manage abnormal situations (alarms) by means of a Human-Machine Interface (HMI).

However, the Smart Meter Extension (SMX) device (a result of Nobel GRID project [18]) is dedicated to create a link between SMs and the external world, since it is able to communicate with different protocols (e.g. DLMS, OpenADR, IEC61850) and compliant with different interfaces (e.g. USB, RS-232, RS-485). SMXs enables the measurement of all the data gathered by the meter through digital signals. Concerning hardware, the power requirement needs are 0.5 A 5 V DC. The data connections are available by means of 3G sim, Ethernet, Internet protocol, Supporting VPN and the format are only in .txt or .json. The data availability in real time (5s delay) have a dimension of 1 MB/day and a transmission frequency every 5 seconds.

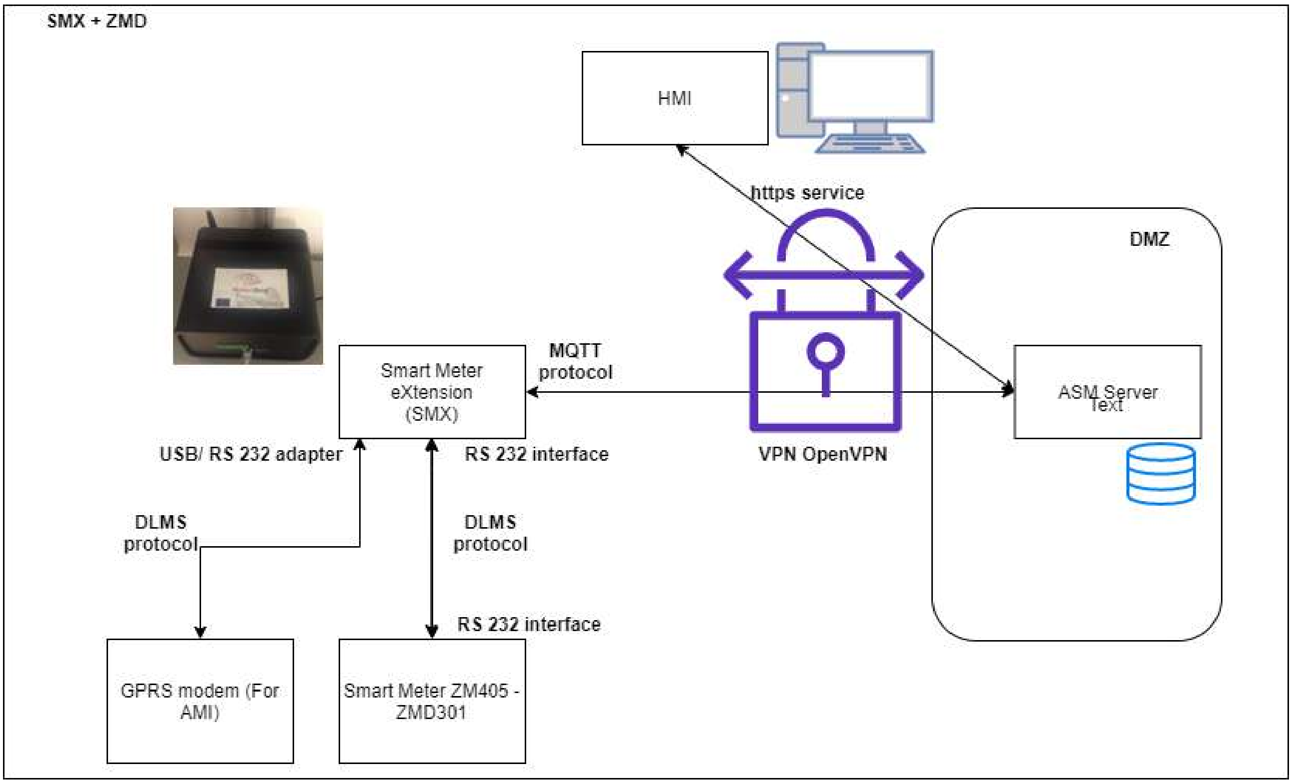

Figure 13 Schema of data gathering through SMX meter in ASM pilot site

Concerning eMobility, three smart charging stations will be involved in the Italian pilot site, 22 kW each (SpotLink EVO), developed by Emotion.

Figure 14 SpotLink EVO smart charging stations

The SpotLink EVO charging station with 2 type 2 sockets, recharges up to 32 A for each socket. Each station has IP54 protection grade, impact resistance IK08 and the protection system differential type A and type B, with an automatic unlocking of the connector in case of power failure. The charging stations are equipped with a single-board computer that allows real-time monitoring and remote management such as power output modulation and remote charging session start/stop.

Figure 15 Raspberry Pi 3 installed inside SpotLink EVO

SpotLink EVO exchanges data through a Teltonika RUT230 modem connected to a single-board computer, a Raspberry Pi 3, with a CPU of quad-core ARM Cortex A53 1.2 GHz, SD of 16 GB, RAM of 1 GB and a Raspbian Stretch 4.14 S.O. Charging station protocols are OCPP (application protocol for communication between charging stations and EMOT central management system) and websocket (computer communications protocol, providing full-duplex communication channels over a single TCP connection). EMOT OCPP server accepts communications and data exchange only with the client program that is installed in the charging station computer. The client has an authentication key that is assigned by the EMOT management software when creating a new charging station (when a new record is created in the charging station table, in EMOT database). The OCPP server accepts the connection by the client only and exclusively if a valid authentication key is used at the time of the request. Charging station data format is JSON and the sampling rate is one second.

Regarding electric vehicles, two models will be used: Renault ZOE and Nissan LEAF. Renault ZOE, acronym of ZerO Emissions, is a five-door supermini electric car produced by the French manufacturer Renault. The ZOE is powered by a 22 kWh lithium-ion battery pack weighing 275 kg, driving a 65 kW (87 bhp; 88 PS) synchronous electric motor supplied by Continental (the Q210). Maximum torque is 220 N·m (162 lb-ft) with a top speed of 135 km/h (84 mph). The NEDC cycle range is 210 km (130 mi). Renault estimates that in suburban use, the ZOE can achieve around 100 km (62 mi) in cold weather and 150 km (93 mi) in temperate conditions. The car features a charging system called "Caméléon" (Chameleon) charger that allows ZOE to be charged at any level of power, taking between 30 minutes and nine hours [34]. The Nissan LEAF, acronym of Leading, Environmentally Friendly, Affordable, Family car, is an electric propulsion car introduced by Nissan on the markets in December 2010. It is equipped with an 80 kW (109 hp) synchronous AC electric motor. The first version equipped a lithium-ion battery, consisting of 48 modules and each of them contains 4 cells for a total of 192, with a capacity of 24 kWh with an autonomy of 199 km NEDC cycle. Since 2016, a 30 kWh Lithium-ion battery with an operating cycle of 250 km NEDC is available as an accessory. Nissan LEAF recharges in alternating current or in direct current. In AC, LEAF uses an on-board charger with a maximum 7.4 kW (32A maximum current, 230V, single-phase) with the Type 2 socket. In DC it uses the CHAdeMO standard up to 50 kW of power. Charging times vary from 5/6 hours at about 7 kW down to 1 hour with direct current charging [35].

Figure 16 EVs parked at ASM headquarters

With respect to EV monitoring, Emotion uses an on-board diagnostic (OBD) device to retrieve data from the EV. OBD is an IoT component, based on a Raspberry Pi 3 and Carberry. Carberry represents the link between car electronics and Raspberry Pi, which allows the development of end-user applications, such as media centres, vehicle diagnostics, data logging, fleet management, tracking, black boxes, burglar alarms, carpeting, internet, and much more. OBD utilizes a TCP/IP communication to a TCP/IP server. The network connectivity of the OBD device is via data SIM (UMTS), thanks to a Raspberry module that works as a modem, and the server is a python software. OBD protocol is MQTT and the sampling rate is 5 seconds. The OBD connects to the diagnostic interface from which it is able to extract the information from the electric vehicle control unit using the CAN-bus protocol. The output data format of the OBD is an ASCII string. When the data is sent to the server, it is reorganized into a wrapper, thus obtaining a grouping of the data in JSON format.

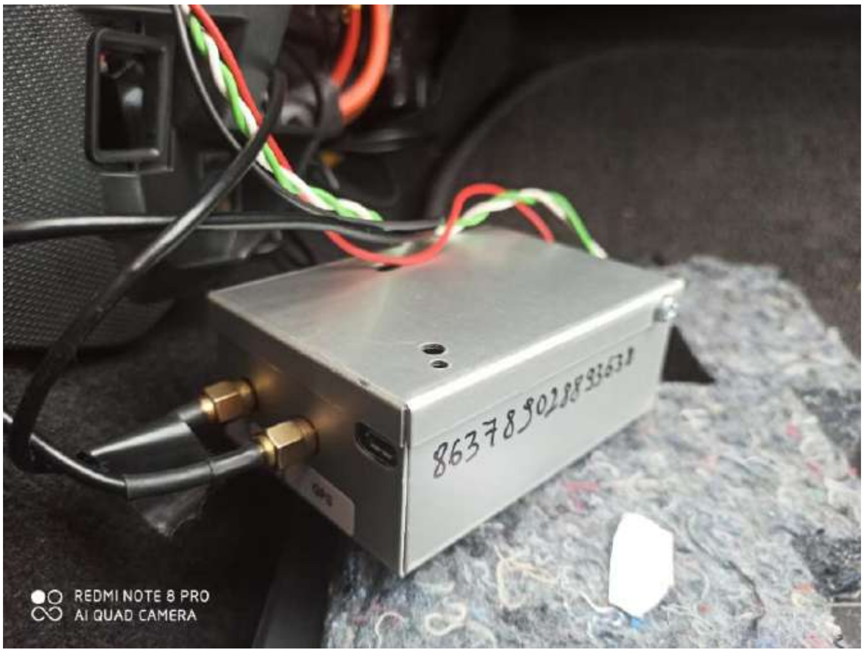

Figure 17 On-board diagnostic device (OBD) installed in EVs deployed on the Italian pilot site

Emotion smart charging stations and electric vehicles send data to a virtual private server (VPS) whose details are:

- CPU: 2 core 3.1 GHz;
- HDD: 50 GB;
- RAM: 4 GB;
- S.O.: Ubuntu 16.04 LTS.

Into Emotion VPS run the EV Wrapper Server, OCPP server and API REST, as shown in Figure 18 .

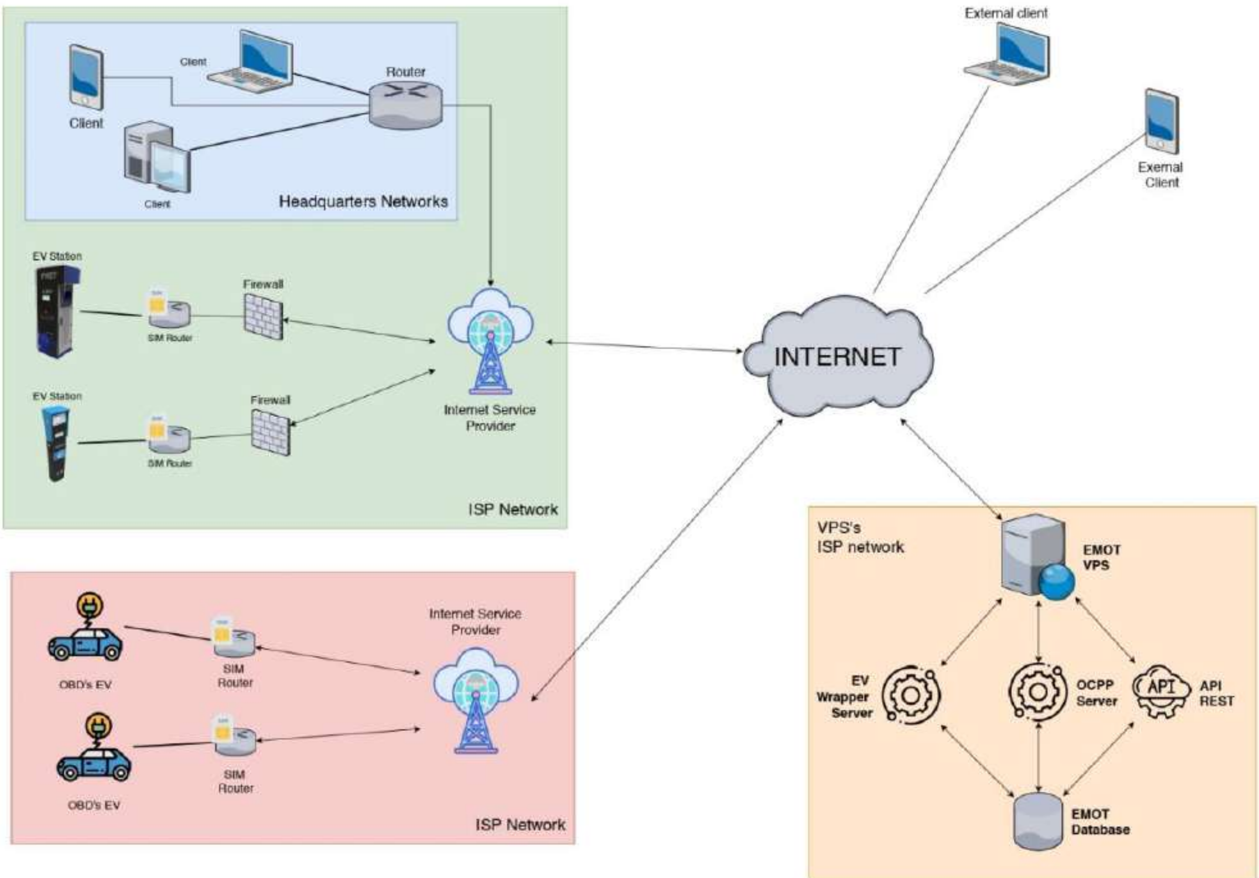

Figure 18 Electric vehicles and charging stations network topology

4.1.3.2 HL-UC 02 Peer-to-peer local energy trading market

For the second scenario, and at client level, the CERTH/ITI Smart House is equipped with multiple smart meters and actuators to support full monitoring and control. A flexible and adaptive BMS is able to coordinate the building operation, offering a variety of solutions from simple scheduling to optimized management based on AI algorithms for forecasting consumption/production. The infrastructure is equipped and integrated with multiple wireless and wired protocols such as ZigBee, Z-wave, BLE, Wi-Fi, EnOcean, Modbus, BACnet, and many more.

The BMS supports Web Services in order to retrieve or send data from the infrastructure towards seamless integration to the overall eDream framework (including the trading platform).

4.1.3.3 HL-UC 03 VPP in Energy Community

At Kiwi portfolio sites, the metering and control of assets is performed via Kiwi's proprietary edge equipment called Fruit. Fruit is Kiwi's third generation IoT platform, used to monitor and control an electrical asset. The Fruit is an innovative and low-cost device which is installed at the customer's site and provides a range of metering and control functions (Figure 19). The device is integrated with the Kiwi KOMP and provides dashboard information on energy usage and asset control options as well as the event status of distributed energy resources.

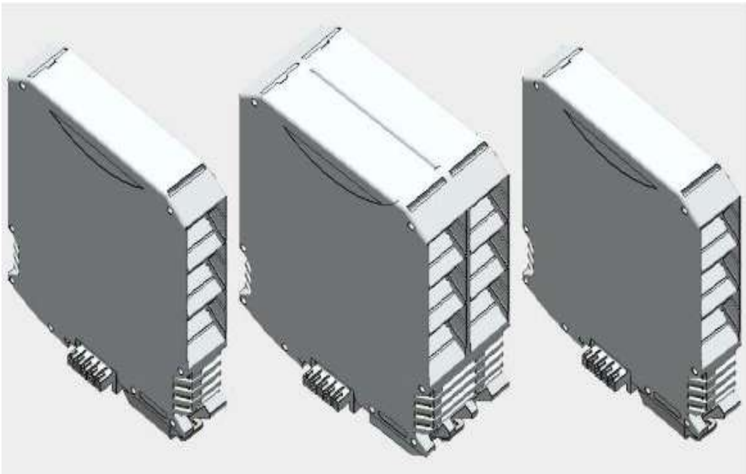

Figure 19 Fruit modular configuration allows for deployment of specific functionality

Kiwi Fruit is a modular solution, which means we only deploy the functionality needed on each site, thus saving engineering time and money. Each deployment will include a Core module, which provides communication and dispatch capabilities, plus pulse measurement temperature/humidity sensors and general-purpose IO and a number of communication options (Wi-Fi, Ethernet). Additional "Segments" can be attached to the Core using a common DIN-rail bus interface, to provide further functionality such as metering, custom communications interfaces and battery back-up (Figure 20).

Metering Segment

On-board connectors:

3 × Live Voltage Inputs
3 × CT inputs
1 × TBus (Core interface)

Supported functionality

1. Total and per phase active and reactive energy
2. Total and per phase current and voltage
3. Total and per phase active and reactive power
4. Frequency

Core Segment

On-board connectors:

2 × Single Pole Dual Throw High Capacity Relay
3 × Pulse inputs (Darlington Output Optocouplers)
1 × RS232 OR 1 × RS485
1 × Digital Input
1 × Ethernet (KOMP via Electric Imp cloud)
1 × Ethernet (Modbus TCP)
1 × Wi-Fi (on-board antenna + external connector)

Supported functionality

1. Dispatch via Relay OR via Modbus TCP OR via Modbus RTU (over RS232 OR RS485)
2. Metering via pulse counting OR via Modbus TCP
3. Monitor temperature and humidity via built-in sensor
4 Status LED (shows uplink connection, server connection, indicates dispatch mode, etc.)

Analogue Segment

On-board connectors:

4 × configurable analogue inputs (0–10V or 4–20mA)
4 × configurable analogue outputs (0–10V or 4–20mA)

Supported functionality

Interface with a range of proprietary controllers and BMS equipment that support analogue input

Figure 20 Kiwi Fruit main functionality

Key features of Fruit include:

- **Low cost:** The high cost of metering and control hardware platform is one of the key challenges in the current market. To move to a smart grid, we need visibility on the asset level and hence there is a higher need for the IoT platform to be connected to an individual asset. These platforms traditionally are costly. This was a good opportunity for Kiwi to design a new platform that cost almost 10 times less than the available solutions on the market. This is done by optimising the second-generation platform and using segmented design, so we only deploy the required functionality.
- **Ease of installation:** Fruit has been designed to minimise installation costs due to its compact form-factor and convenient DIN-rail mounting. It is also equipped with wide-ranging power supply inputs, and has the facility to use pre-wired terminal blocks to avoid time-consuming on-site wiring. Fruit is also equipped with a multi-function status LED, which provides clear visual feedback on the progress of the commissioning process.
- **Security:** Fruit uses an Electric Imp module to provide Wi-Fi connection and local computational capability that connects to the cloud server to communicate with Kiwi's software platform. Electric Imp provides very high levels of cyber/data security. This is achieved through state-of-the-art communication encryption, secure boot to prevent local tampering, and application-code virtualisation to allow transparent and continual firmware. It also includes a door-sensor input for enhanced physical security. Electric Imp is the world's only IoT platform UL Certified for IoT Security. This minimises the work necessary for Kiwi to secure the IoT platform and hence lowers the cost and increases the scalability as well.
- **Real-time data and event processing:** The accuracy of metering and dispatch of frequency response programmes have always been one of the main concerns. Kiwi's IoT platform is able to measure the reading and react in as fast as 2 seconds in frequency response programmes. The resolution is predicted to be even less, up to sub-seconds, in future programmes (example: frequency response programmes in the UK). The platform can measure and react to events in less than 50 ms.
- **Supporting future markets:** Fruit can measure voltage, reactive power, inertia of an asset or LV feeders (using sensors). This would make it suitable for voltage response or inertia programmes, and could also be used for LV network monitoring.
- **Integration with third party controllers:** Fruit is able to communicate with generators, building management systems, SCADA systems, HVAC, pumps, Energy Storage Systems and other assets, using connections such as RJ45, RS232, RS485, Modbus and volt-free contacts. Provision for USB connectivity also exists. Alongside integration with PureDrive Energy Storage System controller, Fruit was also used to deliver flexibility services with systems supplied by NEC, Tesla, Yuassa and Riello among others.

Asset-specific parameters such as fuel level, state of charge or generator fault diagnostics such as short circuits, RoCoF, etc. can be monitored by Fruit via existing mechanisms such as Modbus, volt-free inputs or analogue inputs as necessary. This data can be sent upstream as appropriate for monitoring within the CCF.

Fruit is an approved metering device by National Grid for STOR and frequency programmes and also approved by EMRS for Capacity Market.

4.2 Plan for verification and validation of the eDREAM components via use cases

Once defined the eDREAM use cases, the environments in which they will be deployed and the deployment modalities, in this paragraph the validation plan guideline of the eDREAM components and use cases will be defined. The validation plan is designed to prescribe the scope, approach and resources of all validation activities. In general, the validation plan is based on the following information:

- **Specification:** Brief description of the function/hardware, explaining its main functionalities, the system and functionality requirements in relation to the specific use case and the I/O specifications. The specified I/O could be the conditions of the exchanged data, in case of software applications, but also physical interconnections, when needed.
- **Validation methods**: Methods to be used to validate the system that will serve as a base to analyse which additional tests will be required to minimize risks, increase the Technology Readiness Level and support the future decisions of the development team to improve and assure a successful technology deployment on the demo sites. A high-level testing approach will be used to validate the whole system functionalities. These could be validated through the use of simulations, unit tests, experimental activities in the laboratory etc. in order to verify the functionalities thanks also to the KPIs evaluation and user involvement.
- **Validation protocol**: Explanation of the validation protocol, which constitutes of different pass/fails criteria and validation setup and procedure, characterizing how the validation results are evaluated.

In particular, for the eDREAM platform, with the aims to validate the system and functional requirements, the use cases will be represented as a sequence of states in order to simplify the evaluation of the system compliance with the defined requirements, linking requirements to test cases, and assessing the impact of requirement changes. For each component involved in the specific use case, the functionalities and the compliance with the requirements will be verified in order to check if there are any functional or communication defects.

After this verification and after the integration process and the subsequent deployment of the eDREAM solution on the trial site, the overall functionality of the system will be verified through the use of the defined KPIs and user involvement techniques in order to acquire the information necessary to carry out the refinement of the deployed solution, repeating this step until the objectives that will be set for each KPI and for user acceptance will be achieved. In parallel, actions to verify that the system satisfies the standards, policies, practices, procedures, and conventions will be done taking into account the different jurisdictions, for example, national, provincial and local authorities.

In particular for security and privacy requirements, both the problems related to the use of data from smart meters and the bidirectional communication between different actors will be taken into account. A set of security and privacy goals for eDREAM system will be defined, identifying appropriate and realistic adversary models to analyse the system in terms of the security and privacy goals.

The flow of all the actions that are part of the updated and consolidated eDREAM validation plan (with reference to what is defined in D7.1) is shown in the Figure 21.

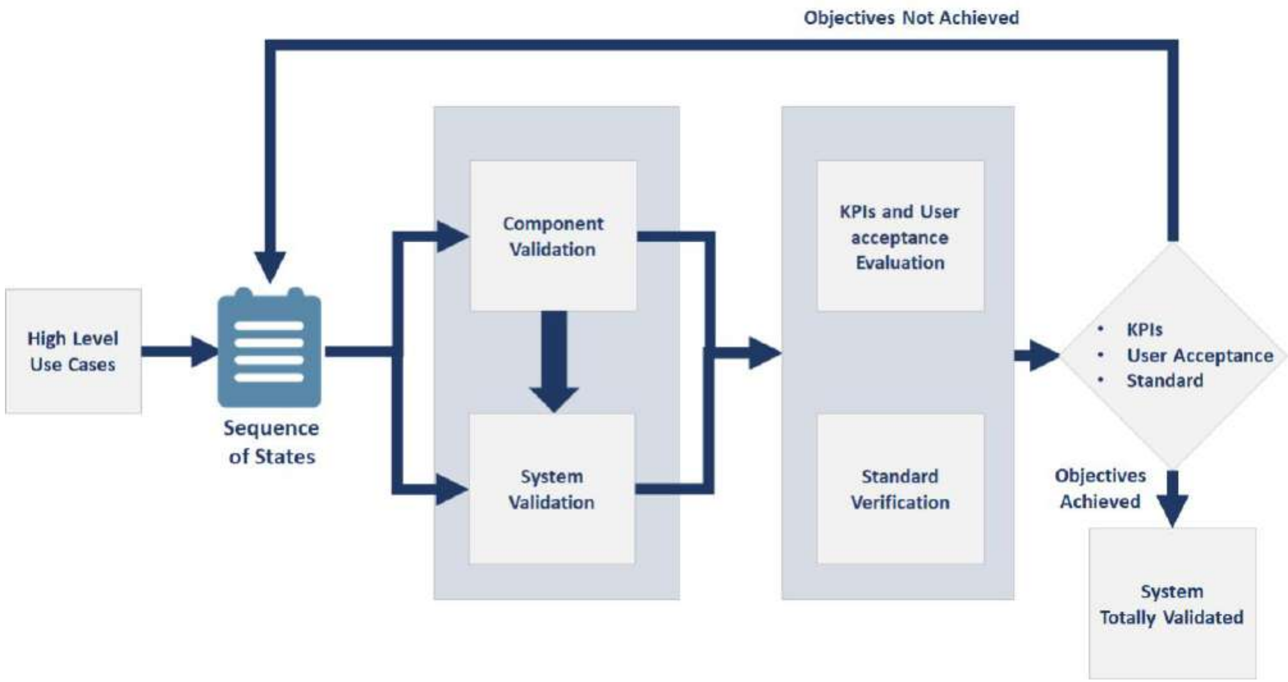

Figure 21 eDREAM consolidated Validation Plan Flow

On the basis of the actions defined in the updated and consolidated eDREAM Validation Plan, the scheduling of these activities has been defined as shown in Figure 22 and Figure 23 which respectively represent: (1) The definition of the time needed to implement each operation of the validation plan flow and (2) the validation plan timeline.

In this regard, it should be noted that the timeline is still temporary and will be updated as soon as the already requested 6-months of project extensions to recover the time lost due to the spread of COVID19 in Europe will be granted. In particular, the activities related to the technical and performance validation and the verification of the compatibility with the user's requirements will be extended until the month 42 instead of month 36 as still currently envisaged.

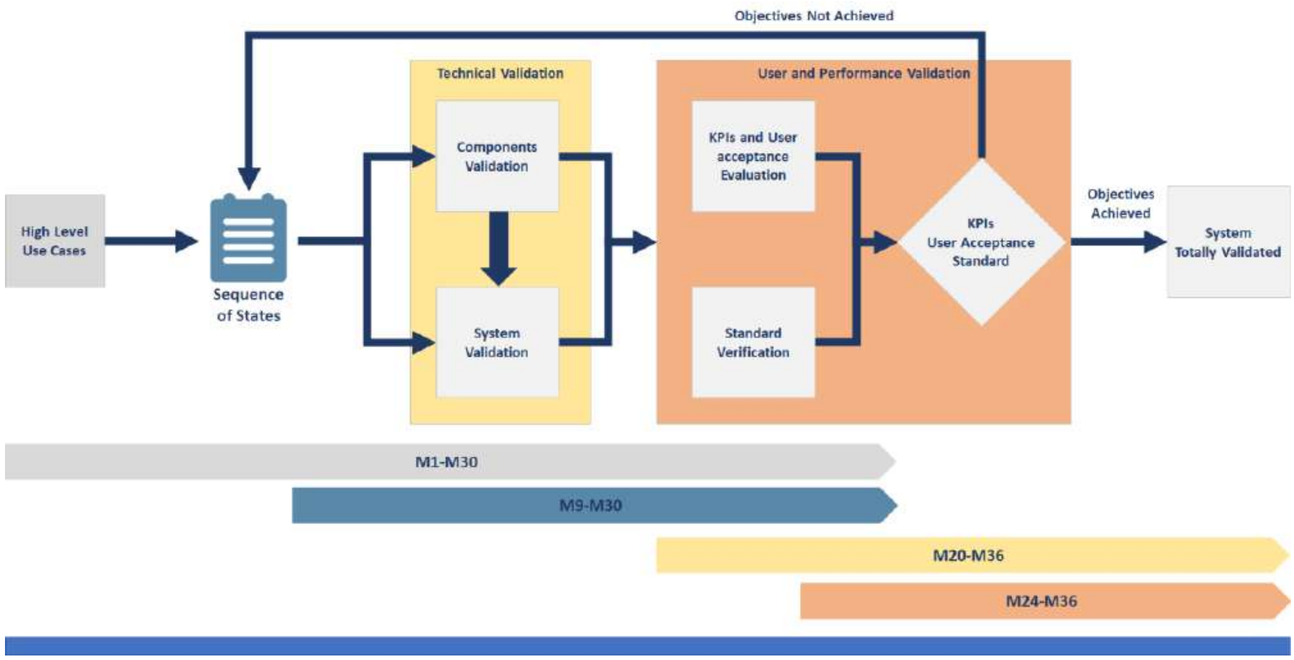

Figure 22 Consolidated eDREAM Validation Plan Flow and Timing

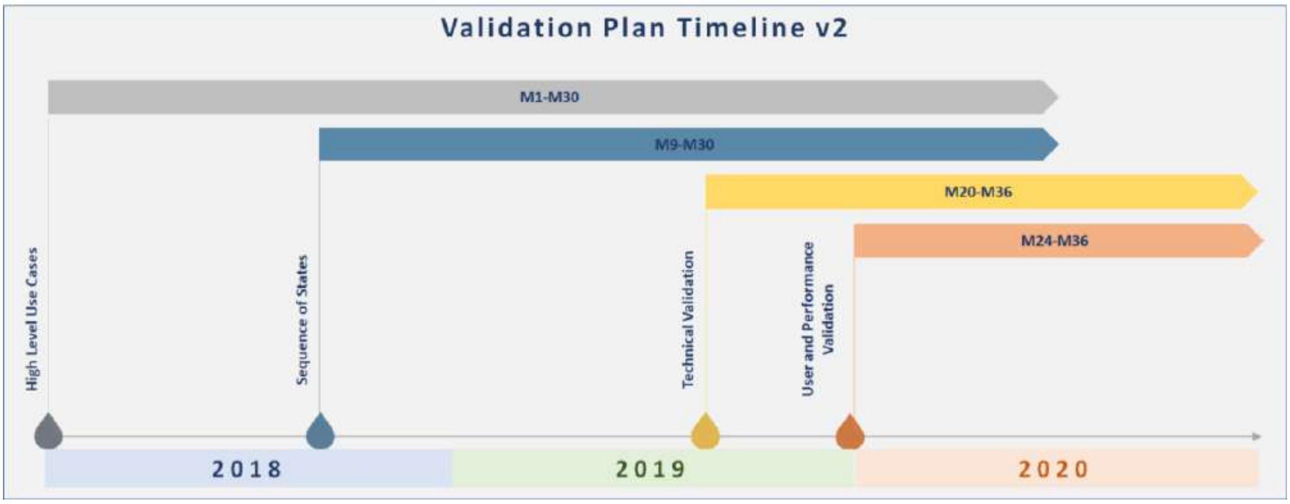

Figure 23 Consolidated Validation Plan Timeline

4.3 Plan for User Engagement in Validation through User Acceptance techniques

4.3.1 User group definition

A preliminary definition of the key stakeholders for the eDREAM project was presented in Deliverable D2.1 "*User group definitions, end-user needs, requirement analysis and deployment guidelines V1*", its subsequent updates and Deliverable D8.1 "Plans for the dissemination, exploitation & communication of project results".

Key stakeholders of the project target audience have been grouped in two target groups: *Energy Sector* and *End Users* (Table 64) and were involved in the requirements elicitation process, contributing to the identification of the business and user needs. Another relevant group for the communication and dissemination strategy is represented by *Facilitators* which can act as promoters or produce technical standards addressing the needs rising up from the development (e.g. Standardisation Bodies).

Energy Sector	End Users	Facilitators
Energy Retailers	Building Occupants	EU Institutions
DSOs	Facility managers & owners	National public authorities
TSOs	System operators	Standardisation Bodies
Distributed Generation Providers	Commercial and Residential Customers	Related EU-funded projects
Centralized Generation Providers	Stakeholders at the Pilot Sites	Organizations & EU Alliances in topics addressed by eDREAM
Energy Aggregators and brokers	Municipalities with pools of buildings	European Technology Platforms and respective clusters

ESCOs	Universities with pools of buildings	Public Bodies & Environmental Organizations
Technology Providers	Energy professional associations	
Scientific community	General Public	

Table 64 Key stakeholders and user groups

As mentioned in D2.1, to achieve the project objectives it is necessary to identify the actors affected by the system and project results and to identify their needs in form of project's requirements. The validation activities will be conducted involving directly the main actors taking into account, as already defined in Chapter 3, the models for user acceptance by using the appropriate tools for collecting feedback.

4.3.2 User Engagement in demonstration activities

User engagement is a crucial step in many demonstration activities and it is basically included in lots of research projects and testing activities before a technology roll-out. This section will consider the most important aspects of customer engagement in a demonstration activity, describing those criticalities representing obstacles and market opportunities at the same time.

Following the official definition from the EC directorate General for Energy, a smart grid is "an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it (…) in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" [19]. A lot of assumptions can be derived from this definition, but in this case, what matters most is the integration of "the behaviour and actions of all users connected to it", where centric role of the users can be easily interpreted. So, the active participation of all users (included final ones), the adaptation of the market models and the evolution towards a customer-centric framework seems to be one of the final goals of the energy transition.

One of the main challenges when debating about empowering the users consists of the knowledge and the information, they could have in the **active participation to the value chain**. In eDREAM project, the adoption of blockchain technology and the implementation of DR assume final users with some kind of technical knowledge that cannot be confirmed a priori. So, the question should be carefully treated when considering a high level of innovation technology and novel business procedures that users might not be confident with. In addition, it must be considered that generic users do not have a clear perception of their energy behaviour, tariffs and practices, so they are requested to learn and be aware of their own consumptions and costs. This phenomenon is well known and described, for instance, in all those projects dealing with hardware and in households display (IHD) installation [20][21].

Once the prosumer is informed and/or trained, (s)he should have an **active role in the process**. With particular regards of active demand projects, the SC3 EU project [22] has analysed a number of these projects, identifying a lack of participation in this kind of projects. Authors recognize the challenge of a real user engagement in projects, but on the other hand benefits in terms of service concepts and procedures can be brought.

In a different work [23], a review of the user engagement impact across several smart grid projects, is proposed. Among the number of interesting considerations, the author analysed in detail **the effect of the**

demand shifting and related effects. When considering domestic customers, the survey highlights that some of the activities seem to be stable in time and it is very unlikely for them to change these habits (collective tasks related to cooking and eating). While others can be easily shifted in different hours (cleaning and solitary tasks).

Following the problems connected to the new hardware installation in households, a common problem seems to be the **interaction between automation devices and customers**. On one hand new equipment and software are needed to enhance the control loads, but final users are mostly unfamiliar with them.

For instance, in [24], a scenario is described where final customers were demanding a higher level of automation and intelligence in their own heating systems, aimed at shifting their electricity demand, that did not correspond to a real and appropriate usage of their equipment. That basically means higher automation level can be accepted, but some criticalities may occur, and they should be taken into account. A study [23] states that many more automation control devices are focused on demand shifting than on economic incentives. Therefore, a vague scepticism may originate from users towards automation devices. After a survey, the author identified as well, some critical points of research projects in the same topic: (1) security of the "smart" process and information and (2) the possibility to override the external control.

The first point deals with the privacy and security constraints. Regarding the last point many customers did not reject the possibility of having a load controlled by an external entity (software, device or operator), but they wanted to be sure to have a top level of control. The categories of the most accepted controllable loads seem to vary and engaged users have shown an openness towards heating systems, while electric vehicles and kitchen appliances seem to be more customer-controlled.

Anyway, the debate of which category of loads can be more easily shifted is still open and it is also tightly connected to the tariff and the adopted DR scheme. In [22] it has demonstrated that engaged users in DR projects are mostly able to achieve the shift, but these changes are not enough to justify a relevant monetary benefit in a long term. It is conceivable that domestic users are the ones with a **limited flexibility capacity** and load shifting potential. Further, the difference of the cost of energy between peak and off-peak is not so relevant. It would require further research to assess whether the load shifting potential can be increased by offering stronger (monetary or non-monetary) incentives. According to that survey, some categories of final users fit better with active DR applications than others. Domestic customers with full-time jobs (they are basically out in the central part of the working day) show limited requirements and benefits for load shifting. On the other hand, SMEs and commercial businesses seem to offer more flexibility, especially when referred to internal temperature control (through heating and cooling system regulation unless it is not used for a primary business process). The installation of proprietary hardware for remote control is not generally accepted and, in some cases, could be considered an obstacle, but the analysis also highlights the need of a more user-oriented business model.

Moreover, another survey [25] demonstrates the preference for a load control tariff rather than a Time-Of-Use (ToU) tariff (in those Countries where available). It seems that the load control tariff could provide "a better sense of control over comfort, timing of activities, and spending as well as ease of use" [23].

The more complex the price structure, the higher is the remuneration. In the presence of smart prosumers with on-site generation, storage systems and dispatchable loads, it should be considered that the increasing **complexity of the energy tariff** is necessary even if it implies a potential barrier in the prosumer engagement [26]. Moreover, the overall control of the DR operator can contrast with the local logic of legacy infrastructure onsite (inverter or other local controller operating with a rule-based strategy). Under this assumption, the time-varying price structure can be more complicated, due to 3 or 4 ToU segments (including higher peak and critical peak times) and a capacity component avoiding the so-called rebound effect (smoothing day peaks, but creating critical peak overnight). In this case, local control might bring limited advantages than a more obscure tariff composition for the customer that must blindly trust on the external optimization provided by an overall control.

In this context of complexity of tariff composition and possible cascade effects, it must be considered the adoption of blockchain technology and smart contracts for enhancing the automation level of the demand response events. Of course, blockchain can answer easily to the requirements for privacy and security in the transactions, but on the other side it could represent a higher level of automation that customer is not able to manage with confidence. Although their quick popularity and diffusion, blockchain cannot represent a general solution for the current demand response problem as it is. The successful adoption of this technology will depend on the effective exploitation of its potentials, like:

- process and cost optimization (automation of the process could bring cost optimization with a higher rentability for customers too);
- added value services;
- trustfulness (the intrinsic feature of blockchain can leverage customers' participation and loyalty to some programs);
- enabling market decentralization through energy communities.

Considering all the aspects described in this sub-section, some features of the interaction between end users and market structure or business models contribute to end user's engagement, as also confirmed in SC3 [22]. Thus, some aspects of a profitable user engagement can be seen as drivers for a viable business model and vice versa. SC3 [22] demonstrates how the development of a business model in similar projects used to consider limited benefits due to the difference between peak and off-peak energy cost. This seems to be the other side of the aforementioned problem about the economic advantage achievable for customers, when engaged in DR scheme, with a difference that those models are basically DSO-oriented.

A more **customer-centric business model** can be more useful for an effective testing and adoption of such innovations and it should be based - at least - on the critical points discussed in previous paragraphs:

- consideration of trained/informed users;
- built model with active role for prosumers;
- customer participation in research projects;
- limited capacity of shifting/curtailment of domestic users;
- identifying the right category of loads for DR;
- security and privacy of process and information;
- acceptance of the external control;
- complexity of tariff/remuneration;
- exploiting peculiarities of smart contracts based on blockchain technology.

4.3.3 User feedback collection tools

Despite the crucial role of the end-user for the creation of a tailored and more effective electricity system, the penetration of RRI and SSH best practices for the user engagement and the promotion of tailored methodologies among the scientific and technological development on smart grids, are still lacking. For that, a state-of-the-art review has been conducted and reported, with a special focus on techniques for user engagement.

A major element of distinction, as reported in [27], are two kinds of perspectives for the user engagement: **theoretical perspective and empirical perspective**. The first one refers to theoretical models used for understanding psychological, economic, sociological, innovation, transitions and marketing perspectives, while the second is based on experiences coming from smart grid projects and their published reports.

A derived consequence of a proper user engagement in the energy practices is the smart energy behaviour, that can have direct implications on the adoption and fostering of energy efficiency, and customer side applications (i.e. Demand Response, renewable energy penetration, efficient use of resources, etc.). As a matter of fact, techniques for the user engagement may vary according to what level of consciousness is related to the activity we may want to make efficient: it can be habitual (i.e. cooking, driving, eating, etc.), or occasional.

The more habitual is the activity we want to make efficient, the more disruptive will be the new proposed practice to adopt. End-user interaction purpose will therefore vary, from frameworks useful to “reconsider” existing wasteful ongoing process towards a new, “more efficient” practice (i.e. participation in demand response programs); to solutions aimed to support the continuation of the adopted energy actions (see Figure 24).

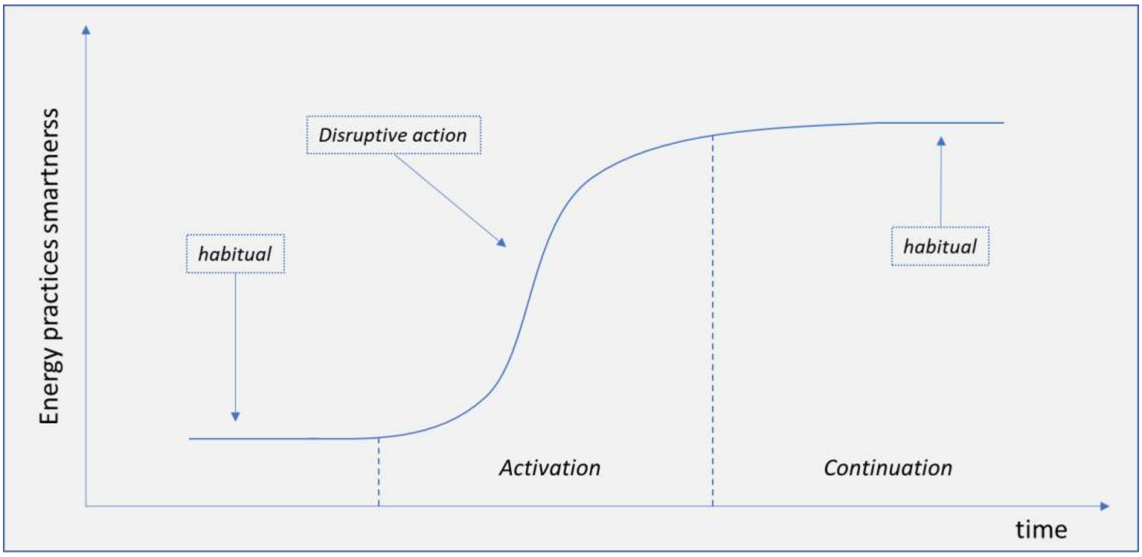

Figure 24 User Engagement and energy practices smartness [27]

These interactions can be collected through specific “User feedback collection tools”. Purpose of this paragraph is to identify and set out an analysis of these tools that will be used for Task 7.3. Starting from this preliminary analysis provided, Task 7.3 will have to select which tool, among the identified here, will be used, with appropriate justification. With this aim, our interest has been focused on **survey and analytics tools** some of which are briefly described as follows:

EU Survey [28]

EUSurvey is a fully open-source online survey management system for creating and publishing forms available to the public, e.g. user satisfaction surveys and public consultations. Launched in 2013, EUSurvey is the European Commission's official survey management tool published under the EUPL licence and built at DG DIGIT (European Commission's Department for digital services) and funded under the ISA programme.

Its main purpose is to create official surveys of public opinion and forms for internal communication and staff management, e.g. staff opinion surveys and forms for evaluation or registration. EUSurvey provides a wide variety of elements used in forms, ranging from the simple (e.g. text questions and multiple-choice questions) to the advanced (e.g. editable spreadsheets and multimedia elements).

Google Forms [29] and Google Analytics [30]

One of the most used application for collecting user’s feedback and creating engagement contents is Google Forms. Google Forms is a very useful tool that allows us to collect data in a simple way, without installing anything on our site and without letting the browser out of the web page. Google Forms “forms” can be linked to spreadsheets in Google Sheets. If a worksheet is linked to the form, the answers will be automatically sent to the sheet. Otherwise, users can view them on the "Summary of Answers" page accessible from the Answers menu. Google Sheets can be linked to Google Analytics, a free tool that has a lot of features, for instance Analytics intelligence and reporting, data aggregation and management. Google automatically groups and analyses the survey answers and presents the data through a simple online interface.

SurveyMonkey [31]

SurveyMonkey is a popular survey platform. It offers advanced solutions that simplify the acquisition of the opinions of the people who matter most, to transform them into usable information. As the title suggests, SurveyMonkey is very suitable to make on-line surveys. The more specific survey levels, on the other hand, are paid. These mainly concern the customized reporting service, the textual analysis of the questions, tricks such as the randomization of questions to avoid incurring technical fraud such as the response set that could spoil the final results. Still on a non-free basis, Survey Monkey allows you to include collaborators in the creation of the survey and to receive telephone assistance from an operator in case of difficulty.

Zoho Survey and Analytics [32]

Zoho Survey is a solution to submit questionnaires to customers, users and potential clients; they are organized with logic and branching, with a very intuitive interface. Zoho relies also an advanced reporting analytics tool.

Typeform [33]

TypeForm is an online service that allows you to promote and share interactive online questionnaires. Typeform is very useful if you want to collect the answers and analyze them for further use. It has important features such as the logical leap and the addition of a thank-you note, that is part of paid membership only. The clean design, ease of use and drag-and-drop selection capabilities make it a pleasure to create online forms. Typeform shows just one question at a time to facilitate user experience. The basic option (free) includes:

- Access to an unlimited number of templates and design tools;
- Possibility to reorganize your work by dividing it into different folders;
- Reporting;
- Data downloaded in an Excel file;
- Receive notifications on your personal email.

4.3.4 Data analysis Approaches

Several techniques will be used to analyse different aspects of the relationships between data collected from the questionnaire and relevant performance factors (PU, PEOU, A and BI as already defined in the section 3.3). First, factor analysis will be used to evaluate the relative importance of factors which influence gathered data. Hence, factor analysis allows to expose the internal structure of a (possibly) large dataset, highlighting its most meaningful parameters in terms of variance and statistical significance. Factor analysis is therefore used for tasks such as dimensionality reduction and feature selection; as an example, it may emerge that certain questions hold the most relevant information, or that they are the solely conditioning parameter which influences the attitude A.

A widely-used tool to perform factor analysis is Principal Component Analysis (PCA) along with maximum likelihood, which identify the principal components of the data under analysis and evaluate them in terms of explained variance on the original dataset. As for the correlation analysis, its main aim is to reveal hidden relationships between parameters by means of specific statistical tools. Such relationships should be therefore quantified to express the agreement between different variables. The most commonly used statistical tools for correlation analysis are Pearson's r and Sparman's rho; the first is mainly used when variables are supposed to be linearly correlated, while the second is useful to model monotonic relationships. For both indexes, a positive value implies that the variables are positive-correlated, meaning that an increase (decrease) in the value of the first variable corresponds to an increase (decrease) in the value of the second. Otherwise, a negative correlation value implies that an increase (decrease) in the value of the first variable corresponds to a decrease (increase) of the second. As both of these indexes are bound between -1 and 1, the absolute value of the correlation coefficient is directly related to the correlation (either positive or negative) between the two variables.

Correlation analysis can give useful insights on data: as an example, if data collected from two questions are highly correlated, it can be inferred that one answer directly affects the other, and vice versa. Hence, parameters which are related to the aforementioned questions (as an example, PO and BI) are consequently correlated, and strategies to improve one parameter by conditioning the other can be therefore evaluated.

As for regression analysis, it can be seen as a tool for revealing causal relationships between data. Informally, regression analysis allows to quantify the mutual influence between variables, also evaluating its causality (that is, whether a change in a variable induces a consequent change in the other, or vice versa). If two or more variables share a causal relationship, regression analysis can identify a (possibly non-linear) transfer function.

Regression analysis may be performed using several tools, such as hierarchical regression, and it can highlight underlying nonlinear phenomena, e.g. if results coming from a question which quantifies perceived usefulness have a positive impact, in mathematical terms, on results coming from a question related to overall users' attitude. As such, from the combination of the outcomes deriving from both correlation analysis and regression analysis, a complex, non-linear relationship between PU, A and BI can be inferred.

Finally, more complex analysis can be performed. As an example, the mediating effect of data which can be related to the attitude among different factors can be evaluated, highlighting that attitude may play a partial mediating role between other factors, such as PEOU and BI.

5 Overall Conclusions and Future Work

In this document the consolidated validation plan of the eDREAM platform was presented, which will be used to evaluate the components developed in technical Work Packages (WP3, WP4, WP5) and their integration (WP6). This validation plan will serve as a basis to verify the coherence of the platform with the predetermined goals and the user expectations, addressing all the risks involved in deployment activities on the demo sites and assuring correct functionality and operability of the system.

The contents of this document are important for all the activities foreseen in WP7 providing the underlying base for all activities related to the verification testing and assessment of eDREAM technologies. Also, the development of the Business Models will take into consideration the results obtained from user acceptance techniques and, in general, for the performance and reliability analysis of the eDREAM platform.

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