MOEEBIUS

Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability

D2.4 Functional and Non-functional requirements of the MOEEBIUS framework and individual components

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Glossary

Acronym	Full name
BDAE	Building Dynamic Assessment Engine
BEPS	Building Energy Performance Simulation
BIM	Building Information Model
BMS	Building Management System
DAE	Dynamic Assessment Engine
DAFM	Demand Aggregation, Flexibility and Management
DER	Distributed Energy Resource
DFMPC	Distributed Fuzzy Model Predictive Control
DoA	Description of Actions
DSM	Demand Side Management
DSS	Decision Support System
ESCO	Energy Service Company
FDD	Fault Detection and Diagnosis
FM	Facility Manager
GUI	Graphical User Interface
HVAC	Heating Ventilation Air Conditioning
IAQ	Indoor Air Quality
IoT	Internet of Things
KPIs	Key Performance Indicators
LCA/ LCC	Life-Cycle Assessment/ Life-Cycle Cost
MOEEBIUS	Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability
PM	Particulate Matter
SOA	Service Oriented Architecture
VOC	Volatile Organic Compounds
VR	Virtual Reality
WSN	Wireless Sensor Network

1 Executive summary

The goal of this document is to provide the final list of system components that consist of the overall MOEEBIUS framework and further map the already defined end users and business requirements to the main functionalities supported by the components of the system.

More specifically, this task defines the distinct technological components that needs to be included in the MOEEBIUS framework [1] , in order to address the needs of end-users as well as the constraints set by the identified business models (T2.2 [3]) and the energy performance assessment methodology (defined in T2.3 [4]). Task 2.4, as reported in this document, breaks down the list of requirements defined in T2.1 into functional and non-functional requirements of the identified individual components and subsequently guides the work to be performed under T3.1 “MOEEBIUS Architectural Design and Technological/ Functional Specifications - Communication interfaces and protocols definition”.

Therefore, this document screens the landscape towards the definition of the different system components that will further enable the detailed specification analysis and architectural design of the MOEEBIUS framework.

2 Introduction

2.1 Scope of this Deliverable

This deliverable presents the results of the Tasks "T2.4 - Overall Requirements of the MOEEBIUS technological components" describing in details the functional and technical requirements of the components that comprise the MOEEBIUS system architecture.

Initially, the report describes the methodology towards the definition of the detailed modules that compose of the MOEEBIUS system, taking into account the end users and business requirements definition, MOEEBIUS Use Cases as well as the overall MOEEBIUS performance framework, formally specified under the activities performed in Task T2.1 "End-User Characteristics and Requirements" and Task T2.3 "Building and District performance assessment specifications and Key Performance Indicators" and presented in the corresponding Deliverables D2.1[2] & D2.3[4].

Moreover, and taking into account the high level objectives of the project, we further analyze the **static and dynamic views** of the MOEEBIUS framework. More specifically the core components that consist of the MOEEBIUS framework are identified (static view) and then the interactions among them are specified (dynamic view). The dynamic analysis remains at a high level as the technical definition of the main workflows associated to MOEEBIUS use cases is provided in T3.1 along with the definition of the MOEEBIUS reference architecture.

In this report, as special focus is given to the elements (functional modules and components of the system) that consist of the MOEEBIUS framework, the definition of **functional and non-functional requirements** is provided. The functional requirements are related to the main system functionalities as requested by the end users of the systems and the different business models examined in the project (T2.1). On the other hand, the non-functional requirements are mainly related to the specificities about the technical implementation of the respective components.

Finally, it should be noticed that although this report "Functional and Non-functional requirements of the MOEEBIUS framework and individual components" is delivered according to the DoA in Month 10, the architectural elements and their detailed requirements fulfilment will remain an open issue till all components and subsystems are built and all modules have been integrated to the MOEEBIUS system. Thus, this document can be considered as a living document acting as the guideline for the development of the respective component that set the MOEEBIUS platform.

2.2 Deliverable Structure

The deliverable is structured and organized in the following chapters:

- Chapter 2 is the introduction of this report, outlining the main objectives and the purpose of the document.
- Chapter 3 presents the methodology for extracting the list of functional and technical requirements of the MOEEBIUS System along with the definition of main system components. Therefore, it presents the basic principles towards the definition of the elements that compose the MOEEBIUS system.
- Chapter 4 provides the details of the various components that comprise the MOEEBIUS Framework. For each module the role and objectives are outlined, along with its main functionalities and interconnections with other system entities.
- Chapter 5 is provided complementary to the static representation of system components in chapter 4 and provides the dynamic view of the proposed framework. More specifically, by taking into account the business models analysis as presented in D2.2, we proceed with a business chain analysis where the different components are mapped to the main business functions of the project, defining in that way the high level work flows of MOEEBIUS platform.
- Chapter 6 and 7 follow the definition of the system components and provide the functional and non-functional requirements of the MOEEBIUS project respectively. This section is very important for the project as it will enable the definition of MOEEBIUS Reference Architecture and will further set the guidelines for the development of the different components of the platform.
- Finally, in Chapter 8 conclusions are drawn for this report, focusing on the interconnection of T2.4 with the upcoming work in the project.

3 Methodological Framework

This section describes the methodology for the definition of the MOEEBIUS architectural elements and further the extraction of functional and non-functional requirements. To end up with the detailed definition of the architectural elements of MOEEBIUS system, the following phases have been followed in an iterative manner:

Phase 1: MOEEBIUS System Definition

As illustrated in Figure 1, the first step in the definition of the MOEEBIUS elements was to review the business scenarios and use cases that the MOEEBIUS framework should address. It should be noticed that the scenarios and use cases defined do not only describe the situations and dynamic states that the system and its functional components will maintain, but they also give a in depth insight of the functional concept of the MOEEBIUS system.

In addition, towards the definition of the system components we take also into account the review of business requirements as defined through MOEEBIUS business models analysis along with the definition of the performance models to be considered in the project. This integrated analysis leads to the definition of the static elements of MOEEBIUS platform. The analysis flow considered for the extraction of system components is depicted in the following figure (Figure 1).

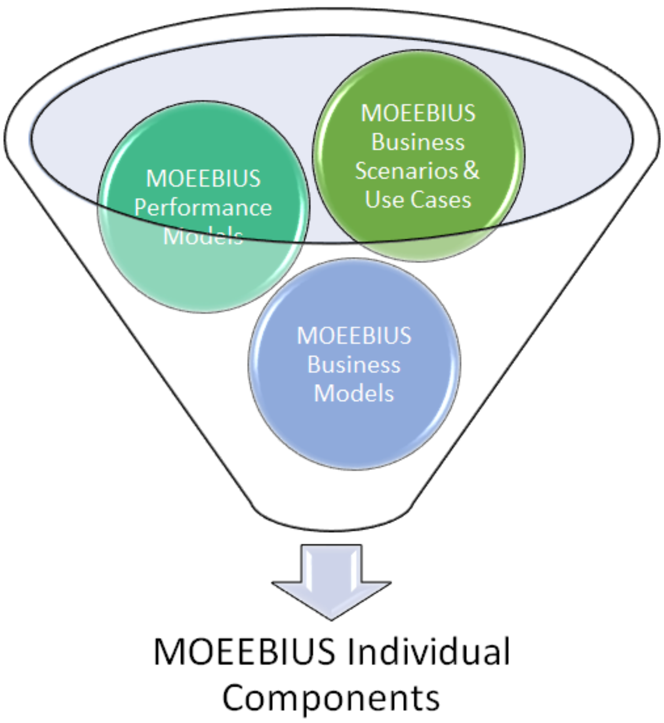

Figure 1 MOEEBIUS System Definition Methodology

Phase 2: MOEEBIUS Dynamic View

The second phase of the analysis is focusing on the dynamic view of system components. Following the definition of static MOEEBIUS elements, the business view of MOEEBIUS platform is provided, highlighting the interactions among system components. We have to point out that the workflow analysis provided in this document remains at a business level, while the detailed analysis of interfaces to cover MOEEBIUS use case requirements is part of the definition of MOEEBIUS reference architecture in WP3.

Phase 3: Detailed Module Functional and Technical requirements

During the final phase of the MOEEBIUS Design Framework, the extraction of functional and non-functional requirements is considered. In this final step of the definition process, a detailed analysis of each functional element of the MOEEBIUS system is performed through requirements analysis further complementing the static and dynamic behaviour of the system.

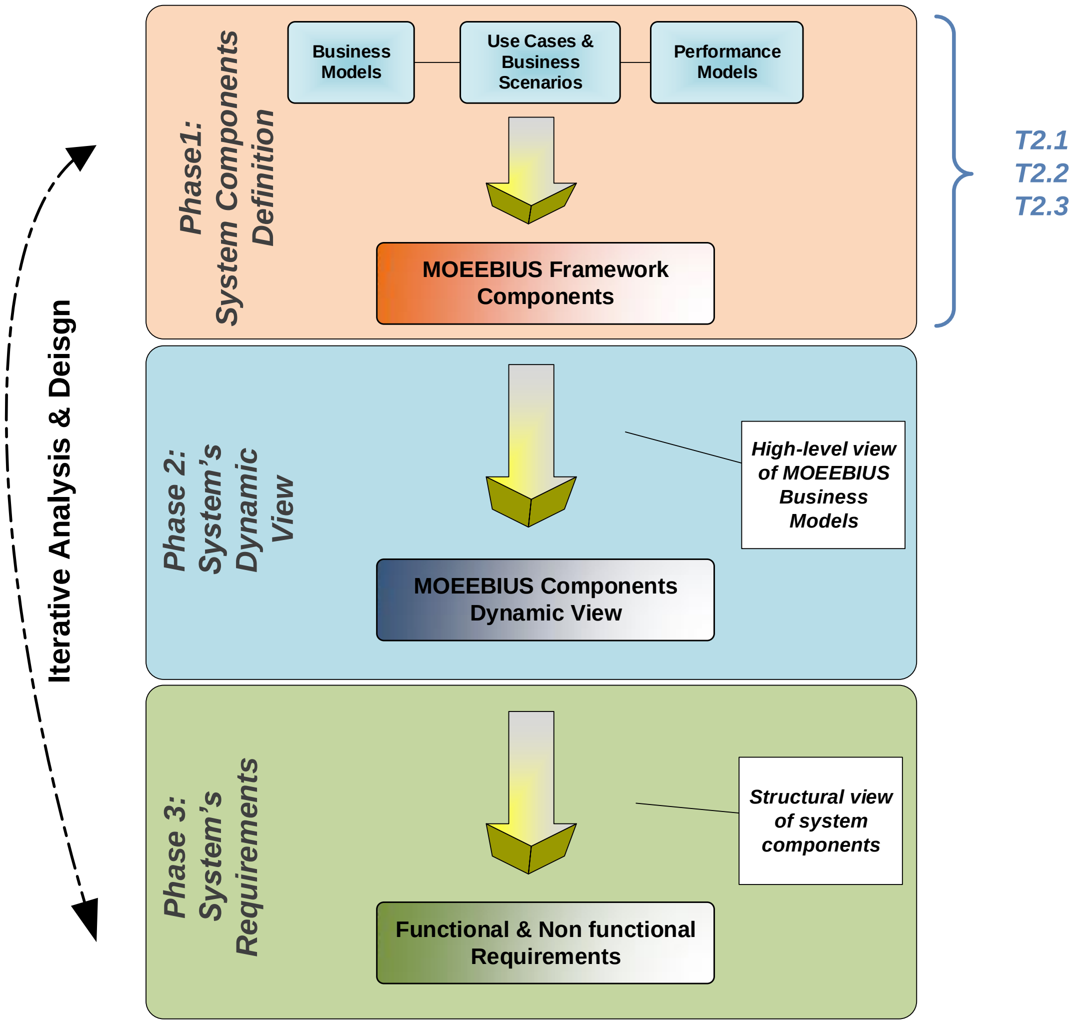

Figure 2 MOEEBIUS Requirements extraction methodology

The goal of this last part of the work is to map end users and business requirements (defined in T2.1) to system requirements and further extend this list towards the definition of the final suite of functional and non-functional MOEEBIUS requirements.

Figure 2 presents the MOEEBIUS methodological framework for the extraction of functional and non-functional system requirements, starting from the initial identification of MOEEBIUS functional elements. This methodology is further adopted on the presentation of work in the following chapters.

4 MOEEBIUS Framework System Components

4.1 Introduction

In previous chapter we illustrated the methodological framework towards the definition of the main system components that consist of the MOEEBIUS framework. In this chapter, the core elements are identified and further analysed. The analysis is provided for each component separately, highlighting though the role of each component as part of the MOEEBIUS conceptual architecture.

Regarding the MOEEBIUS elements presentation, a narrative description of main functionalities is provided along with the definition of inputs/outputs as high-level interfaces. The analysis remains at a business level, while details about the technical implementation and the way these components interact each other are defined along with the specifications analysis of MOEEBIUS system architecture. Therefore, this section provides the initial identification of MOEEBIUS system components towards the definition of functional and non-functional requirements of the platform. We are following a bottom up approach on the presentation of the different functional elements, starting from the building zone elements and ending with the district level management tools.

4.2 MOEEBIUS NOD

The goal of the project is the integration of different -commercially available- hardware equipment (BMS tools, sensors, actuators and metering devices) to further enable the implementation of the MOEEBIUS use cases. In addition, and as part of the activities in the MOEEBIUS project, we are going to develop a prototype IoT hardware device acting both as sensor and control unit. Therefore, and apart from the available commercial solutions, we are going to develop a prototype combo IoT device and integrate it within the context of the MOEEBIUS project.

The MOEEBIUS NOD will represent the system front-end towards appropriately understanding occupant behaviour in the built environment. Its purpose is dual: i) to **gather information about perceived ambient conditions** (with the integration of a variety of sensors such as luminance, temperature, humidity, etc.) at individual spaces and ii) to **collect user responses to these conditions** (through e.g. gesture-enabled control actions over lighting devices and HVAC loads). Therefore, the role of MOEEBIUS NOD component is to act as **combo device** tracking real time context conditions and further enabling the implementation of control actions (as a wireless switch button that send users' control commands to the different device types via MOEEBIUS platform). In such a way, MOEEBIUS provides to the end users /occupants' low-power, low-cost and usable/ intuitive means to express their preferences without the hindrance of going to a wall-mounted switch.

MOEEBIUS NOD will wirelessly interface with Data Acquisition and Management Layer at Building Level, through an associated gateway, reporting sensing and users' settings data to the application layer, similar to other commercial sensors/actuators installed within the context of the project. The gateway is considered as a logical module of MOEEBIUS NOD, either physically placed in the MOEEBIUS NOD device or acting as an external entity for integrating different MOEEBIUS NODs.

MOEEBIUS NOD is the prototype hardware component of the MOEEBIUS project, acting also as a standalone device. The rest of the MOEEBIUS components are software components presented below.

4.3 Data Acquisition and Management Layer/ Building level Middleware

The role of this component is to act as the interface of MOEEBIUS platform with the physical environment. There are two main modules that consist of this software component, presented below.

A Building Level Data Acquisition and Management Layer proxy is hosted in the building environment and provides a bi-directional communication interface to individual sensors and DERs (local loads and generation), acting that way as the gateway with the physical devices. Therefore, the role of this component is to ensure the integration with heterogeneous device types, namely: commercial WSN solutions, BMS tools already installed in premises for the management of the different loads and the integration of MOEEBIUS NOD as the prototype hardware device of the MOEEBIUS platform.

Furthermore, the Data Acquisition and Management Layer component acts as the building level middleware which enables semantic integration and orchestration of the different building elements. The building middleware establishes a seamless, transparent and homogeneous interface to all sensor/actuator/metering components (appliances, smart meters, various sensors etc.). In addition, it provides on top appropriately defined semantic devices, i.e. clusters of semantically components incorporating the necessary semantics (ontology and rules) for efficient grouping and coordinated management of DER clusters.

Therefore the role of this component is twofold: 1) to act as the building gateway that ensures physical interconnection with the different WSN/BMS/NOD solutions and 2) to provide orchestration and data management services that further enable the seamless integration of physical devices in MOEEBIUS platform. On top of this layer, semantically enhanced interfaces are available to the rest of MOEEBIUS applications, reporting information in a seamless and transparent way (following the definition of the MOEEBIUS Common information model).

4.4 Building Energy Performance Simulation Tool

Towards the establishment of the MOEEBIUS building management framework, the incorporation of a Building Energy Performance Simulation engine is considered. The main objective of the component is to provide a Building Energy Performance Simulation platform so as to be able to accommodate and perform simulations on the basis of enhanced, improved and more accurate MOEEBIUS models, profile and short-term weather forecasts, hence, allowing for more accurate predictions of building energy performance. This is the main innovation of the MOEEBIUS Energy Performance Simulation component as it incorporates:

- Building Information models addressing that way the static parameters (energy and contextual) related to building operation
- Dynamic DER models, periodically updated by taking into account real time measurements from the devices at building premises
- Dynamically updated occupancy behaviour profiles as extracted from the Occupancy Behavioural profiling framework (described below)
- Weather forecasting models, towards the extraction of accurate weather forecasts by taking into account the actual environmental conditions
- Enhanced Energy Performance models, as extracted in D2.3 that incorporate not only energy but also comfort and health aspects under a common performance framework.

Moreover, the component will provide the necessary interfaces that will allow for the seamless integration and communication of the simulation engine with the Dynamic Assessment Engine (at building level) and the DER Forecasting, Aggregation and Flexibility Analysis Module (at district level). The MOEEBIUS Energy Performance Simulation component will periodically (or upon request) report to the aforementioned components the results from the simulation process for further exploitation.

In terms of assessment, the software component will integrate the local energy performance models defined at the very early stage of the project and will provide predictions upon specific indicators, enhancing that way the analytical capabilities offered to the end-users of MOEEBIUS through a BEPS specific Graphical User Interface (BEPS GUI).

4.5 MOEEBIUS Occupants' Profiling Engine

The role of this software component is to deliver the MOEEBIUS Occupants' Profiling Mechanism for identifying occupants' preferences in terms of HVAC and Lighting loads operation, considering, also, the health constraints imposed during building operation and thus ensuring the minimum of end users disturbance. This is actually one of the main innovations of the MOEEBIUS concept, as it incorporates end users preferences and needs in the decisions support process for optimized building management.

The MOEEBIUS Occupants' Profiling Engine will perform a user-specific continuous & correlated monitoring of ambient /occupancy conditions and occupants' actions in order to extract:

1. Real time occupancy data along with accurate occupancy profiling models to be further incorporated in BEPS tool
2. Context-aware user preferences and behavioural profiles by understanding comfort (dis)satisfaction boundaries, while considering also health aspects in the profiling extraction process.

Input data from Data Acquisition and Management Layer will be retrieved for the extraction of the associated occupants' behaviour profiles: occupancy presence data, environmental conditions, health related data, users' interaction with physical devices.

The results from the Occupancy Profiling Mechanism will further facilitate the delivery of Context-Aware Flexibility Profiles (see next), reflecting real-time demand flexibility as a function of multiple parameters, such as time, device operational characteristics, environmental context/conditions, energy costs, occupant comfort preferences and health/ hygienic constraints.

4.6 MOEEBIUS Demand Flexibility Engine

Following the extraction of occupants' behaviour profiles, the role of this component is to combine the extracted occupants' profiling data with the device characteristics towards the extraction of accurate demand flexibility models.

The objective of this component is to deliver Context-Aware Flexibility Profiles, reflecting real-time demand flexibility as a function of multiple parameters, such as time, device operational characteristics, environmental context/conditions, energy costs, occupant comfort preferences and health/ hygienic constraints. Therefore, this software component will take into account:

1) Real time semantically enhanced DER operational data (as retrieved from Data Acquisition and Management Layer) and the associated DER models
2) Real time building contextual data considering that way environmental context/conditions and health/ hygienic constraints
3) Real time estimation of occupants' preferences (as retrieved from Occupancy Profiling Mechanism)

for the extraction of dynamic Demand Flexibility profiles. The outcomes from this component (demand flexibility profiles associated with DER operational characteristics) will be further exploited by the Building Level Dynamic Assessment Engine towards the selection of the optimized building level control strategies.

In lack of low-level consumption information (as the sensor and metering devices will be installed in a subset of pilot premises), high-level demand flexibility profiles will be defined, reflecting temporal demand elasticity as a function of multiple contextual (weather conditions) and market (dynamic pricing, e.g. peak pricing, tiered pricing) variables.

4.7 MOEEBIUS Occupants User Interface

Towards the extraction of accurate behaviour profiles, the occupancy profiling mechanism engine will be complemented by a building occupants' specific Graphical User Interface. Through the GUI, the occupants will periodically set their preferences about building conditions and further will be able to get insights about their operational patterns. As mentioned above, the goal of the MOEEBIUS project is to minimize end users disturbance and towards this direction, the users will not continuously define their behavioural preferences, rather these will be extracted by taking into account the user settings.

In addition, and as an extra functionality of building occupants' GUI, we mention the establishment of a framework for triggering personalized messages/ events associated with current building conditions. In order to ensure the active participation of building occupants in MOEEBIUS project activities, we define a behavioural framework with personalized messages for energy efficiency activities to be triggered, aiming that way to fulfil the high level objectives of the project.

To sum up, the role of this user interface, available through the mobile devices of building occupants, is twofold:

1) To set the environment that facilitates the extraction of accurate occupancy and behavioural profiles. The users periodically set their preferences and non-preferences about the contextual conditions of the buildings that are further considered for the extraction of the behavioural profiles
2) To set a graphical user interface, where real time building contextual conditions along with personalized triggering messages be visualized.

The MOEEBIUS Occupants User Interface software component is tightly connected with the occupancy profiling mechanism, though interfaces with the Data Acquisition and Management Layer (for retrieving information about building conditions) and the Building level Dynamic Assessment Engine (for the visualization of personalized behavioural triggering messages) should be defined.

4.8 Building level Dynamic Assessment Engine

Following the definition of the BEPS simulation component in previous section, the definition of the real time building management and automation component is provided towards reducing the gap between actual consumption and predictions. The role of this component is to stand at the core of the MOEEBIUS building management framework and to implement the automation strategies by taking

into account a) real time building conditions, b) building simulation engine results and c) high level control settings as defined by the business stakeholders. The Building level Dynamic Assessment Engine serve two main functions: (i) Fault Detection and Diagnosis (FDD) and (ii) Distributed Fuzzy Model Predictive Control (DFMPC).

Simulation outputs (from MOEEBIUS BEMS) and real-time measurements (from MOEEBIUS Wireless Sensor Network and external sources (weather data)) will be fed to the Dynamic Assessment Engine and comparatively assessed for the identification of performance deviations and their root causes. Through **fault detection** and **diagnosis** (identification of deviation of some metrics through real measurement vs. BEPS anaysis), the dynamic assessment engine will be able to recognize whether the building is beginning to operate sub-optimally; and proactively identify specific performance trends at different spatio-temporal granularity (e.g. abnormal HVAC consumption increase in a specific room) that could progressively lead to significant performance deviations. Subsequently, it will be able to drill-in and analyze parameters affecting the deviating metrics (e.g. ambient/ behavioural trends) to define the root cause of the evolving deviation.

The definition of the root cause will trigger the activation of an innovative **Distributed Fuzzy Model Predictive Control** (DFMPC) engine. The engine will allow for short-term prediction of the building performance outcome (every few minutes) under alternative automated control strategies that aim at mitigating the identified deviation. This will be achieved by adapting the operation (self-adaptation) of the building to performance targets, while preserving occupants' comfort and health at acceptable levels.

To sum up, within the dynamic assessment engine, data referring to BEPS outputs (forecasted demand and predicted energy performance) and real data (occupancy, ambient conditions, weather and consumption) are taken into a model enabling accurate deviations' identification, mobilizing the selection of optimized **predictive maintenance** and **retrofitting actions** and initiating on-the-fly, light-weight, few-minutes-long simulations of the dynamic aspects of building operation and evaluation of alternative **automated control scenarios** that will enable further reduction of the performance gap (in real-time/seconds level). DAE will not optimize in the sense of minimizing energy consumption, but in suggesting control commands and control strategies. The semantically enhanced input data required for the simulation and evaluation process will be retrieved from the Data Acquisition and Management Layer, Building Energy Performance Simulation Tool, MOEEBIUS Occupants' Profiling Engine and MOEEBIUS Demand Flexibility Engine. The output of this assessment process will be fed to the MOEEBIUS DSS giving the opportunity to the ESCO to select and activate the optimized control strategies.

4.9 Predictive Maintenance Advisor Tool

Apart from real time monitoring and control at building level, the definition of a predictive maintenance framework is one of the objectives of MOEEBIUS platform. Towards this direction, the role of this component is to provide the algorithmic framework that will enable systematic monitoring of equipment, materials and HVAC system performance, detecting and diagnosing various mechanical faults or discrepancies, detecting anomalous behaviour and defective equipment/ materials, identifying Indoor Air Quality (IAQ) violations and recommending optimized maintenance actions, which will be based on the prediction of future equipment performance.

The applicability of the predictive and sanitary maintenance tool will primarily be on HVAC equipment (such as boilers, chillers, air handling units, fan-coils, fans, pumps, heat exchangers, dampers, valves, while progressively incorporating other types of devices, e.g. lighting), and will provide information about all detected faults (e.g. valve stuck) and deteriorated performance (e.g. boiler running at the efficiency 5% lower than expected due to likely fouling, HVAC doesn't address IAQ requirements due to low air intake capabilities or needs for filters change). The workflow process that defines the main functionality of this component/tool is provided:

- Monitoring of time series of important process parameters (temperatures, operation failures, flow rates, IAQ parameters), control signals (from the automation system) and electricity consumption
- Systematic comparison of the actual performance with the performance predicted by a model
- Processing of all detected deviations and other symptoms using a rule-based diagnostic engine
- Compiling a list of performance issues and faults, each being accompanied with an indication of fault severity and potential financial impact
- Generating a list of recommended actions/plans to prioritize work of servicemen and technicians when maintaining the building systems

The aforementioned analysis defines the back-end layer of the Predictive Maintenance component. Complementary to this, a Virtual Reality environment for Predictive Maintenance will be developed enabling the fusion of BIM information, equipment and components life-cycle data, discrepancies and anomalous behaviour detection along with sensors data to offer a highly intuitive interface for maintenance managers.

Overall the role of this component is to set the framework for Predictive Maintenance functionality, covering both the algorithmic and the visualization layer of this business application.

4.10 Retrofitting advisor and Investment Evaluation Tool

In addition to real time monitoring and predictive maintenance management tools, a retrofitting advisory application is available for the business stakeholders (namely Retrofitting Advisors).The role of this system component is to provide the functionality towards supporting retrofitting decision-making.

On the one hand this component will enable the decision maker to explore a portfolio of potential building retrofitting projects taking into account national technical codes, regulatory issues, particularities of the buildings and district and financial restrictions. The last point is a main innovation of the MOEEBIUS retrofitting component as the overall process will also evaluate the cost of investment for the selection of the best fitted building retrofitting alternatives.

Having defined the list of potential retrofitting projects, the DSS engine of the component will further select the optimized retrofitting strategy, by solving a multi-objective optimization problem, considering multiple conflicting parameters. Finally, a retrofitting tool UI for the visualization of the retrofitting processes decision-making will be available to the business stakeholders.

The Retrofitting advisor and Investment Evaluation Tool will exploit the results from **Building level Dynamic Assessment Engine**: fault detection and diagnosis component mobilizing the selection of optimized retrofitting actions and **MOEEBIUS Building Energy Performance Simulation** engine for the evaluation of different alternatives about of building performance. On the other hand, the outcomes from the Retrofitting advisor and Investment Evaluation Tool (selection of the optimized retrofitting strategy) will be available to the Facility Manager & ESCO Management DSS Tool for further exploitation.

4.11 Facility Manager & ESCO Management Tool

The role of this component is to provide the core engine for real time building energy performance optimisation and control strategies implementation. This is the decision support tool of the MOEEBIUS platform and provides in real-time automation taking into account the list of high level control scenarios and plans defined by Building level Dynamic Assessment Engine, the high level operational plans identified by the different business applications at building (Predictive Maintenance Advisor & Retrofitting advisor and Investment Evaluation) and district (District level Dynamic Assessment Engine) level and the high level control settings from the business stakeholders: Facility managers and ESCOs. More specifically, outcomes from the dynamic assessment engines will be fed into the DSS, which, on the basis of **multi-objective optimization algorithms** (and taking into account business and contextual parameters) will enable accurate alignment between predicted and actual building performance by **activating the best fitting automation scenario** upon the building systems and components. The implementation of control strategies to the physical devices will be delivered

through the Data Acquisition and Management Layer which provides the interfaces for interaction with the different types of loads/actuators.

To complement building DSS functionality, a GUI will be available for the facility manager to monitor in real time: building contextual conditions, building management set points and the list of potential plans as defined by the different building assessment engines (mainly maintenance and retrofitting plans as the outcomes from the different software components presented above).

Following the definition of system components that consist of the MOEEBIUS Building Level operational framework, we further proceed with the definition and description of the system components that consist of the district layer of MOEEBIUS framework.

4.12 Data Acquisition and Management Layer/ District Level Middleware

Moving to the district level, the main responsibility of Data Acquisition and Management Layer/ District Level Middleware is to act as the building gateway to ensure communication with the Aggregator Hub. As with Building Level Data Acquisition and Management component, there are two main modules that consist of this software component. A proxy is hosted in the building environment and provides a bi-directional communication interface with the aggregator, acting that way as the gateway of the building. The gateway contains the knowledge to send and receive messages at an abstraction level higher than the level of information exchanged between the internal building system elements. Therefore, a certain level of aggregation is performed at the gateway, addressing that way privacy requirements by the end occupants in building premises (only aggregated information is available on DSM Aggregator Side).

Furthermore, the District level Data Acquisition and Management component acts as the district level middleware which enables semantic integration and orchestration of the different building types integrated at district level. The district level middleware establishes a transparent and homogeneous interface to building information, enabling the different business applications at aggregator side to access this information in a seamless way.

4.13 District level Dynamic Assessment Engine

The MOEEBIUS Aggregator layer contains a Dynamic Assessment Engine responsible for the selection and implementation of real time control strategies in aggregated level. The scope of the control and optimization component is to orchestrate, in real time, the different groups of buildings that are part of aggregator’s portfolio by taking into account real time status of each building (information available from District level Data Acquisition and Management Layer) and by exploiting the simulation analysis from the Demand Aggregation, Flexibility and Management Engine, further triggering the appropriate high level control strategies to the buildings of the portfolio.

More specifically, the component will scale-up the combined FDD-DFMPC system as presented for Building Level Dynamic Assessment Engine to enable simulation and assessment of alternative demand response scenarios and strategies for effective peak-load management based on real-life signals received by the grid operators. Such strategies will enable continuous optimization of the district's aggregated and clustered (consumption/demand curves (either through load shedding, or through load shifting), towards optimally accommodating demand response events (through the formulation of dynamic Virtual Power Plants). It will also be possible to dynamically adapt district demand to available generation. The distributed nature of the Dynamic Assessment Engine (as defined above for building level) permits its scalable deployment at district level and the easy accommodation/ communication/ optimization of additional systems applied district-wide (e.g., District heating systems). The aggregation of building loads/consumptions and the district level additional elements (DER, District, heating…) will be based on an explicit model developed in Modelica.

The outcomes from the district energy management and performance assessment engine (alternative demand response scenarios and strategies) will be further triggered to the MOEEBIUS DSS tool of the buildings selected for further analysis and activation of control strategies at building level.

4.14 Demand Aggregation, Flexibility and Management Engine

The role of this component is to support energy optimization and peak load management strategies optimization through the effective utilization of aggregated DER flexibility. Multi-parameter criteria analysis algorithms and tools of DER flexibility should 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 will 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 (under any condition and with limited required incentives)). Loads will be classified considering their response capacity under comfort-based and health constraints, response capability and flexibility or price-sensitivity and flexibility.

In addition, the module should be integrated with an external MOEEBIUS component (Dynamic Pricing Simulation Engine) towards enabling High-level Flexibility profiling. Therefore, the role of the component is constantly collect and analyse energy price data, following market dynamic fluctuations, and further identify how user behaviour is transformed on the basis of variable Electrical Peak Demand, Electrical Energy (Usage), Reactive Demand Tariffs, or through the offering of Incentives and Rebates. This analysis allows for the creation of high-level demand flexibility profiles illustrating the response capacity of demand in price-based control strategies for peak-load management optimization.

Summarizing, the role of this component is to simulate the operation of the portfolio under different parameters and further enable the Aggregators and ESCOs towards the selection of the best fitted high level strategies. Then these high level strategies are further disseminated to the District level Dynamic Assessment Engine towards the implementation of Building level control strategies.

The aforementioned analysis highlighted the different functional components (13 in total) that consist of the MOEEBIUS platform. A short description was provided for each component, focusing on the definition of the core functionalities along with the role of each component in the MOEEBIUS framework. We have to point out that we are not defining as MOEEBIUS components, commercial WSN solutions/ BMS and external services (e.g. price generators) that will be further incorporated in the MOEEBIUS developments. Taking into account this component role identification, the next section provides a business workflow analysis among the MOEEBIUS system components.

5 MOEEBIUS Business Chain Analysis

We presented above the different components that consist of the MOEEBIUS framework. Following this static representation of the system, a dynamic analysis of the MOEEBIUS is provided. This analysis remains at a high level in order to show the preliminary interfaces among the system elements, setting also the first dynamic view of the MOEEBIUS system.

Figure 3 shows the template for the business flow analysis including the different MOEEBIUS components (considering also Commercial WSN solutions incorporated in MOEEBIUS framework) identified.

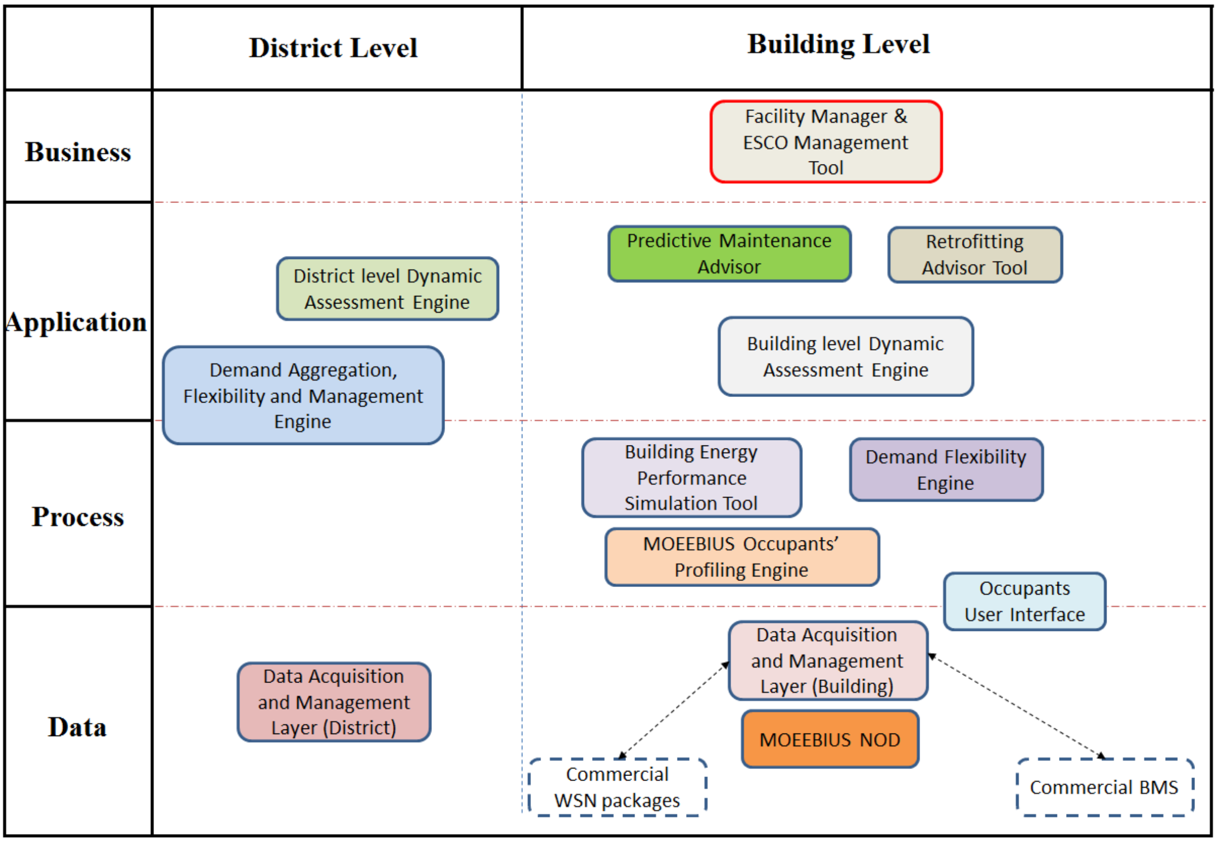

Figure 3 MOEEBIUS Functional Components taxonomy

As presented in Chapter 4, we have identified thirteen (13) system core components: MOEEBIUS NOD, Data Acquisition and Management Layer (Building), Building Energy Performance Simulation Tool, MOEEBIUS Occupants' Profiling Engine, MOEEBIUS Demand Flexibility Engine, MOEEBIUS Occupants User Interface, Building level Dynamic Assessment Engine, Facility Manager & ESCO Management Tool, Predictive Maintenance Advisor Tool, Retrofitting advisor and Investment Evaluation Tool, Data Acquisition and Management Layer (District), District level Dynamic Assessment Engine, Demand Aggregation-Flexibility and

Management Engine which are further taxonomized per functional and application layer.

By taking into account the business flow template presented above, we proceed with the dynamic flows analysis of the system components per each business scenario defined in D2.1. Through this process, the main interfaces among the system components are identified taking into account the business perspective of the project.

5.1 Core MOEEBIUS Scenario

Prior to each business scenario specific analysis, the description of the **core MOEEBIUS scenario** is provided. This is the common subset of MOEEBIUS elements and systems, repeated at each business case and setting the common denominator of MOEEBIUS platform. Thus, and in order to avoid any repetition, we initially describe the information flow for this core MOEEBIUS scenario:

1. MOEEBIUS NOD, the hardware that will be developed to monitor and report building contextual data (environmental/health conditions and user control actions on devices) to Data Acquisition and Management Layer (Building) which acts as the building level middleware. This middleware layer also interacts with other commercial hardware equipment (BMS tools, sensors/actuators…) installed in premises.
2. Data Acquisition and Management Layer (Building) reporting real time building data to:
    a. Building Energy Performance Simulation Tool to continuously update the Simulation Engine models/profiles
    b. MOEEBIUS Occupants' Profiling Engine towards the extraction of accurate occupants profiles (user preferences)
    c. MOEEBIUS Demand Flexibility Engine towards the extraction of Demand Flexibility profiles
    d. Building level Dynamic Assessment Engine towards the selection of optimized control strategies associated to real time building management
3. MOEEBIUS Occupants' Profiling Engine provides occupancy profiling data to Demand Flexibility Engine towards the extraction of Demand Flexibility profiles.
4. In addition, MOEEBIUS Occupants' Profiling Engine periodically updates Occupants Preference Models in Building Energy Performance Simulation
5. MOEEBIUS Demand Flexibility models are periodically updated in Building Energy Performance Simulation (in the same way as with occupancy profiling models in previous step)
6. Towards the extraction of accurate occupancy profiles, interaction with MOEEBIUS occupants User Interface is considered. More specifically:
    a. Building Occupants, through their GUIs, can set their preferences on the different contextual parameters examined in the building

b. Information about the extracted Occupancy Profiling results is further presented through building occupants UIs.

7. MOEEBIUS occupants User Interface further retrieves contextual information from Data Acquisition and Management Layer at building level for visualization
8. Demand Flexibility Engine reports Demand Flexibility data to Building level Dynamic Assessment Engine to facilitate the selection of optimized control strategies about building operation
9. Building level Dynamic Assessment Engine interfaces with Building Energy Performance Simulation Engine responsible for the simulation of building energy performance. More specifically:
    a. Building level Dynamic Assessment Engine provides the settings for the simulation process to BEPS.
    b. The results from BEPS process, along with real time building and flexibility data are analyzed by Building level Dynamic Assessment Engine towards the selection of optimized control strategies.
10. Data Acquisition and Management Layer/Building level middleware interface with MOEEBIUS NOD (along with other actuators) to update the status of devices (following automated control strategies implementation).

The information flow among the system components for the core MOEEBIUS scenario is depicted in the next Figure (Figure 4):

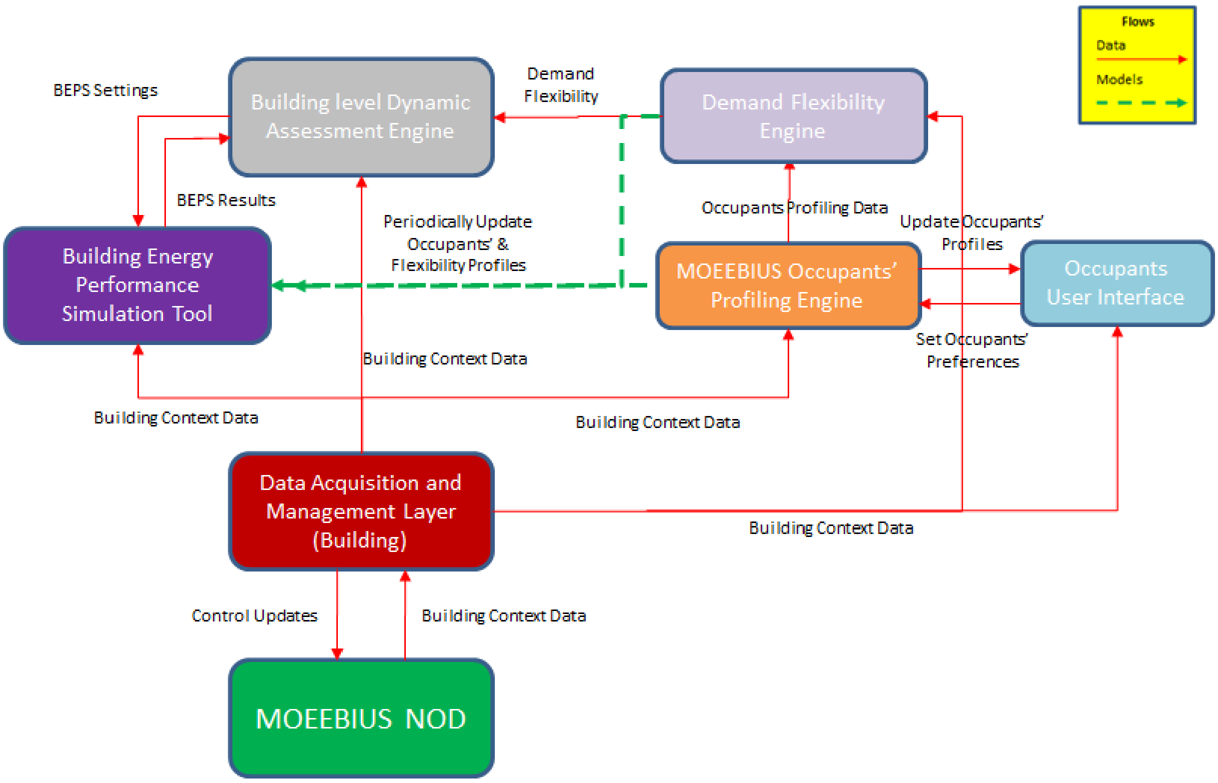

Figure 4 Core MOEEBIUS Framework

By taking into account the baseline definition of core MOEEBIUS scenario, we proceed with the workflow analysis for each business scenario identified in the project.

5.2 Real-time building performance optimization towards the establishment of a sustainable environment

Facility Managers of tertiary buildings have a specific task to deal with their every-day operations of the building: they need to optimise the operation of the building's energy resources (HVAC, Lights, Office equipment, including generation when referring to prosumers) towards reducing overall energy consumption and minimizing energy waste, while balancing the impact on final occupants' comfort. Therefore, the main objective of this business scenario is to ensure the prompt building operation through the establishment of a building energy management and automation framework. Starting from the definition of core MOEEBIUS scenario, we extend this to address the business scenario specific functionalities.

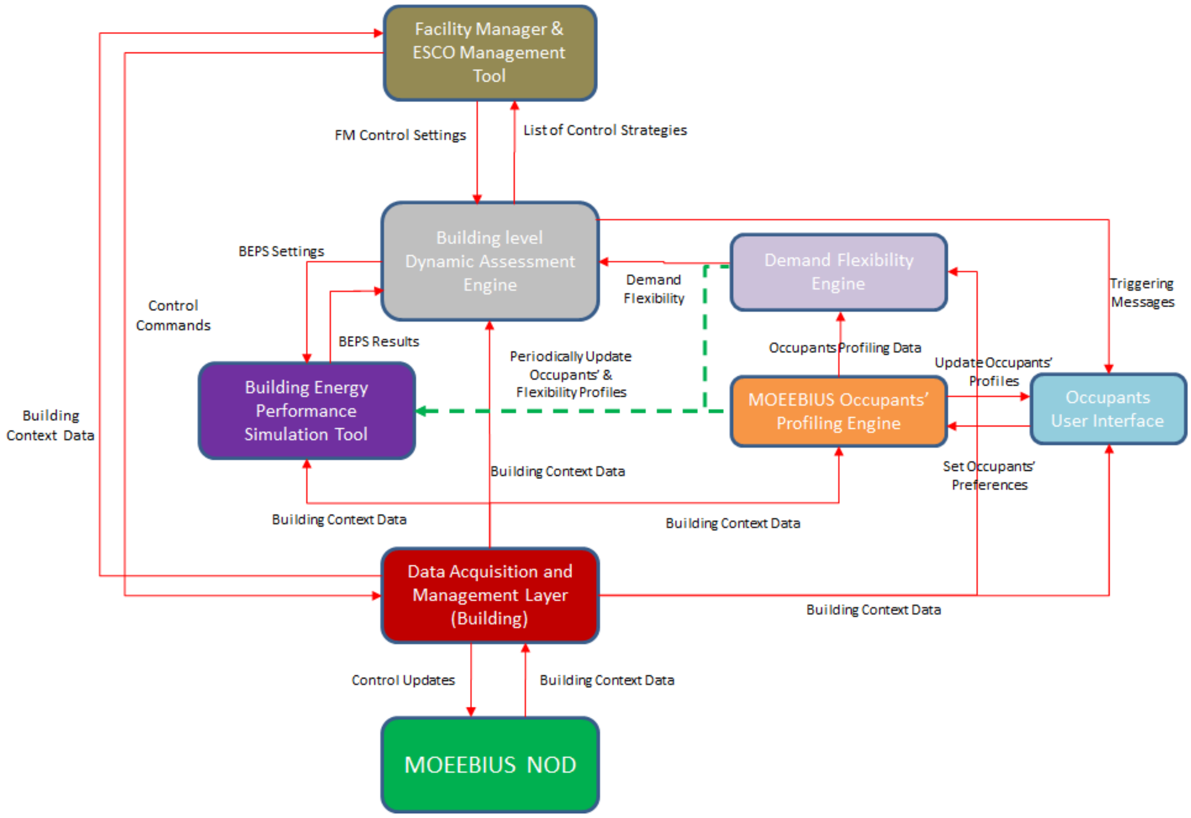

Figure 5 Business Scenario 1 Flow analysis

The business scenario specific information flows among the different system components are presented:

1. The Building level Dynamic Assessment Engine, by selecting through the combined FDD-DFMPC engine the optimized control strategies, provides this information to Facility Manager & ESCO Management Tool, which acts as the

DSS tool of the MOEEBIUS framework. The interfaces among these two system components are defined:
    a. Facility Manager Control Engine set to the Dynamic Assessment Engine the high level parameters for the optimization process and the selection of optimized control alternatives
    b. The list of optimized control strategies are provided from the Dynamic Assessment Engine to the Facility Manager & ESCO Management Tool for further exploitation.
2. In parallel, and when not subject to the MOEEBIUS automated framework, Building level Dynamic Assessment Engine triggers personalized messages to Building occupants UI for visualization. This behavioural triggering framework ensures the active participation of building occupants in MOEEBIUS project activities.
3. In addition, real time building contextual information is reported from Data Acquisition and Management Layer to Facility Manager & ESCO Management Tool for visualization.
4. By selecting the optimized control strategies, the Facility Manager & ESCO Management Tool (through DSS module) triggers the associated (low level) control commands to the physical devices through Data Acquisition and Management Layer/ Middleware layer.

The workflow analysis takes into account the core MOEEBIUS scenario presented above and further extends it to address the specific requirements for real-time building performance optimization.

5.3 Active Participation in Demand Response Schemas through the optimized management of buildings' portfolio

One of the main objective of MOEEBIUS framework is to examine the role of Aggregator as a new stakeholder in energy markets. The aggregator manages customers' portfolio in an optimized way, trading with market stakeholders on behalf of his customers. Therefore, the role of the aggregator is to participate in energy markets offering its **demand flexibility** in a similar way as generating units do. On the other hand, and considering the definition of new business models in the project (as reported in D2.2) the Aggregator offers DSM services directly to his customers (peak load management services, outliers detection etc…). By further exploiting accurate DER and Flexibility models, the Aggregators estimate the amount of flexibility on their portfolio and further aggregate this amount of flexibility towards activating different DSM strategies. The detailed workflow for this case scenario is presented:

1. Building level (aggregated) real time data are available from Data Acquisition and Management Layer (District level Middleware). The role of this component is to act as the Gateway proxy for the building, aggregating building level information and providing this to the aggregator business applications. The aggregation process involves:

   a. Aggregation of building data as retrieved from Data Acquisition and Management Layer (Building).
   b. Aggregation of flexibility data as extracted from Demand Flexibility Engine.
2. Along with real time data, building level (aggregated) simulated data are available from BEPS tool to Aggregator business applications through District level Middleware. The simulation data are further exploited by the different business applications towards the optimized implementation of DSM strategies.
3. The aggregated data are further available from Data Acquisition and Management Layer (District) to:
   a. District level Dynamic Assessment Engine for the selection of optimized District level strategies
   b. Demand Aggregation, Flexibility and Management Engine as the analytics tool for Aggregator
4. In addition to the core data analytics functionality, the Demand Aggregation, Flexibility and Management Engine provides a simulation engine for the evaluation of different potential strategies. The results from this simulation process are further available to District level Dynamic Assessment Engine in order to facilitate the selection of optimized district level DSM control strategies.
5. This component (District level Dynamic Assessment Engine) will trigger the selected DSM level control strategies to the associated building DSS.
6. At the building side, the building DSS (Facility Manager and ESCO Tool) will evaluate the district level control strategies impact (taking also into account real time building contextual and business conditions) and will further transform these high level DSM strategies to low level control commands to the physical devices.

The presentation of this workflow is provided in the next figure (Figure 6):

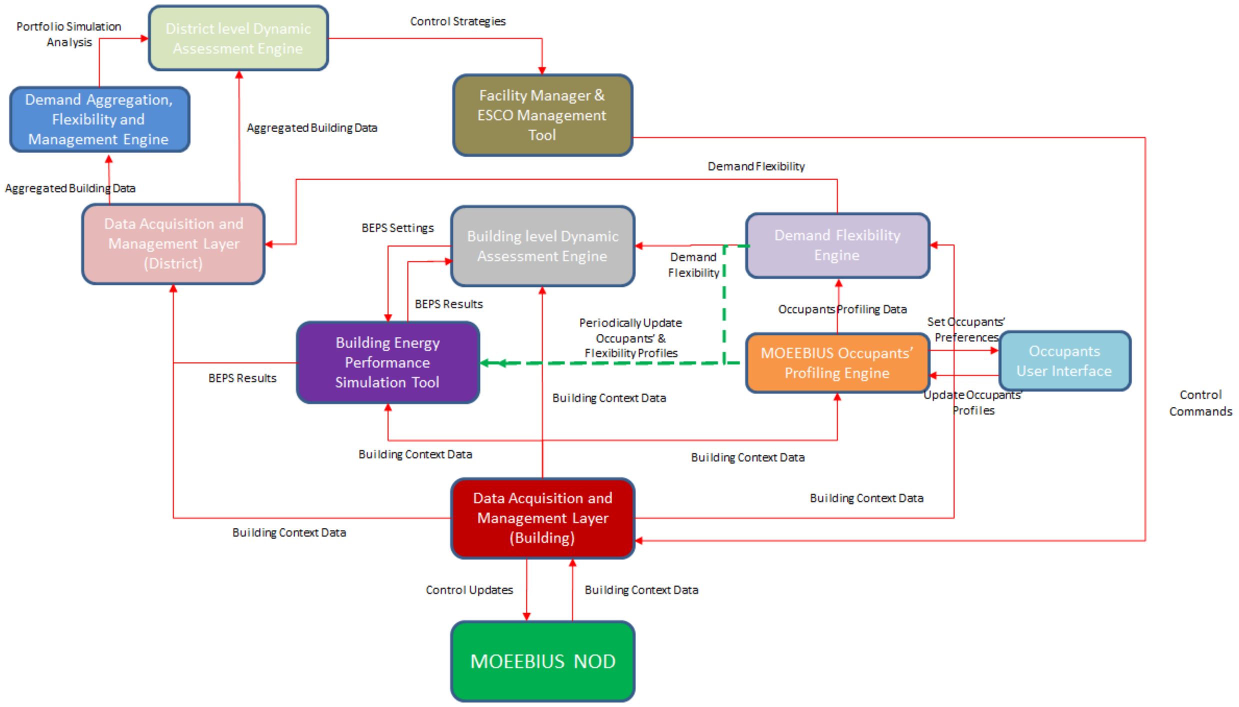

Figure 6 Business Scenario 2 Flow analysis

5.4 Optimized Predictive maintenance diagnostics and decision making tool to ensure high levels of business performance

Apart from building management, predictive maintenance activities will be handled by the MOEEBIUS framework. The goal is to provide capabilities for systematic monitoring of equipment, materials and HVAC system performance, detecting and diagnosing various mechanical faults or discrepancies, detecting anomalous behaviour and defective equipment/ materials, identifying Indoor Air Quality (IAQ) violations and **recommending optimized maintenance actions**, which will be based on the prediction of future equipment performance.

The overall business framework is described.

1. Predictive Maintenance Advisor Tool takes into account real time data towards the extraction of accurate Predictive Maintenance strategies that address also current building conditions.
2. In addition Predictive Maintenance Advisor Tool exploits Building level Dynamic Assessment Engine results (deviations detection) for the selection of Predictive Maintenance strategies. More specifically:
    a. The Predictive Maintenance Advisor set the parameters for the simulated vs. actual analysis of Building level Dynamic Assessment Engine
    b. Deviations from normal building conditions as identified by **Fault Detection and Diagnosis module** of Dynamic Assessment Engine are provided to Predictive Maintenance Advisor for further analysis (further investigation and definition of alternative maintenance actions, respectively, to effectively mitigate the identified deviation)

3. By selecting the optimized Predictive Maintenance strategies, the Predictive Maintenance Advisor Tool reports this information to Building DSS tool for further evaluation and visualization of the associated maintenance plans.
4. The low level control commands from the Facility Manager DSS tool to building devices are triggered through Data Acquisition and Management Layer (Building).

The business flow highlights the steps towards the delivery of predictive maintenance services. Figure 7 depicts the overall business flow for predictive maintenance business application.

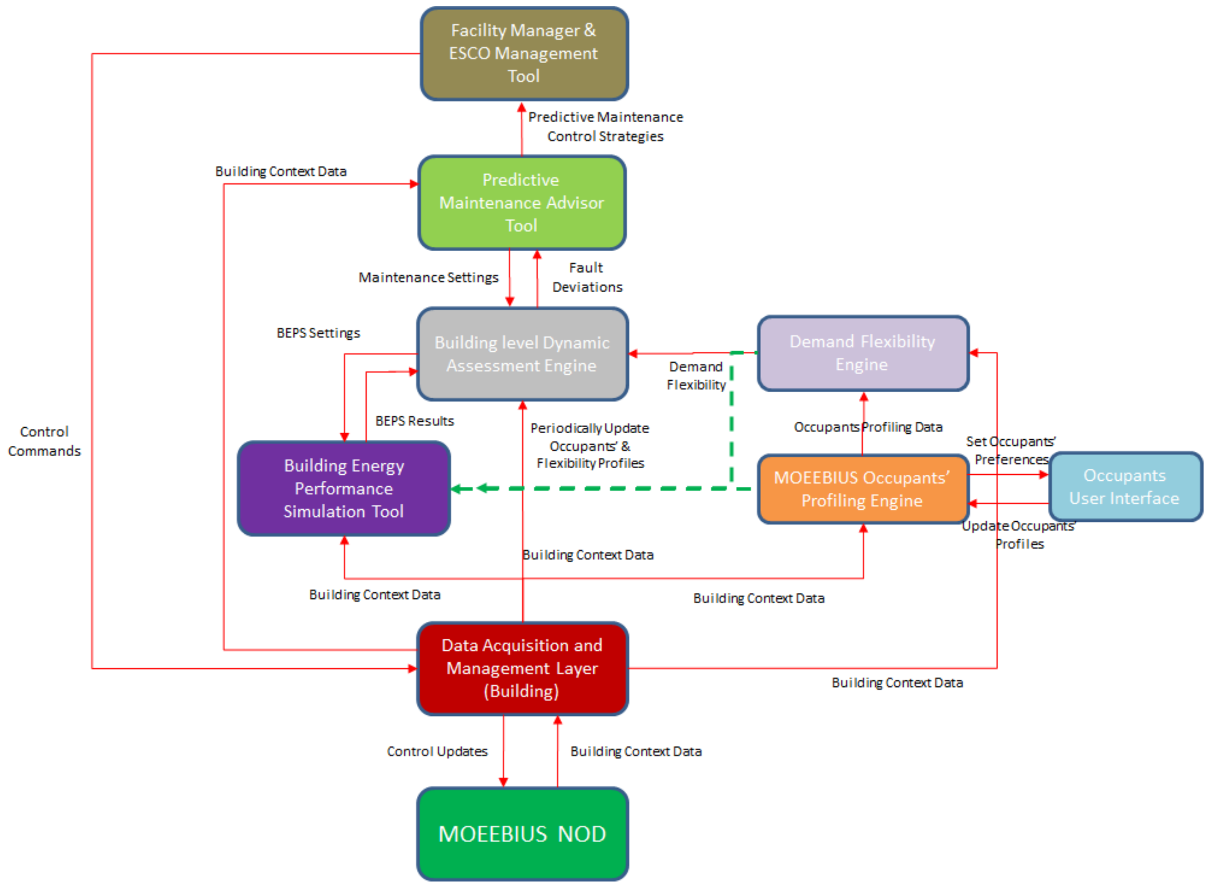

Figure 7 Business Scenario 3 Flow analysis

5.5 Optimized retrofitting decision making on the basis of improved and accurate LCA/ LCC-based performance predictions

One of the main objectives of the MOEEBIUS project is to provide optimized retrofitting decision making services on the basis of improved and accurate LCA/ LCC-based (Life-Cycle Assessment/ Life-Cycle Cost) performance predictions, ensuring that the building performs as intended (regarding structural, environmental and energy performance, along with health, safety and comfort of occupants) and enabling optimized ROI along the building lifecycle.

These retrofitting decision making services, acting on demand, allow the evaluation of **alternative retrofitting projects** from an LCA-LCC point of view and further reduction of the performance gap through targeted actions upon poorly performing equipment and materials. Therefore, the business perspective of this scenario is to set the framework for implementation of macro level retrofitting management plans. The following figure (Figure 8) depicts the workflow for the business scenario.

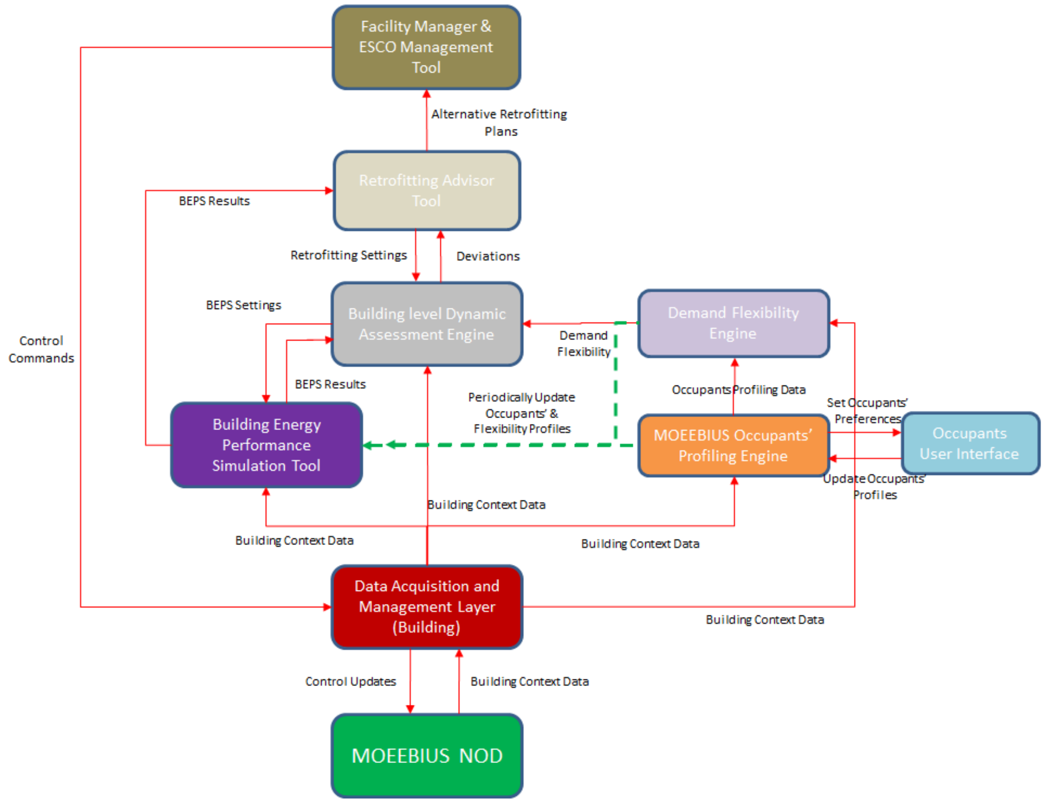

Figure 8 Business Scenario 4 Flow analysis

The workflow is similar to the one presented for predictive maintenance scenario, with the main differentiation that Retrofitting Advisor tool performs at macro level, without requiring continuous access on real time information. The detailed interfaces among the system components for this business case scenario are presented:

1. Retrofitting advisor Tool periodically requests from BEPS engine the results from macro level building performance simulation process. The results from BEPS engine are reported to the Retrofitting advisor Tool for the Retrofitting decision making process.
2. In addition, the Retrofitting advisor Tool access the results of Building level Dynamic Assessment Engine towards the selection of optimized retrofitting plans. More specifically:
    a. The Retrofitting advisor Tool set the parameters for simulated vs. actual analysis from Building level Dynamic Assessment Engine

   b. Deviations from building normal conditions, as identified by the Fault Detection and Diagnosis module of Dynamic Assessment Engine, are reported to Retrofitting advisor Tool for further analysis (further investigation and definition of alternative retrofitting actions, respectively, to effectively mitigate the identified deviation)
3. By further selecting the optimized retrofitting plans as the outcomes from the analytics process, the Retrofitting Advisor Tool reports this information to the MOEEBIUS DSS (Facility Manager and ESCo) tool for further evaluation and visualization of the associated retrofitting strategies.
4. The low level control commands from MOEEBIUS DSS to the building devices are passed through Data Acquisition and Management Layer (Building).

The role of this scenario is: 1) to analyse data coming from MOEEBIUS BEPS (macro level building energy performance simulation) and MOEEBIUS BDAE (fault detections triggering the retrofitting decision making mechanism) for the evaluation of different retrofitting plans and 2) the selection from this list, of the retrofitting plan that best fits to building operation.

5.6 Holistic DSS towards the establishment of a sustainable building level and district level environment

A holistic energy performance optimization framework is required to tackle the different operational frameworks as presented above. Therefore, the goal of this business scenario of the MOEEBIUS project is to promote a dynamic modelling and simulation approach that enables: (1) Improved Predictions on the basis of more accurate and dynamically updated Building Energy Performance Simulation (BEPS) models; (2) Precise allocation and real-time assessment of detailed performance contributions of individual critical building components, (3) Real-time building and district performance optimization through control and predictive maintenance, (4) Optimized retrofitting decision making on the basis of improved (LCA/ LCC-based) performance predictions. Therefore, this business scenario is the integrated scenario, combining the different business functionalities. The detailed business flow diagram is presented:

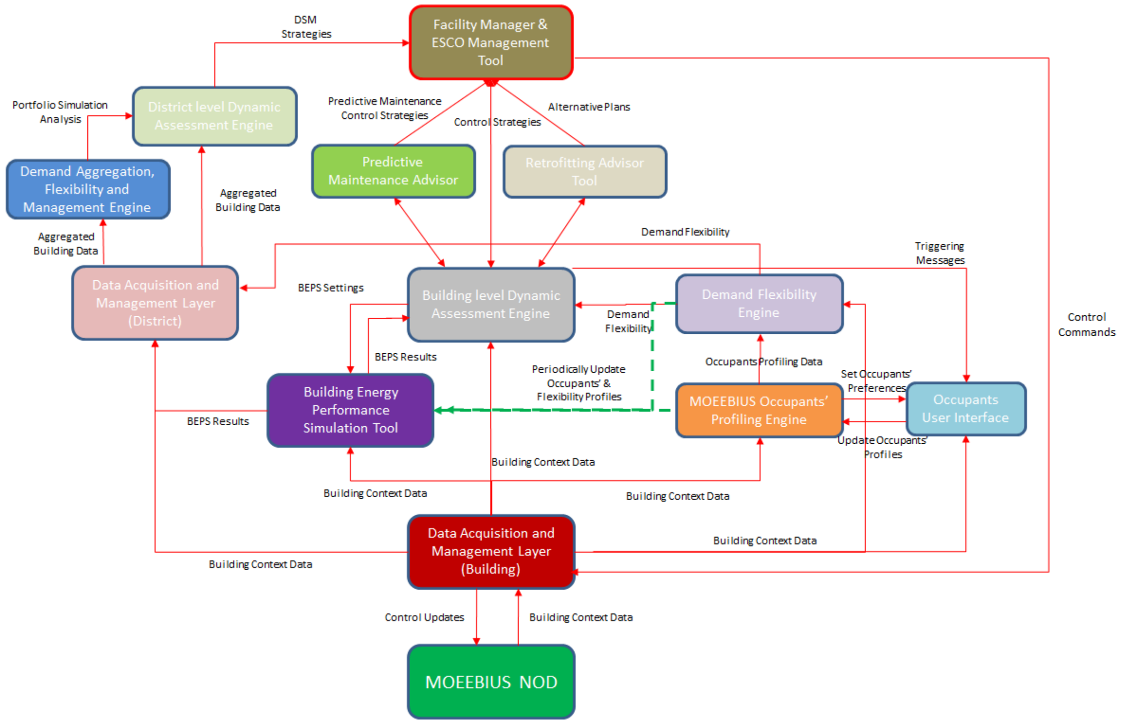

Figure 9 Business Scenario 5 Flow analysis

The workflow analysis is further presented:

1. The different outputs of the heterogeneous business applications, are reported to the MOEEBIUS DSS tool. More specifically:
   a. District level Dynamic Assessment Engine triggers high level DSM control strategies related to Aggregator's business role
   b. Predictive Maintenance Advisor Tool triggers the associated predictive maintenance plans /strategies to ensure the prompt operation of building systems at meso level (Predictive Maintenance framework)
   c. Retrofitting advisor Tool triggers the best fitted retrofitting projects to ensure the prompt building operation at macro level
   d. Building level Dynamic Assessment Engine (through the innovative Distributed Fuzzy Model Predictive Control engine) provides the list of alternative control strategies related to building operation.
2. Taking into account all these heterogeneous inputs, the role of the DSS system is twofold: i) it provides a visual interface to the FM team and the ESCO for the results of the Predictive Maintenance Module and the Retrofitting Advisor, thus supporting the multi-objective decision making process of selecting the most suitable maintenance plans and retrofitting projects; ii) it utilizes the high-level control strategies defined by the FM and the suggestions (control actions) from the District level and Building level Dynamic Assessment Engines and in the means of an optimization process selects the best-fitting control strategy to be applied in the building (or communicated to the FM team for further

evaluation). In the latter mode of operation, information from the Predictive Maintenance Module can also be incorporated (e.g. if one of the boilers of the building is scheduled for maintenance, then the remaining boilers can compensate for this effect, by adjusting their control strategies accordingly).

The business analysis performed in this section, highlights the role of the individual MOEEBIUS components as part of the MOEEBIUS integrated framework. The workflow analysis shows the high level dynamic view of MOEEBIUS platform, defining the core interactions among system components. This initial components' analysis and interfaces definition will facilitate the extraction of the MOEEBIUS functional and non-functional requirements in the next section and will enable the design of MOEEBIUS reference architecture in T3.1.

6 MOEEBIUS Functional Requirements

The previous chapters illustrated the static and dynamic view of the MOEEBIUS system. The static analysis defined the architectural elements of the MOEEBIUS framework while the dynamic analysis, performed through business flow diagrams and by taking into account the updated MOEEBIUS business scenarios, highlighted the core system interactions and information flows.

In this section, the different architectural elements identified are further analysed, focusing on the definition of the functional requirements of the MOEEBIUS framework. We proceed with the taxonomy of these requirements per MOEEBIUS component, enabling that way a clear segmentation of individual components' functionalities which will further facilitate the definition of MOEEBIUS architecture and the development of the respective components during the implementation phase. We are starting the presentation of system functional requirements from the building level of MOEEBIUS framework and moving further to the district level applications.

6.1 MOEEBIUS NOD & WSN framework

The role of this section is twofold: 1) the main part of the work is the explicit definition of the MOEEBIUS NOD requirement, as the prototype hardware device developed in the MOEEBIUS framework 2) the definition of the system requirements for the commercially available WSNs/BMSs integrated in MOEEBIUS project in order to fulfil the different MOEEBIUS applications functionalities.

MOEEBIUS NOD is a hardware combo device, to monitor building context conditions and further enable the interaction of occupants with building devices as the NOD acts as a wireless switch/ dimmer. The complexity of this device, considering also the development of NOD as a prototype, leads to the definition of an extended list of requirements related to the associated functionalities.

The definition of MOEEBIUS NOD requirements is a critical part of the work for the design of the hardware device, as this list of requirements will further enable the definition of Wireless Sensor/Actuator Network specifications in Task 4.1. The list of requirements is presented:

ID	Requirement	Priority
01	**Network Topology**	
01.01	The network of NOD devices should adopt a standardized wireless mesh topology, architecture and information flow (To overcome deployment site obstacles, such as walls in indoor environments, and maximize communication reliability)	High
01.02	The selection of the network topology will take into account the building types and installations and the maximum distance from the gateway etc…	High
01.03	The network of NODs should be able to interface with the	High

	MOOEBIUS middleware or the internet (following the common information model) through a dedicated gateway component. Any type of information captured from the NOD will be reported to the middleware layer	
01.04	The NOD device should receive control input from the user and also acquire and pre-process (normalize) sensor measurement data and send it wirelessly to the network gateway (& coordinator)	High
01.05	The network gateway and network coordinator should preferably be hosted on the same device	Medium
01.06	The gateway should be able to act as a local buffer ensuring efficient integration of the building network to the cloud as well as optional autonomous building operation	High
01.07	The coordinator should preferably be able to push information to the NOD devices (push rather than request-response communication type) under specific circumstances (and configurations)	High
01.08	The status of devices (dimming level and HVAC set point), following control commands triggered by the MOEEBIUS platform, will be the information pushed by the coordinator to MOEEBIUS NOD	High
01.09	Upon booting, the NOD should configure to a specific state which will be provided by the gateway upon request by the NOD	Medium
01.10	The coordinator should enable communication of the gateway with all NODs (network size should be able to scale up to 50 NODs)	High
01.11	The application software of the gateway/coordinator should be able to offer full network monitoring and management services (acquire and manage information about the status and health of the network, joining and disjoining of new devices etc.)	Medium
	Interaction with the User – User Experience	
02.01	User input should be received by the NOD via an intuitive and easy to use interface. The users will be able to set settings on the different device types (HVAC and lighting) and further receive information about the current status of each device (operational status)	High
02.02	The latency for receiving input commands and transmitting the information to the gateway/coordinator should be small enough to feel like real-time to the user	High
02.03	The NOD should be able to report its status (battery level, network configuration information, control & operational status etc.)	Medium
02.04	The NOD should have a common interface to enable users to set settings about both HVAC and lighting within the building premises	High
02.05	The NOD should provide real time status information to the user regarding selected mode of operation (e.g. automatic, manual, scenes) -for luminance and temperature control- and device state (e.g. battery low, connection lost)	High
	Sensing Capabilities	
03.01	The NOD should sense human presence, ambient temperature, humidity, air quality and light conditions in the user's vicinity (~5m) and communicate them wirelessly to the gateway/coordinator	High
03.02	All these sensors should preferably be on-board as the goal is to provide a single combo device	Medium
03.03	The resolution of the different sensor types should be: temperature: (0.5^{o}C), humidity: (10%), luminance: range of 1-1000 lux. For low luminance level required high accuracy (20 lux) while for higher luminance levels (>250 lux) a lower accuracy is enough for the analysis	High

03.04	Air quality aspects should cover VOC, CO2 emissions and PM2.5 aspects	Medium
03.05	The NODs should provide sensing capabilities at various time scales (depending on the building aspect being measured times-tamped data)	High
03.06	The NOD should be able to detect whether it has been moved	Low
03.07	The NOD should have numerous (>1) luminance sensors with a predefined orientation and topology	High
03.08	The NODs should have efficient occupancy sensing capabilities that allow for the accurate sensing of workplace areas of individual occupants, reducing as much as possible noise and false alarms	High
03.09	The NOD should be have the minimum required processing power to pre-process and normalize sensor data locally before transmitting them to the gateway/coordinator	High
	(Building) Control Capabilities	
04.01	NODs should support the efficient, flexible and human-centric (to be further defined) control of Building Lighting and HVAC as defined in MOEEBIUS, by acting as the switch device for users to set their operational settings	High
04.02	The NOD device should enable users to set operational settings for lighting and HVAC devices. These control messages will be further send to MOEEBIUIS platform for further actuation on the associated devices.	Low
	Power Consumption – Battery Life	
05.01	The NODs should consume as little energy as possible for a given set of functions/operations	High
05.02	NOD's battery life should preferably exceed 1 week in normal operating conditions	Medium
05.03	The NODs should be purely battery operated. A rechargeable battery should be used and the NOD should embed the charging circuitry for charging from a USB (type to-be-defined) port	Medium
05.04	In addition to battery charging process, harvesting functionality should be examined as an option for the optimized management of battery consumption	Low
	External Design – Enclosure Characteristics and Form Factor	
06.01	The NOD enclosure should not obstruct or influence the precision of measurements being performed by its internal sensors	High
06.02	The NOD enclosure should be as less intrusive (visually and physically) as possible since it is intended for a table-top use	Medium
06.03	The electronics of the NOD device should have a form factor to suit the enclosure to be designed (this implies an intertwined process of PCB and enclosure design iteration)	Medium
	Other MOEEBIUS NOD Requirements	
07.01	The NOD should provide the capability to change its embedded software and/or its network-related configurations though USB or even over the air	Medium
07.02	The NOD should comprise of an appropriate composition of already existing / mature technological sub-components where possible	Medium
07.03	The NOD should (where possible) utilize commodity, off-the-shelf components as much as possible to drive down the bill of materials and integration costs and enable small/mid-scale procurement with small lead times	High

Table 1 MOEEBIUS NOD Functional Requirements

We have to point out that the above list covers both functional and non-functional requirements for the MOEEBIUS NOD device, providing that way the full list of requirements for this hardware component. A high level taxonomy of the system requirements in main categories (e.g. sensing capabilities, networking issues, user experience etc.…) is considered for the better management of the MOEEBIUS NOD requirements.

Along with the explicit requirements for the MOEEBIUS NOD, we define the list of functional requirements for the rest of the commercial WSN/BMS devices (Sensors, actuators, BMSs) integrated in the MOEEBIUS platform. This list actually defines the types of sensors needed within the MOEEBIUS context to successfully fulfil the different use case scenarios of the project.

ID	Requirement	Priority
	MOEEBIUS WSN framework	
01.01	Access on **occupancy presence/absence data,** through occupancy sensors/BMS tools installed in premises	High
01.02	Access on **building environmental conditions data (luminance, humidity, temperature)** through environmental sensors/BMS tools installed in premises	High
01.03	Access on **device operational data (status, operational model, settings)** through device management sensors/BMS tools installed in premises. Both reporting and control functionalities will be supported.	High
01.04	Access on **energy consumption data (total building, per device)** through metering sensors/BMS tools installed in premises	High
01.05	Real time **health related data** through health sensors/BMS tools installed in premises reporting PM2.5, CO2 and VOC data	High
01.06	Access on **device operational settings (status, operational model, settings)** should be ensured by the WSN/ BMS solution integrated in MOEEBIUS platform	High
01.07	**Sensing and control capabilities** of the commercial WSN/ BMS tools will be at least the same as defined for MOEEBIUS NOD (time stamped data, varying time granularity, data resolution etc..)	High
01.08	Different **network topologies** will be considered for integrating the commercially available solutions, but the final selection should be defined by taking into account the communication protocol capabilities of MOEEBIUS Data Acquisition and Management Layer	High
01.09	The **topology of sensors** installed (number of sensors/ placement of sensors) should take into account the BIM parameters and the pilot specific requirements defined by the different MOEEBIUS applications	High

Table 2 MOEEBIUS WSN framework Functional Requirements

It is clear that this information may come either by commercially available WSN package solutions or via a commercially BMS already installed in premises. The definition of the WSN/BMS requirements is tightly associated with the functionalities supported by Building Middleware Layer (see next section), as this is the layer responsible for the seamless integration of the different types of WSN/BMS in MOEEBIUS platform.

6.2 Data Acquisition and Management Layer (Building)

The role of Data Acquisition and Management Layer (Building) is to act as the middleware layer with the physical environment towards the integration of heterogeneous sensor and actuator types as presented above. In addition, this software component provides a semantically enhanced application interface to the MOEEBIUS business applications. The list of functional requirements for the Data Acquisition and Management Layer is provided:

ID	Requirement	Priority
02	**Interaction with Physical Devices**	
02.01	Both **sensing and actuation functionalities** should be handled by the MOEEBIUS Building level Middleware	High
02.02	The Building level middleware will provide **interfaces with MOEEBIUS NOD**	High
02.03	The Building level middleware will provide **interfaces with the commercial sensors/actuators solutions** selected in the project, taking into account the different communication protocols considered for the integration of these solutions.	High
02.04	The Building level middleware will provide **interfaces with different types of BMS tools** available in premises	High
02.05	Building level information from NOD/ commercial WSN/BMS will be further available (either directly by the specific devices or through a wrapper)to the Cloud based Data Acquisition and Management Layer responsible for the semantic management of information	High
	Interaction with Application Layer	
02.05	Real time **occupancy presence/absence data,** as extracted from occupancy sensors, will be available to the different MOEEBIUS applications	High
02.06	Real time **building environmental conditions data (luminance, humidity, temperature)** will be available to the different MOEEBIUS applications	High
02.07	Real time **device operational data (status, operational model, settings)** for the different types of devices (HVAC, Lighting, other) will be available to the different MOEEBIUS applications	High
02.08	Real time **energy consumption data per device/ metering unit** will be available to the different MOEEBIUS applications	High
02.09	Real time **health metric** values (based on different types of sensors) will be available to the different MOEEBIUS applications	High
02.10	Building Middleware should provide access on **high resolution data** (time series data events or interrupt based events) taking into account the hardware limitations of WSN/BMS types integrated in MOEEBIUS framework	High
02.11	Along with dynamically updated data from WSN, **static BIM parameters** will be further handled by the Building Middleware	High
02.12	Building Middleware should provide limited rule based process on raw data (space and time aggregation, etc...), by **incorporating BIM parameters** to the dynamically retrieved raw data from premises.	Medium
02.13	Along with real time data captured from the building environment, Building Middleware will also **store historical data** for further exploitation (upon request) from the different building applications	High
02.14	Raw data as extracted from MOEEBIUS WSN will be further	High

	associated with BIM elements, providing that way **semantically enhanced interfaces to the MOEEBIUS applications**	
02.15	**Device operational settings (status, operational model, settings)**, as defined by MOEEBIUS business applications, will be further translated to low level control actions on specific Building DERs (actuation functionality)	High

Table 3 Data Acquisition and Management Layer (Building) Functional requirements

In Table 3, we presented the segmentation of Data Acquisition and Management Layer (Building) functional requirements to: requirements about interfaces with physical devices (and MOEEBIUS NOD) and requirements about interfaces with MOEEBIUS software applications. This high level taxonomy highlights the role of the Data Acquisition and Management component as 1) the gateway proxy with the physical environment and 2) the middleware that ensures orchestration and management of the different building elements in a seamless way. This dual role of this component was presented also in Section 4 of the deliverable.

Apart from the list of core functionalities to be supported by the tool, an extensive list of non-functional (mainly technical/operational) requirements are defined in the next section, highlighting that way the core role of this component in MOEEBIUS framework.

6.3 Building Energy Performance Simulation Tool

The role of Building Energy Performance Simulation Tool (Building) is to set the application environment for performing Building Energy Performance Simulations. Following the definition of the requirements for the typical functionalities of a BEPS tool (also provided by already available commercial BEPS tool), the focus is on the extraction of the functional requirements to support the innovative characteristics of the MOEEBIUS BEPS tool. In addition, we are segmenting the analysis on the two core subcomponents that consist of the BEPS platform:

- The back end of the tool which is the extension of Energy plus tool in order to provide enhanced building performance simulations.
- The front end of the tool responsible for the visualization of BEPS analytics results, by taking into account end users requirements from D2.1.

The requirements for the back end (application layer) and the front end (GUI) of the MOEEBIUS BEPS tool are:

ID	Requirement	Priority
03	**User Interaction Requirements**	
03.01	The user must be able to select **temporal**, **spatial** etc. parameter values in order to retrieve a dynamic report about the simulation process	High
03.02	The tool must be interactive - i.e. offer the option to drill-down to **individual details** (e.g. DERs or DER types) of building simulation process	High
03.03	Users must be able to select **metrics/KPIs** and **BIM elements** to **compare** against each other over a time period	High

03.04	Users must be able to evaluate the **impact of different simulation alternatives** by interacting (setting evaluation parameters) with the tool	High
03.05	The user must be able to retrieve multiple contextual Indicators (**energy, environmental, comfort and health indicators)** as the outcomes from the simulation process	High
03.06	Facility Managers should get a comparative view between **real time and simulated energy performance** towards the evaluation of results from the simulation process	Medium
	BEPS Application Layer	
03.07	BEPS tool will perform building energy performance simulations by taking into account **batches of events** from building environment (real time and historical energy and contextual data retrieved from Data Acquisition and Management layer)	High
03.08	BEPS tool should get dynamically updated **DER** (HVAC and lighting) **models** to be incorporated in the simulation process	High
03.09	BEPS tool should incorporate **health related parameters** along with energy parameters at the building performance simulation process	High
03.10	BEPS tool will incorporate dynamically updated **occupant profiles** and **user behavioural preferences** at the simulation process	High
03.11	BEPS tool will incorporate **weather forecasting data** as retrieved from external sources at the building performance simulation process.	Medium
03.12	BEPS tool will incorporate **the enhanced MOEEBIUS energy performance framework** (energy, comfort, business, health KPIs) at the building performance simulation process. Therefore, a multi objective simulation framework will be performed to address the different MOEEBIUS factors	High
03.13	Facility Managers should be able to define **alternative control strategies / high level objectives** for the simulation process, taking into account the different contextual parameters examined (energy, comfort, business, health KPIs)	High
03.14	Along with real time and modelled data, **short term and mid-term forecasting** of building and contextual parameters will enable accurate building performance simulations	Medium
03.15	The BEPS engine should provide interfaces to external system components for **setting and configuring the parameters** about building energy performance simulation process	High
03.16	The BEPS engine should provide as an outcome of the simulation process, **building energy performance certification**	Medium

Table 4 MOEEBIUS BEPS Tool Functional requirements

6.4 MOEEBIUS Occupants' Profiling Engine

One of the main objectives of MOEEBIUS framework is to address building occupants as active elements during building management process. Therefore, a core innovation of the project is the incorporation of Occupants' Profiling Engine in the MOEEBIUS framework. There are different functionalities served by this component, starting from the extraction of accurate occupancy profiles and further integrating contextual aspects in the models for the definition of behavioural/preferences related profiles. The list of functional requirements for this system component is presented:

ID	Requirement	Priority
04	**Occupants' Profiling Engine requirements**	
04.01	Real time **occupancy information** will be extracted by processing of data coming from different types of sensors in premises	High
04.02	Real time and historical occupancy data will be incorporated towards the extraction of accurate **occupancy profiles** in different spatio-temporal granularity	High
04.03	In lack of real time occupancy data, **diversity profiles** will be considered for the extraction of occupancy profiles, taking into account the operational characteristics of the building	Medium
04.04	The estimation of **short term forecasting occupancy** is required for the optimized building management process and thus the component should provide the mechanism for this occupancy forecasting calculation	Medium
04.05	**Real time occupancy and short term occupancy forecasting** information should be available to the application components for further exploitation	High
04.06	The extracted **occupancy profiles (models)** will be available to MOEEBIUS application components for further exploitation	High
	Behavioural Profiling Engine requirements	
04.07	Along with the extraction of occupancy profiles, **user preferences/ behavioural profiles** will be extracted	High
04.08	Different **types of users preferences** [***visual, thermal***] should be examined to be incorporated in the building management process	High
04.09	The extraction of **user profiles** should **take into account real time contextual conditions** (temperature, luminance levels) in building premises	High
04.10	In addition to context based conditions, **user profiling engine** should incorporate **health** parameters	Medium
04.11	The extraction of **user profiles** should take into account the user interactions with building actuators. Therefore, along with sensing data, real time **actuating data** will be retrieved from building premises (through MOEEBIUS WSN)	High
04.12	The extraction of **user preferences** should be either **personalized** or **group based** taking into account details about occupancy as retrieved from building premises	High
04.13	A **training period** is needed for the extraction of accurate occupancy and user preferences profiles	Medium
04.14	During the initial phase or at any reconfiguration process, **setting values from the end users of the systems** (building occupants) will be considered	Medium
04.15	The extracted **behavioural profiles (models)** will be available to MOEEBIUS application components for further exploitation. Therefore common interfaces with these components should be defined	High
04.16	Occupancy patterns and behavioural preferences will be **continuously updated** based on the historical and real time building data. Therefore a local database should store all data needed for the extraction of accurate occupancy and user preferences profiles	High

Table 5 MOEEBIUS Occupants' Profiling Engine Functional requirements

The analysis starts with the extraction of the requirements about Occupants' Profiling Engine, and then the requirements about the MOEEBIUS behavioural profiling framework are presented.

6.5 MOEEBIUS Demand Flexibility Engine

The incorporation of occupancy profiling data to DER building data, leads to the extraction of demand flexibility profiles. Towards the extraction of accurate flexibility profiles, a list of functional requirements is defined as guidelines for the development of this MOEEBIUS component.

ID	Requirement	Priority
05	**Demand Flexibility Engine requirements**	
05.01	The load/DER modelling & flexibility framework should be designed to address the **actual loads** (mainly HVAC and Lighting but also other device types) examined in MOEEBIUS project	High
05.02	Data about **operational characteristics of devices** (real time and historical data about the DER status/mode under different environmental conditions) should be retrieved for the extraction of DER and flexibility profiles	High
05.03	The **controllable devices** will provide **energy sub-metering** functionalities to ensure accurate DER & flexibility modelling	High
05.04	The extraction of demand flexibility profiles should be based on semantically enhanced **DER Models** defined after a short training period	High
05.05	The semantically enhanced DER models will **incorporate contextual parameters** (apart from DER operational characteristics) as part of the modelling process	High
05.06	In **lack of information** required for the **extraction of DER models**, assumptions will be made	Low
05.07	The **short term energy consumption forecasting** (based on real time DER, occupancy and environmental conditions) is required for the optimized building management process.	Medium
05.08	**Context-Aware Load Flexibility Profiles** will be defined. DER models and behavioural profiles will be incorporated, towards the extraction of demand flexibility profiles	High
05.09	Towards the extraction of context aware demand flexibility profiles, input data from **occupancy profiling engine** will be considered. Therefore interfaces with occupancy profiling engine will be defined	High
05.10	High-level **Demand Elasticity Profiles** should be provided in lack of low level information from building environment	High
05.11	Towards the extraction of **price based or weather based flexibility profiles**, input data from external services should be considered. Therefore interfaces with external application services should be defined	High
05.12	A **short term demand flexibility forecasting** (based on demand flexibility profiles, real time occupancy, DER and environmental conditions) is required for the optimized building management process	High
05.13	DER and demand flexibility profiles will be **continuously updated** based on the historical and real time building data. Therefore a local database should store all data needed for the	High

	extraction of accurate profiles	
05.14	The results from both real time and forecasting process (DER and demand flexibility associated with the operational characteristics of DERs) will be **reported to the MOEEBIUS business components.** Therefore, common interfaces should be defined with the rest of MOEEBIUS software elements	High

Table 6 MOEEBIUS Demand Flexibility Engine Functional requirements

6.6 MOEEBIUS Occupants User Interface

This is the graphical user interface for building occupants. The functional requirements for this software component are mainly derived from the list of end user requirements extracted in T2.1, through questionnaire analysis. These requirements are further presented:

ID	Requirement	Priority
06	**Occupants User Interface Requirements**	
06.01	End-users should get informed about **real time environmental condition** (temperature, humidity, etc.) in a personalized way	High
06.02	End-users should get informed about **real time health parameters** (VOC, PM2.5 etc.) in a personalized way	
06.03	End-users should get able to access **energy consumption information** (real time and historical data) in a personalized way	High
06.04	End-users must be able to **set and update preferences** about the **environmental conditions**, **comfort levels** and operational settings of devices (HVAC, Lighting & ON/OFF devices)	High
06.05	End-users should get informed about **environmental and DERs preferences** as extracted from behavioural profiling engine in a personalized way	High
06.06	End-users should get informed **about occupancy profiling data** as extracted from occupancy profiling engine in a personalized way	High
06.07	**Alerts and messages** should be (sparsely) triggered to building occupants through the associated GUI, towards triggering them for energy efficient behaviours	High
06.08	Both **real time and historical information** should be available for the building occupants (in a personalized way)	Medium
06.09	End-users **settings about operational and contextual preferences** should be available to other MOEEBIUS system components (Occupancy Profiling Engine) and thus interfaces with this component should be defined	High

Table 7 MOEEBIUS Occupants User Interface Functional requirements

6.7 Building level Dynamic Assessment Engine

This is the engine that handles the application logic behind the selection of optimized building management strategies. The component takes into account data from heterogeneous sources (BEPS engine, Demand Flexibility Engine, Data Acquisition and Management Layer) and through a combined FDD-DFMPC process triggers the appropriate high level BMS strategies to the different MOEEBIUS business components. As this is the core component of the MOEEBIUS framework,

we specify in details the functionalities provided by this engine and thus a full list of detailed requirements is derived for this component.

ID	Requirement	Priority
07	**Building level Dynamic Assessment Engine**	
07.01	Building level Dynamic Assessment Engine should take into account **real time building data** (consumption, environmental etc.) for the building management process	High
07.02	Building level Dynamic Assessment Engine should take into account the operational status of the device types incorporated in the platform (**HVAC, lighting etc...)**	High
07.03	Building level Dynamic Assessment Engine should take into account real time **health parameters** along with energy related parameters	High
07.04	Building level Dynamic Assessment Engine should retrieve information about **occupants profiles** and **user preferences** from the associated engines	High
07.05	Building level Dynamic Assessment Engine should retrieve information about **demand flexibility** for each specific device integrated in the platform	High
07.06	Along with real time data, **short term forecasting** of energy consumption and demand flexibility will further facilitate the optimization process	Medium
07.07	Along with real time building conditions, **building simulation** data from BEPS tool (at any spatial & temporal granularity) should be available to the Building DAE towards the selection of optimized control strategies	High
07.08	Building DAE should be able to retrieve **real time and historical information** related to building operation on different **time granularity**	High
07.09	Building DAE should access the BIM information to enable the analysis on different **spatial granularity** (individual zones/ aggregated zones)	High
07.10	Building DAE should support building operation in a **fully automated way** where the optimized building control strategies will be selected from a Fuzzy Model Predictive Control engine	High
07.11	The Building DAE engine will allow for short-term prediction of the building performance (**every few minutes**) under **alternative control strategies**	High
07.12	Building DAE should enable end users to **set and configure preferences** about building operational parameters (tariff policies, operational modes etc.)	High
07.13	The **evaluation** of the different control strategies should be delivered under **different performance criteria** (taking into account the enhanced energy performance framework of the project)	High
07.14	Building DAE should **trigger alarms when deviations** occur. Through fault detection and diagnosis, the Dynamic Assessment Engine will be able to recognize whether the building is beginning to operate sub-optimally and proactively identify specific performance trends	High
07.15	Associated with the combined FDD-FMPC engine, a list of **recommendations will be triggered to building occupants** (in form of messages through the respective GUIs), enabling that way the establishment of a behavioural triggering framework	High

07.16	The **results from Building DAE** process will be further available to **MOEEBIUS business application** layers for: (a) real time building automation at Building DSS, (b) triggering predictive maintenance and retrofitting processes. Therefore interfaces with MOEEBIUS business applications should be ensured	High

Table 8 Building level Dynamic Assessment Engine Functional Requirements

6.8 Predictive Maintenance Advisor Tool

As presented in section 4, the role of this component is twofold: 1) to provide the engine for the selection of optimized predictive maintenance strategies and 2) to provide the VR tool to the Predictive Maintenance Managers for visualization of predictive maintenance strategies evaluation. The extended list of functional requirements for this component is provided:

ID	Requirement	Priority
09	**Predictive Maintenance Advisor Tool**	
09.01	Predictive Maintenance Advisor tool should get information about **real time building conditions** (consumption, environmental etc.) for Predictive Maintenance	High
09.02	Predictive Maintenance Advisor tool should take into account the operational status of the device types like **HVAC and lighting**	High
09.03	Predictive Maintenance Advisor tool should take into account real time **health parameters** along with energy related parameters	High
09.04	Predictive Maintenance Advisor tool should receive information about **occupants profiles** and **user preferences**	Medium
09.05	Along with real time data, **simulation data** from BEPS tool will be further exploited by the Predictive Maintenance Advisor tool towards the selection of optimized predictive maintenance strategies	Medium
09.06	Predictive Maintenance Advisor tool should be able to retrieve **real time and historical information** about building operation on different **time granularity**	High
09.07	Predictive Maintenance Advisor tool should retrieve a detailed BIM to enable the analysis on different **spatial granularity** (individual zones/ aggregated zones)	High
09.08	Predictive Maintenance Advisor tool should support the selection of optimized predictive maintenance plans in an **automated way** taking into account real time and historical building contextual conditions	High
09.09	Predictive Maintenance Advisor tool should retrieve notifications about **deviations on building operation, as derived from Building DAE (FDD engine),** towards activating the framework for the selection of optimized maintenance strategies	High
09.10	Predictive Maintenance Advisor tool will provide a UI for the end users to **set and configure preferences** for specific building operations (tariff policies, operational modes etc.)	High
09.11	The evaluation of predictive maintenance strategies should be delivered under **different operational modes and settings**	High
09.12	The evaluation of maintenance plans should address different KPI parameters: **energy, environmental, business and health KPIs**	High
09.13	The overall evaluation analysis should also take into account **financial parameters** as the cost for maintenance activities is a significant factor of the evaluation process	Medium

09.14	A list of **maintenance process specific KPIs** will be calculated by the Predictive Maintenance Advisor tool towards the evaluation of predictive maintenance strategies	High
09.15	Predictive Maintenance Advisor tool should trigger **alarm messages** when deviations on building performance	High
09.16	A list of **recommended actions** to prioritize work of servicemen and technicians when maintaining the building systems will be provided	High
09.17	The optimized predictive maintenance plans are further reported to the **Building DSS tool** for further evaluation	High

Table 9 Predictive Maintenance Advisor Tool Functional Requirements

6.9 Retrofitting Advisor and Investment Evaluation Tool

Following the definition of system requirements for Predictive Maintenance Advisor Tool, we proceed with the definition of functional requirements for the retrofitting advisor tool. The role of this component is: 1) to provide the engine for the selection of optimized retrofitting plans and 2) to provide the GUI for the representation of the selected retrofitting activities.

ID	Requirement	Priority
10	**Retrofitting advisor and Investment Evaluation Tool**	
10.01	The retrofitting decision making process should take into account **BIM information** for the selection of customized to the building retrofitting plans	High
10.02	The retrofitting selection process should specially take into account the operation of **HVAC units** and the **façade** of the building as the main aspects for retrofitting decision making	Medium
10.03	The retrofitting selection process should specially incorporate **behavioural** and **health indicators** at the selection of optimized retrofitting strategies	High
10.04	The retrofitting decision process should take into account the **results from BEPS tool** to further evaluate the impact of different building management strategies (at any spatial & temporal granularity)	High
10.05	Retrofitting advisor tool should retrieve **deviations on building operation, as derived from Building DAE (FDD engine),** towards activating the engine for the selection of optimized retrofitting plans	High
10.06	Along with the building technical parameters, economical aspects should also be considered during the retrofitting decision making process, as the **cost of investment** is a critical parameter for the selection of the final retrofitting plan	High
10.07	ESCOs should be able to **set and configure parameters** for the evaluation of different retrofitting strategies	High
10.08	The **evaluation** of **retrofitting plans** should be performed addressing different indicators: **energy, context, environmental and health KPIs**	High
10.09	The selection of optimized retrofitting plan will follow the **evaluation of different retrofitting strategies**	High
10.10	End-users of the tool will get informed about the **optimized retrofitting strategies** to follow, through a list of retrofitting activities related KPIs	High

10.11	The optimized retrofitting plans are further reported to **Building DSS tool** for further evaluation	High

Table 10 Retrofitting Advisor and Investment Evaluation Tool Functional Requirements

Special focus is delivered on the definition of requirements for the back end of the tool, as the goal of the MOEEBIUS Retrofitting advisor and Investment Evaluation Tool is to incorporate heterogeneous building parameters under a common evaluation framework.

6.10 Facility Manager & ESCO Management Tool

The role of this component is twofold: 1) to provide the DSS system for implementation of control commands by taking into account the high level control strategies from the different business applications (Building and District level Dynamic Assessment Engine, Predictive maintenance, Retrofitting activities) and 2) to provide the GUI tool for Facility Managers and ESCOs. Due to this enhanced functionality, an extended list of functional requirements is provided:

ID	Requirement	Priority
08	**Facility Manager & ESCO Management Tool**	
	Facility Manager & ESCO User Interface Requirements	
08.01	Facility managers should get informed about **real time building conditions** (**consumption, environmental, cost** etc.) in an aggregated way	High
08.02	Facility managers should get informed about the performance of specific building devices like **HVAC and lighting**	High
08.03	Facility managers should be informed about real time **health related parameters** along with energy related parameters	High
08.04	Facility managers are willing to receive information about **occupants profiles** and **user preferences**	High
08.05	Facility managers should retrieve **real time and historical information** about building operation at different **time granularity**	Medium
08.06	Facility managers should retrieve detailed BIM to enable the analysis on different **spatial granularity** (individual zones/ aggregated zones)	High
08.07	Facility Managers must be able to **set and configure preferences** for specific building operations (tariff policies, operational modes etc.)	High
08.08	Facility Managers will have the option to **trigger manual control actions** to specific devices (set point settings, dimming level etc...)	High
08.09	Facility Managers should get information about the **different control alternatives** to further select the optimized management approach for the building	High
08.10	Facility Managers should set **alternative options/modes** for implementing control strategies	High
08.11	Facility Managers should receive **alarm messages** related to deviations from real time building operation	High
08.12	Facility Managers should get informed about the **operational mode** of the building, even when at automation process	Low
	Facility Manager & ESCO Tool Requirements	

08.13	Along with real time building management and optimization (from Building DAE), **predictive maintenance activities** should be incorporated at the DSS for the selection of control plans	Low
08.14	Along with real time building management and optimization (from Building DAE), **retrofitting activities and plans** should be incorporated at the DSS for the selection of control plans	Low
08.15	Along with real time building management and optimization (from Building DAE), **district level strategies** triggered by external stakeholders incorporated at the DSS for the selection of control plans	High
08.16	The **manual configurations and building management settings** from the FM and ESCO user will be also incorporated in the DSS for the selection of control plans. The FM/ESCO user will also set the parameters for the optimization process	High
08.17	The selection of control strategies (by incorporating the different high level control strategies) will be delivered at the DSS level under **different optimization criteria** and indicators	High
08.18	By selecting the optimized control strategies, the **DSS tool triggers the associated control commands** to the physical devices through the building middleware layer	High

Table 11 Facility Manager & ESCO Management Tool Functional Requirements

A high level segmentation of the Facility Manager & ESCO Management Tool functional requirements is considered, presenting first the requirements about Management Tool GUI and then the DSS back-end functional requirements.

We presented above the list of functional requirements for the components that consist of the building layer of the MOEEBIUS. Following this, we are presenting the functional requirements of the district level MOEEBIUS components.

6.11 Data Acquisition and Management Layer (District)

The role of this component is to act as the gateway for district level (District Level Middleware) management. Therefore detailed requirements are defined from the business stakeholders to support the functionalities of Aggregator side application components. The list of requirements for Data Acquisition and Management Layer (District) are:

ID	Requirement	Priority
11	**District Level Middleware**	
11.01	District Middleware should provide access on **high resolution data** (15 minutes granularity)	High
11.02	District Middleware should provide aggregated data (at building level) fully **preserving privacy and security concerns**	High
11.03	District Middleware should provide access about **total building energy consumption** (electricity/ heating) data	High
11.04	District Middleware should provide access about **energy consumption data** for each of the **main device types** examined in the project	High
11.05	District Middleware should provide access about total/ per device type **demand flexibility data** (aggregated data at building level)	High
11.06	District Middleware should provide access on **real time building environmental conditions**	High

11.07	District Middleware should provide access about **real time building contextual data (occupancy data),** fully preserving privacy concerns	Medium
11.08	Along with real time data, District Middleware will provide aggregated **building energy performance simulation data as extracted from BEPS** tool (several BEPS KPI parameters will be available at different spatial and temporal granularity)	High
11.09	Along with real time data, District Level Middleware will **store historical data** for further exploitation from aggregator side business applications	High
11.10	District Middleware should provide limited rule based process on raw data (spatial and time aggregation, etc...), by **incorporating DIM (District Information Model) parameters** to the dynamically retrieved raw data from premises	Medium
11.10	District Middleware should provide **seamless interfaces to aggregator side business applications** for retrieving real time and historical semantically enhanced	High

Table 12 District Level Middleware Functional Requirements

As presented also for Building Data Acquisition and Management Layer, there are two different business layers that consist of the District Data Acquisition and Management Layer: 1) a building proxy (running on Building Data Acquisition and Management Layer responsible for aggregating information at building level) and 2) the District Middleware layer responsible for the orchestration of information from the different assets/ buildings of the portfolio.

6.12 District level Dynamic Assessment Engine

This is the engine that incorporates the business logic towards the selection of optimized DSM control strategy at district level. This is an abstraction of the business level Dynamic Assessment Engine as presented above, addressing though the semantics as met on aggregator side. We specified in details the main functionalities of this engine and thus a list of detailed requirements is provided for this component.

ID	Requirement	Priority
12	**District Level Dynamic Assessment Engine**	
12.01	Along with **building data** as defined in Req. 11, **demand flexibility data** should be considered towards the selection of optimized DSM control strategies	High
12.02	The tool should get access on different information types: **energy, environmental, market** data for the real time portfolio management	High
12.03	The tool should take into account both **real time and historical data** along with static parameters (e.g. contractual data) towards the selection of optimized control strategies	High
12.04	District DAE should also take into account input data from **district simulation process (district BEPS)** towards the selection of optimized DSM control strategies	High
12.05	District DAE will exploit the **simulation results from DAFM module** towards the selection of optimized district level control strategies. Therefore interfaces with DAFM engine should be defined	Medium

12.06	The District DAE should perform the optimization process for the selection of DSM strategies by taking into account different **Context, Energy and Price indicators** at the optimization process	High
12.07	The District DAE will **communicate to prosumers campaign and incentives** for DSM strategies (as outcomes of the optimization process)	High
12.08	Aggregators will communicate campaign and incentives information to **groups of consumers,** by setting different types of filters (spatial, contractual, operational) as parameters of the optimization process	High
12.09	Aggregators can manually **overwrite any DSM command** provided by the optimization process of District DAE	Medium
12.10	Aggregators should dynamically **re-evaluate the performance** of the active campaigns in order to trigger corrective DSM actions	Medium
12.11	Aggregators should be able to define different **contractual agreements** with the consumers towards their optimized participation in DR programmes	High
12.12	A GUI should be provided to the business stakeholders for **monitoring real time portfolio performance** under the different DSM strategies triggered by the stakeholder	High
12.13	By the end of the DSM strategy, the District DAE will calculate the **level of fulfilment of DSM strategy** along with **prosumers compensation for participating in DSM programmes**. The results will be further available to aggregator side applications for further exploitation	High

Table 13 District Level Dynamic Assessment Engine Functional Requirements

Towards the extraction of the functional requirements for the District level Dynamic Assessment Engine, we took into account end user (business aggregators) requirements and the associated Aggregator business models as defined in previous tasks work.

6.13 Demand Aggregation, Flexibility and Management Engine

This is the component of the MOEEBIUS framework to support analytics over streams of data towards the extraction of meaningful information for the business role of Aggregator. Along with the visualization of this information through the associated GUI, the engine provides a simulation framework for the evaluation of different DSM alternatives. The functional requirements of this tool, as extracted through consultation with business stakeholders, are provided:

ID	Requirement	Priority
13	**DAFM User Interface**	
13.01	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
13.02	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
13.03	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

13.03	Users should be able to **select the analytics process**, from the list of functionalities offered by the DAFM component	High
13.04	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
	DAFM application requirements	
13.05	The tool system must support portfolio segmentation over **KPI values from different domains** (Energy, Flexibility etc..), with segmentation levels to be manually defined	High
13.06	The Analytics tool should provide analysis and visualization of **KPI trends**	High
13.07	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
13.08	The Analytics tool should support **metric/KPI classification**, classifying data into predefined groups based on their features	Medium
13.09	The Analytics tool should support **outliers detection** for metrics/KPIs, based on thresholds provided by the end users of the system	High
13.10	The Analytics tool must allow working with **different levels of system detail** (data hierarchy and aggregation)	High
13.11	For **analytics over historical data**, a database with different data types (energy, flexibility etc.…) should be managed by the tool.	High
13.12	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
13.13	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
13.14	In order to retrieve data required for analytics process, **interfaces with Data Acquisition and Management Layer (District)** will be defined. The different data types retrieved from Data Acquisition and Management Layer (District) are presented in Section 11	High
13.15	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
13.16	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

Table 14 Demand Aggregation, Flexibility and Management Engine functional requirements

The aforementioned analysis was performed in order to provide the list of functional requirements of the MOEEBIUS framework. The analysis is delivered per component focusing 1) on the clear distinction of the role of each component in the MOEEBIUS platform and 2) on specifying the functionalities to be supported by each component at the development phase. The overall analysis takes into account the list of MOEEBIUS components and the dynamic interactions among them as identified in chapters 5 and 6 of this document, considering also the end

users and business requirements (D2.1), the MOEEBIUS project business models (D2.2.) and the definition of the MOEEBIUS energy performance framework (D2.3). Following the definition of MOEEBIUS functional requirements, the presentation of the non-functional requirements of the platform is provided in the following section.

7 MOEEBIUS Non Functional Requirements

Along with the definition of functional requirements, a non-exhaustive list of non-functional requirements has been identified for the MOEEBIUS platform. Different types of non-functional requirements are identified in the project, after consultation with technical and pilot partners of the consortium and considering the extraction of MOEEBIUS business models and performance framework, further setting the taxonomy for their presentation. The next table (Table 15) presents the high level taxonomy of non-functional requirements along with a short description of each category type and the priority level.

Non Functional Requirements	Description	Priority Level
Look & Feel	The presentation of project results in a visually appealing way	Medium
Usability	Usability is the ease of use and learnability of the application	Medium
Pilot Specific	Specific Pilot limitations as defined by the selected pilot zones	High
Performance	The level of time and resources needed for the delivery of the framework	High
Accuracy	The levels of accuracy on produced results	Medium
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
Reliability	The system will be stable over time and will not need changes.	High
Interoperability /Compatibility	A system design principle where the implementation takes future growth into consideration.	High
Security/Privacy	Addressing security and privacy aspects	High

Table 15 List of Non-functional requirements

Then, the analysis of MOEEBIUS non-functional requirements for each specific category is provided.

7.1 Look and feel Requirements

The list of look and feel requirements, is defined by mainly taking into account the feedback from the different business stakeholders, as the end users of the tools.

ID	NF-01
Des	A **map view** should be considered as a main UI presenting the different BIM/DIM elements of the building/ district level annotation
Class	Facility Manager Tool, Aggregator Tool
Type	Presentation Requirement
Priority	High

ID	NF -02
Des	The visualization component of each application should provide **different types of animation** for the presentation of the main functionalities offered by each tool
Class	Facility Manager UI, Aggregator UI, Occupant UI
Type	Presentation Requirement
Priority	High

ID	NF -03
Des	Different **types of users** should be defined to get access on analytics processes
Class	Facility Manager UI, Aggregator UI
Type	Presentation/Functional Requirement
Priority	High

ID	NF -04
Des	End-Users should be able to view data either through a **PC monitor** or through a **mobile device** (responsive UIs)
Class	Building Occupant UI
Type	Presentation Requirement
Priority	High

ID	NF -05
Des	The User Interface (pages navigable) must be **simple** and **intuitive** and thus a limited learning curve should be considered for this process
Class	Facility Manager UI, Aggregator UI, Occupant UI
Type	Presentation Requirement
Priority	High

ID	NF -06
Des	The main interest should be on the **presentation of the KPI values** that consist of the energy performance framework of the project
Class	Facility Manager UI, Aggregator UI
Type	Presentation Requirement
Priority	Medium

ID	NF -06
Des	Special focus should be delivered on the **UX design**, considering the best practices (drill in to get insights, drill through for comparative analysis, etc.…) on the development of the associated UIs
Class	Facility Manager UI, Aggregator UI, Occupant UI
Type	Presentation Requirement
Priority	Medium

ID	NF -07
Des	A **VR environment**, as an approach for augmented UIs should be examined as an option for the visualization of predictive maintenance tool information.
Class	Facility Manager UI (Predictive Maintenance Engine)
Type	Presentation Requirement
Priority	Medium

ID	NF -08
Des	The GUI provided by App should support **multiple languages,** addressing the pilot users at different regions
Class	Occupant UI
Type	Presentation Requirement
Priority	Medium

The analysis was presented for the different end user tools (with GUIs) that are defined in the project. A high level segmentation on the different stakeholders is considered for the optimized management of look and feel requirements.

7.2 Security/Privacy Specific Requirements

One of the main aspects of the MOEEBIUS project is to address privacy and security concerns as derived from the end users of the tool, by taking also into account the local legislation. Therefore, the list of Security/Privacy requirements is provided taking into account pilot site representative concerns and security approaches considered in similar commercial solutions

ID	NF-09
Des	**Secure internet communication**
Type	Security/Privacy Requirement
Priority	High
Description	All internet communication must be carried over a secure channel

ID	NF-10
Des	**Private data** protection
Type	Security/Privacy Requirement
Priority	High

Description	The privacy related data (emails, must be stored in the cloud separately and must not be shared with not entitled parties or components

ID	NF-11
Des	**License agreement**
Type	Security/Privacy Requirement
Priority	High
Description	Data owners must agree with storing their data in the platform

ID	NF-12
Des	Support For **Standard Based Authentication** Protocols
Type	Security/Privacy Requirement
Priority	Medium
Description	Usage of standard protocols like OAuth 2.0 will pave the way for smoother security integration in the future.

ID	NF -13
Des	Different **types of users** should be defined to get access on the different functionalities offered by each tool
Type	Security/Privacy Requirement
Priority	High
Description	This is also a security related requirement, as each user should get access on classified information, associated with his business role

ID	NF-14
Des	**Distributed data management**
Type	Security/Privacy Requirement
Priority	High
Description	A clear separation of data should be considered (conceptually and deployment wise) per pilot site and application, ensuring that way access on required data

ID	NF-15
Des	**Data management preserving local legislation**
Type	Security/Privacy Requirement
Priority	High
Description	The local legislation of the countries where the pilot sites are placed should be considered towards handling data captured from pilot premises

7.3 Usability Requirements

The list of usability requirements are mainly related to the usefulness of using the applications. Towards this direction the following list of requirements are defined:

ID	NF -11
Des	**Tools maturity**
Type	Usability Requirement
Priority	High
Description	The tools for interacting with the solution must properly address the capabilities of the actual user. The User apps shall be tailored to the end user needs (End Occupants, Facility Manager, Aggregator etc...).

ID	NF -12
Des	Data must be presented in an **accessible, understandable and flexible** format that enables stakeholders to take action
Type	Usability Requirement
Priority	High
Description	Data must be presented in a fully understandable way by the different stakeholders of MOEEBIUS platform

ID	NF -13
Des	MOEEBIUS apps should ensure the **minimum of occupants disturbance** of building occupants'
Type	Usability Requirement
Priority	High
Description	All MOEEBIUS applications but mainly occupancy and activity profiling engines should ensure the minimum of end users disturbance/interaction with the platform

ID	NF -13
Des	The functions provided by the system apps shall help the respective users to **increase their awareness** taking into account the non-intrusiveness scope of the project.
Type	Usability Requirement
Priority	High
Description	All MOEEBIUS applications but mainly occupancy and activity profiling engines should ensure the minimum of end users disturbance/interaction with the platform

ID	NF -04
Des	End-Users should be able to view data either through a **PC monitor** or through a **mobile device**, providing that way flexibility on accessing the respective information
Type	Usability Requirement
Priority	High

7.4 Interoperability / Compatibility Requirements

This is the list of requirements related to the prompt interconnection of the different applications that consist of the MOEEBIUS platform. As the building/ district level middleware ensures this interconnection, the following list of technical requirements is mainly associated with this specific system component:

ID	NF -14
Des	**External access to cloud** platform
Type	Interoperability / Compatibility Requirement
Priority	High
Description	It should be possible to allow the consortium members securely accessing the cloud platform remotely from their premises, i.e. without need to install their services in the cloud.

ID	NF -15
Des	**Seamless Data Access**
Type	Interoperability / Compatibility Requirement
Priority	High
Description	In order to protect the platform from future potential changes to data sources the data access layer should be capable of accessing different data sources without involving higher architecture layers. This will be ensured by the definition of the MOEEBIUS Common Information Model.

ID	NF -16
Des	**Distributed Messaging Support**
Type	Interoperability / Compatibility Requirement
Priority	High
Description	To be able to handle large number of request with short response time and without any downtime, having this feature would be beneficial.

ID	NF -17
Des	**Big Data Database Support**
Type	Interoperability / Compatibility Requirement
Priority	High
Description	In order to cover potential future big data needs supporting big data databases like Cassandra or MongoDB would be beneficial.

ID	NF -18
Des	**Real-time Data Streaming Capabilities**
Type	Interoperability / Compatibility Requirement
Priority	High
Description	Because this part deals with real time events, in order to not miss any events in the system, supporting high availability features crucial. Also this section should be capable of supporting different message contents such as XML,

	JSON and text and should be compatible with different protocols such as JMS, SOAP, REST and MQTT.

ID	NF-19
Des	Bidirectional and **standardized communication** between internal components and **third party apps** should be ensured
Type	Interoperability / Compatibility Requirement
Priority	High
Description	Standardized communication protocols should be considered for interfaces among system components.

ID	NF-20
Des	**Standards based information models** should be adopted towards setting the common information model among system components
Type	Interoperability / Compatibility Requirement
Priority	High
Description	Standardized information models should be adopted when defining the CIM of the project, support that way the interoperability of MOEEBIUS platform with 3rd party apps.

7.5 Performance & Reliability Requirements

The list of performance and reliability requirements is a strong condition for the prompt operation of MOEEBIUS platform and thus all system component should address the following requirements:

ID	NF -21
Des	**Linear Scalability**
Type	Performance Requirement
Priority	High
Description	Every part of the platform should be equipped with high availability features which provide a predictable linear performance growth rate.

ID	NF-22
Des	**Real time local and global portfolio management**
Type	Performance Requirement
Priority	High
Description	The response of the system shall be fast enough (real-time /second levels) to allow Local and Global management of the portfolio.

ID	NF-23
Des	**High performance on data management**

Type	Performance Requirement
Priority	High
Description	The data management layer of each application should provide analytics over streams of data (historical and real time) in order to ensure a high level performance on the management of huge volumes of data.

ID	NF -24
Des	**No Single Point of Failure**
Type	Reliability Requirement
Priority	High
Description	Through high availability features we should have the possibility of having a system with no single point of failure.

ID	NF -25
Des	**Support for Transactional Behaviour**
Type	Reliability Requirement
Priority	High
Description	The system should be capable of calling a group of services in a transactional manner with rollback capabilities in the cases witch this feature is needed.

ID	NF -26
Des	**Guaranteed Message Delivery**
Type	Reliability Requirement
Priority	High
Description	In some situations like sending sensitive messages to third-party systems while the recipient is offline, this feature would be required.

ID	NF-27
Des	Seamless **operation for a long period**
Type	Performance Requirement
Priority	High
Description	The system shall able to run for long periods of time without data corruption and underperformance.

ID	NF-28
Des	**On start-up go** of MOEEBIUS operation
Type	Performance Requirement
Priority	High
Description	If the system comes online after a downtime period, the current conditions will define the parameters of the tool.

ID	NF-29
Des	**Standby operation** in case of lack of connectivity

Type	Performance Requirement
Priority	High
Description	In case one or more devices are not reachable on the network, the system should **remain online** offering the core functionalities.

7.6 Accuracy Requirements

This is a short list of requirements related to the accuracy level expected from different system applications.

ID	NF-30
Des	**Training period** required to ensure high accuracy levels
Type	Accuracy Requirement
Priority	High
Description	A training period is needed for the initial calibration of the application to building conditions.

ID	NF-31
Des	High **accuracy levels** on simulation and automation process
Type	Accuracy Requirement
Priority	High
Description	The system shall produce accurate results as defined by the needs of the project.

7.7 Services Management & Scalability Requirements

This is the list of requirements related to 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. Again, the following requirements are mainly associated with Building & District Middleware layers:

ID	NF -32
Des	**Service Publication**
Type	Management Requirement
Priority	High
Description	A centralized storage and management solution that plays the role of a proxy for seamless access to services provided by different parties.

ID	NF -33
Des	**Service Access Authorization**
Type	Management Requirement
Priority	High
Description	Having a central access authorization system preferably based on single sign on to facilitate ease of use by different parties.

ID	NF -34
Des	**Service Dependency Management**
Type	Management Requirement
Priority	High
Description	This system will provide us by the relationship between services published by different parties.

ID	NF -35
Des	**Service Traffic Management and Monitoring**
Type	Management Requirement
Priority	High
Description	This feature will provide us with the possibility of real-time monitoring of services in order to detect any faults or stress points and staying compliant with the SLAs.

ID	NF -36
Des	**Custom Application Repository**
Type	Management Requirement
Priority	High
Description	Defining a central storage platform for defining third party applications, access rights and usage metrics.

ID	NF -37
Des	**Centralized Visualization Dashboards with access control level policies**
Type	Management Requirement
Priority	High
Description	This capability allows us to create required dashboards for monitoring different aspects of the platform's functionality and allows access to different parties based on their needs and access level.

ID	NF -38
Des	**SOA Governance**
Type	Management Requirement
Priority	High
Description	This capability allows us to register different shared assets like API services in a centralized manner. It also enables us to manage dependencies between services, manage their lifecycle and check constant compliance with predefined standards and inform consumers about any changes in service definitions.

ID	NF - 39
Des	**Rule Based Business Logic Capabilities**
Type	Management Requirement
Priority	High
Description	For implementing simple rules as services using a rule engine will eliminate the need for implementing web services for every rule in the system as a separated API. This capability drastically reduces the cost of maintenance and implementation of the platform.

ID	NF -40
Des	**Machine Learning Capabilities**
Type	Management Requirement
Priority	High
Description	Having both capabilities of distributed machine learning and performing analytics on a single machine.

ID	NF-41
Des	High level of **scalability** for MOEEBIUS platform
Type	Scalability Requirement
Priority	High
Description	The system must be able to face the variable number of hardware and software elements etc., enabling also the **scalability** of the platform to mass applications.

ID	NF-42
Des	**Extensibility** of MOEEBIUS platform
Type	Scalability Requirement
Priority	High
Description	The system must be able to integrate additional hardware and software components, ensuring that way the ease extensibility of the platform.

We have presented above the list of nonfunctional (technical and non-technical) requirements of the MOEEBIUS project. For the extraction of this list, we took into account end users (in D2.1) and technical parties' feedback. The analysis is performed addressing each component of the MOEEBIUS platform, though special focus should be considered when developing the Data Acquisition and Management Layer (both Building & District) which acts as the central Middleware and Data Repository Layer of the MOEEBIUS platform.

The next section presents the list of pilot specific requirements, considering end users feedback (in D2.1), the definition of project innovative business models (in D2.2) and the preliminary ex-ante pilot audit analysis (T7.2).

7.8 Pilot Site Specific Requirements

The list of pilot specific requirements is presented per pilot site, though some common requirements are defined for all pilot sites.

ID	PIL_01
Des	Due to the type of pilot building premises, the minimum of modifications in building infrastructures should be ensured
Type	Pilot specific requirement
Priority	High
Comments	The installation of sensors equipment will be placed in areas where permanent staff is operating (also considering building zones with sensor equipment already installed)

ID	PIL_02
Des	Due to the type of buildings examined in the project, non-intrusive equipment installations should be ensured
Type	Pilot specific requirement
Priority	Medium
Comments	The installation of sensors and actuators should fully preserve the building operational characteristics (preferable wireless sensors should be installed)

ID	PIL_03
Des	Towards the extraction of accurate occupancy profiles, occupancy sensors should be installed in zones examined in the project
Type	Pilot specific requirement
Priority	High
Comments	Special focus on the extraction of occupancy profiles taking as input occupancy sensing data

ID	PIL_04
Des	Towards the extraction of accurate behavioural profiles, luminance sensors should be installed in zones where lighting management systems are also installed
Type	Pilot specific requirement
Priority	High
Comments	The total number of luminance sensors per zone will be defined on site, but at least one per zone is considered. Preferable one sensor per each single lighting unit managed independently

ID	PIL_05
Des	Towards the extraction of accurate behavioural profiles, temperature/humidity sensors should be installed in zones where HVAC management systems are also installed
Type	Pilot specific requirement
Priority	High

Comments	The total number of temperature/humidity sensors per zone will be defined on site, but at least one per zone is considered. Preferable one sensor per each single HVAC unit managed independently

ID	PIL_04
Des	Towards the extraction of accurate behavioural profiles, health sensors should be installed in zones where HVAC management systems are also installed
Type	Pilot specific requirement
Priority	High
Comments	The total number of health sensors per zone will be defined on site, but at least one per zone is considered. Preferable one combo sensor per each single HVAC unit managed independently

ID	PIL_05
Des	Towards the extraction of accurate DER profiles, sensors for monitoring DER operational parameters and energy metering data should be installed
Type	Pilot specific requirement
Priority	High
Comments	The selection of the DERs integrated should take into account the capability of monitoring operational characteristics and energy consumption

ID	PIL_06
Des	The network topology issues should be thoroughly examined taking into account pilot building limitations
Type	Pilot specific requirement
Priority	High
Comments	Towards integrating heterogeneous types of devices, the network topology issues should be addressed considering also the need for installing extra gateways and routers in premises. Seamless internet connectivity should be ensured in all pilot sites

ID	PIL_07
Des	As a minimum requirement, a mini PC will be available in premises acting as the building gateway for accessing information from the building environment
Type	Pilot specific requirement
Priority	High
Comments	A mini PC will host the proxy of the data management layer for retrieving information required for the different applications of MOEEBIUS project

ID	PIL_08
Des	The evaluation analysis will be performed following the innovative M&V framework defined
Type	Pilot specific requirement
Priority	High

Comments	Towards the evaluation of MOEEBIUS platform in premises, the activities defined in MOEEBIUS M&V protocol should be followed

Following the deployment wise requirements (installation of hardware and software in premises) which are common for all pilot sites, we further proceed with specific requirements for each pilot site of the project.

The U.K. pilot site is the lighthouse pilot for testing and evaluating Demand Response Scenarios (as reported in D2.2 about business models definition). Taking into account the diversity of building types and the special requirements extracted from UK legislation (mainly for Demand Response Implementation) the list of U.K. pilot specific requirements is presented:

ID	UK_01
Des	The installation of innovative MOEEBIUS solution (NOD) should be examined for hotel premises
Class	Building 1: Marriot Hotel
Type	Pilot specific requirement
Priority	High
Comments	This is one of the main innovations of the project, with high willingness to examine this in hotel premises

ID	UK_02
Des	Special interest for HVAC optimized management as one of the highly consuming load type in hotel premises
Class	Building 1: Marriot Hotel
Type	Pilot specific requirement
Priority	High
Comments	HVAC energy consumption is high and thus special focus should be delivered on mitigating this cost

ID	UK_03
Des	MOEEBIUS should share with the personnel, energy related information in order to raise awareness
Class	Building 2: Retailer store
Type	Pilot specific requirement
Priority	Medium
Comments	The information about project MOEEBIUS should be shared with the personnel in order to raise awareness for energy efficiency activities

ID	UK_04
Des	Instillation of sensors/equipment in residential buildings flats / private areas needs to be approved by all flat owners.
Class	Building 3: Residential Premises
Type	Pilot specific requirement

Priority	High
Comments	In order to proceed with any type of installation in private areas, approval from flat owners should be provided

ID	UK_05
Des	The active participation of end users (residential user) in MOEEBIUS activities will be ensured by defining business models with direct benefit for them
Class	Building 3: Residential Premises
Type	Pilot specific requirement
Priority	High
Comments	We need to define market models that provide actual (and significant) benefit for the end users of MOEEBIUS tools

ID	UK_06
Des	Client dashboard cannot be access remotely due to IT security policies in place and potential risk to the building systems
Class	Building 3: Residential Premises
Type	Pilot specific requirement
Priority	High
Comments	We need to ensure security on data and thus the residential users will not have access on data remotely

ID	UK_07
Des	The main interest is on the evaluation of DSM strategies at district level, addressing that way the role of Aggregator in the project
Class	UK Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	As KIWI (a DR Aggregator) is the leading partner in the U.K. pilot site, special focus is on the evaluation of innovative Aggregator business models identified in the project considering also the associated performance indicators

ID	UK_08
Des	The definition of tariff policies should take into account the current market legislation about retailer tariff schemas
Class	UK Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The implementation of dynamic pricing models should take into account the available market approaches

ID	UK_09
Des	The definition of demand response scenarios for UK pilot site should take into account the current legislation promoted by Nationalgrid
Class	UK Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The implementation of demand response scenario that actually fit to current legislation as defined by Nationalgrid

ID	UK_10
Des	Equipment response time – between 2s and 30s for specific Frequency Response programmes
Class	UK Pilot sites
Type	Pilot specific requirement
Priority	Medium
Comments	The implementation of demand response scenarios related to Frequency Response programmes should follow the guidelines defined by Nationalgrid

ID	UK_11
Des	The remuneration about DR participation should be aligned with the current market models for Demand Response
Class	UK Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The different market policies about Demand Response should take into account the commercial market models and the definition of MOEEBIUS performance framework

ID	UK_12
Des	The implementation of project activities should take into account the Decree-Law 118/2013 of August 20th which defines the SCE (Building Energy Certification System), more specifically the RECS (Regulation of Energy Performance of Commercial and Services Buildings).
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Decree-Law 118/2013 of August 20th which defines the SCE (Building Energy Certification System)

The Portuguese pilot site consists of 3 buildings. The buildings span a built area of about 8000 sq.m. that have an annual consumption of 535MWh of electricity and 760 MWh of natural gas. Following the specific characteristics of pilot premises, a list of requirements is extracted.

ID	PT_01
Des	Due to the type of pilot building premises (kindergarten), the safety of the kids is a high priority for the PT pilot.
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	All safety measures (or procedural changes) need to be discussed with the kindergarten administration

ID	PT_02
Des	Due to the type of pilot building premises (kindergarten), the design of UI tool should take into account the lack of end users experience in the domain
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	The end users of the tool are not familiar with the domain and thus we have to provide a simplified version of the tool

ID	PT_03
Des	Due to the type of pilot building premises (primary school), the sensors, actuators and measurement equipment cannot be installed in places which children have access.
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	Specific areas of the pilot sites should be exempted from the pilot selection process

ID	PT_04
Des	Because this building does not have equipment to guarantee an adequate ventilation, special attention should be given to IAQ and ensure a suitable admission of fresh air.
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	Medium
Comments	Special interest on evaluating health related parameters apart from energy related aspects

ID	PT_05
Des	Combination of real time energy consumption towards the selection of optimized retrofitting plans
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	Medium

Comments	Due to almost constant utilization of hot water, special attention should be given to access energy consumption in order to analyse retrofitting the type of equipment and production system

ID	PT_06
Des	MOEEBIUS should share with the personnel energy related information in order to raise awareness
Class	Building 1: Primary School of Venda do Pinheiro
Type	Pilot specific requirement
Priority	Medium
Comments	The information about project MOEEBIUS should be shared with the students in order to raise awareness for energy efficiency, for the school's energy performance and for the impact of their behaviour in the school's energy performance

ID	PT_07
Des	Due to the type of pilot building premises (elementary school), the safety of the kids is a high priority for the PT pilot.
Class	Building 2: Kindergarten of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	All safety measures (or procedural changes) need to be discussed with the school administration

ID	PT_08
Des	Due to the type of pilot building premises (elementary school), the design of UI tool should take into account the lack of end users experience in the domain
Class	Building 2: Kindergarten of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	The end users of the tool are not familiar with the domain and thus we have to provide a simplified version of the tool

ID	PT_09
Des	Due to the type of pilot building premises (kindergarten), the sensors, actuators and measurement equipment cannot be installed in places which children have access.
Class	Building 2: Kindergarten of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	Specific areas of the pilot sites should be exempted from the pilot selection process

ID	PT_10
Des	Because this building does not have equipment to guarantee an adequate ventilation, the special interest of this pilot site is on IAQ and in ensuring a suitable admission of fresh air.
Class	Building 2: Kindergarten of Venda do Pinheiro
Type	Pilot specific requirement
Priority	High
Comments	Special interest on evaluating health related parameters apart from energy related aspects

ID	PT_11
Des	Combination of real time energy consumption towards the selection of optimized retrofitting plans
Class	Building 2: Kindergarten of Venda do Pinheiro
Type	Pilot specific requirement
Priority	Medium
Comments	Due to almost constant utilization of hot water, special attention should be given to access energy consumption in order to analyse retrofitting the type of equipment and production system

ID	PT_12
Des	Because the City Hall has public attendance services, ensuring the quality of the service is a high priority for the PT pilot.
Class	Building 3: City Hall of Mafra
Type	Pilot specific requirement
Priority	High
Comments	This is the lighthouse PT pilot site and thus we have to ensure high quality of services to end users

ID	PT_13
Des	Due to the high costs about HVAC units operation, special interest of this pilot site on the optimized management of this type of device
Class	Building 3: City Hall of Mafra
Type	Pilot specific requirement
Priority	Medium
Comments	We highlight HVAC as the device type of interest but the project should address also additional device types, defined above in the core system functionalities

ID	PT_14
Des	Special interest for this pilot site is foreseen for retrofitting activities of the MOEEBIUS project
Class	Building 3: City Hall of Mafra
Type	Pilot specific requirement

Priority	Medium
Comments	Taking into account the current building status, the interest of the pilot owners is on retrofitting planning and activities

ID	PT_15
Des	Because the building is open to the public, we should use this opportunity to share with the public information about the results achieved with MOEEBIUS project
Class	Building 3: City Hall of Mafra
Type	Pilot specific requirement
Priority	Medium
Comments	Information about MOEEBIUS platform operation should be available to wider public

ID	PT_16
Des	The evaluation of ESCO business models is the main requirement for PT pilot site.
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The main focus of the project should be on the evaluation of innovative EPC defined in the project, addressing both real time management and energy performance certification

ID	PT_17
Des	The definition of tariff policies should take into account the current market legislation about retailer tariff schemas
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The implementation of dynamic pricing models should take into account the available market approaches

ID	PT_18
Des	The implementation of project activities should take into account the Decree-Law 118/2013 of August 20th which defines the SCE (Building Energy Certification System), more specifically the RECS (Regulation of Energy Performance of Commercial and Services Buildings).
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Decree-Law 118/2013 of August 20th which defines the SCE (Building Energy Certification System)

ID	PT_19
Des	The implementation of project activities should take into account the aspects defined in Decree-Law 68-A/2015 of April 30th on energy efficiency and on the application of ECO.AP (Programme for Energy Efficiency in the Public Buildings) in local and regional administration.
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Decree-Law 68-A/2015 of April 30th on energy efficiency and on the application of ECO.AP

ID	PT_20
Des	The implementation of project activities should take into account the aspects defined in Ministerial Order 353-A/2013 of December 4th on ventilation and IAQ requirements for the RECS.
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Ministerial Order 353-A/2013 of December 4th on ventilation and IAQ requirements for the RECS

ID	PT_21
Des	The implementation of project activities should take into account the ethical aspects defined in Law 67/98 of October 26th on personal data protection and regarding the CNDP (National Commission for Data Protection in Portugal).
Class	PT Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Law 67/98 of October 26th on personal data protection and regarding the CNDP (National Commission for Data Protection in Portugal)

Finally, the Serbian pilot site will lead the evaluation of real time automation process. As we incorporate occupancy related parameters in the MOEEBIUS framework, possible ethical issues as derived from local legal legislation are specified through the list of requirements.

ID	SB_01
Des	Due to the type of pilot building premises, the safety of the kids is a high priority for the Serbian pilot.
Class	Kindergarten of Stepa Stepanovic
Type	Pilot specific requirement
Priority	High
Comments	All safety measures (or procedural changes) need to be discussed with the kindergarten administration

ID	SB_02
Des	Due to the type of pilot building premises, the design of UI tool should take into account the lack of end users experience in the domain
Class	Kindergarten of Stepa Stepanovic
Type	Pilot specific requirement
Priority	High
Comments	Information should be available in a simplified way, considering the lack of experience on concepts addressed by MOEEBIUS

ID	SB_03
Des	Due to the type of pilot building premises (Kindergarten school), the sensors, actuators and measurement equipment cannot be installed in places which children have access.
Class	Kindergarten of Stepa Stepanovic
Type	Pilot specific requirement
Priority	High
Comments	Specific areas of the pilot sites should be exempted from the pilot selection process

ID	SB_04
Des	Due to the type of pilot building premises, the safety of the kids is a high priority for the Serbian pilot.
Class	Elementary School of Stepa Stepanovic & Elementary School of Dragan Lukic
Type	Pilot specific requirement
Priority	High
Comments	All safety measures (or procedural changes) need to be discussed with the school administration

ID	SB_05
Des	Due to the type of pilot building premises, the design of UI tool should take into account the lack of end users experience in the domain
Class	Elementary School of Stepa Stepanovic & Elementary School of Dragan Lukic
Type	Pilot specific requirement
Priority	High
Comments	Information should be available in a simplified way, considering the lack of experience on concepts addressed by MOEEBIUS

ID	SB_06
Des	Due to the type of pilot building premises (primary school), the sensors, actuators and measurement equipment cannot be installed in places which children have access.
Class	Elementary School of Stepa Stepanovic & Elementary School of Dragan Lukic
Type	Pilot specific requirement
Priority	High
Comments	Specific areas of the pilot sites should be exempted from the pilot selection process

ID	SB_07
Des	Instillation of sensors/equipment in residential buildings flats / private areas needs to be approved by all flat owners.
Class	Residential Premises
Type	Pilot specific requirement
Priority	High
Comments	In order to proceed with any type of installation in private areas, approval from flat owners should be provided

ID	SB_08
Des	Instillation of sensors/equipment in residential buildings common areas (hallways, stairs, basement …) – needs to be approved by house assembly.
Class	Residential Premises
Type	Pilot specific requirement
Priority	High
Comments	In order to proceed with any type of installation in common areas, approval from house assembly should be provided

ID	SB_09
Des	Due to the high costs about HVAC units operation, special interest of this pilot site on the optimized management of this type of device
Class	SB_ Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Special focus should be delivered on the prompt management of HVAC device types

ID	SB_10
Des	Raising Awareness scenario is the focal business model to be evaluated in SB pilot site
Class	SB_ Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Following business models identification, special focus should be delivered on raising awareness of building occupants about energy consumption

ID	SB_11
Des	The definition of tariff policies should take into account the current market legislation about retailer tariff schemas
Class	SB_ Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	The implementation of dynamic pricing models should take into account the available market approaches

ID	SB_12
Des	The implementation of MOEEBIUS activities in pilot sites should be aligned with Serbian Law on Personal Data Protection ("New Law") came into effect on 4 November 2008 and is applied since 1 January 2009
Class	SB_ Pilot sites
Type	Pilot specific requirement
Priority	High
Comments	Personal data is defined very extensively, namely all information relating to a natural person, irrespective of its form or the medium in which it is kept, is considered as personal data and is subject to the New Law

The aforementioned analysis defines the list of pilot specific requirements, taking into account the review of end users requirements in D2.1 and further the initial activities in D7.2 towards the selection of the pilot zones that consist of the pilot testbed of the MOEEBIUS project. In addition, the definition of MOEEBIUS business models in D2.2 along with the extraction of the MOEEBIUS M&V protocol with the associated KPIs that set the MOEEBIUS energy performance framework, are also considered for the requirements analysis phase. For the prompt presentation of the MOEEBIUS pilot sites requirements, we grouped the common requirements for all pilot sites and further extended this list with pilot specific requirements taking into account feedback from the pilot site representatives.

The list of MOEEBIUS non-functional requirements presented above is complementary to the functional requirements analysis presented in Chapter 6. By proceeding with the definition of MOEEBIUS functional and non-functional requirements we set that the guidelines and constrains for the development of MOEEBIUS platform.

8 Conclusions

This report documents the final list of functional and non-functional requirements of the MOEEBIUS framework following the definition of the system components that consist of the MOEEBIUS platform.

Firstly, we identify the core MOEEBIUS functional components by taking into account the business scenarios and use cases of the project along with the definition of MOEEBIUS performance framework. Following this static description of MOEEBIUS platform, a dynamic analysis is provided showing the interaction among these system components. We have to point out that the dynamic presentation of the MOEEBIUS framework (with the definition of interactions among the system components) remains at a high (business) level, as the detailed interfaces among the system components will be defined in WP3 along with the provision of MOEEBIUS reference architecture.

Furthermore, the list of MOEEBIUS system requirements is provided. The project system requirements were divided in two categories:

- The section about **functional requirements** contains the operations and activities that the MOEEBIUS framework must be able to perform. These requirements are mapped to the different functional components that consist of the MOEEBIUS framework.
- The **non-functional requirements** section is composed on the one hand by the pilot building requirements and on the other hand by the definition of the qualities, attributes and restrictions that the MOEEBIUS solution must meet.

By defining the MOEEBIUS components along with the list of functional and non-functional requirements, we are activating the work for the definition of MOEEBIUS reference architecture. The different functional components identified in this document, will be extensively described in D3.1 as part of the overall MOEEBIUS framework, while the list of system requirements will lead to the definition of MOEEBIUS system specifications. Thus, this document can be considered as a living document and will remain as an open issue till all components and subsystems are built and all modules have been integrated to the MOEEBIUS platform.

9 References

[1]. MOEEBIUS Description of Actions, MOEEBIUS Project (680517)
[2]. MOEEBIUS D2.1 End-user & business requirements, MOEEBIUS Project
[3]. MOEEBIUS D2.2 New Business Models and Associated Energy Management Strategies, MOEEBIUS Project
[4]. MOEEBIUS D2.3 MOEEBIUS Energy Performance Assessment Methodology, MOEEBIUS Project