MOEEBIUS

Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability

D6.2 MOEEBIUS DER Flexibility Analysis, Aggregation and Forecasting Module

Version number: 1.0
Dissemination Level: PU
Lead Partner: HYPERTECH
Due date: 28/02/2018
Type of deliverable: Other
STATUS: Submitted

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680517

Published in the framework of:

MOEEBIUS - Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability

MOEEBIUS website: www.moeebius.eu

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Revision and history chart:

VERSION	DATE	EDITORS	COMMENT
1.0	28/02/2018	HYPERTECH	Submitted to the EC

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Glossary

Acronym	Full name
MOEEBIUS	Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability
DER	Distributed Energy Resources
DAFM	DER Aggregation and Flexibility Analysis Module
ESCOs	Energy Service Companies
DR	Demand Response
VA	Visual Analytics
DSS	Decision Support System
SoTA	State of the Art
KPI	Key Performance Indicators
DSM	Demand Side Management
UI	User Interface
ToU	Time of Use
RTP	Real Time Pricing
CES	Constant Elasticity of Substitution
OLS	Ordinary Least Squares
UCD	User Centred Definition
UX	User Experience
DDAE	District Dynamic Assessment Engine
CPP	Critical Peak Pricing
OMIE	OMI-Polo Español S.A
VPP	Virtual Power Plant
SUS	System Usability Scale

1 Executive summary

The main objective of this document is to provide the updated documentation about DER Forecasting, Aggregation and Flexibility Analysis Module specifications, the development view of the tool along with the early evaluation of the different functionalities supported by the tool.

The role of the module is to support energy optimization and peak load management through the effective utilization of aggregated demand flexibility.

Multi-parameter criteria analysis algorithms and tools of demand flexibility will be utilized by a Visual Analytics component which will provide visualization and interaction mechanisms to the Aggregators and ESCOs for multidimensional analysis, correlation and efficient management of prosumer profiles and prosumer flexibility. Commonalities and complementarities between loads should be identified towards dynamically extracting load clusters for different purposes (Loads with Zero Flexibility, Loads with variable flexibility under specific constraints and incentives, and Loads with High Flexibility). Assets will be classified considering their capacity under comfort-based and health constraints, response capability and flexibility and price-sensitivity.

In addition, the DAFM module should be integrated with a Dynamic Pricing Simulation Engine towards enabling high-level flexibility profiling calculation in absence of low level data from building premises. The engine will constantly collect and analyse energy data, following market dynamic fluctuations and feed the outcomes of the analytics process to building level management system towards managing and illustrating the response capacity of demand in price-based control strategies for peak-load management optimization.

This deliverable is the updated version of D6.1, providing the final development of the DAFM platform for the Aggregator. The tool incorporates the list of features defined for the tool enhanced with a visually appealing GUI to facilitate the business stakeholders. The manual documentation accompanies the development of the module, supporting that way a better understanding of the different views of the system. Finally, the alpha test evaluation of the module is reported. The UCD approach has been adopted in the project (following the establishment of the living lab at the very early phase of the project) and thus an early evaluation of the different system functionalities is taking place prior to the final deployment of the tool.

At the end of the deliverable period, the final version of the tool is available for demonstration incorporating the full list of functionalities specified in the project. The next step of the work is the customization of each module of the system, final integration and demonstration of specific functionalities at the different pilot sites of the project (T6.5 Testing, Parameterization and Verification & T7.6 Results Validation, Impact Assessment and Cost-Benefit Analysis). We have to point out

that customization process will take into account the specific pilot requirements and business models as defined early in the project.

2 Objectives of the report

2.1 Introduction

The main objective of this task is to provide the final development of the DER Forecasting, Aggregation and Flexibility Analysis Module as part of the overall MOEEBIUS framework defined in T3.1 MOEEBIUS Architectural Design and Technological/ Functional Specifications - Communication interfaces and protocols definition ([1]).

Towards this direction and following the development of the DAFM engine during the project period, we report the list of features and functionalities supported by the platform. We have to point out that no major deviations are reported from the initial list presented in D6.1, though slight modifications (both functional and UX-related) are highlighted following end users consultation.

In addition the manual document of the DAFM engine is provided. This work is tightly associated with the definition of the core features. Nevertheless, the presentation of the core functionalities is taking into account the final development and the different views of the system

Finally, the early evaluation of the software module is mandatory to ensure that the final product is in line with the early requirements and needs of the business stakeholders. Towards this direction, both functional and technical evaluation should be performed prior to the deployment of the tool at the different pilot sites of the project.

2.2 Relevance with other Tasks

The purpose of this document is to report the development of the final (stable) version of the DER Forecasting, Aggregation and Flexibility Analysis Module. Therefore, this deliverable is tightly linked with the design of the tool in D6.1 MOEEBIUS DER Flexibility Analysis, Aggregation and Forecasting Module specifications.

We have to point out that the DAFM engine is part of the integrated District Level management framework and thus, there is clear interconnection with the work performed in T6.5 Testing, Parameterization and Verification towards the integration and configuration of the DAFM engine as part of the overall MOEEBIUS framework (taking also into account the definition of the MOEEBIUS reference architecture in T3.1 MOEEBIUS Architectural Design and Technological/ Functional Specifications - Communication interfaces and protocols definition).

By setting the final version of the DAFM engine, we may further proceed to the evaluation of the platform at the different pilot sites (T7.3-T7.5) towards T7.6 Results Validation, Impact Assessment and Cost-Benefit Analysis.

2.3 Structure of the document

The structure of the document is further provided:

- Chapter 2 documents the main objectives of this document and the relation with other MOEEBIUS tasks
- In chapter 3, we are providing the updated list of functionalities and features supported by the DAFM engine. We have to point out that the updated list of functionalities is delivered following consultation with the external stakeholders (as part of the LL establishment) as an early feedback to the final development of the tool
- In chapter 4, the manual documentation of the application is provided. The manual is providing a detailed workflow presentation of the different views of the system
- The next chapter (Chapter 5) focuses on the alpha test evaluation of the DAFM engine. The evaluation analysis covers both the functional and technical evaluation of the tool along with the UX evaluation
- Chapter 6 provides a summary of the work along with the main conclusions related to the deployment of the DAFM engine at the different pilot sites.

The presentation of the work in this deliverable is in line with the early design of the platform in D6.1 MOEEBIUS DER Flexibility Analysis, Aggregation and Forecasting Module specifications.

3 MOEEBIUS DAFM Engine Design Specification – Updated Version

This is an updated version of D6.1 MOEEBIUS DER Flexibility Analysis, Aggregation and Forecasting Module specifications towards the definition of the final list of features supported by the DAFM module. The 2nd (and final) version of the list of functionalities is taking into account end users feedback during the reporting period. An overview of MOEEBIUS DER Flexibility Analysis, Aggregation and Forecasting Module architecture is presented in the next section followed by the final list of DAFM features.

3.1 MOEEBIUS DAFM Overall Architecture

As specified in D3.1 and D6.1, the high level (conceptual) architecture definition of the DAFM engine is the following:

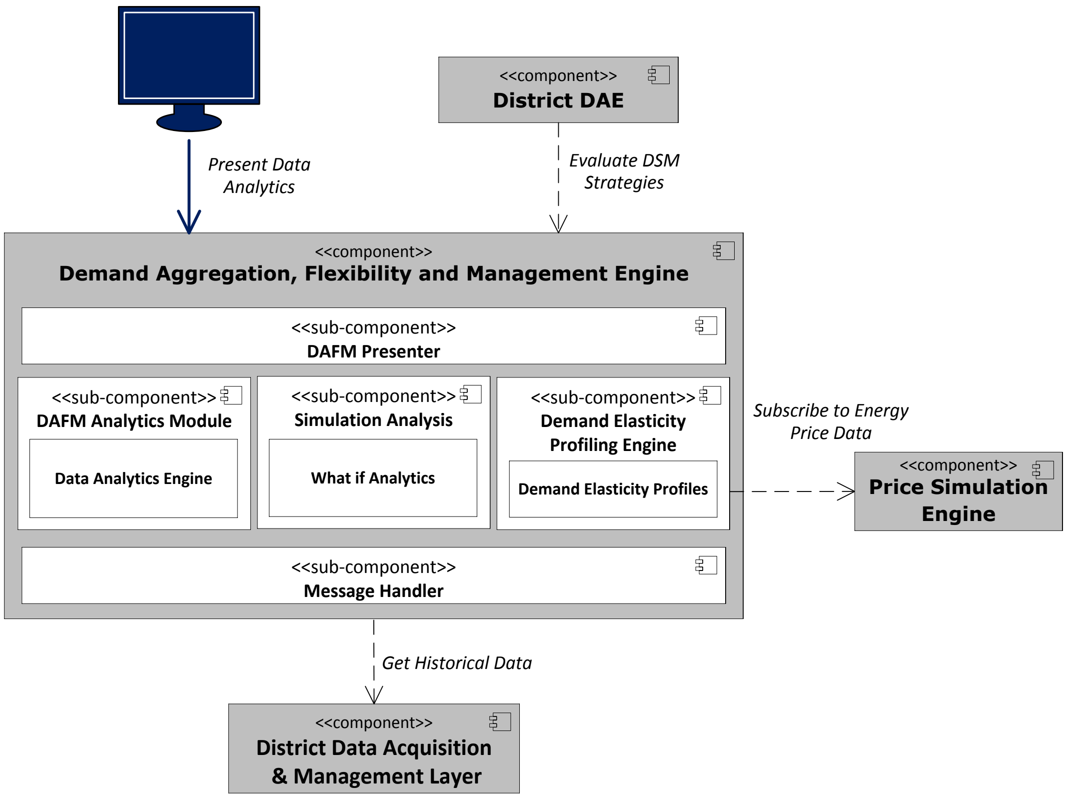

Figure 1 DAFM Engine Conceptual Architecture

A short description of the core components that consist of the DAFM engine is provided:

- **Message Handler**: The role of this module is to (de)serialize any type of data retrieved from Aggregator's Database (District Data Acquisition and Management Layer)
- **DAFM Analytics Module**: This is the application module of the DAFM Component which is responsible for analyzing the data series associated with portfolio operation. Different analytics techniques will be incorporated in the

DAFM engine, considering clustering/classification and trends/ outliers extraction as the core functionalities. The outcomes of this process will be further available for visualization through DAFM dashboard.

- **Simulation Analysis (What if analytics) Engine**. The role of this component is to act as a "what if simulation engine" to enable the evaluation of different DSM strategies. In the updated version of the simulation engine, we are decoupling the business layer from DSS/optimization layer.
- **Demand Elasticity Profiling Engine**. As a side functionality incorporated in the DAFM engine toward the extraction of high level demand elasticity profiles. More specifically, the role of this component is to retrieve input data (energy consumption, prices) and perform analytics towards the extraction of demand profiles that will further enable triggering the appropriate price based DSM strategies. The detailed algorithmic framework of this software component is provided in Section 5.
- **DAFM Presenter**: The role of this component is to set the front end view of the platform and enable data analytics presentation through Aggregator UI. The DAFM Presenter acts as the mediator between the analytics module and the view layer of the application (Aggregator UI).

The updated functional and technical specifications analysis of the different sub-modules is presented in the following section.

3.2 MOEEBIUS DAFM functional and technical specifications definition

By setting the design specifications of the DER Forecasting, Aggregation and Flexibility Analysis Module in the 1st version of the deliverable, we proceed with the final list of functional and technical specifications. The analysis is provided for each sub-system that consists of the DAFM engine.

3.2.1 DAFM Message Handler

The role of this software component is to set the interface layer with the MOEEBIUS District Level Middleware which acts as the data management layer of the application. We have expanded the data model defined early in the project to address the specific attributes required for the business functionalities implemented in the project.

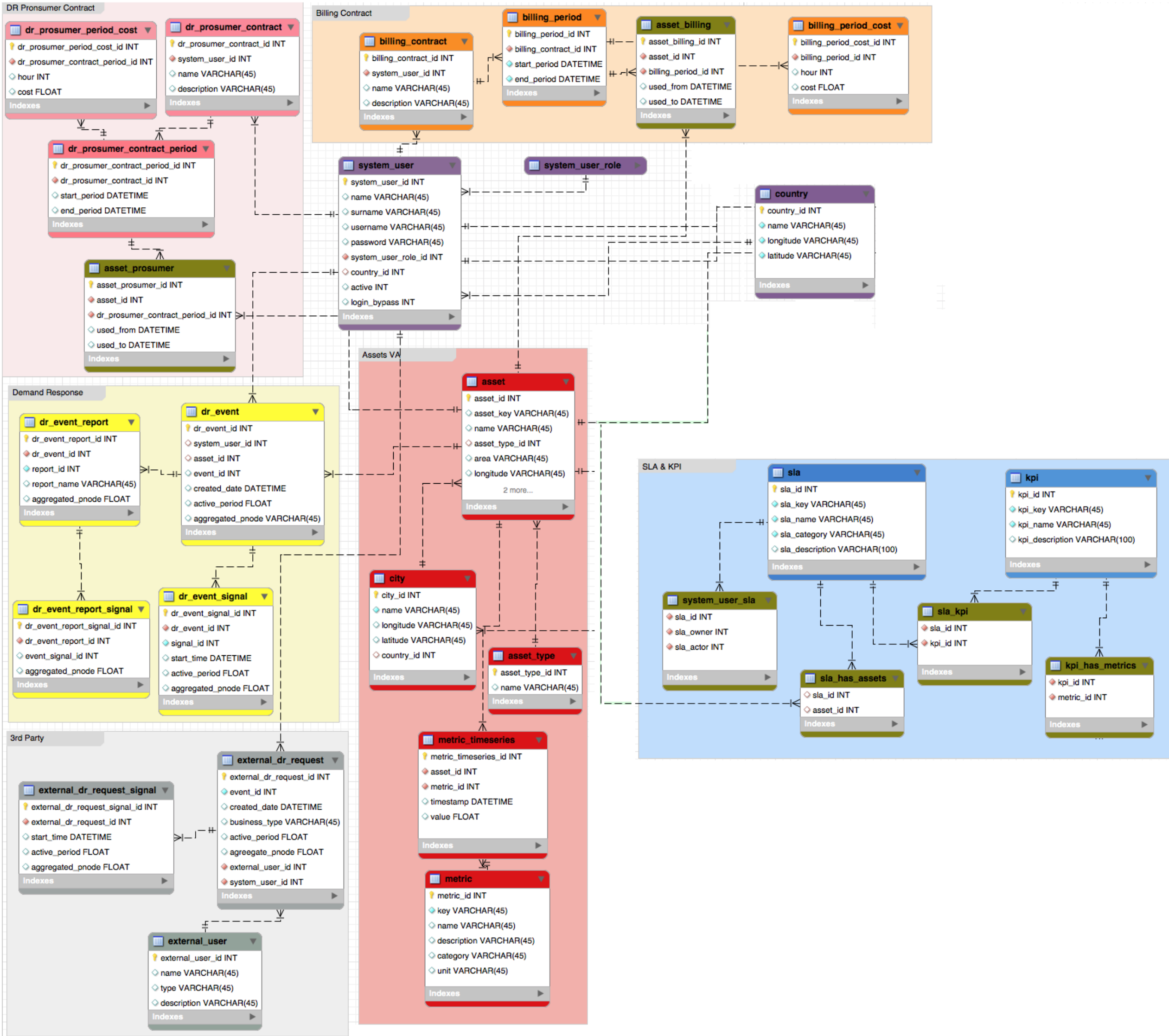

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Figure 2 Internal Data Model of DAFM Engine

The updated list of metrics that consist of the data attributes of the application are presented in the following table:

ENERGY_CONSUMPTION (ACTUAL & SIMULATED)
ENERGY_COST (ACTUAL & SIMULATED)
CO2_EMISSIONS (ACTUAL & SIMULATED)
WEATHER_CONDITIONS (External Temperature)
DEMAND_FLEXIBILITY_POTENTIAL
DEMAND_FLEXIBILITY_REQUEST
ACTUAL_ DEMAND_FLEXIBILITY

This is the final list of metrics (for KPI calculation) defined towards the performance assessment analysis.

By taking into account the data structure of the DAFM module, the updated list of interfaces with MOEEBIUS District Level Middleware is defined and further presented in the following table.

Access on historical datasets

getAssetsMetricTimeseries: REST service

The application **JSON request** has the format


```
{
        "assetKeyList": ["DK1004", "RPI8013"],
        "startDate": "2017-07-10T10:16:49.250Z",
        "endDate": "2017-07-18T11:16:49.250Z",
        "metricType": "ENERGY_CONSUMPTION"
}
```


While the **JSON response** has the format


```
[
  {
  "assetKey": "DK1004",
```


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```
    "metricType": "ENERGY_CONSUMPTION",
    "metricTimeseries":     [
            {
        "value": 2.11,
        "timestamp": "2017-07-18T10:45:01.898Z"
      },
            {
        "value": 0.16,
        "timestamp": "2017-07-18T11:00:01.816Z"
      },
            {
        "value": 2.1,
        "timestamp": "2017-07-18T11:15:01.831Z"
      }
    ]
  },
    {
    "assetKey": "RPI8013",
    "metricType": "ENERGY_CONSUMPTION",
    "metricTimeseries":     [
            {
        "value": 1.49,
        "timestamp": "2017-07-18T10:45:01.908Z"
      },
            {
        "value": 0.44,
        "timestamp": "2017-07-18T11:00:01.833Z"
```

```
      },
          {
        "value": 2.07,
        "timestamp": "2017-07-18T11:15:01.842Z"
      }
    ]
  }
]
```


The DAFM application performs analytics over historical data; thus there is no need to support publish-subscribe messaging patterns. On the other hand, this feature is supported by the District Data Acquisition and Management Layer, the component responsible for the real time management of portfolio performance.

We have to point out that special effort was delivered towards the configuration and adaptation of the data structure to the different demo sites (ongoing work towards the final calibration and demonstration of the DAFM engine at the different pilot sites).

3.2.2 DAFM Analytics Module

This is a core part of the application, supporting the different functionalities of the tool. By taking into account the (business) stakeholders' needs and requirements:

1) Define the list of business functionalities and features to be supported by the tool
2) Select the appropriate data analytics and visualization techniques
3) Compile the different analytics and visualization techniques as part of a unified framework

The detailed list of business cases was reported in the 1st version of the deliverable. A summary is provided in this section, enhanced with additional features defined during the reporting period.

Descriptive Visualization

Prior to any data mining process, a better understanding of portfolio performance is required. This information visualization feature follows a **top-down approach**, by presenting first an overview of customers' portfolio performance and further enable drilling in for the detailed presentation of specific attributes.

Simple statistics (aggregation, normalization etc..) are utilized for data analysis, complemented with simplified visualization techniques (lines, Histogram, pies, bars, Kiviat diagrams with colour coding) towards the extraction of portfolio insights.

Portfolio Analytics

Apart from descriptive visualization of Aggregator's portfolio data, a core functionality and main innovation of the tool is the incorporation of **data mining** features for the analysis and extraction of patterns in the portfolio. This is part of the back-end operation of the system, with the incorporation of machine learning techniques for knowledge extraction. We are presenting the final list of features to be supported by the DAFM engine.

Scenario Id	**Portfolio Analysis based on Energy Consumption**
Scenario Description	The main idea behind this functionality is to provide the Aggregators a tool for clustering of portfolio assets based on energy consumption data. This analytics process could further facilitate energy market participants to define billing strategies for the consumers based on the specific operational profiles (energy consumption during the night, energy consumption based on the day of the week etc…)
Metrics	Energy Consumption (either aggregated information or daily load profile) following a normalization process through feature extraction analysis.
Workflow	1. Aggregated/Total energy consumption for a predefined period 2. Clustering analysis for the definition of groups of assets with similar characteristics. Definition of cluster groups by taking into account different business objectives. a. Energy consumption (Total) b. Energy Cost c. CO_2 emissions 3. Complementary to clustering analysis, it is of high interest for the business stakeholders to identify **outliers in portfolio performance**. Towards this direction, **regression analysis** techniques will be incorporated in the analytics process, further enabling the definition of trends and outliers detection. 4. Special interest at incorporating **feature's extraction** techniques towards identifying the lead parameters for consumption values. 5. The analysis may be further extended to address energy cost or CO_2 emissions metrics.

Visualization Widgets	**Bubble Chart/Tree map:** for an overview of portfolio performance **Scatter Plot/ Parallel coordinates plot:** for trends analysis and outliers detection (features extraction) **Box Plot:** for outliers detection and clusters visualization

Table 1 Portfolio Analytics Feature

Predictive analytics

This is about the (aggregator) business model defined in D2.2 towards measuring building actual consumption and comparing it with a pre-set list verifying if adjustments are needed (identification of deviations between performance predictions and actual measurements). In this case, outliers' detection in portfolio performance may further lead to the implementation of DSM strategies from aggregator side (see next section).

Scenario Id	**Predictive Analysis Scenario**
Scenario Description	Predictive analytics is an extension of traditional ESCO service offered by Aggregators. The cloud based predictive analytics solution should enable dynamic analysis between **actual** and **predicted/simulation** conditions towards further enabling best fitted implementation of energy management strategies.
Metrics	Energy Consumption (actual and simulated) Data
Workflow	1. (Actual vs. Simulated) energy consumption for a predefined period and then clustering analysis for the definition of groups of assets with similar characteristics. 2. The clustering analysis will highlight assets with energy consumption deviations (→ potential to trigger energy management programmes) or low energy consumption deviations (→ successful load forecasting for this specific group of assets) 3. Special focus at incorporating feature's extraction techniques as part of the back end functionality; towards identifying parameters that may lead to deviations between actual and predicted energy consumption values.
Visualization Widgets	**Bubble Chart/Tree map:** for an overview of portfolio performance **Scatter Plot/ Parallel coordinates plot:** for trends analysis and outliers detection → features extraction **Box Plot:** for outliers detection and presentation; clusters representation

Table 2 Predictive Analytics Feature

Time of Use Optimization Analytics

As indicated in D2.2 (New Business Models and Associated Energy Management Strategies), one of the main objectives of DR aggregator is to provide demand management services to control peak demand and reduce annual energy bills by 30-50%. More specifically, the framework should automatically (in advance) notice a potential peak load (KWmax) and direct the energy management system for cutting functionality without intruding end-user comforts.

Towards this direction **ToU (during peak hours) optimization management** is one of the business objectives for the stakeholders' analytics tool.

Scenario Id	**ToU optimization management**
Scenario Description	One of the Aggregator's needs as examined in the project is **ToU optimization**, where an optimization process is taking place to reduce energy consumption at peak hours. This enables customers to lower energy costs by shifting energy consumption from high price to low price hours. The engine designed in MOEEBIUS should constantly collect and analyse energy consumption data (under different tariff schemas), in order to identify how user behaviour is transformed on the basis of variable Demand Tariffs. This is actually the main objective of the feature; to provide portfolio analytics by taking into account participation in ToU schemas.
Metrics	Energy Consumption (ToU Peak hours), Energy Consumption (ToU Off peak), Baseline definition (Portfolio Analysis)
Workflow	1. Aggregated/Total energy consumption for high/low demand period and then clustering analysis for the definition of groups of assets with high/low consumption during peak/off-peak hours. 2. Clustering and classification techniques will be utilized towards the definition of end user clusters. Complementary to clustering analysis, it is of interest for the business stakeholders to identify outliers in portfolio performance. 3. Towards this direction, regression analysis will be incorporated in the analytics process, further enabling the definition of trends and outliers during peak and off-peak consumption hours.
Visualization Widgets	**Bubble Chart/Tree map:** for an overview of portfolio performance **Scatter Plot/ Parallel coordinates plot:** for trends analysis and outliers detection **Box Plot:** for outliers detection and presentation; for clusters presentation

Table 3 ToU optimization management Analytics Feature

Time of Date Optimization Analytics

Complementary to ToU optimization, it is of high interest for the stakeholder, to analyse portfolio performance at specific (customizable) hours of the day. This case scenario is similar to the previous though the focus is on the analysis at specific hours of the day.

Scenario Id	**Time of Date Optimization Analytics**
Scenario Description	Complementary to the ToU optimization scenario, the Aggregator needs to understand portfolio performance at specific hours of the day; namely to define high/low consumption clusters during specific hours of the day. The engine designed in MOEEBIUS should constantly collect and analyse energy consumption data (time stamped), in order to identify how user behaviour is affected as specific hour periods. This is actually the main objective of the feature; to provide analytics over consumption data with special focus on specific time periods.
Metrics	Energy Consumption (Selected hours), Energy Consumption (Non selected Hours), Baseline definition (Portfolio Analysis)
Workflow	1. Aggregated (Total) energy consumption for predefined time period and further clustering analysis for the definition of groups/assets with high/low consumption patterns at specific time periods. 2. Clustering and classification techniques will be utilized towards the extraction of clusters. Complementary to the clustering analysis, it is of interest for the business stakeholders to identify outliers in portfolio performance. 3. Towards this direction, regression analysis will be incorporated in the analytics process, further enabling the definition of trends and outliers at the selected time period.
Visualization Widgets	**Bubble Chart/Tree map:** for an overview of portfolio performance **Scatter Plot/ Parallel coordinates plot:** for trends analysis and outliers detection **Box Plot:** for outliers detection and presentation; for clusters presentation

Table 4 Time of Date Optimization management Analytics Feature

Flexible DSM Analytics

This is the main objective of the DR Aggregator as an energy stakeholder in the market. To get a better understanding of portfolio performance (in terms of demand flexibility), that will further facilitate: 1) optimal placement in energy markets 2) definition of contractual agreements.

This case scenario is in line with the business model defined in D2.2 towards Flexible DSM participation in energy markets.

Scenario Id	**Flexible DSM management**
Scenario Description	Addressing the role of DSM Aggregator as the entity responsible for handling portfolio demand flexibility, the objective of this feature is to enable clustering analysis towards the extraction of groups of assets with high potential to participate in demand response campaigns.
Metrics	Energy Consumption, Potential Demand Flexibility, Demand Flexibility Request, Actual Demand Flexibility
Workflow	1. Aggregated/Total demand flexibility potential (normalized data) and then clustering analysis for the definition of groups of assets with high demand flexibility potential. 2. In addition, clustering analysis by taking into account DR participation KPI towards the evaluation of assets performance during DR events. 3. Complementarity to the classification of assets in different groups, feature's extraction towards getting insights about demand flexibility potential. 4. Furthermore, it is of interest for the business stakeholders to identify outliers in portfolio performance. Towards this direction, regression analysis techniques will be incorporated in the analytics process, further enabling the definition of trends and outliers at demand flexibility potential.
Visualization Widgets	**Bubble Chart/Tree map:** for an overview of portfolio performance **Scatter Plot/ Parallel coordinates plot:** for trends analysis and outliers detection **Box Plot:** for outliers detection and presentation; for clusters presentation

Table 5 Flexible DSM Analytics Feature

We have adopted a common presentation approach for the different case scenarios towards the incorporation of the different features in the unified DAFM framework. The analysis covers: a) workflow analysis, b) selection of the metrics, c) data mining/analytics and d) visualization techniques for each case scenario.

3.2.3 Demand Elasticity Profiling Engine

As a main functionality for the DAFM engine, we are highlighting the role of the Demand Elasticity Profiling Engine. A high level definition of this engine was reported in the 1st version of the deliverable. In the second version, a refinement of the model is provided to meet the project specific objectives.

Tightly coupled with the definition of the Elasticity Profiling is the dynamic price generator module. The updated description of this model and the associated component is provided in the next section.

3.2.3.1 Price Simulator Component

The role of the price simulator component is to feed energy price data to the MOEEBIUS platform. The most common alternatives (as presented also in the 1st version of the deliverable) for dynamic pricing schemas were defined at the early phase of the project:

- Time-of-use pricing (ToU) is a rate where the price per kWh depends on the time when electricity is consumed. Usually periods and prices are known well in advance, but offers where the definition of the day/night intervals may change according to the day-ahead spot price also exist. Prices can also be defined as average prices for different time periods but be directly indexed to the day-ahead spot price.
- Critical peak pricing (CPP) is a top-up rate whereby electricity prices substantially increase for the few days a year when wholesale prices are highest, but where prices are lower than average during the rest of the year. E.g. French Tempo tariff is a contract with a fixed price all year except for a maximum of 20 days with very high prices. These days are notified to customers the day before.
- With real-time pricing (RTP) wholesale electricity prices are directly passed through to final consumers and bills are calculated based on at least hourly metering of consumption, or with even higher granularity (e.g. 15 minutes). The price of such offers is composed of the wholesale price of electricity plus a supplier margin.

While the preliminary analysis was focusing mainly in ToU and RTP pricing schemas, the final decision in the project is to examine the impact of **ToU** and **CPP** schemas. RTP schemas are not applicable at the MOEEBIUS pilot sites, nevertheless the DAFM engine (and specifically the Elasticity Profiling Engine) was developed to address RTP market scenarios (validation in a test environment).

In the UK pilot site, KIWI will evaluate the impact of **CPP** pricing strategy in a small subset of the portfolio. This is a viable model for the partner, considering the nature

of the DR market in the UK. In addition KIWI has previous experience in this type of market models, as they are currently testing a similar concept as part of their commercial solutions portfolio. The users will actively participate in DSM project activities, towards proactively react in abnormal market or grid conditions. KIWI will be responsible to set the parameters for DR campaigns. The structure of the CPP schema for the UK pilot site is presented in the following figure.

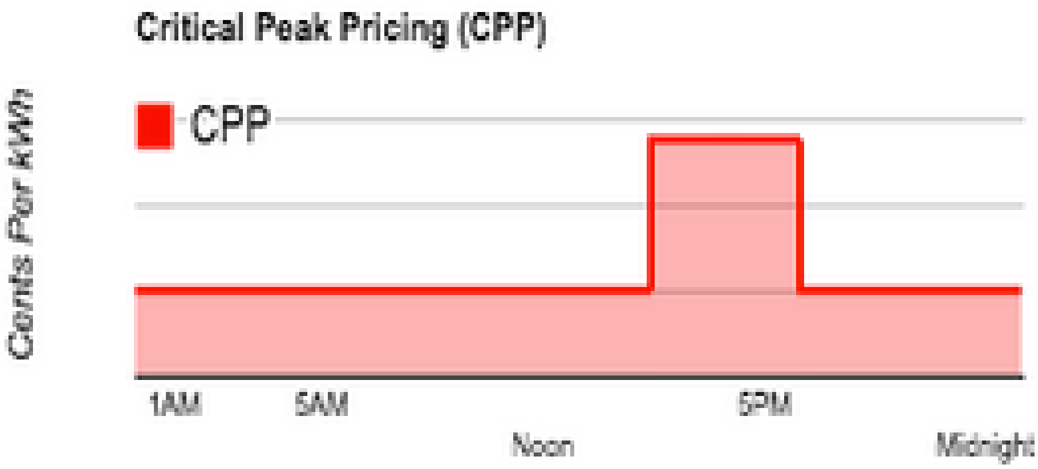


Figure 3 Critical Peak Pricing Schema

In this case scenario, a flat tariff schema is the baseline, with a Critical Peak pricing event activated as a behavioral triggering message. A thorough analysis of the CPP contract to be examined is part of the work toward the selection and modeling of this business case in the project.

On the other hand, BEOLEK (the Serbian partner) will evaluate the impact of **ToU** tariffs in a small subset of the portfolio. An indicative ToU **format** is presented in the following figure.

WEEKDAY			
13%	Low Tide	23:00 – 06:00	4.99p
24%	Tide Weekday	06:00 – 16:00	11.99p
19%	High Tide	16:00 – 19:00	24.99p
16%	Tide Weeknight	19:00 – 23:00	11.99p

WEEKEND			
24%	Low Tide	23:00 – 06:00	4.99p
5%	Tide Weekend	06:00 – 23:00	11.99p

Figure 4 Time of Use Pricing Schema

A simplified ToU schema is selected from BEOLEK for demonstration to their customers. The ToU program selected in the project is giving customers: 5 RDN

(5.0 €cents) per kWh tariff for overnight and low consumption hours and a 15 RDN (15 € cents) figure for peak demand hours.

In Spain & Portugal, RTP programs is defined towards linking the impact of energy prices to energy consumption data. The RTP programs are based on OMIE market prices, adding on top a cap to cover network fees and taxes. As mentioned above, no RTP schema will be tested in reality; the overall evaluation will remain in a lab testing environment.

The overall architecture about the energy prices simulator is presented in the following schema.

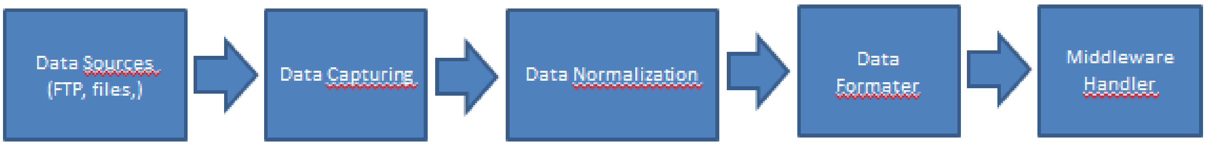


Figure 5 Energy Prices Simulator flow

The main consideration about the energy prices simulator has been its flexibility to adopt different data sources and energy market spot data formats. The figure below describes the main entities and their relationships as implemented in the energy price simulator to address different case scenarios.

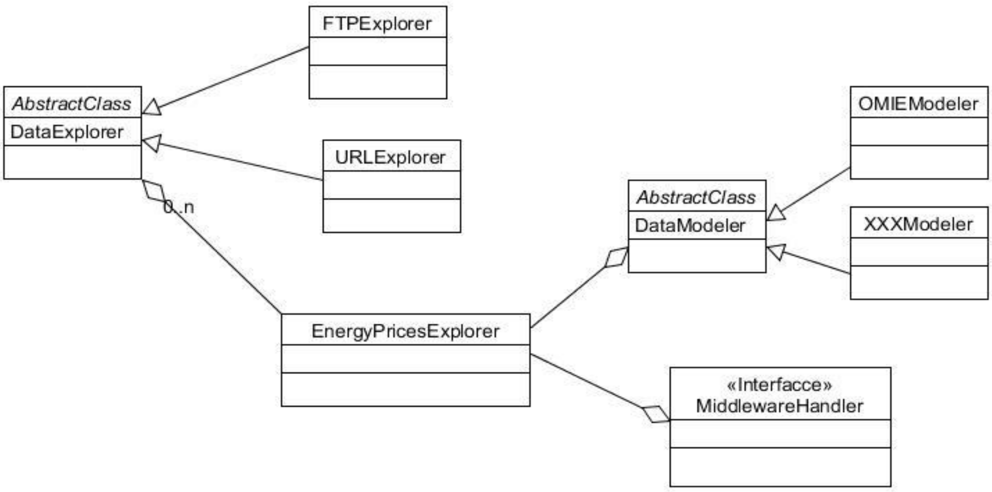


Figure 6 Energy prices simulator main entities and hierarchy

The Energy-Price main modules are:

- EnergyPricesExplorer: This module handles the data flows of the energy prices simulator module. It is the module that triggers the rest of the modules.

- DataExplorer: Implements the basic functionality to fetch data from remote data sources. It is specialized to get data from FTP servers, remote URL or any other source.
- DataModeler: Is the module that transform data retrieved by the DataExplorer into internal data format handled by the rest of the Energy-Prices module.

Once the energy price simulator processes market data (either static data in case of ToU or dynamic data in case of RTP), the outcome is forwarded to the Elasticity Profiling Module (next section). The endpoint for inserting new data points located on Elasticity Profiling module and accepts POST requests with body in JSON. The message will be a sequence of items containing the information described below.

- pointname: The value of the pointname field will link the item at the Cassandra repository with the asset in the DAFM repository
- country: The country will make reference to the country of the gathered market spot.
- building: Not used in the current context.
- timestamp: Day and time to which the item value makes reference.
- reliability: Describes if the values is the outcome of the successful process (1) or if the value is given as a default value (0)
- value: Energy price for the specified day and time period.

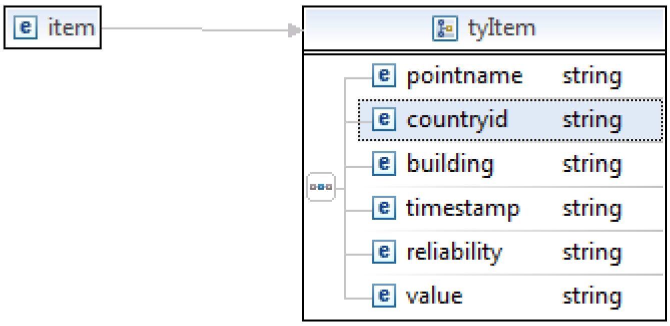


Figure 7 JSON message content description

Example of the JSON containing 3 data items is described below (in practice each post will contain 24 values, from 00h to 23h).


```
[{
        "pointname" : "UK4001",
        "countryid" : "UK",
        "buildingid" : "",
```

"timestamp" : "2017-03-01T00:00:00",
"reliability" : "1",
"value" : "1.77"
},
{
"pointname" : " UK 4001",
"countryid" : " UK ",
"buildingid" : "",
"timestamp" : "2017-03-01T01:00:00",
"reliability" : "1",
"value" : "6.55"
},
{
"pointname" : "DK4001",
"countryid" : " UK ",
"buildingid" : "",
"timestamp" : "2017-03-01T02:00:00",
"reliability" : "1",
"value" : "10.04"
}]

3.2.3.2 Elasticity Profiling Module

By defining the different tariff structures to be examined in the project, we proceed with the solid definition of the Elasticity Profiling Module specifications. As stated in the 1st version of the deliverable the Price-based Flexibility Profiling engine is based on the augmented Constant Elasticity of Substitution (CES) model ([10]) which assumes that the **elasticity of substitution** between two pricing periods is a constant regardless of the nominal level of the load. The same assumption applies also for **own-elasticity** which measures the reduction of the customer's demand in a certain time interval due to the increase in the price of that interval.

Based on the calculated elasticities, the proposed model is able to predict changes in load consumption as function of prices and the temperature and vice versa, i.e. the tool can estimate the pricing structure that is capable to achieve the utility-defined objectives for peak load reduction and revenue, under a given set of temperatures.

The detailed modelling framework was presented in the 1st version of the deliverable; in this version we are specifying how this model is adapted to address the MOEEBIUS requirements. This specifications analysis is applicable to the different tariff schemas defined in previous section.

Time of Use price schema

We presented above an indicative ToU schema. The adaptation of this market concept in MOEEBIUS specific business scenarios is presented in this section.

The 1st step of the process is to select the time-periods to apply high/low prices (as a supportive mechanism for the pilot stakeholders). A dynamic approach has been adopted towards ToU adaptation.

A clustering analysis over consumption data reveals the **peak & off peak** hours (by taking into account specific business objectives e.g. peak load reduction or maximum RES exploitation); analysis to further facilitate ESCOs and Utilities at the definition of Time of Use tariff schemas. This analysis may apply to the whole or part of the portfolio. The results from clustering analysis are presented in the following figure:

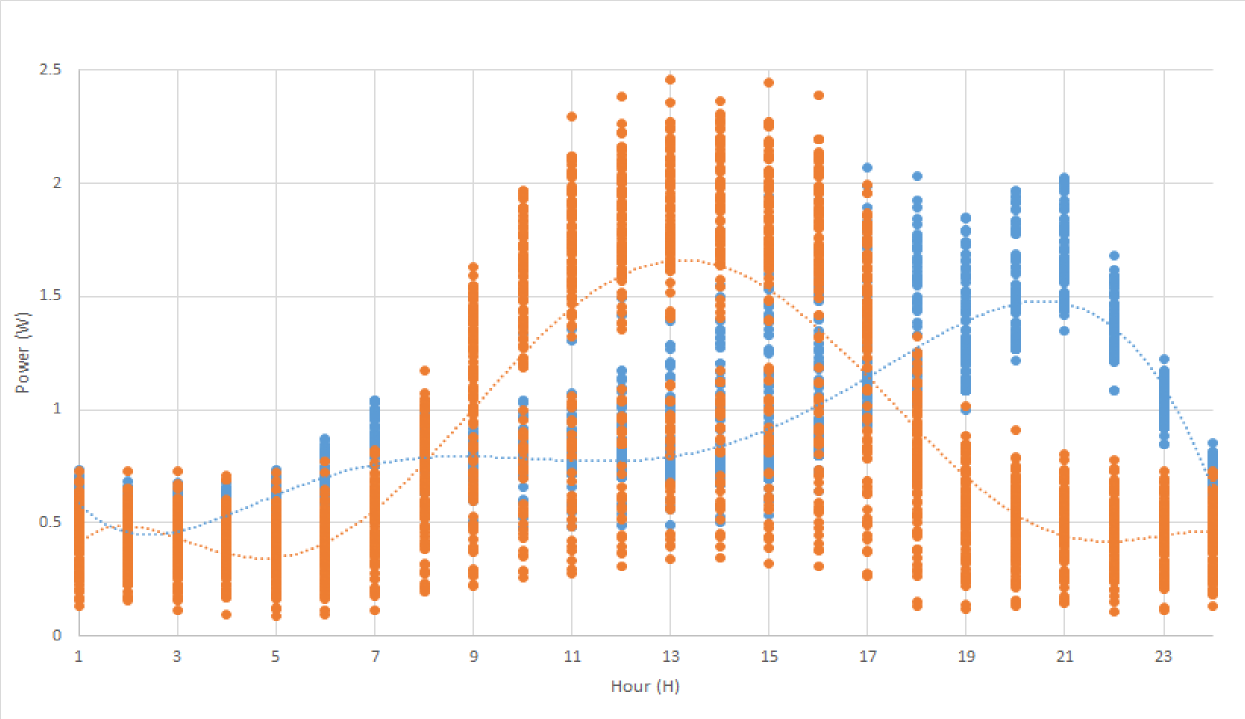


Figure 8 Typical Load Profiles (multiple assets)

	Peak	Off Peak
ToU-1 (Commercial)	09:00 - 17:00	00:00 - 09:00 & 17:00 - 24:00
ToU-2 (Residential)	17:00 - 23:00	00:00 - 17:00 & 23:00 - 24:00

Table 6 Definition of ToU schemas

The next step (Step 3) of the analysis is training and demonstration of ToU schemas towards demand elasticity calculation. Following a 2-months demonstration period (and considering availability of both real time and baseline (simulation) data), we can further extract the results about demand elasticity (the detailed modeling framework about own-elasticity and elasticity of substitution was presented in the 1st version of the deliverable).

For the selected assets of the portfolio (Residential users), we calculate the parameter values for **own elasticity** & **elasticity of substitution (**as non-unit

values expressing the percentage deviation of consumption due to the percentage modification of energy prices – further explanation of price elasticity in D6.1**)**:

ToU	**Peak (17:00 - 23:00)** Own Elasticity	**Off Peak (23:00 – 17:00)** Elasticity of Substitution
ToU-2 (Residential)	- 0.06	0.03

Table 7 Definition of own elasticity & elasticity of substitution parameters

To point out that the calculation of **own elasticity** & **elasticity of substitution** is based on simulated data, taking into account actual consumption data as retrieved from the Serbian pilot site. The actual demonstration of the dynamic pricing schema in Serbian pilot site will take place the following months as part of the actual project validation in WP7.

Following the extraction of demand elasticity profiles, we proceed with demand elasticity profiles incorporation in the MOEEBIUS DAFM business framework (what if simulation analysis module).

There are different case scenarios examined towards DSM strategies implementation:

1. Business as usual case scenario: we can compare actual vs. baseline data to estimate real time demand flexibility following the implementation of ToU schemas.
2. Change of tariffs: By modifying tariff volumes (available from price generation engine), we can simulate the impact of dynamic ToU schemas in the portfolio.
3. Change of tariffs in a subset of the portfolio: By modifying tariff volumes (available from price generation engine) in a subset of the portfolio, we can simulate the impact of dynamic ToU schemas under different DSM conditions.

Indicative results from what-if simulation analysis are presented in the following figures.

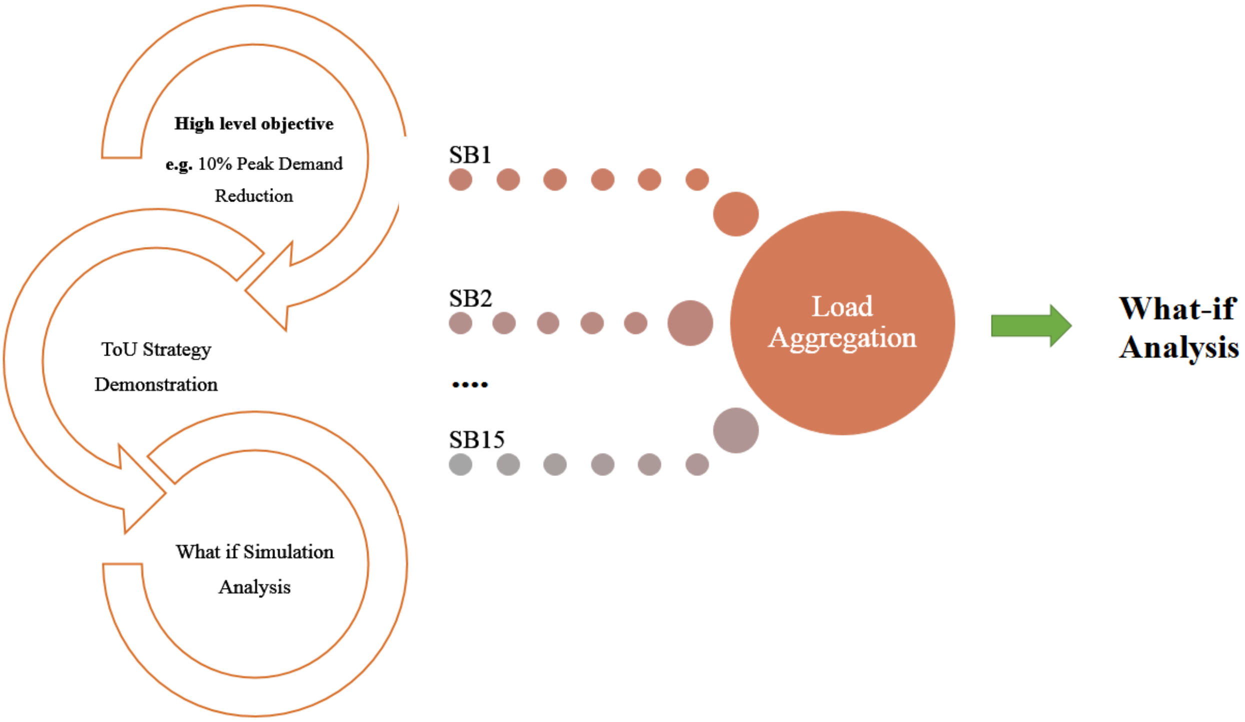


Figure 9 What-if simulation analysis framework

By incorporating energy consumption data in the overall analysis, we calculate the impact of dynamic prices (ToU and price elasticity calculation) in total (aggregated) consumption curve (Figure 10)

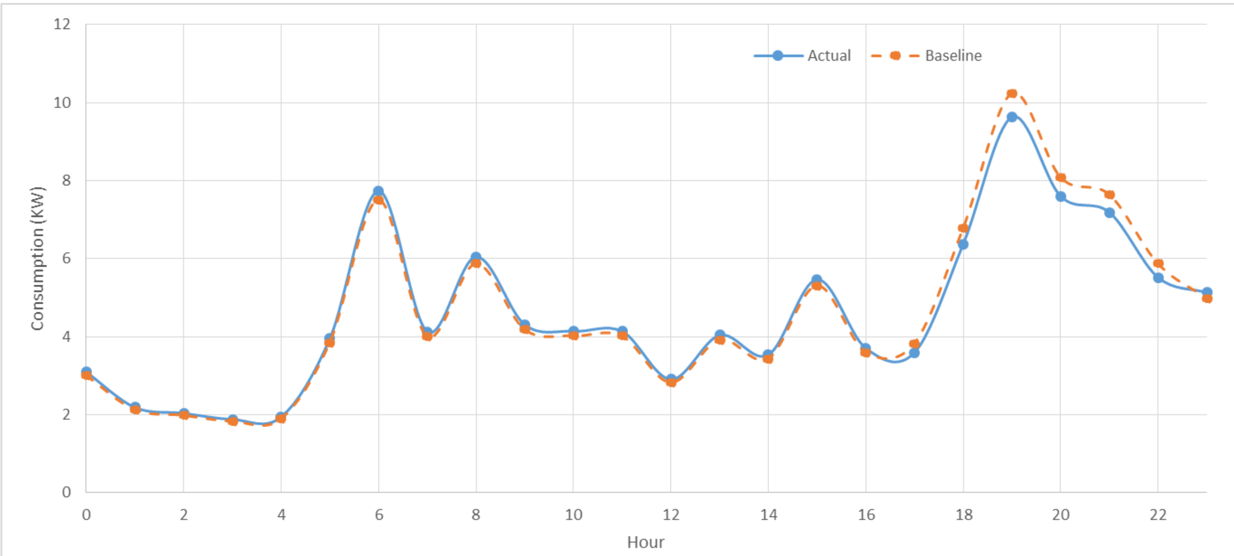


Figure 10 ToU schema demonstration

Total peak demand reduction: ~ 4%, considering the demonstration of ToU-2 (as specified for the Serbian pilot site). Following what if analysis and evaluation of simulated ToU schemas, we calculate the potential impact in terms of peak demand reduction: ~ 7.3% in the following figure (Figure 12).

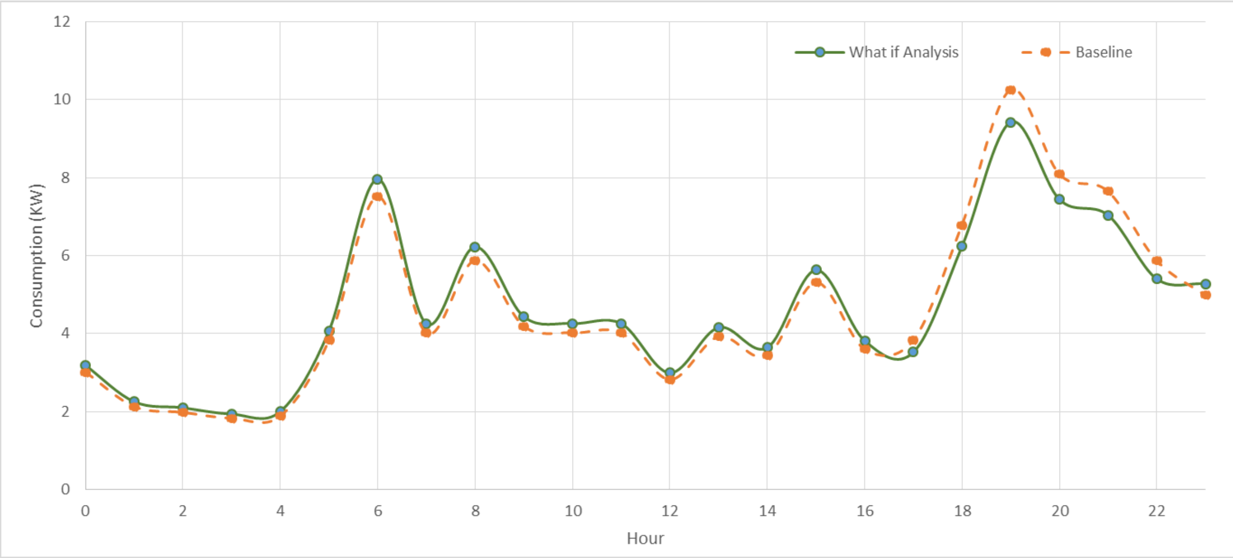


Figure 11 What if analysis demonstration

We presented above the framework about ToU strategies implementation; further depicted in the following figure.

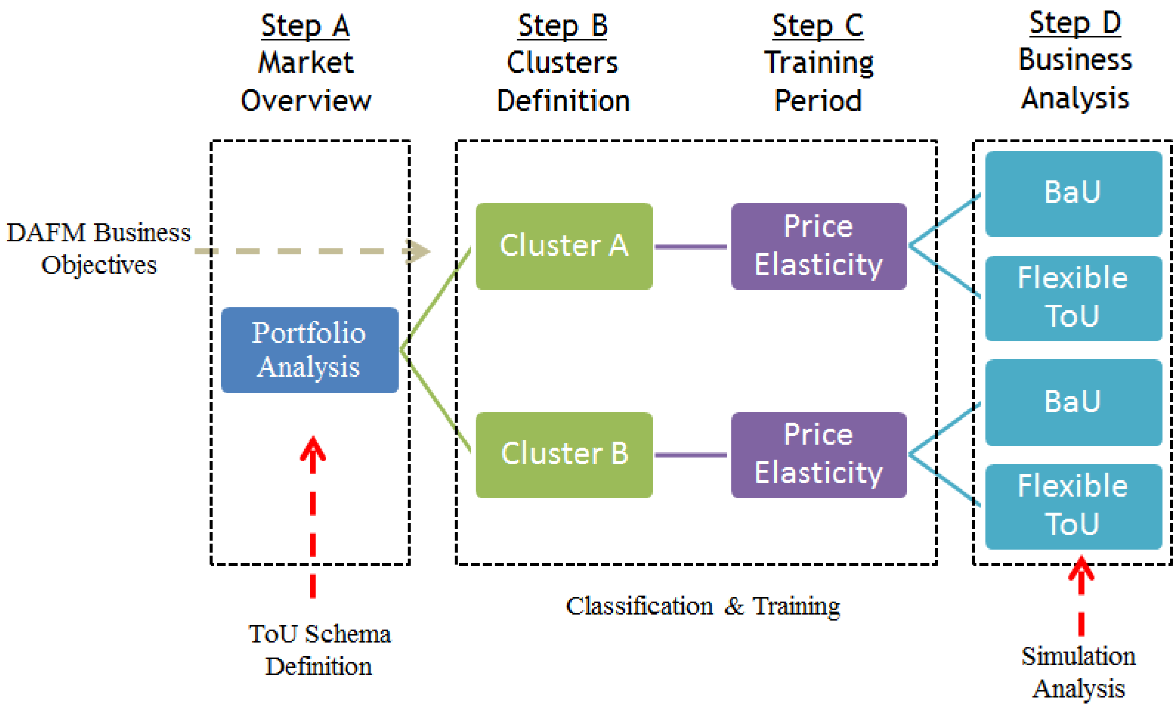


Figure 12 ToU Schema definition –Workflow Analysis

As a main outcome of this analysis we highlight the incorporation of both **own-elasticity** and **elasticity of substitution** parameters in a unified framework. The next step is to apply the framework at the MOEEBIUS pilot sites during the demonstration period (we have selected the Serbian pilot site for demonstration;

the configuration of the tool to the Serbian pilot site demonstration will take place in WP7).

Critical Peak Pricing

This is the most interesting case scenario examined in the project as:

1) CPP is the most viable way to promote the implementation of implicit DSM strategies in European energy market.
2) We consider CPP as the means to define a behavioural based triggering framework in the project.

Each CPP event at a specific point of time is associated with the demand consumption at that point of time; thus the **own-elasticity** profile should be defined to express this correlation. The detailed workflow analysis for the implementation of CPP schemas in the project is presented in the following figure.

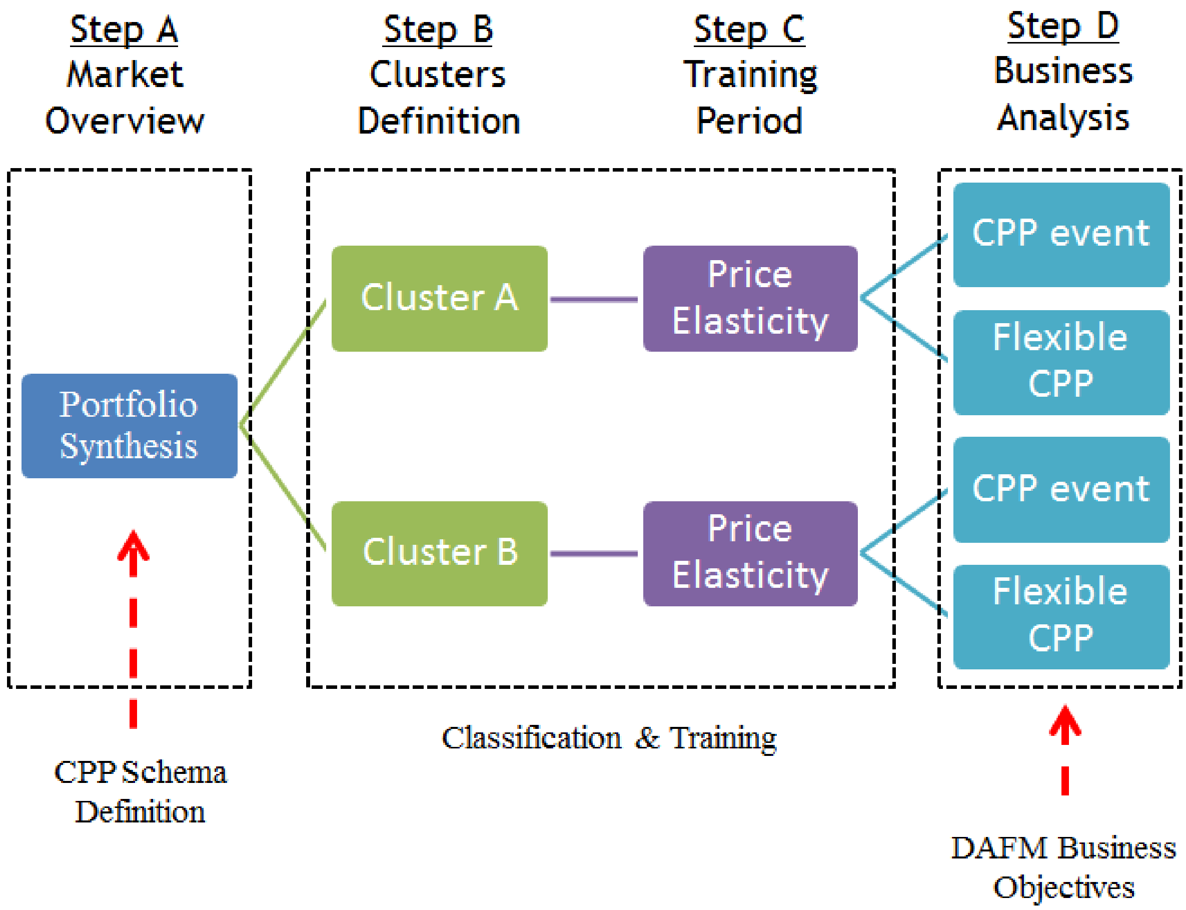


Figure 13 CPP Schema definition –Workflow Analysis

The 1st step of the process is the definition of CPP values based on existing market schemas. Following a review analysis over the market and existing approaches, we are presenting the framework selected for demonstration in MOEEBIUS project

(further incorporated in the price generation engine). The detailed presentation is provided in Annex I.

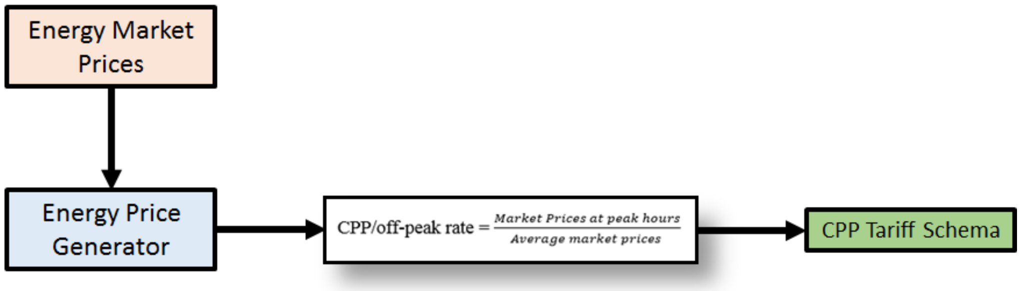


Figure 14 CPP tariffs generator

The next step of the process is portfolio segmentation towards the definition of portfolio clusters to further implement CPP analysis. Criteria for clustering analysis are: a) the time of the day and b) assets consumption → to support a dynamic management of demand flexibility by taking into account portfolio demand characteristics. We have to point out that this is an intermediate step, as we can calculate demand elasticity parameters for each specific asset of the portfolio.

The results of clustering analysis are presented in the following figure.

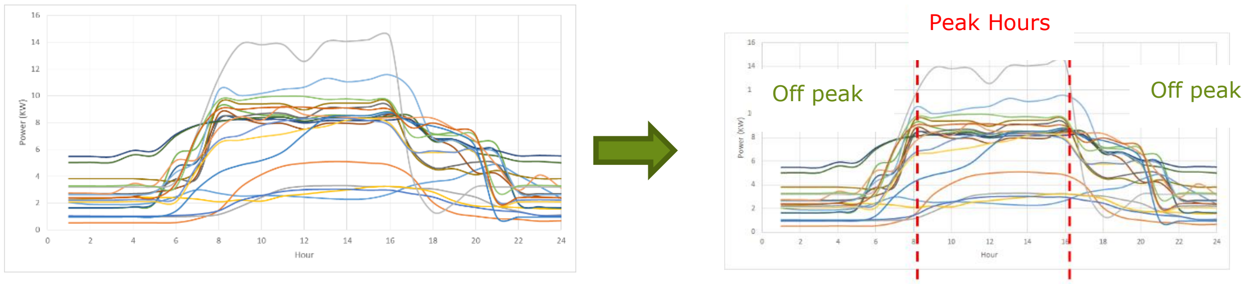


Figure 15 Typical/Average Commercial Profiles & Definition of portfolio clusters

The outcome of this process is the definition of portfolio clusters. Taking into account commercial costumer daily load profiles, we provide cluster analytics towards the extraction of peak/off peak hours (as depicted in the figure above). The next table presents the results of clustering analysis towards the definition of specific portfolio groups.

Clusters	**Peak (KW & hours)**	**Off Peak (KW & hours)**
Cluster A (Residential)	1.4 KW (17:00 – 22:00)	0.8 KW (22:00 – 17:00)
Cluster B (Commercial)	4.2 KW (09:00 – 16:00)	2.6 KW (16:00 – 09:00)

Table 8 Definition of portfolio clusters

The 3rd step of the methodology is the demonstration of CPP schemas and further (following a 2-month training period) demand elasticity calculation (own elasticity), as presented in the following table (non-unit values as explained in previous section)

Clusters	**Peak**	**Off Peak**
Cluster A (Residential Users)	- 0.08	- 0.06
Cluster B (Commercial Users)	- 0.05	- 0.02

Table 9 Price Elasticity parameters calculation

The results are extracted from a thorough analysis of the dynamic pricing program dataset (link[1]) that was applied in a large (~1100) number of households (endpoints) in London, from 01/01/2013 until 31/12/2013. This dataset included half-hourly consumption data for each asset for three different price bands demonstration. The aforementioned analysis goes beyond the individual (asset level) analysis as presented in D6.1.

By incorporating demand elasticity profiles in MOEEBIUS DAFM business layer, we further support **real time business optimization** for the implementation of successful DSM strategies. In MOEEBIUS project, we highlight the importance of peak load management to address specific market and operational needs (e.g. cost minimization at peak hours, maximum RES exploitation etc…). These high level objectives set constrains to the selection of best fitted CPP strategies. There are different business alternatives towards demand side management strategies implementation:

1. Change of CPP values: By modifying tariffs, we can calculate the impact of CPP volumes in the portfolio. The time of day affects demand flexibility potential.
2. Change of CPP values in a subset of the portfolio: By modifying CPP, we can calculate the impact of flexible CPP schemas in different DSM strategies. (This is a case scenario not examined in practice as end users are unwilling to participate in that flexible market schemas- partial selection of assets)

The framework towards CPP strategies implementation is presented in the following figures.

Figure 16 CPP Schemas - Concept Demonstration

[1] https://data.london.gov.uk/dataset/smartmeter-energy-use-data-in-london-households

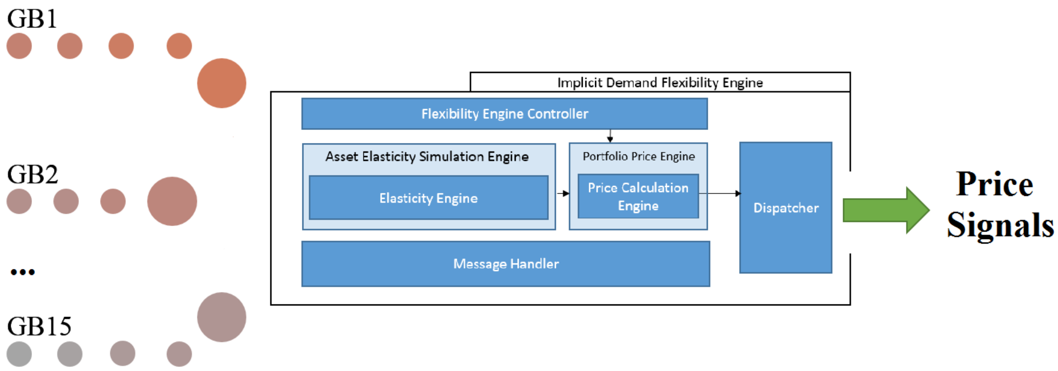


Figure 17 CPP Schema – Implementation Framework

The results from the demonstration of a CPP event are presented in the following figure (for a pool of 15 users in the UK pilot site). CPP event (x10 price) from 19:00 - 21:00 leading to peak demand reduction ~ 8.7 %.

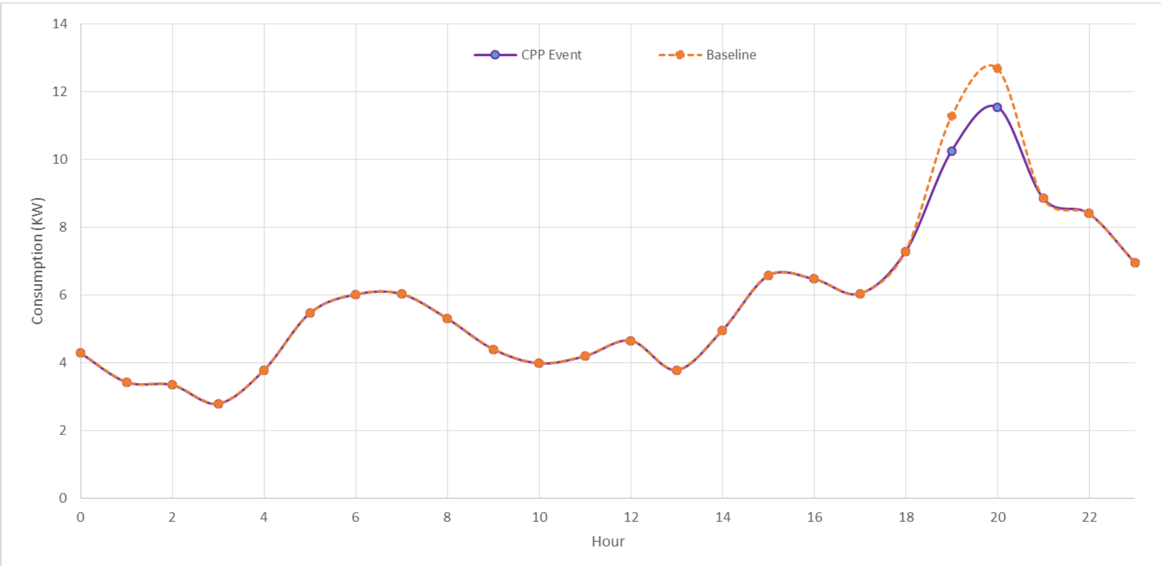


Figure 18 CPP Event Demonstration and Impact

We presented above the detailed framework towards CPP schemas evaluation in MOEEBIUS project. The next step of the work is the definition of specific requirements and adaptation of the framework to pilot specific needs.

Real Time Pricing Schema

This is the most complex scenario, though we have adapted this similar to the ToU schema. As RTPs are not applicable in E.U., our proposal is to transform RTPs to dynamic ToU schemas. This transformation enables us to proceed with a hybrid evaluation (simulation based evaluation using actual data) approach.

The 1st step of the analytics process (add–on to the holistic framework) is the transformation of RTP into ToU alternatives. By taking into account batches of RTP

information from energy markets, we periodically cluster them towards dynamic ToU schemas definition. The analytics process is presented in the next figures.

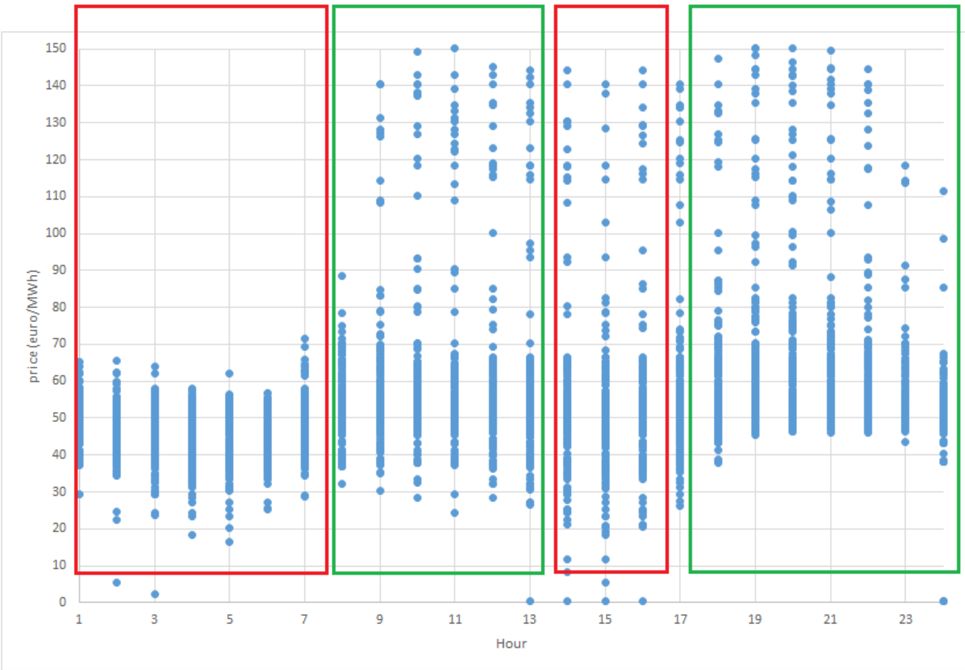


Figure 19 RTP Clustering Analysis

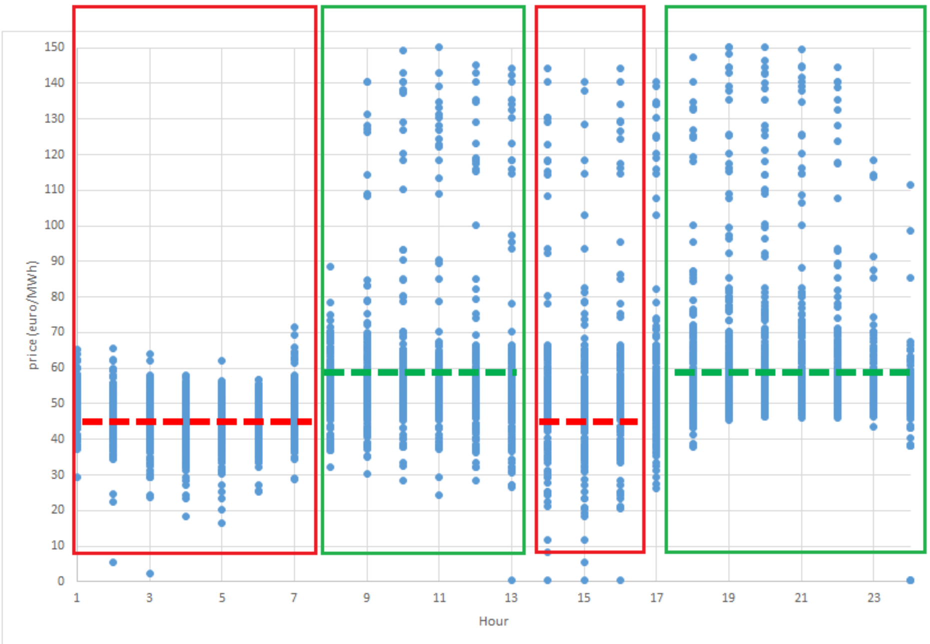


Figure 20 RTP to ToU Transformation

	Peak (60 €/MWh + extra fees)	**Off Peak (45 €/MWh + extra fees)**
ToU period	08:00-14:00 & 16:00 - 24:00	00:00-08:00 & 14:00 - 16:00

Towards the evaluation of RTPs schemas, we are incorporating the extracted ToU tariffs in the holistic elasticity profiling framework. We further proceed with "what-if simulation" analysis and demand flexibility calculation at the different time periods (and different DSM operations). That way, we manage to incorporate the dynamic aspect of energy markets (through RTP schemas) to the MOEEBIUS Demand Side Management framework as examined in the project.

The workflow analysis towards demand flexibility calculation (by taking into account demand elasticity profiles as presented above) is presented in the following figure.

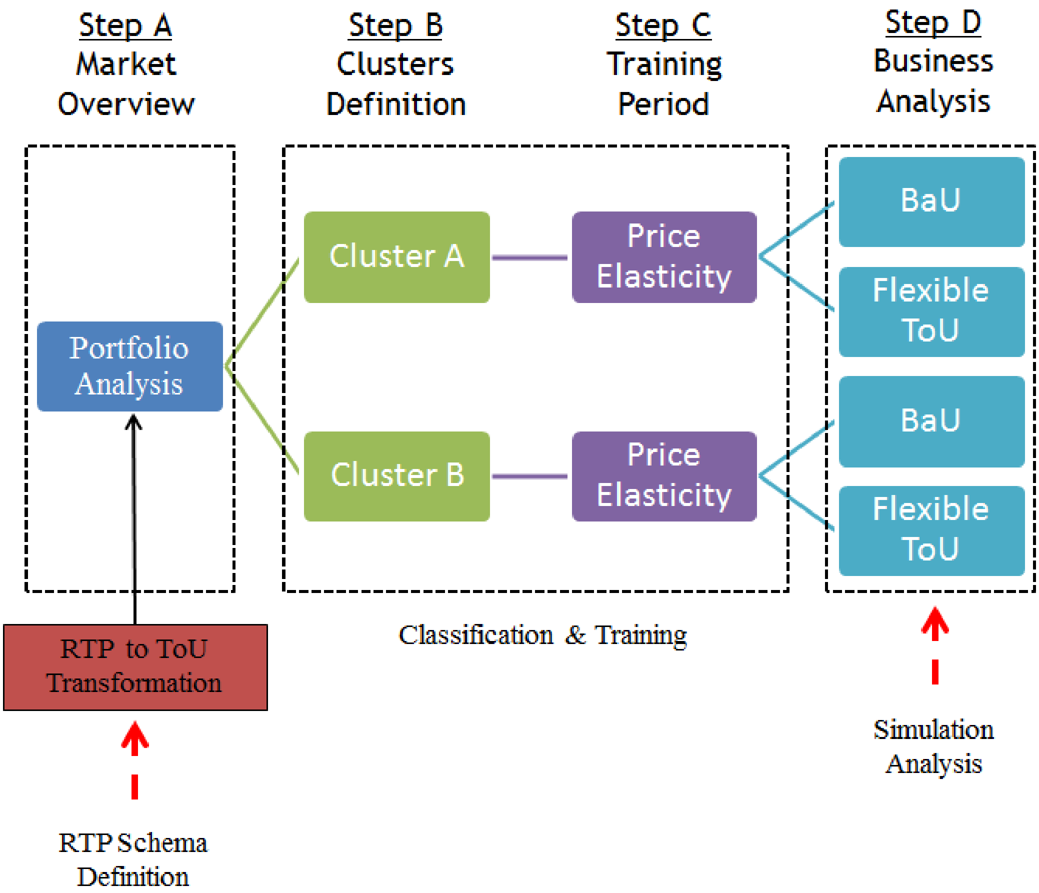


Figure 21 RTP Schema definition –Workflow Analysis

In contrary to ToU schemas where we can apply (as part of business analysis) dynamic ToU tariffs towards demand flexibility calculation, this is not the case for RTPs as the dynamic aspect is inherently incorporated in energy market prices.

Thus, the main goal in this case scenario is about the selection of clusters of consumers to participate in targeted Demand Side Management strategies (simulation based evaluation of dynamic ToU schemas). As mentioned at the beginning, this functionality will be not actually tested in reality; a lab set up will be established in order to evaluate the technical implementation of the software solution.

We presented above the overall framework towards price elasticity calculation as a means for demand flexibility calculation. The outcome of this process is twofold:

a) Real time demonstration of CPP campaigns
b) Offline evaluation of dynamic pricing strategies as part of the analytics

In order to exploit the outcomes of this analytics process we define the following interfaces:

Request for Demand Flexibility Potential: {asset_ID, time, price signal}

Response about Demand Flexibility Potential: {demand_flex_potential}

The next step of the work is to incorporate the results of analytics process in the DSS layer of DAFM Cockpit.

3.2.4 Simulation Analysis Engine

In the 2nd version of the deliverable, we highlight the role of Simulation Analysis component, to incorporate district level business optimization as examined in the MOEEBIUS project. As defined in the DoA, MOEEBIUS should enable effective **peak-load management** and transformation of **demand-driven Virtual Power Plants** (VPPs) to active energy market commodities, competitive against traditional resources (power generation) used for the provision of balancing and ancillary services to the distribution grid.

Especially, **peak-load management** holds a significant position in MOEEBIUS, since it enables through properly managing the flexibility offered by the demand side and optimally coordinating highly flexible district-wide systems the: (a) maximum penetration of RES into the energy mix, (b) significant peak demand reduction, (c) enhanced security of energy supply and (d) significant associated monetary costs for prosumers (energy cost savings and avoidance of high energy charges during peak periods, incentives, rebates, etc.) and Aggregators (trading an inexpensive and highly competitive commodity – demand flexibility – in the balancing and ancillary services markets).

Towards this direction, **comfort-based** and **price-based** demand flexibility are thoroughly analyzed within MOEEBIUS in order to mobilize the definition and execution of highly effective demand response strategies at district level towards (a) the evaluation of alternative **peak-load management strategies** and (b)

definition of **VPP setups** (utilizing the aggregated flexibility of DERs) under alternative automated control strategies.

Highlighting the importance of simulation analysis engine, we are adopting a modular approach at the development of this software (**Simulation Analysis**) component by decoupling the business layer from optimization-DSS layer.

The business objective module will incorporate the different business models examined in the project, namely:

- Implicit Demand Side management (ToU & RTP) strategies to address peak load management.
- Implicit Demand Side management (CPP) strategies to address peak load management.
- Explicit Demand Side management towards dynamic VPP formation.

While the aforementioned business features are developed as separate models, a unified interface with DSS layer (of DAFM engine) is considered (demand flexibility request over a period of time):

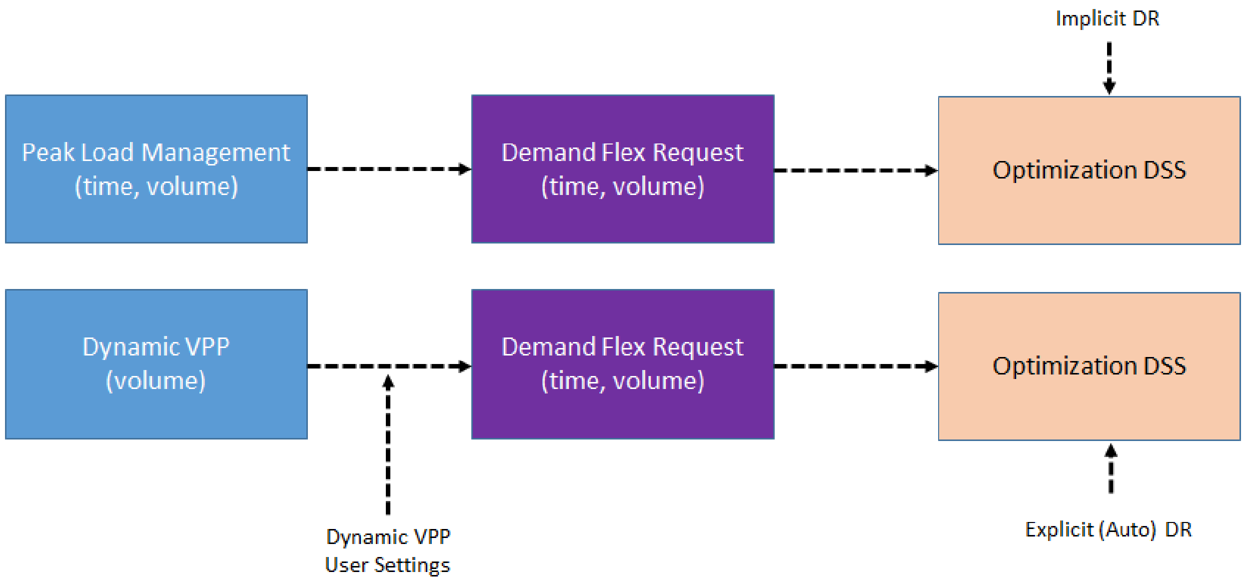


Figure 22 MOOEEBIUS Business Objectives

The JSON representation of the message format between business and DSS layer is presented in the following table:

The JSON body request should have the format:

{

"space": "North",

"type": "PriceDR",

"dsm_request": {

"value": "",

"timePeriod":""

}

The configuration parameters required for the simulation analysis are: the **type of DR request** (directly associated with the type of contract) (in MOEEBIUS project: implicit/price or explicit demand response type), the region (optional), the demand side request over a time-period.

Figure 23 Interface of MOEEBIUS DAFM Business-DSS layer

Subsequently, the goal of the simulation engine is to set an optimization framework for the selection of portfolio assets that best fit to the specific business conditions (in MOEEBIUS Demand Side Management Strategies).

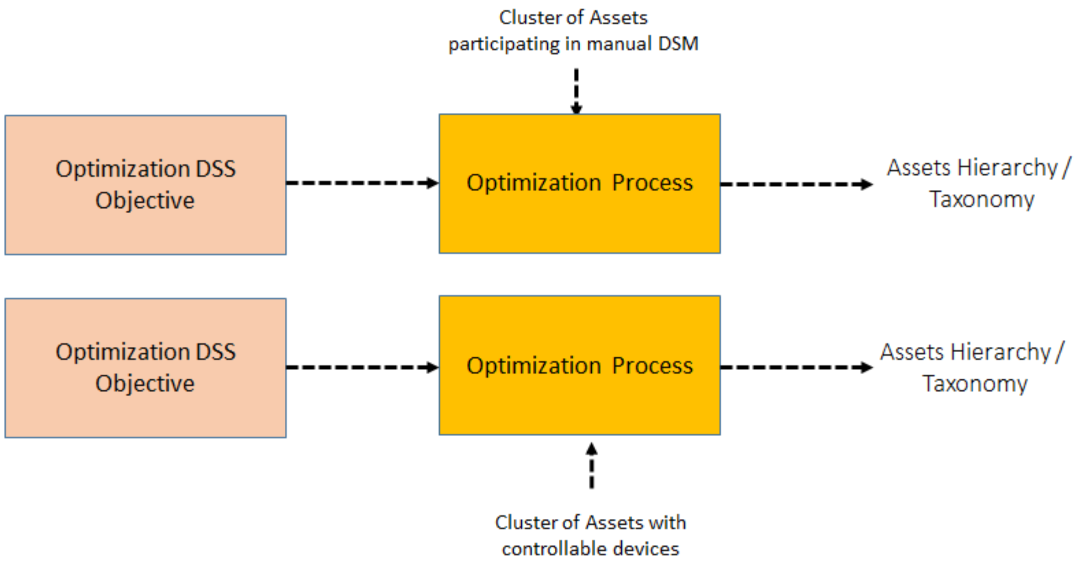


Figure 24 MOEEBIUS DAFM engine DSS

The role of this component is twofold: to allow for "what–if" simulation functionality (feature of DAFM engine) and further support the implementation of real time Demand Side Management Strategies (integration of DAFM engine with D-DAE).

The algorithmic framework of this module (updated version) is reported in this section. The objective of the optimization process is the maximization of DSM participation (max DSM Reliability) considering the different business objectives and

assets demand flexibility potential (following consultation with the business partners of the consortium).

$$\mathbf{max}\ level\ of\ DSM\ fulfilment$$

$$s.t. Type\ of\ Demand\ Response\ Event\ (Business\ parameters)$$

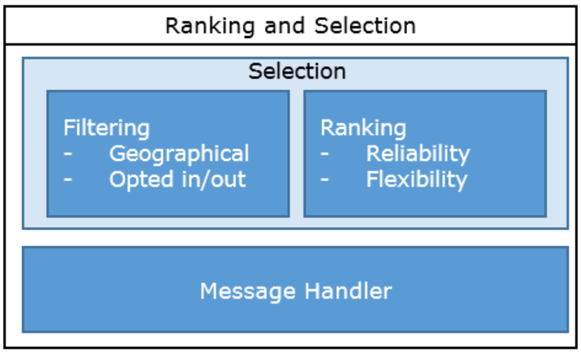
$$s.t. Asset\ Region\ (Context\ parameters)$$

$$s.t. Time\ Period\ (Context\ parameters)$$

Input parameters:

$$Demand\ Flexibility\ Potential\ (time - series)^*$$

Algorithmic Process: Assets Hierarchy by taking into account Demand Flexibility Availability &reliability




```java
            Float flexMax = Collections.max(assetsForOptimisation.getFlexList());
            Float triggerMax = Collections.max(assetsForOptimisation.getTriggerList());
            Float drResponseMax = Collections.max(assetsForOptimisation.getDrResponsivenessList());

            //Note that (+, -) indicate the reverse effect that each "objective" has on the ranking process
            //NB: this ranking method is very crude: an asset with potential flex of 10000000 and #trigger = 100, will
            //      most of the times be triggered because of its significant flex potential.

            // WEIGHTS here hand-picked like cherries
            for ( AssetFlex i : assetsForOptimisation.getAssetFlexList() ) {
                Float ranking = 0.0f;
                ranking += (0.4f * i.getFlexibility()/flexMax);
                ranking -= (0.4f * i.getTriggers()/triggerMax);
                ranking += (0.2f * i.getDrResponsiveness()/drResponseMax);
                i.setRanking( ranking );
                //TODO The following may be more appropriate but highly depends on the values above
                i.setRanking( (float) Math.max(0.0d, (double) ranking));
//          }
```

Output parameters:

$$Assets\ Hierarchy/Ranking$$

** For price-based flexibility derived from demand elasticity component and "request for demand flexibility" interface;*

**for context based flexibility derived through Clustering/Group Analysis by taking into account DSM contract type, Region and time-period.*

Table 10 Algorithmic framework – MOEEBIUS Simulation Analysis Engine

A fuzzy system is defined as the analytics technique towards the selection of the assets (assets hierarchy & taxonomy) to address the different business objectives defined in the project.

The results of the analytics process are reported:

I. to the DAFM UI for presentation (part of "what-if" analysis feature of DAFM engine)
II. to the MOEEBIUS District Level DSS as a triggering message for the implementation of real time DSM strategies.

The message structure is presented:

The response of the simulation analysis is presented as:


```
{
 "market" : "CPP value or null",
 "ParticipationList": [
   {
     "assetId": "asset01",
     "value": "xxxx"
   },
   {
     "assetId": " asset02",
     "value": "xxxx"
   },
   {
     "assetId": " asset03",
     "value": "xxxx"
   }
 ]
}
```


Table 11 Interfaces with MOEEBIUS District DSS- Response Message

We presented above the functional view of the MOEEBIUS DER Forecasting, Aggregation and Flexibility Analysis Module, highlighting the updated (and final) list of features and functionalities supported by the application.

While the skeleton of the application was defined in D6.1, some modifications were defined during the reporting period, further presented in this document as part of the final version of the tool. More specifically:

- Incorporation of extra analytics in the DAFM functionality
- An extended version of price elasticity engine to address the different dynamic pricing policies
- Incorporation of a dynamic DSS engine to enable the implementation of price driven DSM strategies
- Detailed definition of the algorithmic framework to support the demonstration of simulation analytics feature.

Along with the functional view of the tool, the presentation view of the DAFM tool is presented in the following section.

4 MOEEBIUS DAFM Engine Manual Documentation

By presenting the final list of functionalities supported by the tool, we proceed with the documentation of the DAFM platform functionalities (manual of the tool). We have to point out that the analysis is performed in line with the definition of core features of the application. Starting with the intro screen of the DAFM engine, we present the different views of the DAFM GUI associated with the platform functionalities (workflow analysis).

MOEEBIUS DAFM Analytics Home Page & Descriptive Visualization

By providing user credentials, a map view is the main view of the system (dashboard) towards presenting aggregated information about portfolio energy, business and contextual performance as part of the "**Descriptive Visualization**" feature.

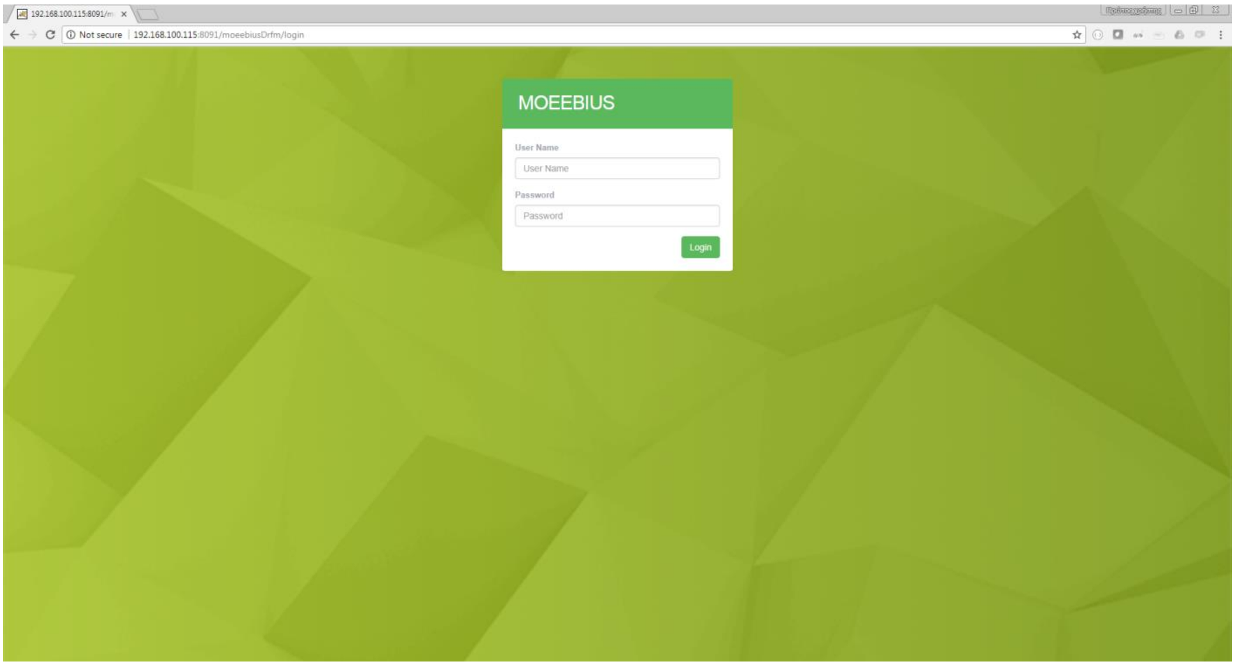


Figure 25 DAFM Engine Credentials Screen

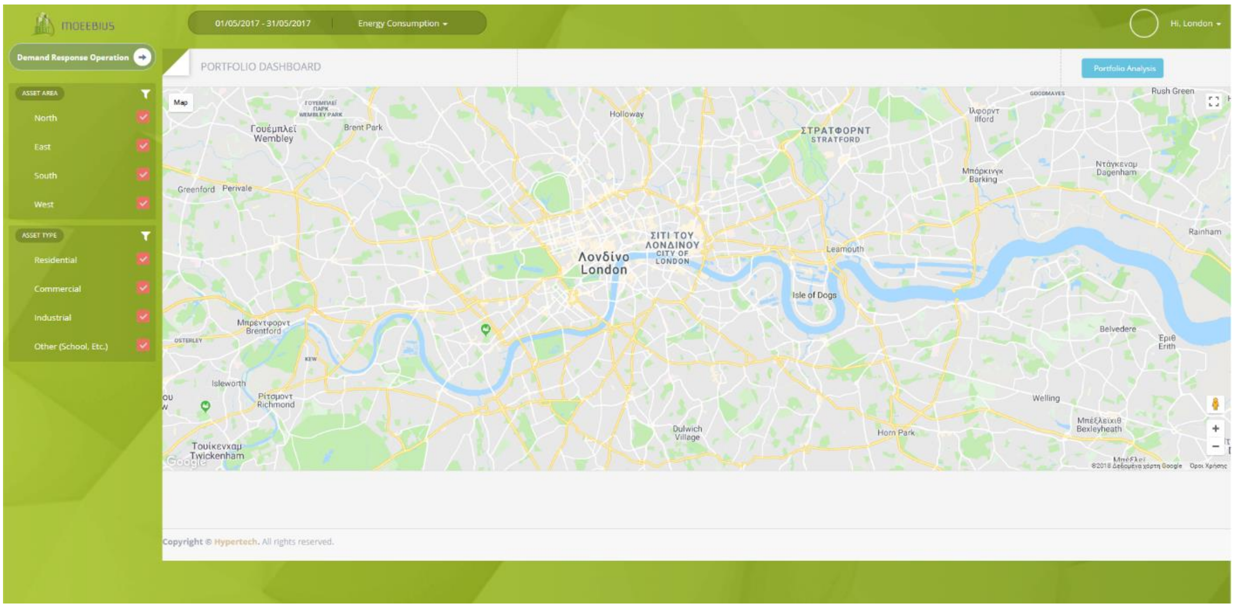


Figure 26 DAFM Engine Dashboard View

Different filters apply to enable custom analytics by taking into account:

- Time-period Selection: Selection of time period for the analysis
- Zone Selection: Selection of a geographical zone for visualization
- Asset Type Selection: Selection of Asset Type {residential, commercial, industrial, etc…}
- Metrics Selection: Selection of metrics/ indicators for visualization

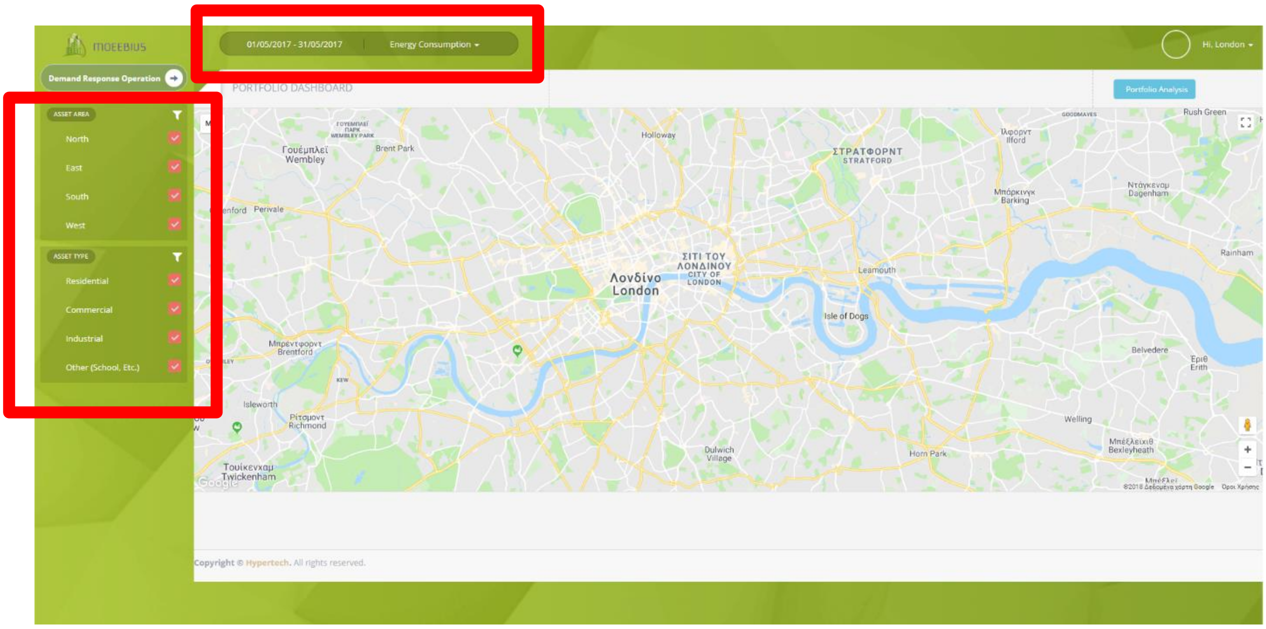


Figure 27 Filter Selection View

The list of assets that set the portfolio of the ESCO/Aggregator are further presented as points on the map

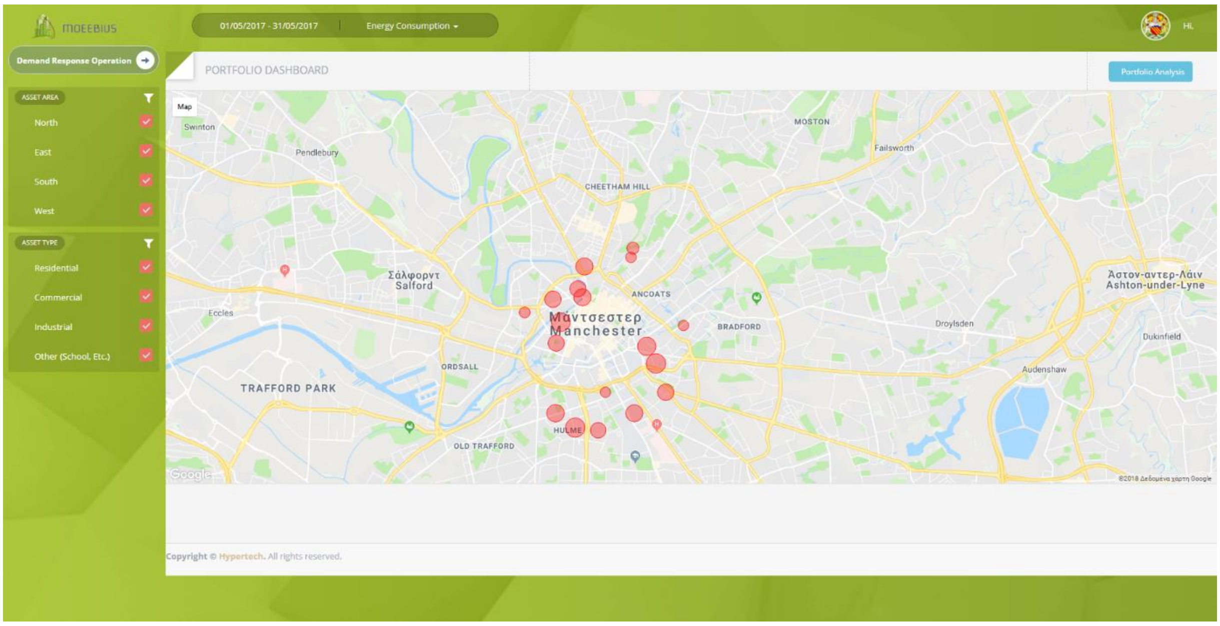


Figure 28 DAFM Engine Dashboard View –Portfolio Overview

The size of each point is proportional to the value of the metric selected for visualization. Through the selection of an asset from the map view, the user drill in the view and get insights about each asset performance (over a list of metrics and KPIs). A comparative view is supported by this visualization (asset vs. portfolio performance). A Kiviat diagram is presenting the performance of an asset (selection of metrics) compared to the normalized performance of the Aggregator portfolio.

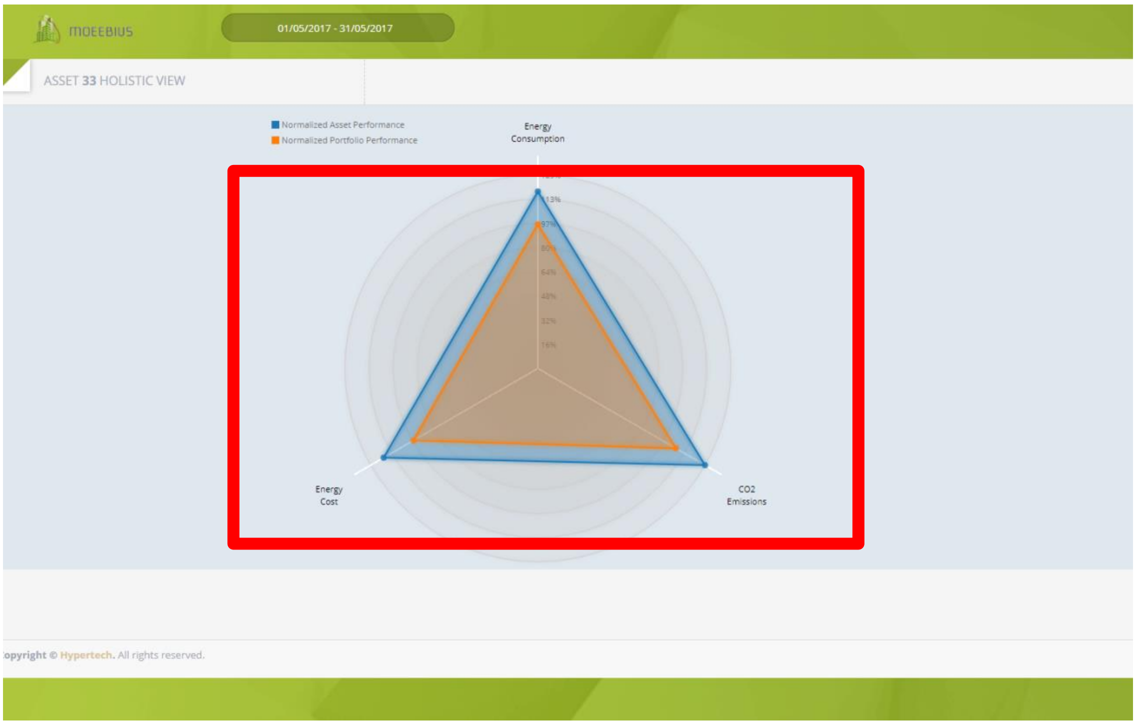


Figure 29 Insights - Asset KPIs values

Then, by selecting a specific KPI metric we get a (dynamic) time series analysis of asset performance for the selected metric. Once again, the time series is complemented by a comparative view. Asset time series analysis compared to the portfolio time series analysis for the selected period. The visualization is presented in the following figure.

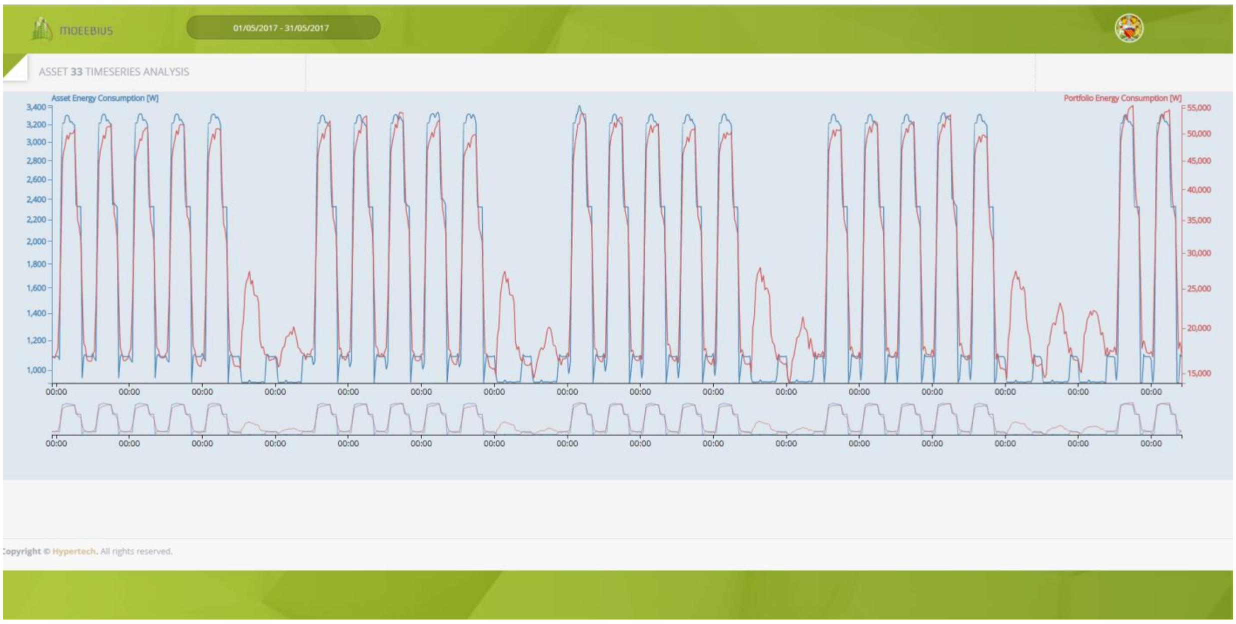


Figure 30 Asset Time-series analysis

At the level of building blocks (district level analysis), MOEEBIUS will validate the business role of the Demand Side Aggregator to enable the transformation of demand-driven Virtual Power Plants (VPPs) with enhanced **aggregated flexibility capabilities** to participate in event-, time-, location- or price-based Demand Side Management Strategies

A "Demand Side Management" feature is highlighted also as an innovative feature of the DAFM engine as we are providing a separate view for DR Aggregators to support the management of assets demand flexibility and further support triggering of DR campaigns. The different views of the DAFM tool, taking into account the case scenarios examined in the project, are presented in the following figures.

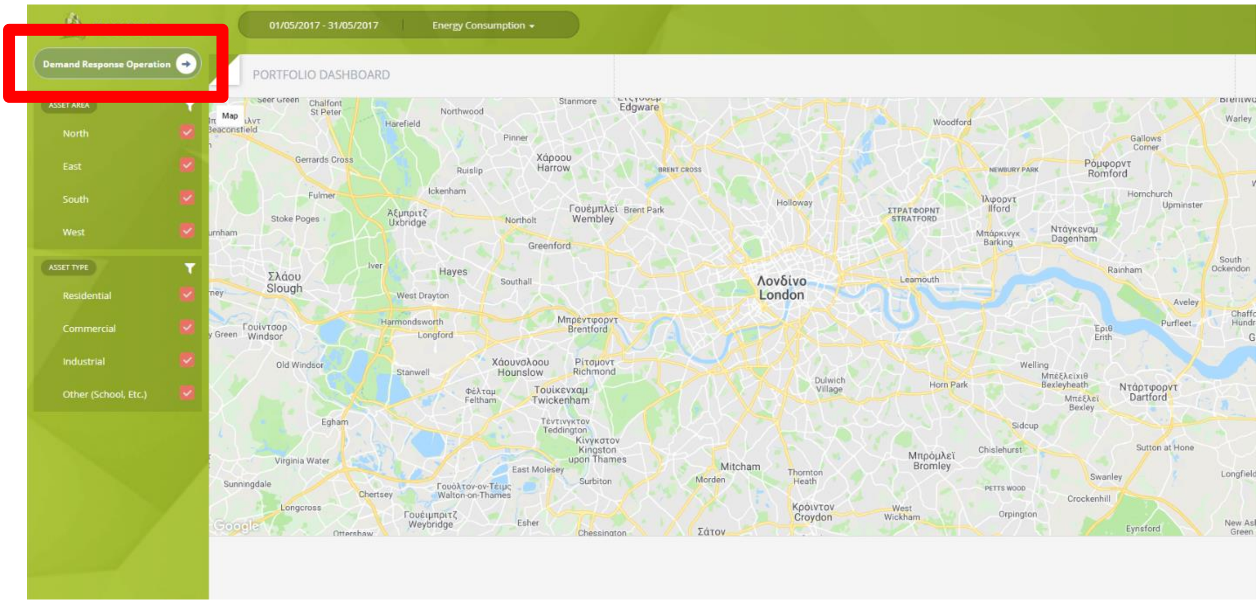


Figure 31 Selection of DR oriented DAFM view

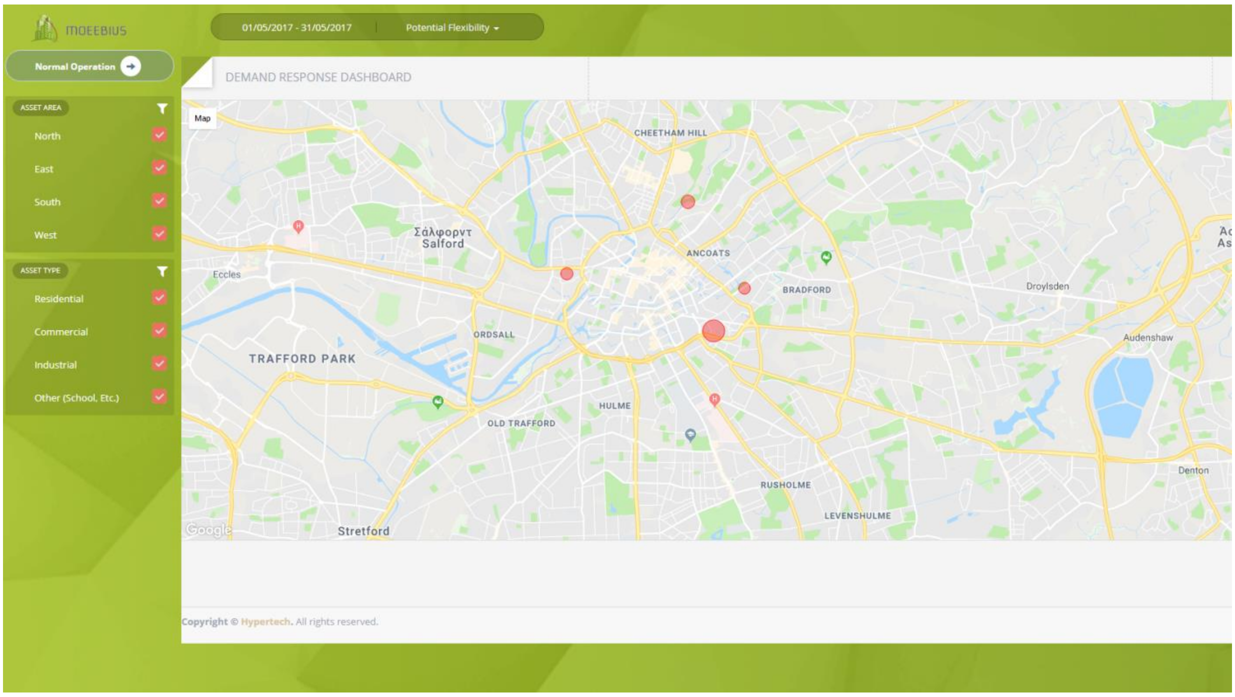


Figure 32 DR Portfolio Overview Screenshot

MOEEBIUS DAFM Portfolio Analytics

Moving beyond descriptive statistics and visualization, a data mining feature is incorporated in the DAFM engine and presented in this section.

By selecting “portfolio analytics” tab,

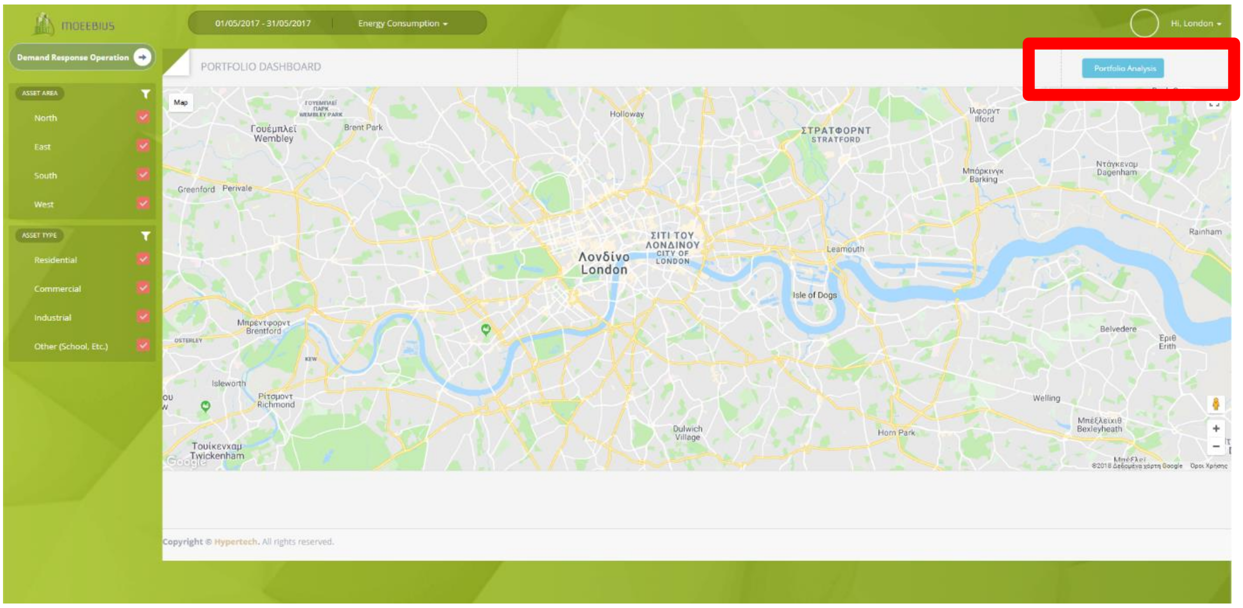


Figure 33 Portfolio Analysis feature

we drill through to portfolio performance, in line with the definition of the different business scenarios in the project. A drop down menu facilitates the selection of the business strategy.

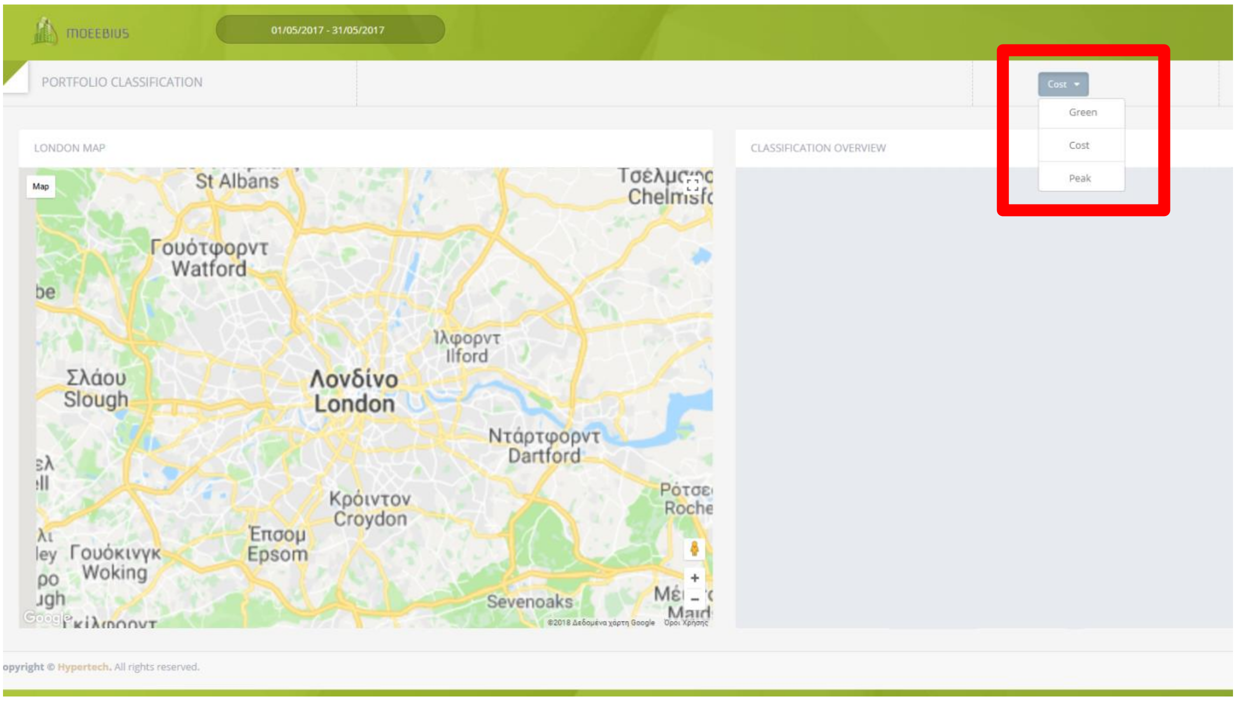


Figure 34 DAFM Engine Analytics Business Scenario Selection

The results of clustering process are presented through the combinational: map and boxplot view (map view with colour coding in line with clusters definition, box plot for metrics & KPIs representation).

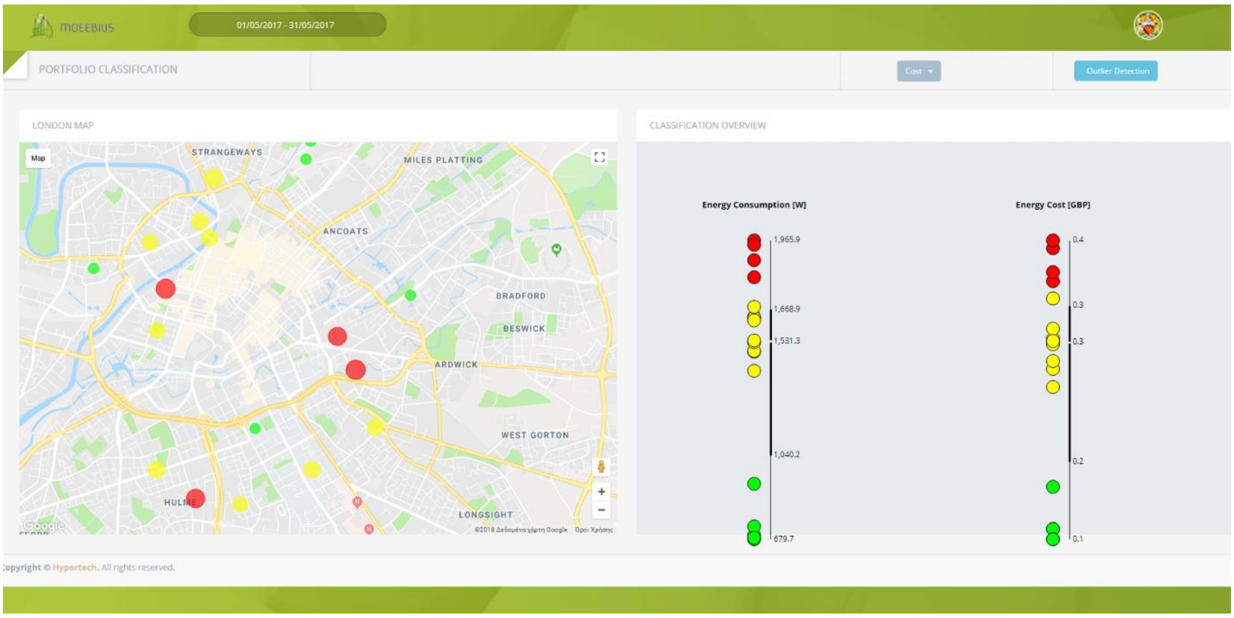


Figure 35 DAFM Engine Analytics – Cluster Analysis

The same functionality is available for "Demand Response" analytics, taking into account the potential of assets to offer demand flexibility. A subset of portfolio assets is participating in DR campaigns and thus the cluster analysis is provided to a subset of portfolio assets, considering specific business objectives as defined in the project.

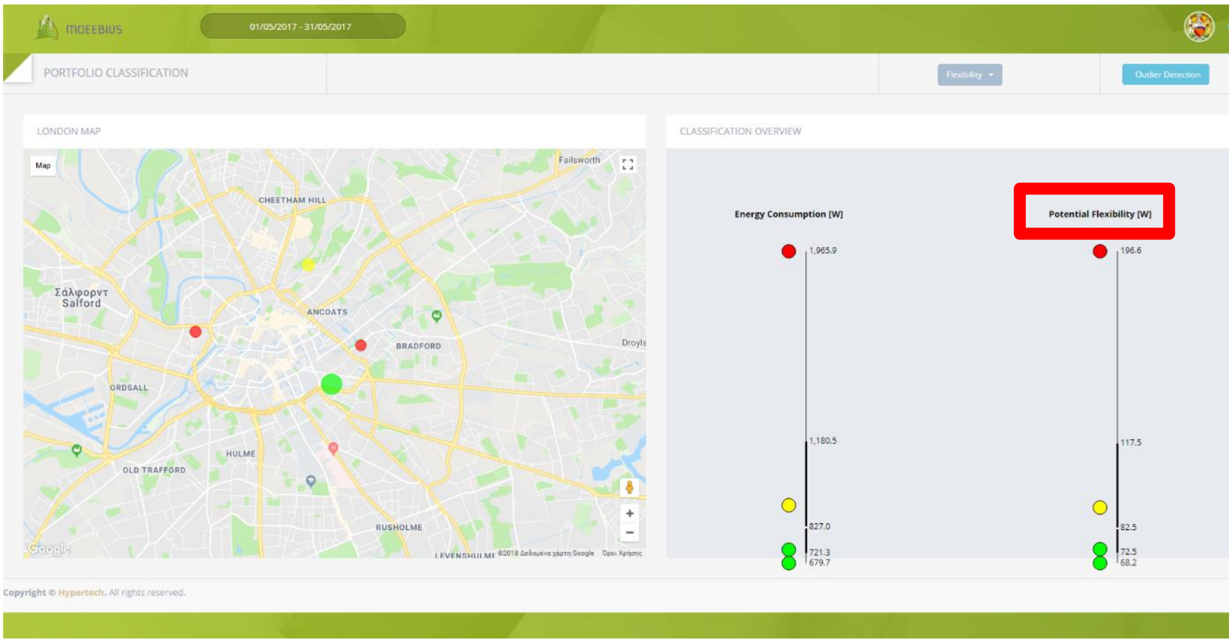


Figure 36 DAFM Engine Analytics – Demand Flexibility Cluster Analysis

In addition to clustering /classification analysis, "trend analysis" functionality is supported by the tool. The main objective of this feature is to correlate heterogeneous data attributes and KPIs in order to extract trends and subsequently

outliers in portfolio performance. The next figure presents a screenshot of the outlier's analytics process.

Figure 37 DAFM Engine Analytics – Outliers Detection

In addition to the map and boxplot view where insights about business strategy performance are provided, additional plots are available to visualize: asset's trend performance (bottom left graph) and the results of outliers' detection analysis (bottom right graph).

The latest graph is actually in line with the expectations about the DAFM tool; to provide a dynamic dashboard that enables the evaluation of different business scenarios over a time period through several KPIs.

MOEEBIUS DAFM Simulation Analytics

Complementarity to the data analytics functionality (as presented above), the DAFM engine supports the implementation of "what if" simulation/optimization analysis within the context of demand side management strategies as examined in the project.

The business stakeholder (namely Aggregator) may dynamically set the input parameters to get insights about portfolio performance under different Demand Side Management strategies. Furthermore, the feature also supports the implementation of actual demand side management scenarios (as examined in the project), by interfacing/ triggering demand side management request to the District Dynamic Assessment engine ("Demand Side Management" feature presented above). The different views of this feature are presented in the following figures.

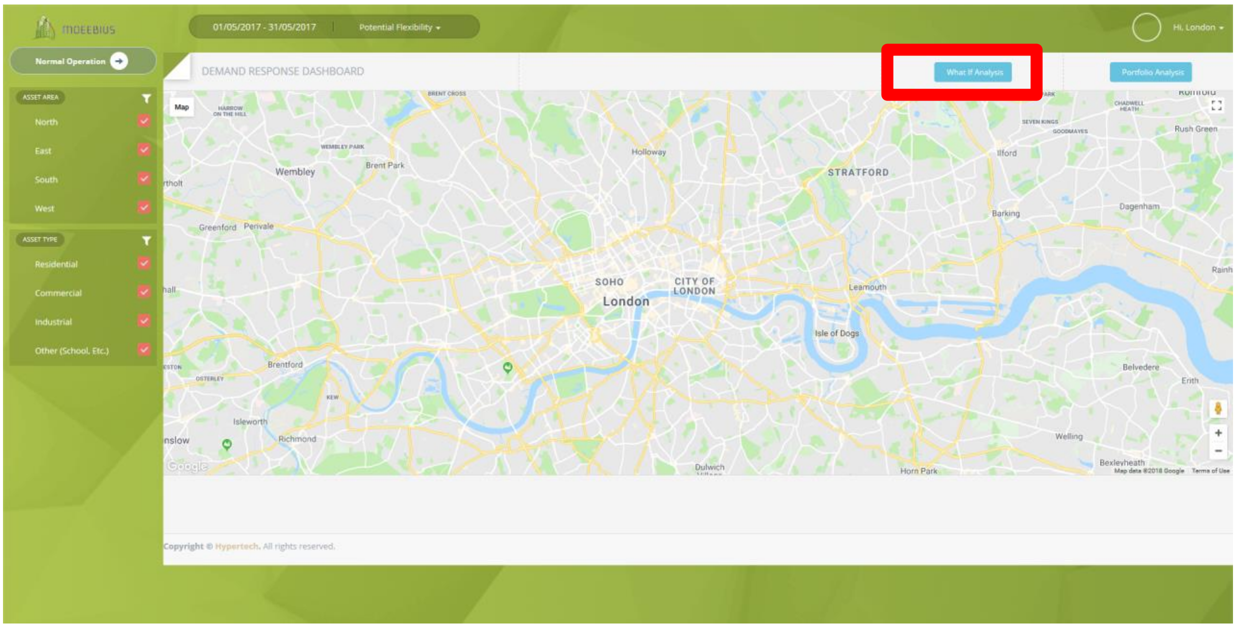


Figure 38 Simulation Analysis Feature – What if analysis

The next figure presents a screenshot with the simulation analysis results, highlighting the list of assets to participate in DR campaigns.

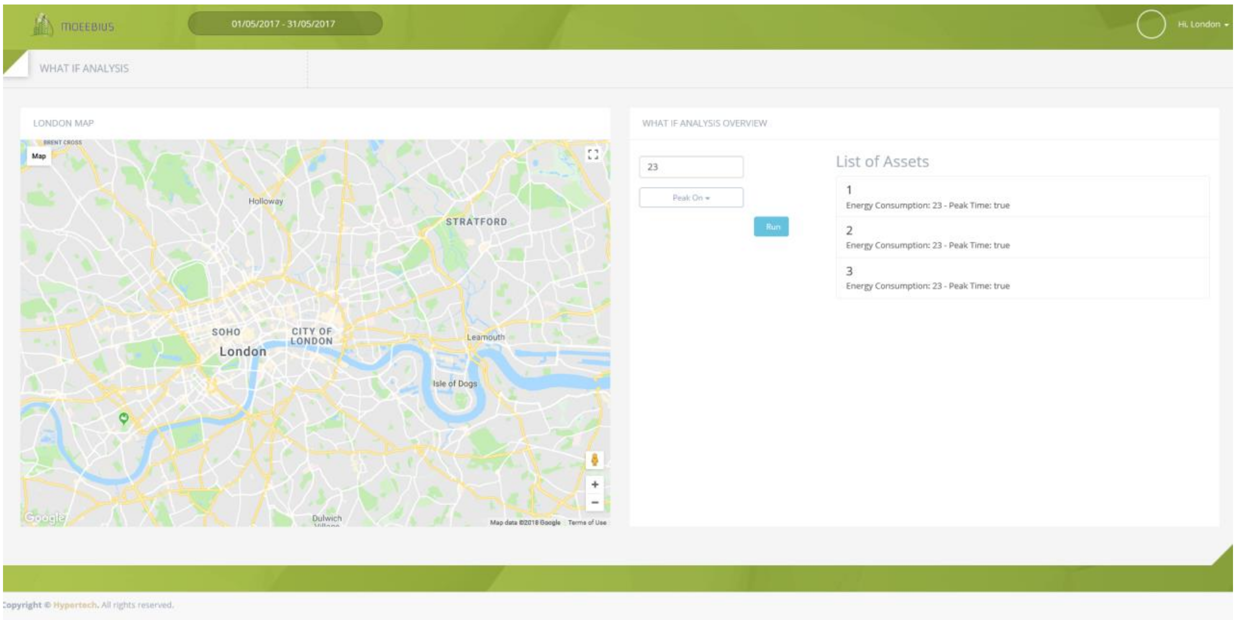


Figure 39 DAFM Engine Analytics – Simulation Analysis

We presented above the manual documentation for the DER Forecasting, Aggregation and Flexibility Analysis Module (DAFM module). The presentation of the different views of the system takes into account the list of functionalities supported by the tool and thus we provide the detailed document that will facilitate the

business stakeholders to better understand the scope of the DAFM platform; namely:

- Descriptive visualization Feature
- Portfolio Data Analytics Feature
- What-if simulation analysis Feature
- Price elasticity module & Real time DR campaign implementation as the back end/ analytics functionalities offered by the tool.

Along with the manual documentation of the DAFM Engine, the results from the early (lab) evaluation of the DAFM tool are presented in the next section.

5 MOEEBIUS DAFM Engine Evaluation

As presented in the introductory section, one of the main objectives of this document is to report the results from the early evaluation of the tool. During the reporting period an early evaluation of the DAFM platform took place, covering both functional and technical evaluation. As a first step, the methodological framework towards the evaluation of the engine is defined. Then, the results from the evaluation analysis are presented to ensure that the final development is in line with the initial list of requirements.

5.1 DAFM Engine Evaluation Framework

A hybrid approach was conducted for the evaluation of the DAFM Cockpit functionalities:

- **Technical evaluation** of the system where the technical partners performed several functional and technical tests to the DAFM Cockpit.
- **End users experience** evaluation where the pilot representatives performed the UX evaluation of the tool, highlighting features to be further incorporated as functionality of the tool.

The definition of performance criteria are presented as part of the methodology while the results from test analysis are presented in the next section.

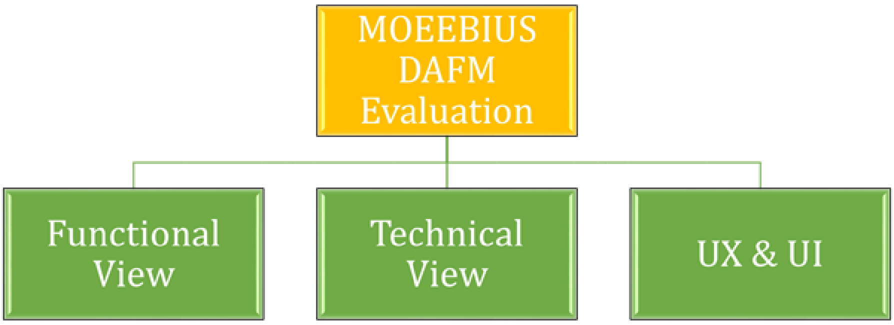


Figure 40 DAFM Engine Evaluation Framework

The list of functional criteria for evaluation are derived from the list of requirements defined early in the project:

Requirement	Priority	ID
DAFM User Interface		
Aggregator must be able to select the KPIs and set the **temporal, spatial, operational** etc. values in order to retrieve dynamic reports about clusters of prosumers	High	1
The tool must be interactive - i.e. offer the option to **drill-down** to **individual** (building) details, focusing on the performance of each customer of the portfolio	High	2
Users should be able to **select from a list KPIs** to compare prosumers performance over a selected time period. The KPIs selected will set the parameters for customized analytics	Medium	3

Users should be able to select the **analytics process**, from the list of functionalities offered by the DAFM component	High	4
Users must be able to evaluate the **potential impact of different DSM strategies** through interaction with the DAFM simulation engine incorporated in DAFM component	High	5
DAFM application requirements		
The tool system must support **portfolio segmentation over KPI** values from different domains (Energy, Flexibility etc..), with segmentation levels to be manually defined	High	6
The Analytics tool should provide analysis and visualization of **KPI trends**	High	7
The Analytics tool should support **clustering analysis**, classifying data into non-predefined groups (clusters) based on their similarity on certain features (context, health, flexibility etc.)	High	8
The Analytics tool should support **metric/KPI classification**, classifying data into predefined groups based on their features	Medium	9
The Analytics tool should support **outliers detection** for **metrics/KPIs**, based on thresholds provided by the end users of the system	High	10
The Analytics tool must allow working with **different layers of system detail** (data hierarchy and aggregation)	High	11
The DAFM clustering mechanism should be further exploited for the **simulation of different DSM strategies**, towards the selection of portfolio consumers that best fit to specific DSM scenarios	High	12
The results from **simulation process** should be available to **District level Dynamic Assessment Engine**, towards the selection of real time best fitted DSM strategies. Therefore interfaces among these two components should be defined	High	13
In order to retrieve data required for analytics process, interfaces **with Data Acquisition and Management Layer (District)** will be defined.	High	14
The tool should extract **price based flexibility profiles** by taking into account the amount of building level demand and the input parameters from an external price simulator engine	High	15
In order to **retrieve data related to DSM strategies** implementation (level of fulfilment at DSM strategy, prosumers compensation for participating in DSM programmes), required for simulation process, **interfaces with District DAE will be defined.**	High	16

Table 12 List of functional requirements for DAFM Engine

In addition, the technical criteria for the evaluation of DAFM engine:

Technical Requirements	Description	Priority Level	ID
Database Structure	For analytics over historical data, a database with different data types (energy, flexibility etc.…) should be managed by the tool	Medium	1
Usability	Usability is the ease of use and learnability of the application	Medium	2
Performance	The level of time and resources needed for the delivery of the framework	High	3

Accuracy	The levels of accuracy on produced results	Medium	4
Management/ Scalability	The capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged in order to accommodate that growth	High	5
Reliability	The system will be stable over time and will not need changes.	High	6
Security/Privacy	Addressing security and privacy aspects	High	7

Table 13 List of technical requirements for DAFM Engine

We presented above the list of criteria to be considered towards the functional and technical evaluation of the platform. Complementary, the end user experience evaluation is conducted through questionnaires circulated to the pilot representatives to evaluate the list of features supported by the platform. The questionnaire template is presented in the following figure as part of the methodology.

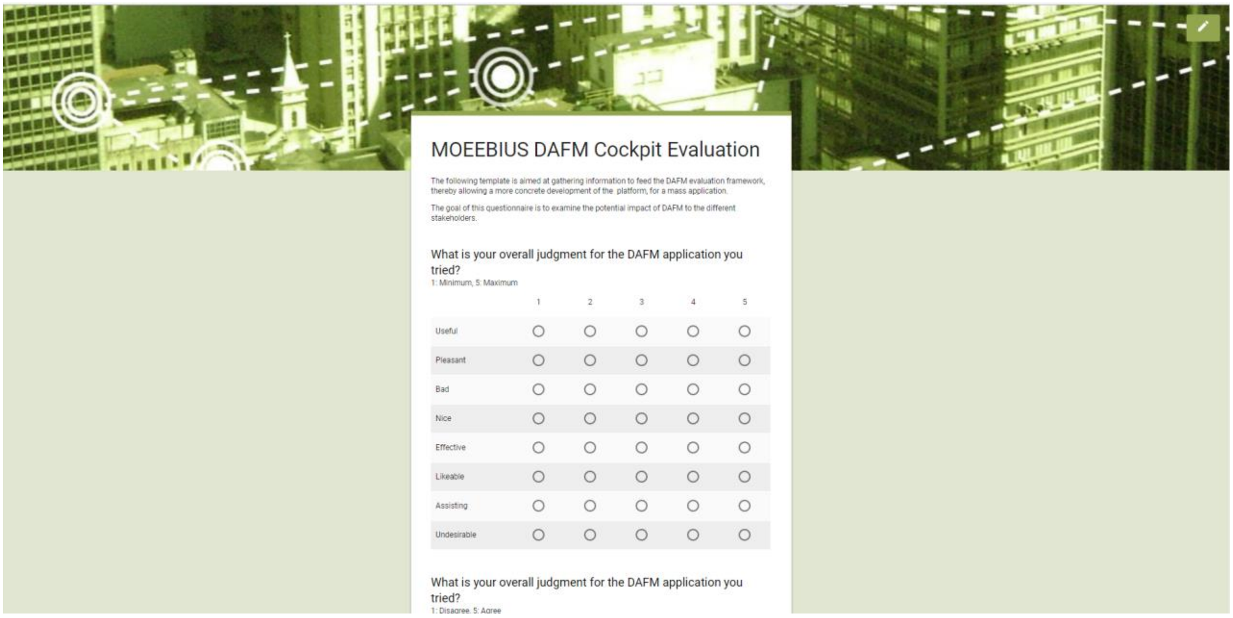


Figure 41 Questionnaire template –DAFM engine evaluation

The three pillars that consist of the DAFM engine evaluation were defined above. The results from the evaluation analysis of the DAFM engine are presented in the following section.

5.2 DAFM Engine Functional Evaluation

Starting with the functional evaluation of the tool, we defined a non-exhaustive list of evaluation criteria. For the functional evaluation of the tool, the validation is performed by taking into account the list of potential features along with the level of coverage.

ID	Test Scenario	Coverage
1	Tool to support **filters** for KPIs and temporal, spatial, operational analysis	√
2	Tool to support drill-down to individual (building) level information about energy performance	√
3	Tool to support KPIs selection to compare prosumers performance over a selected time period.	√
4	Tool to support different types of analytics (related to test scenarios…)	√
5	Tool to support potential impact of different DSM strategies	√
6	Tool to support portfolio segmentation with segmentation levels to be **manually** defined	√
7	Tool to support visualization of KPI trends	√
8	Tool to support clustering analysis, classifying data into non-predefined groups (clusters)	√
9	Tool to support metric/KPI classification	Partially
10	Tool to support outliers detection for metrics/KPIs	√
11	Tool to support data hierarchy and aggregation	√
12	Tool to support simulation of different DSM strategies	√
13	Tool to support integration with District level Dynamic Assessment Engine	√
14	Tool to support integration with Data Acquisition and Management Layer (District)	√
15	Tool to support integration price based flexibility profiling functionality	√
16	Tool to support remuneration for participation in DR campaigns	√

Table 14 Level of Coverage - Functional requirements of DAFM Engine

We presented above the list of the different tests scenarios to evaluate the core functionalities of the platform. The full list of functional requirements has been addressed during the development phase. An exception is reported about metric/KPI classification as we have incorporated this as part of the clustering features towards the dynamic selection of assets to meet specific business needs.

In the following section, we are presenting the list of scenarios performed about the technical evaluation of the platform.

5.3 DAFM Technical Evaluation

The results from the test scenarios performed to support the technical evaluation of the DAFM engine are presented.

Technical Evaluation			
T1	**Scalability**	The capability of the system to handle a growing amount of work, or its potential to be enlarged to accommodate that growth	Reliability Level (%)
T2	**Reliability**	Describes the ability of the system to function under stated conditions for a specified period of time	Reliability Level (%)
T3	**Speed of Communication**	Test of interfaces with external system components	Response Time (sec)
T4	**Stability/ Availability**	The ratio of (a) the total time a functional unit is capable of being used during a given interval to (b) the length of the interval.	Availability (%)
T5	**Performance**	The time the system takes to react to a given input.	Availability (%), Response Time (sec)
T6	**Security/ Privacy**	Addressing security and privacy aspects	Narrative

Table 15 Level of Coverage - Technical requirements of DAFM Engine

The detailed results from the different tests are reported.

Stability/Availability

The deployment of the DAFM Analytics engine as a standalone server application ensures high level of availability. Actually, the level of availability for the DAFM application is tightly associated with the server availability and the DAFM Cockpit Database availability. For the lab testing period, a **100%** availability level is

reported, though the actual evaluation of this KPI will be performed at the different demonstration sites.

To secure a high a level of availability, the system should be running on a cluster environment, e.g., a private or public cloud, which offers fault tolerance as a service to the system. In any case, maintenance updates of firewalls and routers as well as necessary server reconfigurations due to version conflicts after updates will expect to decrease the level of availability still at around **98%**.

Reliability

The DAFM Analytics engine is evaluated as a reliable tool; for the lab testing evaluation period the reliability level was over **97%** taking into account the availability of DAFM engine as a service. For the lab testing period, we considered a simulated portfolio of 20 assets with the processing requirements to not expand beyond the hardware characteristics of the workspace environment (8 GB RAM, i5@3.3GHz).

Speed of Communication & Performance

This test scenario is performed for the evaluation of possible latencies to the functionalities of the DAFM application. The system should ensure low latency to external system components. There are two main KPIs examined for this evaluation scenario:

- **Speed of connection/interface**: with data management layer (queries in Data Acquisition and Management Layer (District) for accessing historical data) which is mainly affected by the number of requests from DAFM Engine and the simultaneous calls from the rest of business applications.
- **Performance**: Latency due to the analytics process and further integration with the Distract DAE component.

We have to point out that the number of assets considered for lab testing is rather low and thus no latency is reported as a result of data retrieval or analytics (analytics process is performed in a limited dataset: 20 assets, 3 metric types, 1 month period).

Scenario ID	Scenario Description
1	Single Metric, Single Asset: 1 week period data
2	Single Metric, Single Asset: 1 month period data
3	Multiple Metrics, Single Asset: 1 week period data
4	Multiple Metrics, Single Asset: 1 month period data
5	Single Metric, Multiple Assets : 1 week period data

6	Single Metric, Multiple Assets : 1 month period data
7	Multiple Metrics, Multiple Assets: 1 week period data
8	Multiple Metrics, Multiple Assets: 1 month period data

Table 16 List of Test Scenarios

The results of testing "speed of communication" are presented in the following figures:

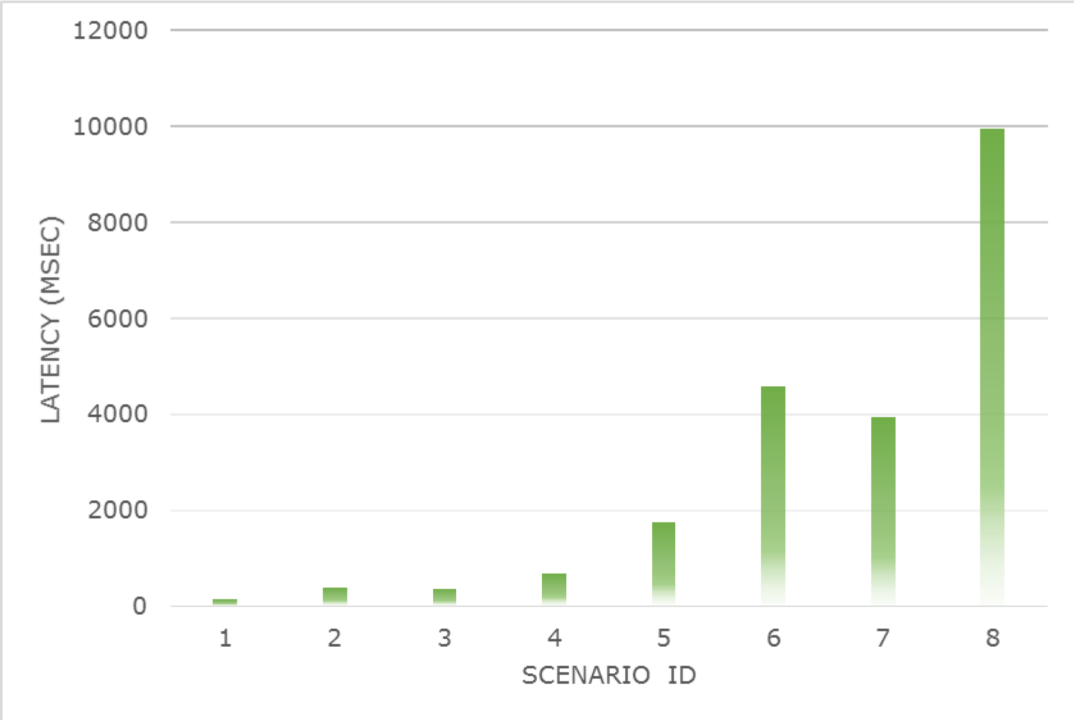


Figure 42 Speed Latency - per scenario

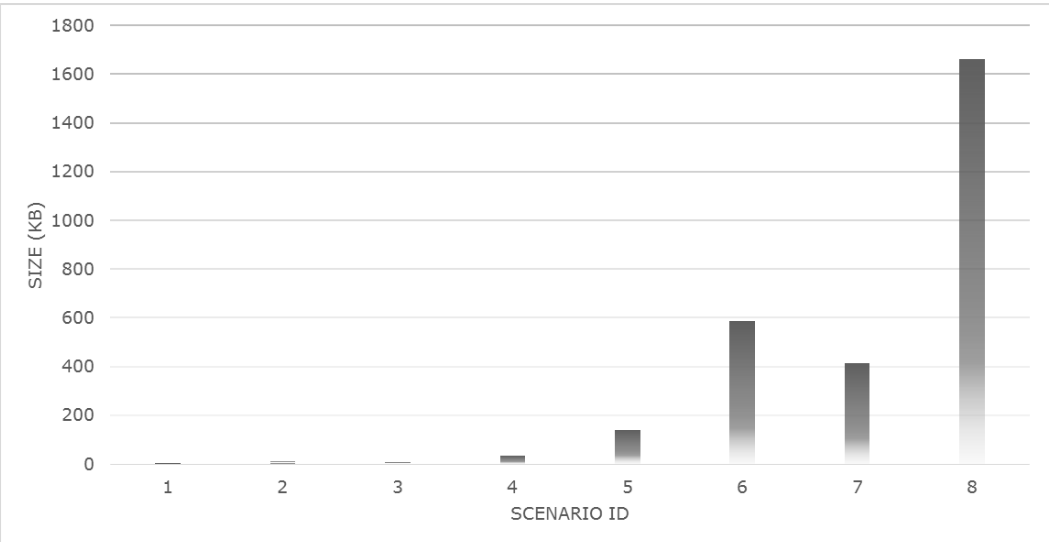


Figure 43 Amount of data – per test scenario

For testing reasons, HTTPS 1.1 and REST are used with a varying number of clients. We highlight the potential of DAFM Data Engine to provide the options to compound requests, for example by requesting data from several assets and for several metrics at the same time. By combining the requests for 50 entities into a single request, we manage to decrease the amount of exchanged data and the latency of communication.

Scalability

The role of the DAFM tool is to offer analytics over large volumes of data and thus we have to examine the hypothetical scenario of multiple assets integration. The DAFM tool exploits this multi-thread functionality offered by the development environment towards gathering datasets from different end points. In addition, the adaptation of standardized technologies (development framework and application libraries) for data handling and analytics secures the scalability and expandability of the application.

We evaluated the system with ten thousand entities. The results from the evaluation analysis are presented in the following figure:

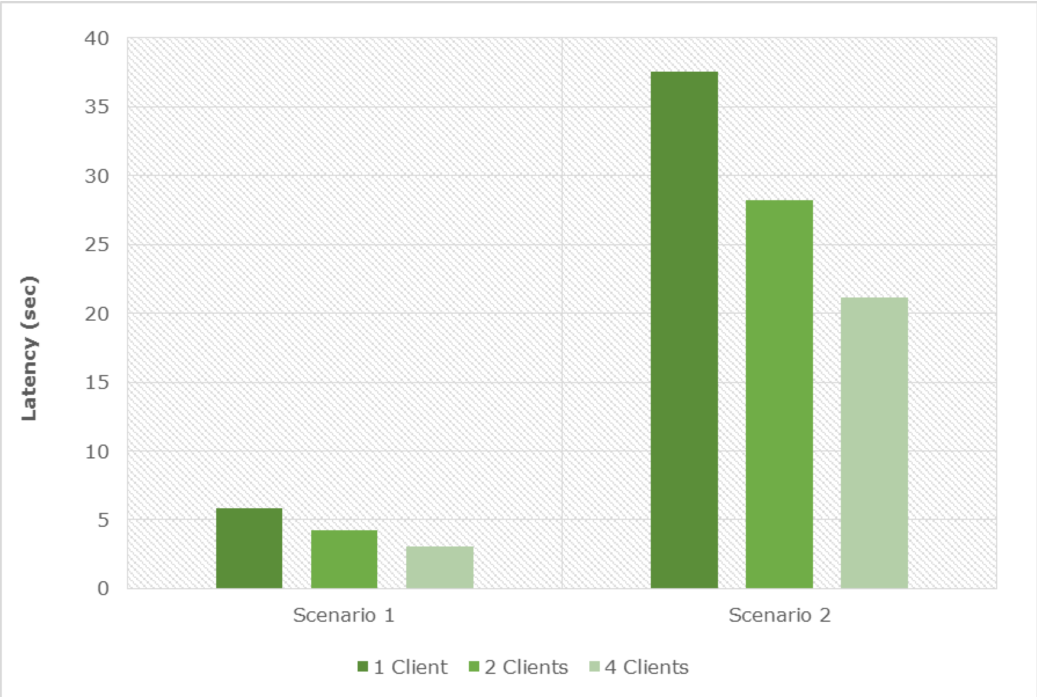


Figure 44 Latencies for thousand assets (in seconds)

In Figure 44, the latencies for two request types involving all assets are shown: getting a list of all asset IDs and getting the consumption values for all assets for the **last 12 hours** (48 values). For easier reading, the latencies are shown in seconds for this plot. The graph highlights the scalability of the system: with 4 concurrent clients (end points) the result reflects the use of the 4 cores of the server (hardware) leading to around 2 times faster completions of both request types.

Due to the huge amount of data the server has to send to the client, the speed of the connection between client and server becomes the bottleneck of the system.

However, assuming a sufficiently fast connection for the data transfer with respect to the amount of data to be transferred, the system scales very well with the number of cores.

The system is able to deal with fast-increasing volume of meter data, at a high frequency, e.g., 15 minutes. Towards further exploitation of application in large scale demonstration, we have defined a framework for using Spark to scale big data analytics. Data mining and machine learning algorithms thus will be transformed to Spark programs to be parallelized in a cluster environment.

Security & Privacy

Considering privacy and security of data management, we have followed the high level principles as defined in the Ethics management plan of the project.

Most specifically, about privacy: username/password authentication is the mechanism integrated to ensure classified access to the data. In addition, fully anonymized (and scrambled) data are stored in the platform, as there is no functional requirement about personal information handling towards the delivery of system functionalities.

Addressing also the security concerns, the development of the DAFM engine is in line with the overall development of the MOEEBIUS platform. A VPN network has been established towards accessing data from the building environment while the deployment of the MOEEBIUS platform in private cloud infrastructure ensures the maximum security level for the application.

We presented above the technical and functional evaluation of DAFM module. The end user experience evaluation of the tool is reported in Section 5.4.

5.4 DAFM UX & UI Evaluation

In addition to the technical evaluation of DAFM components, we proceed with the UX& UI evaluation of the system. The list of criteria for evaluation are presented in the following table, keeping the same typology.

ID	Name	Description	KPIs
End users Evaluation			
UE1	**User Friendliness**	User Experience evaluation- Easiness to understand the functionalities provided by the tool	Questionnaire Analysis
UE2	**Usability**	Easiness on using the tool	Questionnaire Analysis
UE3	**Appearance**	Look & Feel Evaluation - GUI evaluation-View Sequence	Questionnaire Analysis

UE4	**Portability**	Responsiveness of the tool in different working environments	Questionnaire Analysis
UE5	**Efficiency**	The time the system takes to react to a given input	Questionnaire Analysis
UE6	**Coherence**	Inconsistency in the system functionalities	Questionnaire Analysis

Table 17 List of UX/ UI evaluation criteria

The subjective questionnaire included the John Brook [System Usability Scale (SUS)] framework for evaluation. It is not within the scope of the project to extensively present the SUS methodology (see more in [11]), but the results from the analysis are presented in the following (a total number of 12 users from MOEEBIUS Living Lab were contributed at this early evaluation of system functionalities).

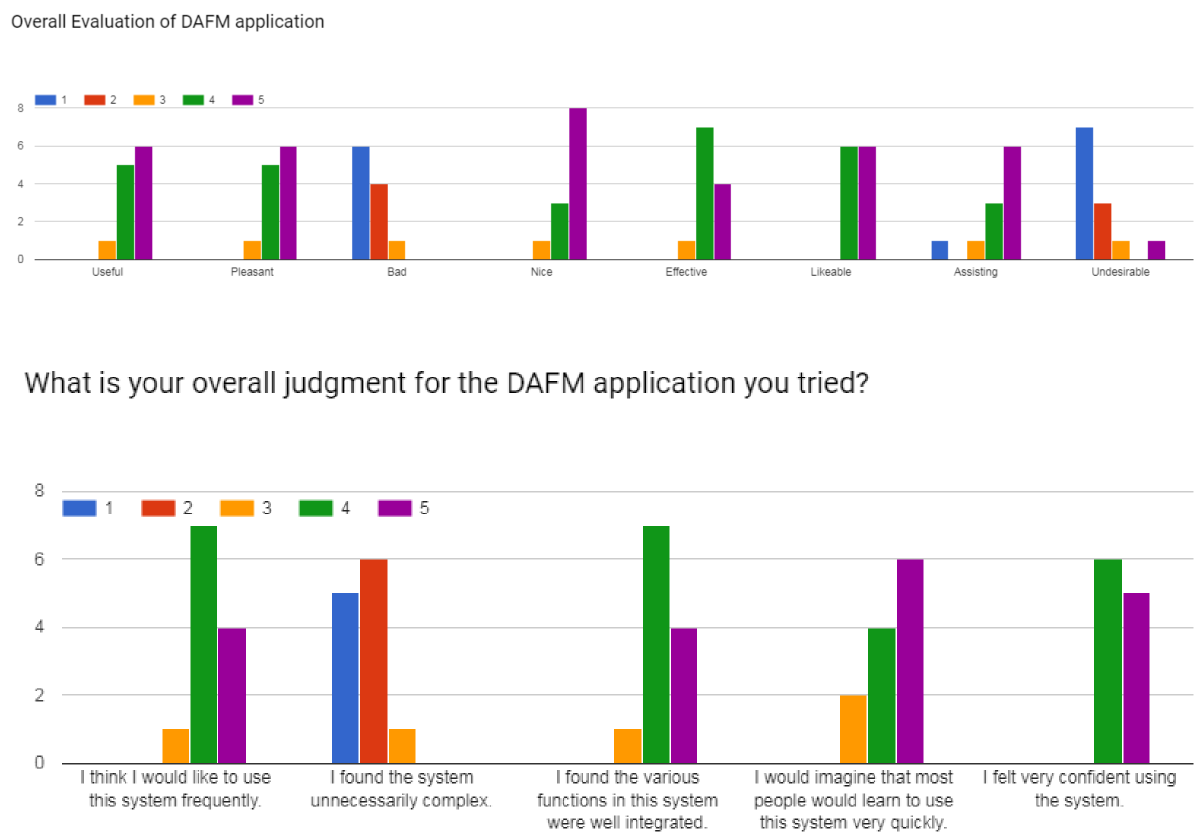


Figure 45 Overall evaluation of DAFM Engine

The overall system is characterized by lack of privacy?

12 responses

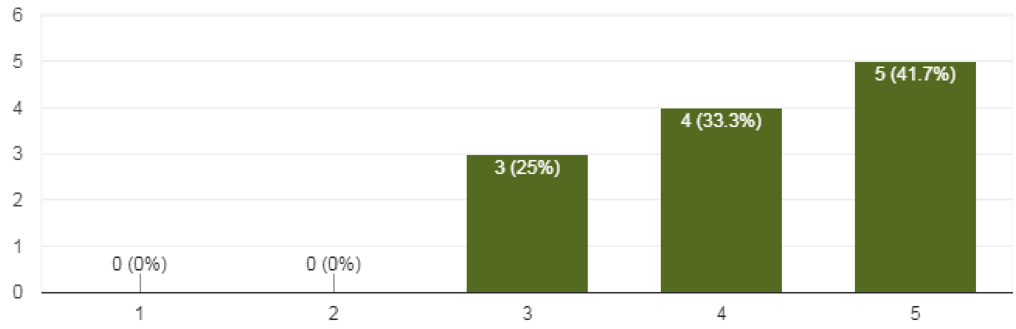
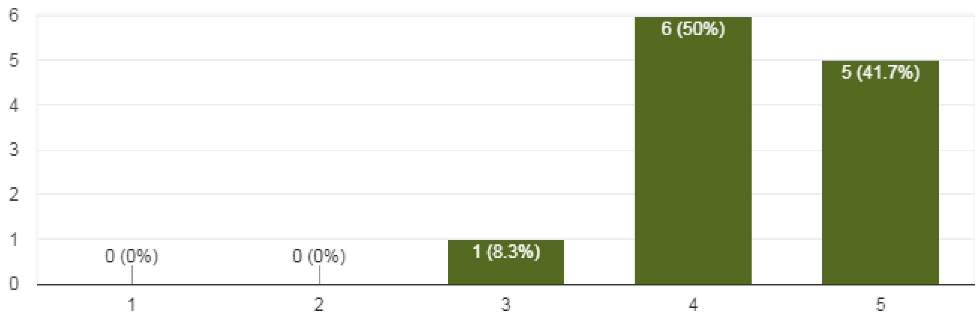


Figure 46 Evaluation of Privacy DAFM Engine

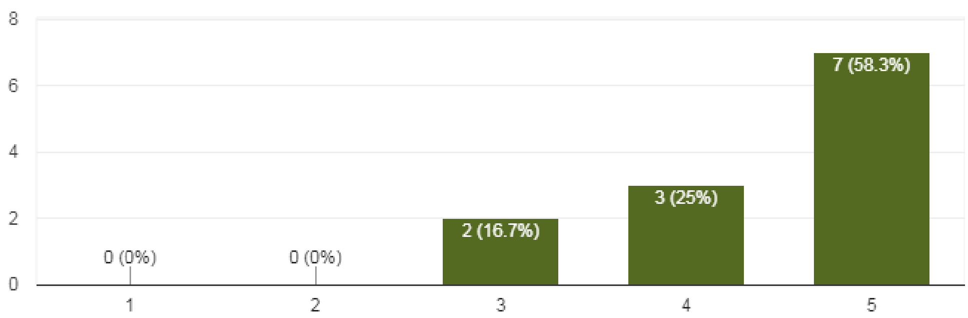
Do you think that the visual interface of the application is appealing

12 responses



Is it easy to locate the required information on the screen?

12 responses



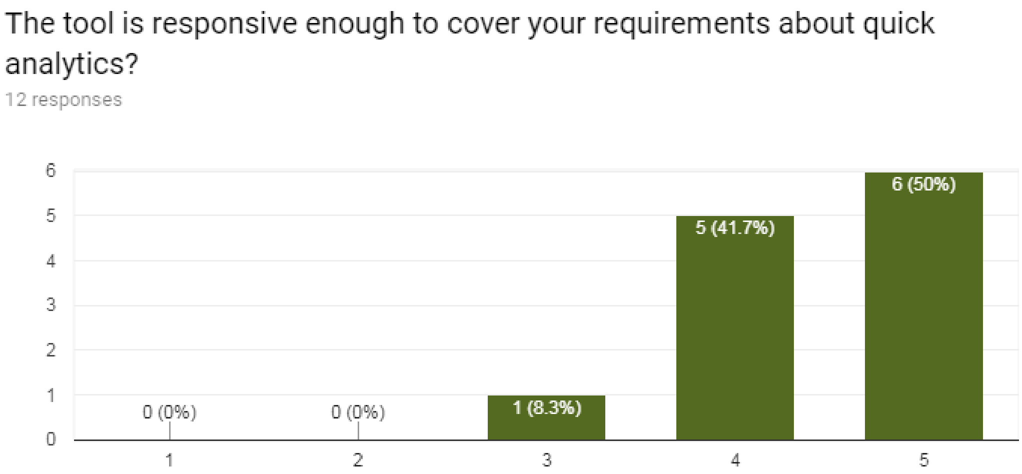


Figure 47 Evaluation of Visualization - DAFM Engine

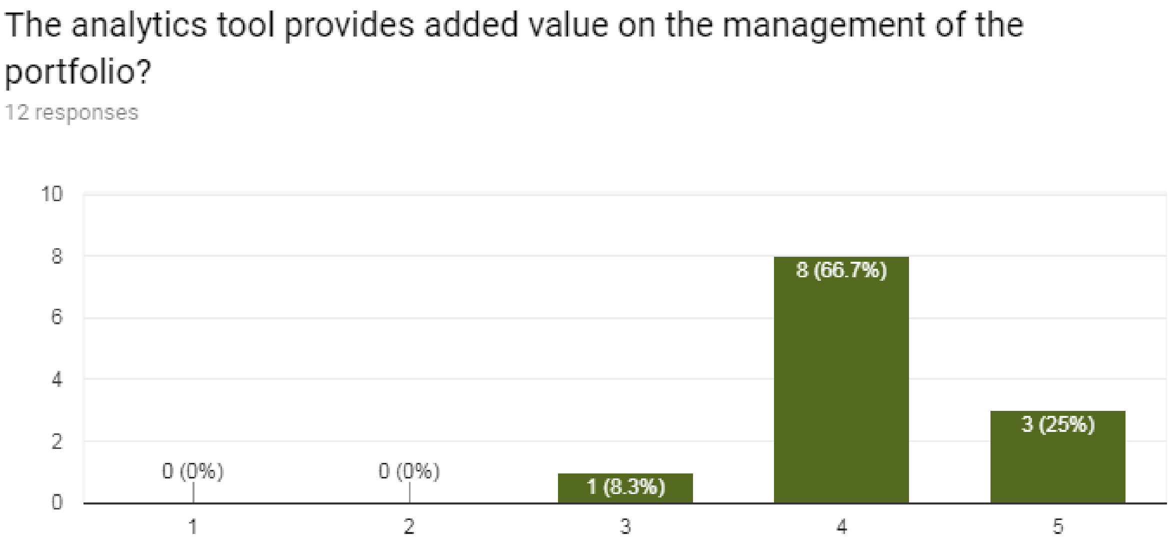


Figure 48 Evaluation of DAFM for portfolio management

As part of the commentary from the pilot users we highlight:

(+) Tool customized to aggregator specific needs

(+) An easy to understand tool that goes beyond existing analytics tools

(+) Clear distinction of system functionalities

(-) Lack of meaningful data - not easy to extensively evaluate the tool with no large volumes of data

(-) DR strategies configured to address project specific needs and requirements.

We presented above the detailed framework and activities performed towards the evaluation of DAFM Engine. The next step of the work is the deployment-wise configuration of the engine at the different demonstration sites and further the long term evaluation of the applications. Each demo specific evaluation of DAFM Engine will be reported as part of the work in WP7.

6 Conclusions

This report presents the final version of the MOEEBIUS DER Forecasting, Aggregation and Flexibility Analysis framework. By taking into account the requirements and specifications definition at the early phase of the project, we proceed with the final design and development of the DER Forecasting, Aggregation and Flexibility Analysis module.

Special focus is provided to the manual documentation of the tool (complementary to the development of the engine) to facilitate the business stakeholders at using the tool during the demonstration period of the project.

In addition, and following the UCD approach adopted in the project, we proceed with the early phase evaluation of the tool, covering both functional, technical and UX evaluation of the platform. The feedback gathered from the business stakeholders was important towards the development of the final version of the DAFM engine.

The next step of the work is the final deployment and evaluation of the tool as part of the integrated MOEEBIUS framework. This is the work to be reported as part of T6.5 Testing, Parameterization and Verification prior to the final deployment and evaluation of the engine at the different pilot sites of the project (T7.6 Results Validation, Impact Assessment and Cost-Benefit Analysis).

7 References

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8 Annexes

8.1 Definition of CPP market schemas

CPP has not been as widespread as ToU and RTP so far in the U.S. and Europe. Only several utilities have carried out pilot CPP programs, as optional or default service, towards large commercial and industrial (C&I), and residential customers. Nevertheless, empirical evidence supports the view that CPP can achieve significant load reductions during critical periods. In California, households supplied with sophisticated end-use controls dropped an average of 41% of baseline load (i.e., load that would have occurred absent the CPP price signal) over 2-hour hot-weather CPP events. In the absence of end-use controls, households dropped an average of 13% of baseline load over 5-hour hot-weather CPP events (Herter et al., 2006).

CPP mainly includes four schemes [3]: fixed-period CPP (CPP-F), variable-period CPP (CPP-V), variable peak pricing (VPP) and critical peak rebates. CPP stakeholders typically release in advance the triggering conditions of CPP events and corresponding values of critical peak prices. Customers are typically informed of critical events day-ahead, and accordingly customers can adjust their plans of electricity consumption day-ahead.

Within the context of the project, the VPP schema is selected for demonstration and evaluation. The literature shows that this is the most flexible schema to promote the successful implementation of DSM strategies (high-use customers respond significantly more, in kW reduction, than do low-use customers, while low-use customers save significantly more, in percentage reduction of annual electricity bills, than do high-use customers; customers response in a different way during different periods of the day).

In theory, CPP rates are designed to closely reflect short-term wholesale electricity. The dynamic pricing in wholesale market could help to make a closer alignment of retail prices with underlying wholesale costs (wholesale market data are also available through the energy price generator). Towards this direction, a thorough market analysis is provided towards the selection of best fitted CPP prices. The main principles are:

- CPP are usually assessed for certain hours on event days (often limited to 10-15 per year) ~ 3%.
- The on-peak & off-peak rates could be set equal to the average prices of peak hours and off peak hours in energy markets.
- Since the average price is the quotient of total suppliers' cost and total market volume, the rates in the tariff could be calculated by the equation below:

$$\text{CPP rate} = \frac{\text{market volume1} * \text{market price1} + \cdots + \text{market volume n} * \text{market price n}}{\text{market volume1} + \cdots + \text{market volume n}} + \text{taxes}$$

- At the same time, the CPP schema should have the ability to encourage customers to shift load in response to the rate design.