Platone

PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

## Platone

## PLATform for Operation of distribution NEtworks

# D7.3 v1.0

# CBA Methodology

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**Abstract**

Deliverable 7.3 describes the Cost-Benefit Analysis methodology that was developed for the project Platone. The methodology development was based on successful previous examples such as the Joint Research Institute example. In addition, the methodology included a Multi-Criteria Analysis dimension. This document analyses the important aspects of the methodology and provides examples of its application on the Use Case of the Platone demos.

**Keyword list**

Cost-benefit analysis, multi-criteria analysis

**Disclaimer**

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## Executive Summary

“Innovation for the customers, innovation for the grid” is the vision of project Platone - Platform for Operation of distribution Networks. Within the H2020 programme “A single, smart European electricity grid”, Platone addresses the topic “Flexibility and retail market options for the distribution grid”. Modern power grids are moving away from centralised, infrastructure-heavy transmission system operators (TSOs) towards distribution system operators (DSOs) that are flexible and more capable of managing diverse renewable energy sources. DSOs require new ways of managing the increased number of producers, end users and more volatile power distribution systems of the future. Platone is using blockchain technology to build the Platone Open Framework to meet the needs of modern DSO power systems, including data management. The Platone Open Framework aims to create an open, flexible and secure system that enables distribution grid flexibility/congestion management mechanisms, through innovative energy market models involving all the possible actors at many levels (DSOs, TSOs, customers, aggregators). It is an open source framework based on blockchain technology that enables a secure and shared data management system, allows standard and flexible integration of external solutions (e.g. legacy solutions), and is open to integration of external services through standardized open application program interfaces (APIs). It is built with existing regulations in mind and will allow small power producers to be easily certified so that they can sell excess energy back to the grid. The Platone Open Framework will also incorporate an open-market system to link with traditional TSOs. The Platone Open Framework will be tested in three European demos and within the Canadian Distributed Energy Management Initiative (DEMI).

Task 7.2.2 of Platone focuses on the development of the CBA (Cost Benefit Analysis) methodology. CBA is the main tool for investors and governments for ex-ante evaluation, design and development options for large projects. The objective of any CBA is to assess the economic viability and sustainability of a project by comparing the costs and the expected benefits within a certain time frame, typically related to the expected useful life of the project. In Platone an MCA (Multi-Criteria Analysis) dimension is applied to the CBA where non-monetary benefits are included in the analyses. The inclusion of non-monetary benefits is important to projects that aim in providing societal and environmental benefits, such as Platone. The methodology developed in this task is based on the methodologies proposed by JRC (Joint Research Institute) and ISGAN (International Smart Grid Action Network).

The proposed methodology includes 7 steps. The sequence of steps is applied to each use case of a demo separately and KPIs are the key data input used to quantify benefits. The first step is the identification of assets that participate in the use case. Existing and new assets are distinguished. The second step is the mapping of assets to functionalities. Each asset can have multiple functionalities and more than one asset can be mapped to the same functionality. In the third step, the said functionalities are mapped onto benefits, again without one-to-one association. Then, in step 4 the baseline values of KPIs are established, i.e., the business-as-usual – without Platone – value of KPIs. In step 5, the cost of assets is calculated. In step 6, benefit formulas are formulated which are based on the values of KPIs and the baseline conditions. Finally, in step 7, the costs and benefits are compared to assess the worthiness of the project with regards to the specific use case.

The application of the CBA methodology, developed in Task 7.2.2, on the demo use cases is also described in this report. At this stage of the project, not all use cases are finalised. Therefore, the methodology was applied to a subset of use cases. However, the examples cover all demos and a variety of cases highlighting the fine details and advantages of the methodology. In addition to the development of the CBA methodology, this report describes in detail, the necessary data inputs, required for calculating the CBA results at the end of the project. The data inputs are largely based on the KPIs of each use case. Additional inputs include parameters that are part of the benefit formulas and their appropriate values will be based on the relevant literature and input from the demo leaders.

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# 1 Introduction

The project "PLATform for Operation of distribution Networks – Platone" aims to develop an architecture for testing and implementing a data acquisition system based on a two-layer Blockchain approach: an "Access Layer" to connect customers to the Distribution System Operator (DSO) and a "Service Layer" to link customers and DSO to the Flexibility Market environment (Market Place, Aggregators, …). The two layers are linked by a Shared Customer Database, containing all the data certified by Blockchain and made available to all the relevant stakeholders of the two layers. This Platone Open Framework architecture allows a greater stakeholder involvement and enables an efficient and smart network management. The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, transmission system operators (TSOs), Market, customers and aggregators. In particular, the DSOs will invest in a standard, open, non-discriminatory, blockchain-based, economic dispute settlement infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will allow the DSO to acquire a new role as a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone strongly contributes to aims to removing technical and economic barriers to the achievement of a carbon-free society by 2050 [1] **Error! Reference source not found.**, creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in three European demos (Greece, Germany and Italy) and within the Distributed Energy Management Initiative (DEMI) in Canada. The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme "A single, smart European electricity grid" Platone addresses the topic "Flexibility and retail market options for the distribution grid".

As part of the deliverable 7.3, a hybrid MCA-CBA will be carried out in order to estimate the expected monetary and non-monetary benefits from the Platone Smart Grid Project taking into account different points of view in order to evaluate global benefits and understand costs and benefits allocation among stakeholders.

## 1.1 Task 7.3.2 Application of MCA-CBA Analysis

In this task, the approaches for a common methodology of a combined MCA and CBA will be tested. In cooperation with the pilot projects the approaches developed in task 7.2.2 shall be used to estimate, in cooperation with the DSOs, the expected benefits that can be derived from the deployment of the solutions tested in the demos. The results of this exercise shall be used to identify the existing barriers in the regulatory frameworks and market designs that limit the deployment of the business cases at a larger level.

## 1.2 Objectives of the Work Reported in this Deliverable

The objective of the work reported in this deliverable is to combine the CBA with MCA into a new innovative method which can estimate the expected monetary and non-monetary benefits from the Platone Smart Grid Project while also being applicable to other Smart Grid Projects.

## 1.3 Outline of the Deliverable

In this deliverable, Chapter 2 focuses on the background and the objectives of Multi-Criteria / Cost-Benefit Analysis while in Chapter 3 the methodology of MCA – CBA is described and analysed. In chapters 4, 5 and 6 the MCA – CBA methodology is applied to the German, Greek and Italian demos. Finally, in chapter 7 we provide the conclusions of the MCA – CBA.

## 1.4 How to Read this Document

This document is part of the Work Package 7 of the Platone Project and thus the reader should be familiar with the general objectives and innovations of the Platone Project as well as the general idea behind the implementation of Smart Grids. Furthermore, the reader should be familiar with the Italian

[2], Greek [3] and German [4] demos of the Platone Project and how these demos operate in order to fully comprehend their cost benefit analysis. Finally, this deliverable combines the CBA approach proposed by JRC [5] with the multi-criteria CBA methodology proposed in the ISGAN paper [6] while adding new elements and ideas, and so, as a result, the reader should be familiar with the general idea of the aforementioned methods. Towards the end of the project, the deliverable 7.4 ‘Results of CBA and SRA’ will use the methodology presented in this deliverable to make the necessary calculations and extract useful conclusions.

# 2 Background and Objectives of CBA

The application of Multi-Criteria Analysis (MCA) and Cost-Benefit Analysis (CBA) is part of the Task 7.3 of the Platone project, along with the Scalability and Replicability Analysis which collectively form Work Package 7.

The Multi-Criteria Analysis and Cost-Benefit Analysis are innovative business models which can provide an ex-ante evaluation of design and development options for large projects to the investors and governments. The main purpose of these analyses is to evaluate and identify the benefits and the beneficiaries of the project from an economic, social and environmental aspect and assess the economic viability and sustainability of a project by comparing the costs with the expected benefits within a certain time frame, which is typically the expected life cycle of the project. CBA is an important decision support tool which evaluates the worthiness of innovative Smart Grids solutions in view of an extended roll-out. As CBAs for development projects are usually largely based on estimated values of expected benefits and costs, the outcomes of Platone demonstration projects can contribute to improving these benefits' evaluation giving to the estimation a solid foundation, based on measured impacts. In addition, the realization of demonstration projects gives practical indications about all the cost items that have to be taken into account in the CBA. Expected benefits from Smart Grid projects typically affect a wide range of stakeholders (e.g.: producers, consumers, system operators, aggregators, market players, etc.) as well as higher level and more general interests (e.g. environment, society, etc.). Therefore, CBA applied to this class of projects requires taking into account different points of view in order to evaluate global benefits and understand costs and benefits allocation among stakeholders. Moreover, the attribution of economic value to technical improvements and innovations often depends on regulatory and other boundary conditions in each country and there is interest to possibly evaluate also non-monetary benefits through a qualitative impact analysis. CBA could be done with several scopes, i.e. either at demo level considering current costs and the measured benefits only, or at a larger scale by scaling up the expected outcomes and evaluating the changing of costs due to time and scaling up. The main interest certainly concerns the CBA outcome considering wide scale deployments, but the up-scaled values of costs and benefits may be affected by higher estimation uncertainties.

In this deliverable, a hybrid MCA-CBA will be carried out based on the method proposed in 2012 by the JRC (Joint Research Institute) [5] for Europe and the MC-CBA toolkit developed by ISGAN (International Smart Grid Action Network) [6], combining the advantages of the two families of techniques, while also utilising the experience gathered in other relevant European projects such as GRID4EU.

The JRC methodology [5] builds upon the Electric Power Research Institute (EPRI) methodology [7], which was developed in the USA, providing modifications and additions in order to take into account both technological and regulatory differences present in Europe. The main idea behind the JRC methodology for CBA is that assets provide a set of functions that can in turn enable Smart Grid benefits which can be quantified and eventually monetised.

The MC-CBA toolkit developed by ISGAN [6] aims to complement the aforementioned CBA by adding the multi-criteria factor. Typically, smart grid projects are responsible for a wide range of impacts which span from the electrical power system to the entire society. Often, these impacts are not easily quantifiable thus an assessment based on their monetary value is not attainable. In this context, traditional approaches such as the CBA become unsuitable. The reliable assessment of several planning options can be obtained by using hybrid approaches which combine monetary appraisal tools within a generalised framework based on MCA. A combined MC-CBA approach preserves the advantages of each methodology while overcoming their respective weaknesses. This methodology aims at supporting the decision makers by providing an assessment framework which rejects any personal bias by preserving the stakeholders' interests and allows for an output-based assessment of the smart grid alternatives based on an automated comparison procedure.

The MC-CBA toolkit decomposes the decision-making problem by dividing the impacts in three main areas:

- Economic Impacts (Net Present Value, Internal Rate of Return and Cost-Benefit Ratio),
- Contribution towards the smart grid realisation (Role of the smart grid project in government policies),
- Externality impacts (e.g., social impact, consumer satisfaction etc.).

Since the systematic assessment considers simultaneous effects, which belong to the different areas, companies are able to verify the performance achieved by the different options, while government bodies can consider both monetary and non-monetary impacts according to different views. Since the combined approach does not require to monetise all impacts, it is suitable for taking into account the effects of power system planning on society and environment.

# 3 CBA Methodology description

The CBA methodology developed in Platone includes 7 distinct steps, which are largely based on the JRC methodology [5]. Each step defines a clear set of inputs, actions and outcomes, that usually are then forwarded to the next steps. The step approach allows for a clear path to accomplishing the CBA objectives, breaking down the workload into smaller clear batches. The 7 steps of the Platone CBA are the following:

**Step 1**: Identification of the assets introduced in each of the use cases of the German, Greek and Italian demos. In this step the newly introduced Platone Assets are identified as well as already existing assets that are essential for the project's realisation.

**Step 2**: Mapping the assets into Smart Grid functionalities. In order to identify the functionalities of the assets we utilised the objectives set for each Use Case in the aforementioned demos.

**Step 3**: The aforementioned functionalities as well as the KPIs analysed in each use case are identified and mapped into benefits (monetary and non-monetary) from an economic, social and environmental aspect.

**Step 4**: The Baseline Condition (Business as Usual) is established for each KPI in order to have a solid foundation upon which comparisons could be made after the new Smart Grid assets are introduced.

**Step 5**: Identification and quantification of the assets' costs. This procedure includes the initial investments costs for the purchase and installation of the new assets as well as their operational costs. The operational costs of the already existing assets will also be considered as part the Cost Benefit Analysis.

**Step 6**: Determination of the Benefit Formulas - monetization of benefits after the Assets are implemented. In this step we try to come up with the formulas that quantify the benefits in terms of money in order to be able to fully and clearly interpret the benefits in an articulate way.

**Step 7**: Comparison of the Baseline Condition and the Realised / Estimated condition to evaluate the cost – effectiveness of the project. In this final step we determine the worthiness of the assets' implementation taking into account both the monetary final impacts as well as the social impacts in order to have a complete overview of the situation.

These CBA steps aim to combine the existing approach of CBA proposed by JRC [5] with the multi-criteria CBA methodology proposed in the ISGAN paper [6]. This will enable us to evaluate project alternatives on the basis of the monetary and non-monetary criteria as described above. The hybrid MC-CBA approach will combine the economic analysis with a quantitative and qualitative impact analysis, which includes the costs and benefits of wider social impacts, such as security of energy supply, consumer participation and improving market operation. Finally, the CBA will be carried out by associating the KPIs provided by each demo to specific benefits. This is the approach that we proposed and agreed upon and it is slightly different than the JRC approach where the assets are associated to functionalities and the functionalities into benefits. This particular approach will contribute to a better understanding of the Estimated Condition and a more accurate quantification and monetization of the benefits after the full deployment of the Smart Grid Assets. Finally, the aforementioned data will be used to compare the costs and the benefits and eventually evaluate the cost-effectiveness of the project.

The Cost-Benefit Analysis requires a number of data entries as input. This data primarily is an output of the demo activities. In an effort to align with the priorities and concepts that are defined within the demos, the CBA activity will make use of the benefit definitions provided by the demos, in the form of the KPIs. The CBA will extent, interpret and, when necessary, monetize these KPIs accordingly in order to calculate the tangible benefits each asset will provide. However, these benefits are not standalone, but are defined with respect to the status quo, i.e., any Business-as-Usual (BaU) or baseline scenarios. Therefore, the CBA analysis requires as data input:

- The KPI values in BaU or baseline scenarios that are measured without the deployment of the corresponding asset for which the CBA is performed.
- The corresponding KPI after the deployment of the asset under analysis in order to evaluate the relative benefit between the two cases.

These two data entries cover the *benefit* part of the Cost-Benefit Analysis. For the *cost* part each asset under evaluation should come with at least one of the following costs of purchase, deployment, operation and maintenance. Therefore, one more data entry required for the CBA is:

- Cost of purchase, deployment, maintenance, operation or other associated with each individual asset deployed for the Platone demonstrations and evaluated by the CBA of the project.

Finally, one integral data point necessary for the CBA is the definition of all the parameters that are necessary in order to translate KPIs into the associated benefits. For example, a KPI that quantifies peak reduction (in kW) at an MV/LV transformer can be quantified into the benefit of *upgrade capacity deferment* by associating such reduction with the *cost of transformer upgrade per kW*. That cost is a parameter-data entry that should be provided or agreed upon with the demo leaders:

- Quantification parameters that translate KPIs to benefits

# 4 German demo

## 4.1 Demo description

The German Demonstration project of Platone [4] aims to implement an EMS that enables to monitor and balance a local network and new strategies of energy supply. The demo site is located in Abbenhausen, Twistringen, Germany. Within the frame of the field test trial, four different UCs will be implemented enabling energy communities to:

- Maximize the consumption of local generation, minimize the demand from the feeding grid and maximize the duration of an islanding period,
- Adhere to a fixed power value at the point of connection defined by a third party (e.g. DSO request or in response to a market signal),
- Satisfy the energy deficit left by insufficient local generation within previously defined timeslots (“Bulk supply”),
- Export the energy surplus generated by excess local generation within previously defined timeslots (“Bulk-export”).

This will be achieved by introducing a set of Smart Grid assets:

- A local **Energy Management System (EMS)** that will monitor local generation, demand and storage capacities and control available flexibilities in such a way that the consumption of the locally generated energy will be maximized, and the energy demanded from the MV grid will be minimized.
- A **Battery Energy Storage System (BESS**) and **Household Energy Storage** that will enable generated energy surplus to be stored and released at times of generation deficit.
- A **Sensor** located at the grid connection that will measure the power exchange of all 3 phases within the MV grid and provide data to the EMS. Additionally, sensors located in private customer households will provide measurements of energy consumption and State of Charge (SOC) or State of Energy (SOE) of storages and provide data to the EMS.
- **Renewable Energy Sources** which mainly consist of photovoltaic systems owned by private customers installed as rooftop systems. It is to expected that the number of privately owned PV systems will continuously rise in the coming years, leading to an increase of the amount of generated energy.
- **Flexible Loads** which will contribute to the energy supply and export.
- **Weather Forecast** that will enable the EMS to predict energy generation and consumption.
- A **Blockchain Access Platform (BAP)** that will provide encryption functionalities.
- The **Platone DSO Technical Platform (DSOTP)** that will act as a middleware enabling connection to sensors in the field and providing services (e.g. balancing, forecasting) to the EMS.
- A **Cloud Data Management Platform** from which measurement data is accessible for EMS via a backend. The interface also provides data to estimate the state of charge of batteries, flexible loads and potential available storage capacity.

**Table 1: German demo assets participating in the CBA**

| Asset Name | Use Case involvement | Asset Description | Asset Type | Type of associated costs |
|---|---|---|---|---|
| **ALF-C** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE- 4 | Local Energy Management System | New installation asset | Investment and operational costs |

| | | | | |
|---|---|---|---|---|
| **Battery Energy Storage System (BESS)** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE- 4 | Enable generated energy surplus to be stored and released at times of generation deficit. | New installation asset | Investment and operational costs |
| **Sensor** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE-4 | Measures the power exchange of all 3 phases and total power with the MV grid and provide data to the EMS | Installation of new standardised assets (PLMulti2, PMU) | Investment and Operational Costs |
| **Weather Forecast** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE- 4 | Enables the EMS to predict energy generation and consumption and total load/energy demand | Existing asset (data provided by external services) | Operational Costs |
| **Household Energy Storage** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE-4 | Renewable Energy Storage | New installation assets | Operational Costs |
| **Renewable Energy Sources** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE-4 | Generation in Avacon's LV networks is mainly caused by photovoltaic systems owned by private customers installed as rooftop systems | Existing asset and new installation assets | Costs paid by owner/household |
| **Flexible Loads (Probably not realized within the project)** | UC-DE-3, UC-DE-4 | Energy Supply / Export | Existing asset and new assets | Costs paid by owner/household |
| **Blockchain Access Platform (BAP)** | UC-DE-2, UC-DE-3, UC-DE- 4 | Provides encryption functionalities | New installation asset | Investment and operational costs |
| **Platone DSO Technical Platform (DSOTP)** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE-4 | Acts as a middleware enabling connection to sensors in the field and providing services to the EMS | New installation Asset | Investment and operational costs |
| **Cloud Data Management Platform** | UC-DE-1, UC-DE-2, UC-DE-3, UC-DE-4 | Enables measurement data to be accessible for EMS via a backend and provides data to estimate the state of charge of batteries, flexible loads and potential available storage capacity | Existing asset | Operational Costs |

The ALF-C (Energy Management System), the Battery Energy Storage System, the Blockchain Access Platform, the Platone DSO Technical Platform, that will be implemented as part of the Platone project and will lead to Smart Grid functionalities which can be interpreted by the relevant KPIs and result in Smart Grid Benefits.

## 4.2 CBA Application

### 4.2.1 UC-DE-1: Islanding

Use case UC-DE-1 aims to enable a local network to behave like an energy community that practises energy sharing in order to maximize self-sufficiency by maximizing self-consumption of locally generated energy up to a virtual island mode at which the community is temporarily independent from the energy provision from the medium voltage network. UC-DE-1 demonstrates the energy generation and consumption behaviour of future local low-voltage networks, in which private households have formed a community in order to maximize the self-consumption of locally generated energy.

**Table 2: Functionalities, KPIs and Benefits in UC-DE-1**

| Functionalities | KPIs | Benefits |
|---|---|---|
| **1) Load Balancing (Virtual Islanding)** | KPI 1: Reduction of Energy Exchange along the MV feeder | Reduced Distribution Equipment Maintenance Cost |
| **2) Use of network control systems for network purposes** | KPI 2: Reduction of power recuperation peaks | Deferred Distribution capacity Investments |
| **3) Maximization of local generation consumption / Minimization of the demands satisfied by public grid** | KPI 3: Increase in self-consumption | Distribution Operations Cost |
| | KPI 4: Maximization of Islanding Duration | Reduced $CO_2$ Emissions |

#### 4.2.1.1 Use Case 1 Functionalities

The field test trial and application of UC-DE-1 will take place in a rural LV network consisting of family houses, agricultural buildings and a large amount of installed generation capacities provided by roof top photovoltaic systems. A local EMS (ALF-C) will monitor local generation, demand and storage capacities and control available flexibilities in such a way that the consumption of the locally generated energy will be maximized, and the energy demanded from the MV grid will be minimized.

When local generation exceeds local demand, surplus energy will automatically be stored in local storages. When local consumption exceeds local generation, stored electrical energy in local batteries will be discharged. The optimization of self-consumption targets minimizing the load exchange with the MV grid along the MV/LV grid connection point up to a level at which the community is virtually islanded. In cases in which generation and demand cannot be balanced due to a lack of available storage capacity or flexibility, the residual load will be supplied by imported power from the MV grid.

A sensor located at the grid connection will measure the power exchange of all 3 phases between the medium voltage and the low voltage grid. The measured values indicate the real time flow of power along the feeder and indicates the residual power demand or generation excess. Measurement data by sensors is provided to the EMS. Based on the provided information the EMS will increase or decrease the load demand of individual storages or flexible loads in order to balance the grid. Flexible assets in the field are equipped with sensors and controllers to increase or decrease demand and to command charging or discharging of the local large Battery Energy Storage System and private customer household storages. Household battery storages provide an interface for data exchange enabling the ALF-C to collect measurement data and trigger setpoints for control of battery charging. Historical measurement data and weather data provided by external service providers enable the EMS to predict energy generation and consumption to maximize self-sufficiency.

Controllers in the field are able to interrupt the charging of household batteries in case of the BESS charging and discharging in order to increase total consumption or feed within the community. Flexible loads may be provided by storage heaters and heat pumps. Storage capacities will be provided by a local BESS and battery storages from households. In order to avoid customers sacrificing comfort due to a decrease of room heating, control of loads will be limited.

The communication between sensors, controllers and EMS will be web based on LTE or DSL and open protocols.

#### 4.2.1.2 UC-DE-1 KPIs

**KPI_DE_1 - Reduction of Energy Exchange along the MV feeder**

UC-DE-1 is targeting to maximize consumption of locally generated energy and minimize consumption of energy provided by the feeding MV grid and analysis of change of energy exchange and peak loads along the feeding MV/LV transformer

This KPI evaluates the ability of the developed solution to reduce and avoid the energy consumption from the feeding grid by measuring the deviation of energy consumption in times of UC-DE-1 application and times UC-DE-1 is not applied.

KPI_DE_1 Formula

$$RED = \frac{\sum_{t=1}^{T} |Energy\ Exchange\ no\ Islanding|_{i;t} - \sum_{t=1}^{T} |Energy\ Exchange\ Islanding|_{i;t}}{\sum_{t=1}^{T} |Energy\ Exchange\ Islanding|_{i;t}} * 100$$

RED = Reduction of energy demand

The reduction of energy demand from the MV Grid is expected to be 70%

**KPI_DE_2: Reduction of power recuperation peaks**

UC-DE-1 targets the reduction of power peaks along the MV/LV grid connection point. A coordinated control of a local BESS, household energy storages and flexible loads enables the avoidance of power peak at grid connection point. This KPI evaluates the ability to reduce power peaks of an EC caused by fluctuating generation or demand within a defined period of time dt.

KPI_DE_2 Formula

$$Peak\ Reduction = \frac{|P|_{Max,\ no\ Islanding}(T) - |P|_{Max,\ with\ Islanding}(T)}{|P|_{Max,\ no\ Islanding}(dt)} * 100$$

**KPI_DE_3 - Increase in self-consumption**

UC-DE-1 is targeting the reduction of power exchanges along the MV/LV grid connection point. The balancing algorithm shall maximize the consumption of locally generated energy by storing generated surplus in local battery storages (BESS and household energy storages) and make use of stored generation surplus in times of higher demand. This KPI measures the increase of self-consumption in times of UC-DE-1 is applied by comparing the energy export in the period dt with the application of UC-DE-1 and in for the time period of investigation T without the application of UC-DE-1.

KPI_DE_3 Formula

$$IoSC = \frac{\sum_{t=1}^{T_0} |Energy\ Export\ no\ Islanding|_{i;t} - \sum_{t=1}^{T} |Energy\ Export\ Islanding|_{i;t}}{\sum_{t=1}^{T} |Energy\ Export\ Islanding|_{i;t}} * 100$$

IoSC= Increase of self-consumption

The self-consumption is expected to be 80%.

**<u>KPI_DE_4 - Maximization of Islanding Duration</u>**

UC-DE-1 is targeting to maximize the total duration or number of times in which the load exchange along the grid connection point is zero or close to zero. This KPI measures the success of maximizing the duration of time at which a load exchange along grid connection point is avoided.

KPI_DE_4 Formula

$$\mathrm{MoID} = \frac{\sum_{t=1}^{T} t_{Islanding;\, P_{Breaker} \approx 0}}{\sum_{t=1}^{T} t_{No\ Islanding;\, P_{Breaker} \approx 0}} * 100$$

MoID= Maximization of Islanding Duration

The KPI target is to increase the duration of islanding compared to benchmark. It is expected that in 80 % of the time of the day the load flow along the grid connection point will be kept between ± 10 kW.

#### 4.2.1.3 Use Case 1 Benefits

**<u>Social and Environmental Benefits</u>**

- **<u>Reduced $CO_2$ Emissions</u>**: Improving the performance for end – users in many aspects can be translated into reduced $CO_2$ emissions produced by fossil-based electricity generators. This benefit can be achieved by maximizing the islanding duration achieving the highest self-consumption possible.
- **<u>Increase in self consumption</u>**: With the implementation of smart grids, households can store excessive generated energy in local batteries and use it when needed, thus eliminating energy exchange between LV grid and connection point and leading in lower MV/LV transformer maintenance costs.

**<u>Economic Benefits</u>**

- **<u>Deferred Distribution Capacity Investments</u>**: Closer monitoring and load management on distribution feeders could potentially extend the time before upgrades or capacity additions are required.
- **<u>Reduced Distribution Operations Cost</u>**: Automated or remote-controlled operation of capacitor banks and feeder switches eliminates the need to send a line worker or crew to the switch location in order to operate it. This reduces the cost associated with the field service workers and service vehicle.
- **<u>Saving of curtailment of renewable generation</u>**: In times of high generation putting the network at risk of violating voltage limits or thermal limits of equipment, that forcing the grid operator to temporarily curtail local feed in to maintain system stability and avoid protection tripping.

#### 4.2.1.4 UC-DE-1 Benefit formulas

Explaining the parameters used in the formulas:

$C^{E-I}$: Average reduction in the cost of imported energy achieved by islanding €/MWh

This parameter monetizes the reduction in energy demand (MWh) achieved by employing UC-DE-1. Based on how much, on average, each MWh produced within the island is less expensive than the corresponding imported MWh coming from the transmission system, the economic benefit is quantified. Note that it is possible that this parameter is negative, i.e., locally produced energy is more expensive than imported energy, hence there would be a negative benefit, i.e., added cost for the DSO. Regulation affects such parameters.

$C^{TR}$: MV/LV transformer average cost per capacity increment in €/MW

This parameter monetizes the reduction in energy demand (MWh) achieved by employing UC-DE-1. Based on how much, on average, each MWh produced within the island is less expensive than the corresponding imported MWh coming from the transmission system, the economic benefit is quantified. Note that it is possible that this parameter is negative, i.e., locally produced energy is more expensive that imported energy, hence there would be a negative benefit, i.e., added cost for the DSO.

$C^{E-O}$: Average increase in the value of exported energy achieved by islanding €/MWh

This parameter monetizes the reduction in energy demand (MWh) achieved with by employing UC-DE-1. Based on how much, on average, each MWh produced within the island is less expensive than the corresponding imported MWh coming from the transmission system, the economic benefit is quantified. Note that it is possible that this parameter is negative, i.e., locally produced energy is more expensive that imported energy, hence there would be a negative benefit, i.e., added cost for the DSO.

$C^{C}$: Average reduction in the cost renewable generation curtailment as result of feed-in management (€)*

This parameter monetizes the reduction of the amount of generation curtailments (kWh) of decentral generators (DG) and the costs (€) that have to be paid to effected aggregators or owners of DG by applying Use Case 1.

If in decentral grid section the local feed in exceeds the network's hosting capacity and puts the network at risk of violating voltage limits or thermal limits of equipment, grid operators have the option to temporarily curtail local feed in to maintain system stability and avoid protection tripping. In recent, resulting in total annual cost for curtailments actions of 709,5 M€ in 2019 (6.482 GWh).

The curtailments in distribution networks are caused by high feed in from wind farms and photovoltaic systems. The application of Use Case 1 on a large scale in the distribution network might lead to a reduction of peaks of load flows from low voltage networks into medium voltage networks, decrease the number of congestions in higher voltage networks and reduce the required number of feed-in curtailments of renewable generation in higher voltage networks. This consequently will lead to a reduction of the amount of renumeration to be paid to owners of effected RES. All the input numbers will not be measured within the pilot. They just can be interpolated based on assumptions.

$C^{CO2}$: Average $CO_2$ emissions per MWh of energy (tons)*

This parameter defines how much $CO_2$ is emitted per MWh of energy on average by an electric system (in this case Germany). This parameter allows us to calculate how much $CO_2$ emissions are reduced due to the reduction in energy demand achieved in UC-DE-1.

$M^{CO2}$: Monetization parameter of $CO_2$ (tons)

The $CO_2$ emissions saved by the deployment of UC-DE-1 are measured in tons. In the context of MCA, our methodology monetizes $CO_2$ emissions in order to introduce their savings benefit in the CBA, using parameter $M^{CO2}$.

* Grid operators in Germany are fully unbundled from all generation assets and particularly DG are usually operated by private companies. The tools to control these units however are limited. Large

generation plants like windfarms are connected directly to the DSO SCADA, but most smaller units are oftentimes only equipped with a long wave radio receiver and the radio receivers are usually clustered per HV/MV-substation. Historically, all units can accept setpoints to limit their momentary power output to 60%, 30% or 0% of nominal power.

KPIs used in the formulas:

**B-DE-1: Total Benefit of UC-DE-1:**

$RED$: *(KPI 1)* Reduction of energy demand

$PR$: (KPI 2) Peak Reduction

$IoSC$: *(KPI 3)* Increase of self-consumption

$$\textbf{B-DE-1} = RED \cdot C^{E-I} + PR \cdot C^{TR} + IoSC \cdot C^{E-O} + C^{C} + RED \cdot C^{CO2} \cdot M^{CO2}$$

Where:

Deferred Distribution Capacity Investments: $PR \cdot C^{TR}$

Reduced Distribution Operations Cost: $RED \cdot C^{E-I}$

Increase in self consumption: $IoSC \cdot C^{E-O}$

Saving of curtailment of renewable generation: $C^{C}$

Reduced $CO_2$ Emissions: $RED \cdot C^{CO2} \cdot M^{CO2}$

#### 4.2.1.5 UC-DE-1 Asset Cost formulas

**ALF-C**

$$K_{\text{ALF-C}} = I_{\text{ALF-C}} + O_{\text{ALF-C}} \cdot Lifetime$$

$K_{\text{ALF-C}}$: Total Cost of the ALF-C asset

$I_{\text{ALF-C}}$: Investment Cost of the ALF-C asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{\text{ALF-C}}$: Annual Operational Cost of the ALF-C asset

**Battery Energy Storage System (BESS)**

$$K_{\text{BESS}} = I_{\text{BESS}} + O_{\text{BESS}} \cdot Lifetime$$

$K_{\text{BESS}}$: Total Cost of the Battery Energy Storage System asset

$I_{\text{BESS}}$: Investment Cost of the Battery Energy Storage System asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{\text{BESS}}$: Annual Operational Cost of the Battery Energy Storage System asset

In future battery storages might be procured by DSO for grid optimization purposes, customers for the increase of self-sufficiency or selling of flexibility or energy on markets. Consequently, it is uncertain who will make the investments (DSO or customers).

**Sensor**

$$K_{\text{sensor}} = O_{\text{sensor}} \cdot Lifetime$$

$K_{\text{sensor}}$: Total Cost of the Sensor asset

$O_{\text{sensor}}$: Annual Operational Cost of the Sensor asset

**Weather Forecast**

$$K_{\text{forecast}} = O_{\text{forecast}} \cdot Lifetime$$

$K_{\text{forecast}}$: Total Cost of the Weather Forecast asset

$O_{\text{forecast}}$: Annual Operational Cost of the Weather Forecast asset

**Household Energy Storage**

$$K_{\text{HES}} = O_{\text{HES}} \cdot Lifetime$$

$K_{\text{HES}}$: Total Cost of the Household Energy Storage asset

$O_{\text{HES}}$: Annual Operational Cost of the Household Energy Storage asset

In an operative environment these costs are carried by the customers. There might be costs for communication and controllers on site, but not for the assets itself.

**Renewable Energy Sources**

$$K_{\text{RES}} = O_{\text{RES}} \cdot Lifetime$$

$$K_{\text{CUR}} = O_{\text{Feed-in Tariff}} \cdot Curtailed\ Energy$$

$K_{\text{RES}}$: Total Cost of the Renewable Energy Sources asset

$O_{\text{RES}}$: Annual Operational Cost of the Renewable Energy Sources asset

$K_{\text{CUR}}$: Total Costs of Feed-in curtailment

$O_{\text{Feed-In Tariff}}$: Feed-In Tariff (€/kWh) to be paid for the curtailment of energy

Curtailed Energy: The amount of energy (kWh) not feed-into the grid due to curtailment

In an operative environment these costs are carried by the customers.

Renumeration for PV-curtailment might occur.

**Flexible Loads**

$$K_{\text{load}} = O_{\text{load}} \cdot Lifetime$$

$K_{\text{load}}$: Total Cost of the Flexible Loads asset

$O_{\text{load}}$: Annual Operational Cost of the Flexible Loads asset

In an operative environment these costs are carried by the customers.

**Blockchain Access Platform**

$$K_{\mathrm{BAP}} = I_{\mathrm{BAP}} + O_{\mathrm{BAP}} \cdot Lifetime$$

$K_{BAP}$: Total Cost of the Blockchain Access Platform asset

$I_{BAP}$: Investment Cost of the Blockchain Access Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{BAP}$: Annual Operational Cost of the Blockchain Access Platform asset

**Platone DSO Technical Platform**

$$K_{\mathrm{DSOTP}} = I_{\mathrm{DSOTP}} + O_{\mathrm{DSOTP}} \cdot Lifetime$$

$K_{DSOTP}$: Total Cost of the Platone DSO Technical Platform asset

$I_{DSOTP}$: Investment Cost of the Platone DSO Technical Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{DSOTP}$: Annual Operational Cost of the Platone DSO Technical Platform asset

**Cloud Data Management Platform**

$$K_{\mathrm{CDMP}} = O_{\mathrm{CDMP}} \cdot Lifetime$$

$K_{CDMP}$: Total Cost of the Cloud Data Management Platform asset

$O_{CDMP}$: Annual Operational Cost of the Cloud Data Management Platform asset

**Total cost K**

$$K_{\mathrm{total}} = K_{\mathrm{ALF\text{-}C}} + K_{\mathrm{BESS}} + K_{\mathrm{sensor}} + K_{\mathrm{forecast}} + K_{\mathrm{HES}} + K_{\mathrm{RES}} + K_{\mathrm{load}} + K_{\mathrm{BAP}} + K_{\mathrm{DSOTP}} + K_{\mathrm{CDMP}}$$

### 4.2.2 UC-DE-2, 3 and 4

UC-DE-2,3 and 4 are not included in the Cost Benefit Analysis at this point because they are not yet finalized and they are subject to change. After they are finalized, the Cost Benefit Analysis can be performed in a similar way as in Use Case 1. More information about the UC-DE-2,3 and 4 regarding the KPIs, the functionalities and the benefits, as they currently stand, can be found in the following chapter 4.2.2.3 “Available Information”. Benefits, benefit formulas and cost formulas will be finalised at a later stage and the full report will be utilised in D7.4 ‘Results of CBA and SRA’. **For reference and future usage, the available information is presented below in the context of the CBA**

#### 4.2.2.1 UC-DE-2: Flexibility Provision

UC-DE-2 demonstrates how the flexibility required to enable a local balancing mechanism could temporarily be allocated to other uses, for example the provision of flexibility to a third party, e.g., the connecting grid operator. UC-DE-2 uses the available flexibility in a given local energy community to maintain an externally defined non-zero setpoint at the point of connection.

#### 4.2.2.2 UC-DE-3 and 4: Bulk Energy Supply and Export

UC-DE-3 and 4 aim to enable the DSO to increase efficiency of operation of existing network and reliability of energy supply in future network cost. The applied mechanism may contribute to reducing the number and amount of curtailment of RES feed-in and reduce social costs for the society.

Furthermore, it may contribute to decrease the demand and cost to build and reinforce the electricity network. The principle is based on an energy deliver/export approach.

The Energy Management System (EMS) is responsible for local balancing of a bounded LV grid section. In addition, the EMS balances generation and demand to avoid or minimize the load exchange at the grid MV/LV-connection. A higher-level grid operation will allow the EMS to import or export unlimited energy almost every 24 hours. The amount of energy or value of power is determined by the EMS in such a way, that the community can operate as “islanded” again for the next 24 hours. The time slots of different communities along a MV-line are staggered, so that a more continuous load flow at the medium voltage line can be achieved, thus reducing the factor of coincidence of peak load and peak load level accordingly.

#### 4.2.2.3 Available Information

##### 4.2.2.3.1 UC-DE-2 Functionalities

Table 3: Functionalities, KPIs and Benefits in UC-DE-2

| Functionalities | KPIs | Benefits |
|---|---|---|
| **1) Fixed non-zero power exchange between the energy community and the distribution network for a limited duration.** | KPI 5: Responsiveness | This KPI evaluates the ability of the ALF-C together with an energy community, battery storages and other flexibility, to maintain a given value for the load exchange at the MV/LV grid connection point.<br><br>This functionality enables a community or low voltage networks to provide active power as a service to DSO, TSO, flexibility or reserve power markets. |

Local energy communities are likely to emerge in Europe in the near future but will most likely retain an interconnection to the distribution grid. These communities will require a large share of flexibility to enable their primary UC of islanding. Situations could arise that require the community to provide flexibility to third parties – driven by technical circumstances or following economic considerations (market incentives). UC-DE-2 demonstrates the ability and practical feasibility of a local community to maintain constant non-zero power exchange with the distribution network for a previously defined duration.

##### 4.2.2.3.2 UC-DE-2 KPIs

**<u>KPI 5 - Responsiveness</u>**

This KPI focuses on the assessment of response times of requests for flexibility and latencies of the IT infrastructure. The promptness of the implementation of a triggered setpoint ($P'_{Breaker}$) into a measurable value ($P_{Breaker}$) is an important indicator of the value of flexibility provided by local network or energy communities.

KPI 5 Formula

$$\text{Responsiveness} = t_{(P'_{\text{Breaker}} = P_{\text{Breaker}})} - t_{\text{Setpoint trigger}}$$

#### 4.2.2.3.3 UC-DE-3 and 4 Functionalities

Table 4: Functionalities, KPIs and Benefits in UC-DE-3 and UC-DE-4

| Functionalities | KPIs | Benefits |
|---|---|---|
| **1) Enabling temporary islanding even in times of energy deficit of the local community** | KPI 6 - Accuracy of the achievement of a given setpoint | Reduced $CO_2$ Emissions |
| **2) Forecasting of residual energy generation and residual energy demand of an energy community** | KPI 7 – Success of Energy Supply / Export in Bulk | Reduced Distribution Equipment Maintenance Cost |
| **3) Determination of a setpoint schedule for individual local asset to meet energy community setpoint schedule** | KPI 8 - Forecast of total Energy Demand | Reduced Distribution Operations Cost |
| **4) Execution of power exchange schedule for the energy community for the grid connection point LV/MV (time and power of load exchange)** | | Deferred Transmission capacity Investments |
| 5) **Execution of defined power exchange between energy community and the distribution network** | | Deferred Distribution capacity Investments |

An operator of Avacon triggers the EMS to apply UC-DE-3 and sets a schedule of target value $P'_{Breaker}$ for the period (t+1) for the power exchange at the grid connection point. The schedule can be defined for a duration for the next 1 to 24 hours.

The schedule contains time slots for the import of energy in which $P'_{Breaker} \neq 0$ and time slots in which no power shall be exchanged along the grid connection point ($P'_{Breaker} = 0$), following the principle of UC-DE-1. During the application of UC-DE-3, the total amount of imported energy shall meet the total amount of energy deficits that the community will have. The energy deficits will therefore have to be forecasted by the operator. During the energy package delivery, the energy package shall be stored in local battery storages. To maintain the given setpoint $P'_{Breaker}$ deficits shall be covered by energy provided by batteries located in the local network whereas generated surplus shall be buffered in available batteries.

After the user input has been confirmed, the EMS begins with the application of UC-DE-3. The EMS receives weather forecasts provided by an external service provider and measurement values provided by sensors located at the LV/MV grid connection point, flexible assets such as BESS, household energy storages and flexible loads as well as household grid connection points. Based on the received data and historic measurement values the EMS forecasts the local generation and demands and determines the best strategy to reach and maintain the setpoint schedule by utilizing the available flexibility for the pre-defined duration.

A sensor located at the grid connection will measure the power exchange of all 3 phases with the MV grid $P_{Breaker}$ and provide data to the EMS. Based on the information the EMS determines deviations between $P_{Breaker}$ and $P'_{Breaker}$ and dispatches setpoints to increase or decrease the load in the grid in order to reach $P'_{Breaker}$. Additionally, sensors located in private customer households will provide measurements of energy consumption and SOC/SOE of storages and provide the data to the EMS. Historical measurement data and weather forecasts provided by external service providers enable the EMS to predict energy generation and consumption to maximize the duration of time of maintaining $P'_{Breaker}$. In cases that the generation and demand cannot be balanced to reach ($P'_{Breaker}$) due to a lack of available storage capacity or flexibility, the UC will be terminated.

UC 4 makes use of the same principles, steps and components described as in UC-DE-3. The difference is that the energy packages are made up of surplus energy, which is exported out of the low-voltage network ex-post.

#### 4.2.2.3.4 UC-DE-3 and 4 KPIs

**KPI 6 - Accuracy of the achievement of a given setpoint**

The accuracy of reaching and maintaining a defined setpoint is a quality feature of flexibility that can be provided by local networks and communities. The ability to achieve and maintain a setpoint exactly helps to avoid power fluctuations in medium voltage network.

This KPI is intended to evaluate the precision of balancing consumption with generation of a hole energy community in order to achieve a given active power setpoint defining the load exchange at the grid connection point.

During the application of UC-DE-2 the KPI shall measure the relation between the reached (measured) active power exchange ($P_{Breaker}$) along the grid connection point and the target value ($P'_{Breaker}$).

KPI 6 Formula

$$\text{Accuracy of Setpoint reaching} = \frac{\bar{P}_{Breaker}(dt)}{P'_{Breaker}(dt)} * 100$$

The accuracy of Setpoint reaching is expected to be 80%.

**KPI 7 - Success of package-based energy supply/export**

During the application of UC-DE-3, the success of delivery of energy packages shall be documented. This KPI evaluates the success of delivery of energy packages to an EC/ the success of export energy packages of energy an EC. The KPI is determined by comparing the total number of energy packages provided successfully and the number of packages initially triggered for delivery.

KPI 7 Formula

$$\text{Success of energy supply/export in bulks} = \frac{Total\ number\ of\ successful\ deliveries\ (\mathrm{T})}{Total\ number\ triggered\ deliveries(T)} * 100$$

The Target value for the KPI is set to 70%.

**KPI 8 - Forecast of total Energy Demand**

The forecast of generation and load for an EC is a fundamental function for the EMS to increase the quality of strategy of activation of DER. It enables the EMS to balance generation and demand with a higher quality in order to maintain a given setpoint defining the load exchange along the LV/MV grid connection point and enables to forecast generation deficits or generation surplus within a given period of time.

The KPI aims to evaluate the accuracy of algorithm to forecast the total net energy demand as result of local generation and demand by comparing the amount of energy imported into the local network of the

EC or exported out of the local network of the EC with the forecasted amount of energy to be actual exchanged within a given period of time.

KPI 8 Formula

$$FEE = \frac{\sum_{t=1}^{T} |Energy\ Exchange\ Measured|_{i;t}}{\sum_{t=1}^{T} |Energy\ Exchange\ Forecasted|_{i;t}} * 100$$

FEE= Forecast of Energy Exchange

The Target value for the KPI is set FEE = 80%.

#### 4.2.2.3.5 UC-DE-3 and 4 Benefits

**Social and Environmental Benefits**

- **Reduced $CO_2$ Emissions**: As described previously in Use Case 1 benefits. In use cases 3 and 4 this can be achieved by having an accurate forecast of total energy demand.

**Economic Benefits**

- **Deferred Distribution Capacity Investments**: As described previously in Use Case 1 benefits.
- **Deferred Transmission Capacity Investments:** Reducing the load and stress on transmission elements increases asset utilization and reduces the potential need for upgrades. Closer monitoring, rerouting power flow and reducing fault current may enable utilities to defer upgrades on lines and transformers.
- **Reduced Distribution Equipment Maintenance Cost**: As described previously in Use Case 1 benefits.
- **Reduced Distribution Operations Cost**: As described previously in Use Case 1 benefits Use Case 3 and 4 Benefit formulas.

# 5 Greek demo

## 5.1 Demo description

The Greek demo [3] is led by the Greek DSO HEDNO and is situated in the Mesogeia area in the Attica region, which encompasses a mix of rural, urban and sub-urban areas servicing Athens as well as the islands Kea, Andros and Tinos. The area supplies approximately 225,000 customers in its LV and MV networks, varied from households to small, medium and large industries. The area benefits from installations of various forms of renewables, windfarms and PV including net metering and rooftop PVs as well. Part of this Mesogeia area will be the test site for the purposes of the Greek demo.

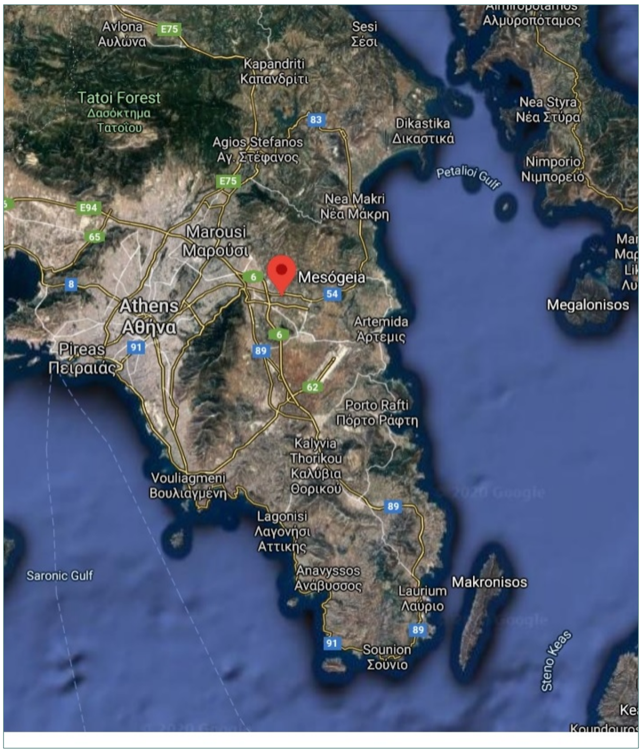


Figure 1: Mesogeia area

After completion of the first year of the Platone project, the Greek demo reviewed its potential and made its original objectives more concrete and detailed through the UC definition process. The Greek demo objectives are the following:

- To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).
- To improve grid operation through advanced grid observability.
- To achieve optimal dispatching, addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level.
- To investigate potential provision of ancillary services to the TSO by the users of the distribution network.
- To assess the penetration limits of DERs for better control and planning of the distribution network.

Table 5: Greek demo assets participating in the CBA

| Asset Name | Use Case Description | Asset Description | Asset Type | Type of associated costs |
|---|---|---|---|---|
| **SCADA** | UC-GR-1,2 > UC-DE-3 | Voltage and current flow measurements at the top of the distribution feeders | Existing asset | Operational costs |
| **AMR** | UC-GR-1,2 > UC-GR-3 | Metering devices in MV and LV, not the Platone PMUs | Existing asset | Operational costs |
| **GIS** | UC-GR-1,2 > UC-GR-3 | A Geographic Information System is designed to capture, analyse, manage and present the spatial or geographical network data. | Existing asset | Operational costs |
| **DSO Data Server** | UC-GR-1,2 > UC-GR-3 | Dockerised database of HEDNO that hosts DSO data (both network data and AMR data for MV and LV customers) | Existing asset | Operational costs |
| **Low-Cost PMUs** | UC-GR-1,2 > UC-GR-3 | | New installation asset | Investment and operational costs |
| **Blockchain Access Platform (BAP)** | UC-GR-3 | Provides encryption functionalities | New installation Asset | Investment and operational costs |
| **Platone DSO Technical Platform (DSOTP)** | UC-GR-3 | Acts as a middleware enabling connection to sensors in the field and providing services to the EMS | New installation asset | Investment and operational costs |
| **State-Estimation tool** | UC-GR-1,2 > UC-GR-3 | Estimates the actual operational network state, identifies measurements with gross errors (bad data), suppresses measurement errors and reconciles inconsistent data | New installation asset | Investment and operational costs |
| **DER control algorithm** | UC-GR-3 | Optimal dispatching of DERs in distribution networks using network tariffs | New installation asset | Investment and operational costs |

## 5.2 CBA Application

### 5.2.1 UC-GR-3: Distribution Network limit violation mitigation

The objective of UC-GR-3 is to use network tariffs in order to incentivise a more efficient operation of the network while respecting operation limits (voltages, lines overload). In detail, RES systems and customers with flexible loads are connected to the distribution network with the flexible loads considered aggregated for the scope of the UCs regarding their management in the MV level. State of the network is known with a good degree of certainty based on the state vector that the State Estimation tool produces using the available measurements and the topology data from the AMR, GIS, SCADA and PMUs. The DSO communicates network tariffs in a day-ahead context. These tariffs appropriately reflect the potential of the network exceeding its physical limits resulting in violations and/or curtailment of demand/generation. Compared to the Business-as-Usual scenario of the flat network tariffs, the DSO aims at reducing such negative effects by the use of variable day-ahead network tariffs, which incentivise the appropriate actions of the -assumed as- rational users of the distribution network.

**Table 6: Functionalities, KPIs and Benefits in UC-GR-3**

| Functionalities | KPIs | Benefits |
|---|---|---|
| **Use of network tariffs for network purposes** | KPI_GR_07 - Generation curtailment reduction | Reduced Distribution Operations Cost |
| **Curtailment of excessive generation** | KPI_GR_08 - Demand curtailment reduction | Deferred Distribution capacity Investments |
| **Curtailment of demand for network security purposes** | KPI_GR_11- Network limit violation occurrences reduction | Reduced Distribution Equipment Maintenance Cost |
| | | Reduced $CO_2$ Emissions |

#### 5.2.1.1 Use Case UC-GR-3 Functionalities

The conditions of the use case are the following:

Customers' consent is required for participation in the flexibility mechanism, so it is assumed that the customers are rational and part of the load is flexible. Moreover, it is assumed that there is a good degree of certainty in the estimation of the network state.

For the implementation of the Use Case, the technical conditions that need to be fulfilled are the installation of smart metering, the existence of smart appliances for load shifting and the normal operation of DSO systems (e.g., AMR, GIS, SCADA) during the preparation and demonstration period.

Lastly, on the regulatory aspect of this Use Case, it is required that a dynamic network charging scheme is allowed.

The functionalities of the use case are the following:

Use of network tariffs for network purposes: One of the functionalities of UC-GR-3 is the setup of an operation scheme where network tariffs are volatile. This volatility is slower than a real-time pricing scheme but faster than traditional network tariffs. The goal is to use tariffs to increase efficiency in network operation.

Curtailment of excessive generation: A secondary functionality of UC-GR-3 is the possibility of curtailment of generation in times when it is necessary in order to keep the distribution network within limits, both voltage and line limits.

Curtailment of demand for network security purposes: The third functionality deployed in UC-GR-3 is an emergency action by the DSO to curtail demand in times when it is necessary in order to keep the distribution network within limits, both voltage and line limits. Compared to generation curtailment, this action usually incurs a high cost that is the last option of a system operator.

#### 5.2.1.2 Use Case UC-GR-3 KPIs

**KPI_GR_07 - Generation curtailment reduction**

The indicator compares the amount of energy from Renewable Energy Sources (RES) that is not injected to the grid (even though it is available) due to operational limits of the grid, between the Variable Network Tariff scenario and the Business-as-Usual scenario.

$$\Delta C_{RES} = \frac{\sum_{t\in T}\sum_{i\in I} E_{g_{i,t}}^{BaU} - \sum_{t\in T}\sum_{i\in I} E_{g_{i,t}}^{R\&I}}{\sum_{t\in T}\sum_{i\in I} E_{g_{i,t}}^{BaU}} * 100$$

$E_{g_{i,t}}^{BaU}$: energy curtailment of the $i$-th RES facility at period $t$ in Business-as-Usual - Flat Network Tariff scenario (kWh)

$E_{g_{i,t}}^{R\&I}$ : energy curtailment of the $i$-th RES facility at period $t$ in the Variable Network Tariff scenario (kWh)

$I$: set of RES facilities under consideration

$T$: set of time intervals of the period under consideration (excluding periods of scheduled maintenance and outages).

**KPI_GR_08 - Demand curtailment reduction**

The indicator compares the amount of energy consumption that needs to be curtailed due to operational limits of the grid, between the Variable Network Tariff and the Business-as-Usual scenario.

$$\Delta C_{DEMAND} = \frac{\sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{BaU} - \sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{R\&I}}{\sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{BaU}} * 100$$

$E_{d_{i,t}}^{BaU}$ : demand curtailment of the $i$-th flexible customer facility at period $t$ in Business-as-Usual – Flat Network Tariff scenario (kWh);

$E_{d_{i,t}}^{R\&I}$ : demand curtailment of the $i$-th flexible customer facility at period $t$ in the Variable Network Tariff scenario (kWh);

$I$: set of flexible customers under consideration;

$T$: set of time intervals of the period under consideration.

**KPI_GR_11- Network limit violation occurrences reduction**

This indicator evaluates the difference between the number of network limit violation occurrences under a 24-hour timeframe in the Variable Network Tariff scenario and the equivalent one in the Business-as-Usual scenario.

$$NV = \frac{N_{total_{violations}}^{BaU} - N_{total_{violations}}^{R\&I}}{N_{total_{violations}}^{BaU}} * 100$$

$N_{total_{violations}}^{BaU} = N_{RES}^{BaU} \cup N_{demand}^{BaU}$ : Total number of network limit violation occurrences in Business-as-Usual - Flat Network Tariff scenario;

$N_{total_{violations}}^{R\&I} = N_{RES}^{R\&I} \cup N_{demand}^{R\&I}$: Total number of network limit violation occurrences in Variable

Network Tariff scenario;

$Nc_{RES}$: number of occurrences of RES generation curtailment;

$Nc_{demand}$: number of occurrences of demand curtailment.

#### 5.2.1.3 Use Case UC-GR-3 Benefits

**Environmental and social benefits**

- **Reduced $CO_2$ Emissions**: Improving the performance for end – users in many aspects can be translated into reduced $CO_2$ emissions produced by fossil-based electricity generators. This benefit can be achieved by maximizing the islanding duration achieving the highest self-consumption possible.

**Economic Benefits**

- **Deferred Distribution Capacity Investments**: Closer monitoring and load management on distribution feeders could potentially extend the time before upgrades or capacity additions are required.
- **Reduced Distribution Operations Cost**: Automated or remote-controlled operation of capacitor banks and feeder switches eliminates the need to send a line worker or crew to the switch location in order to operate it. This reduces the cost associated with the field service workers and service vehicle.
- **Reduced Distribution Equipment Maintenance Cost**: As a result of the implementation of Smart Grids, the maintenance works needed on the grid is less frequent because the loads are more equally distributed along the grid. Moreover, the Smart Grids are capable of online diagnosis and reporting of the equipment condition which can help for the identification of the exact part of the grid that needs maintenance.

#### 5.2.1.4 Use Case UC-GR-3 Benefit formulas

Explaining the parameters used in the formulas:

$C^{RES}$: Generation curtailment cost (€/MWh)

This parameter is the cost that the DSO is incurring for curtailing RES generation for network security purposes. In Platone, this cost is the lost revenue for RES operators/aggregators, which is equal to the feed-in-tariffs of their RES generators.

$C^{DEM}$: Demand curtailment cost (€/MWh)

This parameter is the cost that the DSO is incurring for curtailing demand for network security purposes. Generally, this cost is analogous to the concept of Value of Lost Load (VOLL). VOLL is a parameter that system operators use in order to determine the loss of social welfare during interruptions. Usually, VOLL is very difficult to calculate. Beyond VOLL, it could be allowed that some aggregators can have special contracts that determine a different curtailment cost that is lower than VOLL in exchange for other privileges.

$C^{INV}$: Distribution capacity investment deferment per unit of curtailment reduction (€/MWh)

This parameter monetizes how, on average, curtailment reduction due to DER flexibility leads to capacity investment deferment. This is caused by both a reduction in voltage and line limit violations.

$C^{MAINT}$: Equipment cost reduction due to reduced network limit violations (€/violation)

This parameter monetizes how, on average, decrease in network limit violation results in less severe equipment depredation and hence less equipment cost.

$M^{CO2}$: Monetization parameter of $CO_2$ (tons)

This parameter defines how much $CO_2$ is emitted per MWh of energy on average by an electric system (in this case Greece). This parameter allows us to calculate how much $CO_2$ emissions are reduced due to the reduction in RES curtailment achieved in UC-GR-3. Note that demand curtailment reduction is not considered fully as well because demand is usually postponed to a later time period is curtailment occurs.

$P^{CO2-DEM}$: Percentage of demand not postponed due to curtailment (%)

This parameter is the average demand that is not postponed when curtailment occurs, such as lighting.

**B-GR-3: Total Benefit of UC-GR-3:**

$\Delta C_{RES}$: *(KPI-GR-07)* Generation curtailment reduction

$\Delta C_{DEM}$: (*KPI-GR-08*) Demand curtailment reduction

$NV$: *(KPI_GR_11)* Network limit violation occurrences reduction

**B-GR-3** $= \Delta C_{RES} \cdot C^{RES} + \Delta C_{DEM} \cdot C^{DEM} + (\Delta C_{RES} + \Delta C_{DEM}) \cdot C^{INV} + NV \cdot C^{MAINT} + (\Delta C_{RES} + \Delta C_{DEM} \cdot P^{CO2-DEM}) \cdot M^{CO2}$

Where:

Distribution Operations Cost: $\Delta C_{RES} \cdot C^{RES} + \Delta C_{DEM} \cdot C^{DEM}$

Deferred Distribution capacity Investments: $(\Delta C_{RES} + \Delta C_{DEM}) \cdot C^{INV}$

Reduced Distribution Equipment Maintenance Cost: $NV \cdot C^{MAINT}$

Reduced $CO_2$ Emissions: $(\Delta C_{RES} + \Delta C_{DEM} \cdot P^{CO2-DEM}) \cdot M^{CO2}$

#### 5.2.1.5 Use Case UC-GR-3 Asset Cost formulas

**SCADA**

$$K_{\text{scada}} = O_{\text{scada}} \cdot Lifetime$$

$K_{scada}$: Total Cost of the SCADA asset

$O_{scada}$: Annual Operational Cost of the SCADA asset

**AMR**

$$K_{\text{AMR}} = O_{\text{AMR}} \cdot Lifetime$$

$K_{AMR}$: Total Cost of the AMR asset

$O_{AMR}$: Annual Operational Cost of the AMR asset

**GIS**

$$K_{\text{GIS}} = O_{\text{GIS}} \cdot Lifetime$$

$K_{GIS}$: Total Cost of the GIS asset

$O_{GIS}$: Annual Operational Cost of the GIS asset

**DSO Data Server**

$$K_{\mathrm{dsods}} = O_{\mathrm{dsods}} \cdot Lifetime$$

$K_{dsods}$: Total Cost of the DSO Data Server asset

$O_{dsods}$: Annual Operational Cost of the DSO Data Server asset

**Low-Cost PMUs**

$$K_{\mathrm{PMU}} = I_{\mathrm{PMU}} + O_{\mathrm{PMU}} \cdot Lifetime$$

$K_{PMU}$: Total Cost of the Low-Cost PMUs asset

$I_{PMU}$: Investment Cost of the Low-Cost PMUs asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{PMU}$: Annual Operational Cost of the Low-Cost PMUs asset

**Blockchain Access Platform**

$$K_{\mathrm{BAP}} = I_{\mathrm{BAP}} + O_{\mathrm{BAP}} \cdot Lifetime$$

$K_{BAP}$: Total Cost of the Blockchain Access Platform asset

$I_{BAP}$: Investment Cost of the Blockchain Access Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{BAP}$: Annual Operational Cost of the Blockchain Access Platform asset

**Platone DSO Technical Platform**

$$K_{\mathrm{DSOTP}} = I_{\mathrm{DSOTP}} + O_{\mathrm{DSOTP}} \cdot Lifetime$$

$K_{DSOTP}$: Total Cost of the Platone DSO Technical Platform asset

$I_{DSOTP}$: Investment Cost of the Platone DSO Technical Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{DSOTP}$: Annual Operational Cost of the Platone DSO Technical Platform asset

**State-Estimation Tool**

$$K_{\mathrm{est}} = I_{\mathrm{est}} + O_{\mathrm{est}} \cdot Lifetime$$

$K_{est}$: Total Cost of the State-Estimation Tool asset

$I_{est}$: Investment Cost of the State-Estimation Tool asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{est}$: Annual Operational Cost of the State-Estimation Tool asset

**DER control algorithm**

$$K_{\mathrm{DER}} = I_{\mathrm{DER}} + O_{\mathrm{DER}} \cdot Lifetime$$

$K_{DER}$: Total Cost of the DER control algorithm asset

$I_{DER}$: Investment Cost of the DER control algorithm asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{DER}$: Annual Operational Cost of the DER control algorithm asset

# 6 Italian demo

## 6.1 Demo description

The Italian Demo [2] aims to enable network users to participate in the grid optimized management (using services such peak shaving, energy shifting etc.) through the flexibility mechanism. Thanks to the coordination of Areti and the cooperation of all the partners involved in the WP3, the Italian Demo will develop an innovative system, i.e. “a complete end-to-end local flexibility market TSO-DSO coordinated”, enabling distributed resources connected in medium and low voltage grids to provide grid services, allowing the inclusion of all the stakeholders. The solution proposed will allow the development of a new model of cooperation between citizenship and municipality, bringing multiple benefits.

The trial will involve several areas of the city of Rome where specific portions of the electricity distribution network managed by Areti have been identified and selected as representative location for the project activities.

To develop the flexibility market, the Italian demo has designed an innovative, dedicated architecture, which is able to manage different information flows generating the possibility for an open and liquid market share. A brief first overview of all the components that compose the System Architecture, is highlighted below:

- Market Platform, a blockchain-based platform that enables the management of flexibility requests from System Operators (SOs) and flexibility offers from Aggregators. In detail, it collects requests and offers and then matches them according to predefined rules and priorities;
- Aggregator Platform, an operational platform that facilitates Aggregator to manage the flexibility assets. Here, several tools are able to analyse data coming from different distributed energy resources (DERs), evaluate and aggregate available flexibility from several points of delivery (PoDs);
- DSO Technical Platform, an innovative platform that allows DSOs to improve reliability and aspects of service by exploiting flexibility made available from DERs connected to their grids. It is also able to predict grid congestions and voltage violations;
- Access Layer, a structure composed by three main components Light Node, Blockchain Access Layer and Shared Customer Database. The Light Node and the Blockchain Access Layer compose a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture. The Shared Customer Database instead is a repository system where all data related to flexible PoD are collected and available to all the stakeholders involved in the process.

Table 7: Italian demo assets participating in the CBA

| Asset Name | Use Case involvement | Asset Description | Asset Type | Type of associated costs |
|---|---|---|---|---|
| **Light Node** | UC-IT-1, UC-IT-2 | It is a device able to gather PoD metering data from smart meter. It receives Setpoint from DSO Technical Platform and makes it available to Customers Activation Systems such as Energy Management System (EMS), smart appliance etc. to activate flexibility. | New Installation Asset | Investment and operational costs |

| | | | | |
|---|---|---|---|---|
| **Smart Meter** | UC-IT-1, UC-IT-2 | Smart meter of 2nd generation to measure electrical PoD data | Existing | Investment and Operational costs (DSO) |
| **EV charging infrastructure** | UC-IT-1, UC-IT-2 | EV charging Infrastructure | Existing Asset to be updated | Investment and Operational costs (DSO only for this project, but for customer as rule) |
| **Flexibility Resources** | UC-IT-1, UC-IT-2 | Storage System | Existing and new installations | Investment and Operational cost (DSO only for this project, but for customer as a rule) |
| **Aggregator Platform** | UC-IT-1, UC-IT-2 | Platform used by the aggregator to manage flexibility provided by customers | New Installation Asset | Investment and Operational cost (Aggregator) |
| **Blockchain Access Platform (BAP)** | UC-IT-1, UC-IT-2 | Provides encryption functionalities | New Installation Asset | Investment and Operational cost<br>(DSO) |
| **Platone DSO Technical Platform (DSOTP)** | UC-IT-1, UC-IT-2 | Platform for grid forecast and flexibility services management | New Installation Asset | Investment and Operational cost<br>(DSO) |
| **Market Platform** | UC-IT-1, UC-IT-2 | Platform to manage flexibility market sessions | New Installation Asset | Investment and Operational cost<br>(Market operator) |
| **Shared Customer Database** | UC-IT-1, UC-IT-2 | Database to store and share with platforms and stakeholders' flexibility data | New Installation Asset | Investment and Operational cost<br>(DSO) |

## 6.2 CBA Application

In the Italian demo UC-IT-1 and UC-IT-2 are structurally similar, with one focusing on voltage and the other on congestion management. Currently UC-IT-1 is not completely developed. However, it is supposed that the same approach used for UC-IT-2 can be applied also to UC-IT-1. Therefore, **our application will cover both UCs when necessary but will mostly focus on UC-IT-2, while taking into account the UC-IT-1 will have similar attributes with regards to CBA.**

### 6.2.1 UC-IT-1,2: Voltage, Congestion Management

#### 6.2.1.1 UC-IT-1 Voltage Management

Table 8: Functionalities, KPIs and Benefits in UC-IT-1

| Functionalities | KPIs | Benefits |
|---|---|---|
| **Evaluation of Market Liquidity for voltage management service -> *Allow grid users and aggregators to participate in ancillary services market*** | KPI-IT-01 | • Reduced Ancillary Service Cost<br>• Deferred Transmission capacity Investments<br>• Deferred Distribution capacity Investments<br>• Reduced Distribution Operations Costs<br>• Reduced number of outages |
| **Forecast of customers' energy behaviour at PoD** | KPI-IT-02 | • Improving reliability of forecast system<br>• Deferred Distribution capacity Investments<br>• Reduced number of outages |
| **Forecast of grid voltage drop** | KPI-IT-03 | • Improving reliability of forecast system<br>• Deferred Distribution capacity Investments<br>• Reduced number of outages |
| **Flexibility Effectiveness** | KPI-PR-04 | • Reduced number of outages<br>• Reduced Ancillary Service Cost |

#### 6.2.1.2 UC-IT-1 Functionalities

In the day-ahead market, the Flexibility Resource (FR) Owner sends to the Aggregator Platform the list of resources available for the day after. The list is subsequently transmitted by the Aggregator Platform to the Italian Shared Customer Database (SCD). For each Point of delivery (PODs), the SCD collects quarterly measures and data useful for flexibility and sends them to the DSO Technical Platform, the TSO simulator and the Aggregator Platform.

The other processes take place in parallel:

- Detection of voltage violations on the distribution grid by the Italian DSO Technical Platform and definition of local flexibility requests, in the event the issue cannot be solved through its own solutions.
- Definition of voltage violations on the transmission network by the TSO simulator and request of flexibility to solve them in HV grid.
- Day ahead forecasting and real time monitoring of voltage violations for a better control and management of grid operations and prevision of possible outages/voltage drops.
- Gathering by the Aggregator Platform of flexibility offers from customers in LV and MV and offering to the Market Platform.

At gate closure, all day ahead requests and offers are stored in the Market Platform, which matches the offers with the DSO's requests and orders them economically; then, it repeats the same procedure with the TSO requests.

The list of awarded offers is sent to DSOTP for evaluating the grid constraints violations. Finally, the market platform receives the list of offers compliant with local grid constraints and sends it to all the stakeholders.

At this step, the Aggregator Platform sends a reservation to the FR Owner for the resources that will be selected for the day-ahead market.

The same steps are also followed in the Real Time sessions. Indeed, in these Market sessions, the offers to be matched with DSO and TSO Real Time requests are the ones still valid because not matched in previous market sessions.

The activation phase begins when the DSO and TSO need flexibility. The DSOTP and the TSO simulator communicate to the market Platform to move a specific offer. The Market Platform sends the order to the DSOTP, which divides it for every POD and dispatches the set point to the Light Nodes. The Light Nodes make available the set points to the BMS and measures the electrical quantities to be sent to the SCD for the evaluation of the energy flexibility.

For the settlement phase, the Market Platform acquires data from the Smart Communication Device (SCD) and calculates the difference between market baseline and electrical quantities measured in the same time frame, uploaded in the SCD by Light Nodes. The Market Platform runs the settlement algorithm and finds the outcomes. Settlement outcomes are transmitted to the Aggregator Platform, the DSO and the TSO Simulator.

Finally, the DSO pays the flexibility to the Aggregator, who can pay the fee to the FR Owner.

#### 6.2.1.3 UC-IT-2: Congestion Management

This use case describes the steps to prevent congestion issues in transmission and distribution systems, by using flexible resources, contemplating all the phases concerned (procurement, activation and settlement) in the day-ahead and real time flexibility market. The DSO can use flexible resources connected to the distribution system and the TSO can use flexible resources connected to distribution systems under the DSO's approval. The state of the grid is assessed and monitored respectively by the DSO in order to keep the electrical quantities of the system within admissible ranges.

**Table 9: Functionalities, KPIs and Benefits in UC-IT-2**

| Functionalities | KPIs | Benefits |
|---|---|---|
| **Evaluation of Market Liquidity for congestion management service** | KPI-IT-01 | • Reduced Ancillary Service Cost<br>• Deferred Transmission capacity Investments<br>• Deferred Distribution capacity Investments<br>• Reduced Distribution Operations Costs<br>• Reduced number of outages |

| | | |
|---|---|---|
| **Forecast of customers' energy behaviour at PoD** | KPI-IT-02 | • Improving reliability of forecast system<br>• Deferred Distribution capacity Investments<br>• Reduced number of outages |
| **Forecast of grid congestions** | KPI-IT-03 | • Improving reliability of forecast system<br>• Deferred Distribution capacity Investments<br>• Reduced number of outages |
| **Flexibility Effectiveness** | KPI-PR-04 | • Reduced number of outages<br>• Reduced Ancillary Service Cost |

#### 6.2.1.4 UC-IT-2 Functionalities

The Use Case describes the main steps to prevent congestion issues in transmission and distribution systems by exploiting flexibility resources, contemplating all the phases concerned (procurement, activation and settlement) in the day-ahead and real time flexibility market. The DSO can use flexible resources connected to the distribution system and the TSO can use flexible resources connected to distribution systems under the DSO's approval. The state estimation is assessed and monitored by the DSO in order to keep the electrical quantities within admissible ranges. In the day ahead market, the FR Owner sends to Aggregator Platform the list of the resources available for the day after. The list is subsequently transmitted by the Aggregator Platform to the Shared Customer Database (SCD). For each Point of delivery (PoDs), the SCD collects quarterly measures and data useful for flexibility and sends them to the DSO Technical Platform, the TSO simulator and the Aggregator Platform.

In addition, three more processes take place in parallel:

- Forecast of congestion issues on the distribution grid by the DSO Technical Platform and definition of local flexibility requests, in the event the issue cannot be solved through its own solutions;
- Definition of congestion issues on the transmission network by the TSO simulator and request of flexibility to solve them in HV grid;
- Collection of flexibility offers by the Aggregator Platform from customers in LV and MV and offering to the Market.

At gate closure, all day ahead requests and offers are stored in the Market Platform, which matches the offers with the DSO's requests first and orders them economically and then, it repeats the same procedure with the TSO requests.

The list of awarded offers is sent to the DSOTP for evaluating the grid constraints violations. Finally, the market platform receives the list of offers compliant with local grid constraints and sends them to all the stakeholders.

The same steps are also followed in the Real Time sessions. Indeed, in these Market sessions, the offers to be matched with DSO and TSO Real Time requests are the ones still valid because not matched in previous market sessions.

The Market Platform sends the order to the aggregator platform which then forward it to DSOTP, which divides it for every POD and dispatches the set point to the Light Nodes. The Light Nodes make available the set points to the customers' systems (e.g., EMS, storage systems etc.) and measures the electrical quantities to be sent to the SCD for evaluation of the energy flexibility.

For the settlement phase, the Market Platform acquires data from the SCD and calculates the difference between market baseline, provided by aggregator (acting as BRP), and electrical quantities measured in the same time frame, uploaded in the SCD by Light Nodes. The Market Platform runs the settlement algorithm and finds the outcomes. Settlement outcomes are transmitted to the Aggregator Platform, the DSO and the TSO Simulator.

Finally, the DSO pays the flexibility to the Aggregator, who can pay the fee to the FR Owner.

### 6.2.2 UC-IT-1,2 KPIs

Both for UC-IT-1 and 2, the same KPIs following are defined:

**KPI-PR-04 – Flexibility Effectiveness**

This KPI aims to measure the effectiveness of flexibility provision. The KPI measures the sum of successfully provided flexibility in relation to the requested demand for flexibility.

KPI Formula:

$$Flexibility\ Effectiveness = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N}\sum_{i=1}^{N}\frac{|Quantity\_provided_{i,t}|}{|Setpoint_{i,t}|}\cdot 100$$

where:

*$Quantity\_provided_{i,t}$* : amount of quantity (kW, kVAr, etc.) exchanged with the grid by *i*-th flexible resource in the period *t*

*$Setpoint_{i,t}$* : amount (kW, kVAr, etc.) of *i*-th request of flexibility in the period *t*

*N*: set of flexible resources that made flexibility available

*T*: examined period

For each flexibility service (congestion solving, voltage regulation), the separate value of this KPI will be calculated.

**KPI-IT-01 – Market Liquidity**

This KPI aims to measure the market liquidity. The ratio of the sum of flexibility offered to the requested demand for flexibility is measured.

KPI Formula:

$$Market\ Liquidity\ Up = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}|Flexibility\_offered\_up_{i,t}|}{\sum_{j=1}^{R}|Flexibility\_requested\_up_{j,t}|}\cdot 100$$

$$Market\ Liquidity\ Down = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}|Flexibility\_offered\_down_{i,t}|}{\sum_{j=1}^{R}|Flexibility\_requested\_down_{j,t}|}\cdot 100$$

where:

$Flexibility\_offered\_up_{i,t}$: amount (kW, kVAr, etc.) of flexibility to increase generation/decrease demand offered from *i*-th flexible resource in the period *t*

$Flexibility\_offered\_down_{i,t}$: amount (kW, kVAr, etc.) of flexibility to decrease generation/increase demand offered from *i*-th flexible resource in the period *t*

$Flexibility\_requested\_up_{j,t}$: amount (kW, kVAr, etc.) of *j*-th request of flexibility to increase generation/decrease demand in the period *t*

$Flexibility\_requested\_down_{j,t}$: amount (kW, kVAr, etc.) of *j*-th request of flexibility to decrease generation/increase demand in the period *t*

N: set of flexible resources that made flexibility available

R: number of SOs flexibility requests

T: examined period

**KPI-IT-02 – Forecast Reliability – Customer profile**

This KPI evaluates the reliability of the tool performing forecasting of power flow exchanged by each Resource with the grid. The indicator is calculated for forecasted time range (next 24h or next 4h).

KPI Formula:

$$FC_{Next24h}(\,or\;FC_{Next4h}) = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N_t}\sum_{i=1}^{\mathrm{N_t}}\left|\frac{RL\_profile_{i,t} - FC\_profile_{i,t}}{RL\_profile_{i,t}}\right| \cdot 100$$

where:

| | | |
|---|---|---|
| $RL\_profile_{i,t}$ | : | real profile [kW or kVAr] of *i*-th customer in the period *t* |
| $FC\_profile_{i,t}$ | : | forecasted profile [kW or kVAr] of *i*-th customer for the period *t* |
| $N_t$ | : | number of customers in the period *t* |
| $T$ | : | examined period |

**KPI-IT-03 – Forecast Reliability – Grid Profile**

This KPI evaluates the reliability of the tool performing forecasting of power flow in significant assets of the grid. The indicator is calculated for forecasting time range (next 24h or next 4h).

$$Power\_Flow\_FC\_Next24h\;(or\;Power\_Flow\_FC\_Next4h) =$$

$$= \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N_t}\sum_{i=1}^{\mathrm{N_t}}\left|\frac{RL\_Power\_Flow_{i,t} - FC\_\_Power\_Flow_{i,t}}{RL\_\_Power\_Flow_{i,t}}\right| \cdot 100$$

where:

$RL\_Power\_Flow_{i,t}$: real power flow [kW or kVA] of *i*-th asset in the period *t*

$FC\_Power\_Flow_{i,t}$: power flow forecasted [kW or kVA] of *i*-th asset for the period *t*

$N_t$: number of assets of same category (e.g. Primary Substation nodes, Secondary Substation nodes etc.) in the period *t*

T: examined period

**Project KPI KPI-PR-04 is a more inclusive variation of the Italian KPI-IT-01. Therefore, only KPI-PR-04 will be used in the CBA.**

#### 6.2.2.1 UC-IT-1,2 Benefits

**Economic Benefits**

- **Deferred Distribution Capacity Investments**: Closer monitoring and load management on distribution feeders could potentially extend the time before upgrades or capacity additions are required.
- **Reduced Ancillary Service Cost:** Thanks to a higher liquidity of the market, flexibility resources are more reliable and so fewer ancillary resources are required to manage the grid.

- **Improving reliability of forecast system:** Improving monitoring of customers' energy behaviour power flow exchanged by each resource with the grid allows to enhance reliability of forecasts.
- **Reduced number of outages**: Automated congestion control with flexible final user resources decrease the possibility of outages and discontinuance of the services preserving SOs from high maintenance costs of equipment as well as penalties and fees respectively.

#### 6.2.2.2 UC-IT-1,2 Benefit formulas

Explaining the parameters used in the formulas:

$I^V$: Average worst voltage/congestion improvement per kW of flexibility effectiveness (p.u.)

This parameter transforms the flexibility effectiveness to voltage improvement caused by said flexibility.

$C^{D-V}$: Network upgrade deferment cost per p.u. improvement of worst congestion (€/p.u.)

This parameter transforms the voltage improvement to network upgrade deferment.

$N^{O-V}$: Number of outages improvement per p.u. improvement of worst voltage profile (outages/p.u.)

This parameter transforms the voltage improvement to number of outages reduction.

$C^O$: Average cost per outage (€/outage)

This parameter describes the average monetary cost of outages in Italy.

$C^{AS}$: Ancillary services cost reduction per flexibility effectiveness (€/kW)

This parameter transforms the flexibility effectiveness into ancillary services cost reduction.

$E^{FRC}$: Effect of forecast reliability of customer profiles on total benefit (%/%)

This parameter translates forecast reliability to how it affects the overall benefit in (%).

$E^{FRG}$: Effect of forecast reliability of grid profiles on total benefit (%/%)

This parameter translates forecast reliability to how it affects the overall benefit in (%).

$G$: Effect of forecast reliability of grid profiles on total benefit (%/%)

This parameter translates forecast reliability to how it affects the overall benefit in (%).

**B-IT-1,2: Total Benefit of UC (1,) 2**

KPIs used in the formulas

$FlexEff$: (KPI-PR-04) Flexibility Effectiveness

$FR_C$: (KPI-IT-02) Forecast Reliability

$FR_G$: (KPI-IT-03) Forecast Reliability

**B-IT-1,2** $= (FlexEff \cdot I^V \cdot C^{D-V} + FlexEff \cdot I^V \cdot N^{O-V} \cdot C^O + FlexEff{\cdot}C^{AS}){\cdot}(FR_C{\cdot}E^{FRC}){\cdot}(FR_G{\cdot}E^{FRG})$

Where:

Capacity deferment: $FlexEff \cdot I^V \cdot C^{D-V}$

Reduced number of outages: $FlexEff \cdot I^V \cdot N^{O-V} \cdot C^O$

Reduced Ancillary Service Cost: $FlexEff{\cdot}C^{AS}$

Improving reliability of forecast system: ${\cdot}(FR_C{\cdot}E^{FRC}){\cdot}(FR_G{\cdot}E^{FRG})$

Reduction factor due to forecast reliability, customer profile: $FR_C{\cdot}E^{FRC}$

Reduction factor due to forecast reliability, grid profile: $FR_G{\cdot}E^{FRG}$

#### 6.2.2.3 Use Case 1 and 2 Asset Cost formulas

**Light Node**

$$K_{\text{node}} = I_{\text{node}} + O_{\text{tnode}} \cdot Lifetime$$

$K_{node}$: Total Cost of the Light Node asset

$I_{node}$: Investment Cost of the Light Node asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{node}$: Annual Operational Cost of the Light Node asset

**Smart Meter**

$$K_{\text{meter}} = I_{\text{meter}} + O_{\text{meter}} \cdot Lifetime$$

$K_{meter}$: Total Cost of the Smart Meter asset

$I_{meter}$: Investment Cost of the Smart Meter asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{meter}$: Annual Operational Cost of the Smart Meter asset

**EV charging Infrastructure**

$$K_{\text{EV}} = I_{\text{EV}} + O_{\text{EV}} \cdot Lifetime$$

$K_{EV}$: Total Cost of the EV charging Infrastructure asset

$I_{EV}$: Investment Cost of the EV charging Infrastructure asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{EV}$: Annual Operational Cost of the EV charging Infrastructure asset

**Flexibility Resources**

$$K_{\text{flex}} = I_{\text{flex}} + O_{\text{flex}} \cdot Lifetime$$

$K_{flex}$: Total Cost of the Flexibility Resources asset

$I_{flex}$: Investment Cost of the Flexibility Resources asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{flex}$: Annual Operational Cost of the Flexibility Resources asset

**Aggregator Platform**

$$K_{\text{agg}} = I_{\text{agg}} + O_{\text{agg}} \cdot Lifetime$$

$K_{agg}$: Total Cost of the Aggregator Platform asset

$I_{agg}$: Investment Cost of the Aggregator Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{agg}$: Annual Operational Cost of the Aggregator Platform asset

**Blockchain Access Platform**

$$K_{\mathrm{BAP}} = I_{\mathrm{BAP}} + O_{\mathrm{BAP}} \cdot Lifetime$$

$K_{BAP}$: Total Cost of the Blockchain Access Platform asset

$I_{BAP}$: Investment Cost of the Blockchain Access Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{BAP}$: Annual Operational Cost of the Blockchain Access Platform asset

**DSO Technical Platform**

$$K_{\mathrm{DSOTP}} = I_{\mathrm{DSOTP}} + O_{\mathrm{DSOTP}} \cdot Lifetime$$

$K_{DSOTP}$: Total Cost of the Platone DSO Technical Platform asset

$I_{DSOTP}$: Investment Cost of the Platone DSO Technical Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{DSOTP}$: Annual Operational Cost of the Platone DSO Technical Platform asset

**Market Platform**

$$K_{\mathrm{market}} = I_{\mathrm{market}} + O_{\mathrm{market}} \cdot Lifetime$$

$K_{market}$: Total Cost of the Market Platform asset

$I_{market}$: Investment Cost of the Market Platform asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{market}$: Annual Operational Cost of the Market Platform asset

**Shared Customer Database**

$$K_{\mathrm{db}} = I_{\mathrm{db}} + O_{\mathrm{db}} \cdot Lifetime$$

$K_{db}$: Total Cost of the Shared Customer Database asset

$I_{db}$: Investment Cost of the Shared Customer Database asset *(assuming that the lifetime of the asset matches the lifetime of the project, unless specified otherwise)*

$O_{db}$: Annual Operational Cost of the Shared Customer Database asset

**Total cost K**

$$K_{\mathrm{total}} = K_{\mathrm{lightnode}} + K_{\mathrm{smartmeter}} + K_{\mathrm{EV}} + K_{\mathrm{flex}} + K_{\mathrm{agg}} + K_{\mathrm{BAP}} + K_{\mathrm{DSOTP}} + K_{\mathrm{market}} + K_{\mathrm{db}}$$

# 7 Conclusion

This report presented the CBA methodology developed in WP7 of Platone and its theoretical application on the Platone demo use cases. The methodology consists of 7 sequential steps that include defining assets, functionalities, benefits, baseline cases and costs. The methodology additionally has an extra dimension which is the MCA, where non-monetary benefits are considered in the CBA. One of the key aspects of the methodology developed for Platone is that CBA is performed on a per-use-case basis and the utilisation of the KPIs of each use case without requiring additional data inputs from the field.

The theoretical application of the methodology included the performance of the 7 steps as described above, based on the currently available information on the use cases. First, assets were mapped to functionalities and those functionalities to benefits. Then, the KPIs of the use case were identified along with the baseline and were used to build appropriate formulas that can be used to perform the quantification of those benefits at a later stage. Finally, formulas for the costs of all assets associated with each use case were built.

Concluding, the MCA-CBA analysis will be carried out by utilising the KPIs of each demo and linking them with assets, functionalities and benefits. The formulas provided in this report can be used to monetize the costs of each asset (operational and investment costs) and the benefits (monetary and non-monetary) and thus provide an important decision support tool. This analysis will be used to evaluate and identify the benefits and the beneficiaries of the project from an economic, social and environmental aspect and assess the economic viability and sustainability of a project. The methodology proposed in this report will be used at a later stage during deliverable 7.4 ‘Results of the CBA and SRA’ for the expected calculations and conclusions.

# 8 List of Tables

# 9 List of Figures

# 10 List of References


[1] European Commission, “2050 long-term strategy,” 2018. [Online]. Available: https://ec.europa.eu/clima/policies/strategies/2050_en.

[2] Platone, “Deliverable D3.3 v1.0, Delivering of technology (v1),” 2021. [Online]. Available: https://www.platone-h2020.eu/Project/Deliverables.

[3] Platone, “Deliverable D4.1 v1.0, Report on the Definitions of KPIs and UCs,” 2020. [Online]. Available: https://www.platone-h2020.eu/Project/Deliverables.

[4] Platone, “Deliverable 5.2 v1.0, Detailed Use Case Descriptions,” 2020. [Online]. Available: https://www.platone-h2020.eu/Project/Deliverables.

[5] M. S. Jiménez and C. Filiou, “Guidelines for conducting a cost-benefit of Smart Grid projects,” 2012.

[6] F. Pilo and M. Troncia, “MC-CBA toolkit : model and case study Discussion paper”.

[7] A. Faruqui and R. Hledik, “Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects,” 2010.

# 11 List of Abbreviations

| Abbreviation | Term |
|---|---|
| AMR | Automatic Meter Reading |
| BAP | Blockchain Access Platform |
| BaU | Business as Usual |
| BESS | Battery Energy Storage System |
| BMS | Building Management System |
| CBA | Cost-Benefit Analysis |
| DER | Distributed Energy Resources |
| DSL | Digital Subscriber Line |
| DSO | Distribution System Operator |
| DSOTP | Platone DSO technical platform |
| EC | Electrical Circuit |
| EMS | Energy Management System |
| EPRI | Electric Power Research Institute |
| EV | Electric Vehicle |
| FR | Flexibility Resource |
| GIS | Geographic Information System |
| HEDNO | Hellenic Electricity Distribution Network Operator |
| ISGAN | International Smart Grid Action |
| JRC | Joint Research Centre |
| KPI | Key Performance Indicators |
| LTE | Long term evolution |
| LV | Low voltage |
| MCA | Multi-criteria analysis |
| MV | Medium voltage |
| PMU | Phasor Measurement Unit |
| PoD | Points of Delivery |
| RES | Renewable Energy Sources |
| SCADA | Supervisory Control and Data Acquisition |
| SCD | Smart Communication Device |
| SO | System Operator |
| SOC | State of Charge |
| SOE | State of Energy |
| TSO | Transmission System Operator |
| UC | Use Case |