MOEEBIUS

Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability

D7.2. MOEEBIUS Living Lab Activities Planning

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Table of content

List of tables

List of figures

Glossary

Acronym	Full name
BEPS	Building Energy Performance Simulation
BIM	Building Information Modelling
BSC	Business Scenarios
DCP	Dissemination and Communication Plan
DER	Distributed Energy Resources
DR	Demand Response
DSM	Demand Side Management
DSS	Decision Support System
EE	Energy Efficiency
ESCO	Energy Service Company
EU	European Union
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technologies
IT	Information Technology
KPI	Key Performance indicator
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
M&V	Measurement and Verification
UC	Use Cases
UK	United Kingdom

1 Executive summary

The Living Labs are the core of the MOEEBIUS framework. They will be used to test two main innovative aspects of the project:

- Coupling monitoring and simulation in order to optimize operation and identify problems.
- Allowing MOEEBIUS to dynamically learn user preferences and proactively feed the MOEEBIUS Building Performance Simulation Engine with updated occupant behavior profiles.

This deliverable describes the designed methodology for the activities plan to be developed at the Living Labs. All these activities will be consecutively executed. First of all, the validation framework is defined by specifying the Living Lab sites, the validation scenarios, collecting end-user requirements and analyzing the current state and performance of the buildings with an ex-ante evaluation. Following, the first intervention actions will take place in the roll-out phase, with the installation of the required equipment, the calibration of the models and the realization of a first trial in order to evaluate, optimize and re-calibrate the models and develop a second improved trial phase. After this, the results will be validated, and an analysis of the impact and cost-benefit will be done.

The Innovative MOEEBIUS solutions will be validated in real-life conditions over an extensive 20-month pilot roll-out period in three different pilot sites located in London (United Kingdom), Mafra (Portugal) and Belgrade (Serbia).

As a key part in MOEEBIUS, evaluation comprises the means towards validating cost-effectiveness, techno-economic feasibility and the impact generated by the project, whilst assessing the transferability and replication potential of MOEEBIUS results, along with end-user acceptance.

Since end-users involvement is an essential factor for the project success, in parallel, a series of activities is planned to disseminate the project and its results so to get the end-user engagement. The Living Labs activities will also include Dissemination and Communication actions in order to establish an efficient communication, awareness and engagement framework involving all the MOEEBIUS pilot sites´ stakeholders.

2 Objectives of the report

This report aims at planning the Living Lab activities for the coming evaluation and validation of the project outcomes. In this early stage, a methodology to structure these activities is defined, which comprises the project validation framework along with the description of the activities to carry out in the Living Labs (from installation of the required equipment to optimization of MOEEBIUS framework). Additionally, a roadmap for MOEEBIUS final evaluation considering technical aspects, user experience, impact realization and cost-effectiveness validation is described.

The Living Lab Dissemination and Communication Plan introduction serves to provide the main steps to be followed, which mainly are the raising of awareness, engagement and acceptance from pilots´ stakeholders, including trainings to contribute to the adoption of the MOEEBIUS concept and operation and the involvement of end users in the validation process. This Plan consist of training activities planning, material and questionnaires.

SOLINTEL (SOL) acts as Living Labs coordinator while KIWI, ISQ and BEOLEK are, respectively, in charge of the pilot sites located in United Kingdom, Portugal and Serbia. SOLINTEL is acting as the support point for these led partners in the Pilot Roll-Out and Validation Process, and coordinates the workshops and activities for Living Lab stakeholders (Task T8.3). The following schema depicts the management structure of the partners involved in this process:

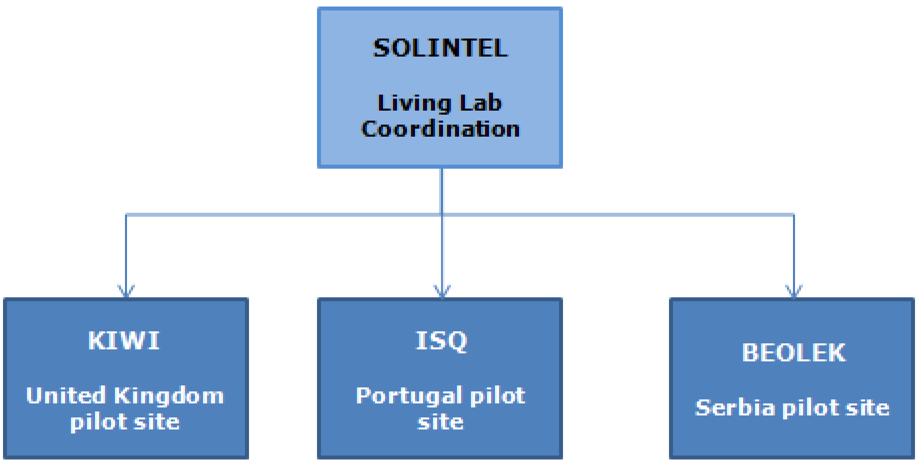

Figure 1. Structure of Living Lab coordination

3 Methodology

The living labs play a key role in testing, refinement and validation of the MOEEBIUS framework at both building and district levels. Additionally, they will be also served as demonstrators showing the running MOEEBIUS framework, with emphasis on the benefits achieved and their potential.

Following are presented the four main groups of activities planned for the Living Labs:

(1) *<u>Validation framework</u>*

- **Living Lab Sites (MOEEBIUS pilots)**. The MOEEBIUS framework will be validated in 3 large-scale pilot sites, located in Portugal, UK and Serbia, incorporating diverse building typologies, heterogeneous building and district energy systems and spanning diverse climatic conditions. In order to span a greater range of climatic conditions, three locations with quite different climates have been chosen for the pilot deployment in Mafra (Portugal), Belgrade (Serbia) and London (UK).
- **Validation scenarios**. The scenarios for the validation of the MOEEBIUS framework will be determined considering the different use cases that define the technical perspective of the respective business needs.
- **End-User Characteristics and Requirements**. A set of questionnaires was distributed to the MOEEBIUS stakeholders (Building Occupants, Facility Managers/ESCOs and Aggregators). The main objective was to extract stakeholders' specific needs and further derive the list of end users and business requirements.
- **Ex-ante evaluation in the project pilot sites**. An ex-ante evaluation in the project pilot sites will take place for the creation of a realistic and accurate performance baseline to be used as a reference during the impact assessment phase (Task T7.6) of the project.

(2) *<u>Installation, calibration, evaluation and optimization</u>*

The Roll-Out phase of the MOEEBIUS pilots will be driven through these four steps:

- Installation of the required equipment
- Initial calibration of MOEEBIUS models and profiles
- First real-life trial of the MOEEBIUS framework and evaluation of gap reduction
- Optimization of DR and EE strategies, further calibration of models and roll out of the second trial phase.

(3) *Results Validation, Impact Assessment and Cost-Benefit*

A roadmap is proposed for MOEEBIUS consolidation and final evaluation of project outcomes considering technical aspects, user experience, impact assessment and cost-effectiveness validation.

Three main pillars of the results validation will be defined in order to evaluate the fulfilment of the project objectives:

- Technical assessment of the MOEEBIUS framework
- Impact analysis assessment of the MOEEBIUS framework
- User acceptance assessment of the MOEEBIUS framework

(4) *Living Lab DCP*

The MOEEBIUS Living Lab is expected to contribute significantly in the MOEEBIUS dissemination framework, supporting, among others, knowledge transfers and experience sharing within an Open Innovation and EU Competitiveness Reinforcement Ecosystem. It will benefit the project getting the project's outcomes widely disseminated to the appropriate target communities, at appropriate times and via appropriate methods [3].

A Gantt Chart is provided for the living lab dissemination activities as shown in the following figure:

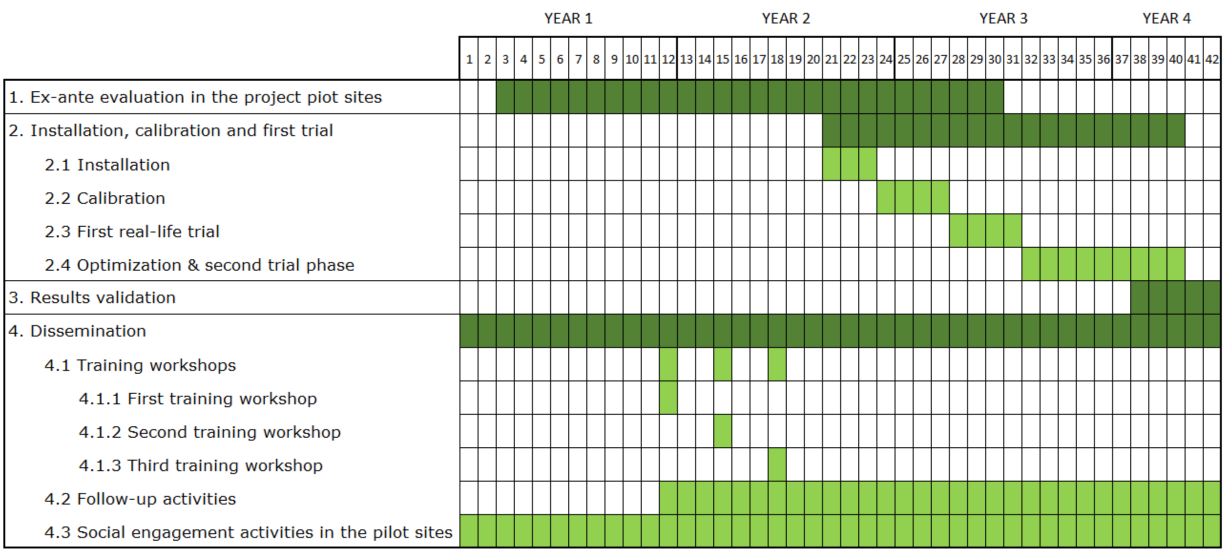

Figure 2. Gantt chart for the Living Labs activities

4 Validation framework

Before starting the deployment of the MOEEBIUS framework on the pilot sites and its validation, it is necessary to prepare a pilot validation framework that facilitates assessing the fulfilment of the project objectives as well as to the key requirements established.

In this way, the validation scenarios must be defined, determining all the use cases and future actions prior to the start of validation process. On the other hand, it is also very important to have in mind and take into account the end-user needs and requirements related to MOEEBIUS concept, intending to get engaged the system stakeholders in project activities.

Furthermore, among these pre-validation activities, an ex-ante evaluation will be carried out to analyse and create a performance baseline by characterizing the performance of the buildings in current state, before implementing the MOEEBIUS project framework in the three pilot sites, then this baseline created will be also used as a benchmark for the future impact assessment.

4.1 MOEEBIUS pilots

The deployment of the MOEEBIUS framework will be carried out in a variety of buildings (office, retail, educational, sports, residential, hotel) and building blocks under different environmental, social and cultural contexts in three dispersed geographical areas: London in UK, Mafra in Portugal and Belgrade in Serbia. Prior to the MOEEBIUS framework deployment, an iterative functional testing will be conducted in the KUBIK facility, a three story building owned by TECNALIA, which provides the required equipment and well-known boundary conditions to validate the complete set of MOEEBIUS components.

In the following sections, the pilot sites will be specified with key characteristics like building types that consist the pilot site, areas, location, equipment etc., which define the conditions for the development and validation of MOEEBIUS framework.

4.1.1 United Kingdom pilot site

The buildings (hotels, retail store and residential buildings) span a built area of about 22.500 sq.m that have an annual consumption of 3.100 MWh in electricity and 80 MWh in natural gas. Among these buildings, it is estimated that there are 1.200 occupants forming a diverse occupant profile, which will enable a thorough evaluation of the MOEEBIUS framework by varying occupancy profiles.

The pilot site comprises:

1. The Marriott County Hall, a hotel located in Central London. The building was originally constructed in 1939 and an additional wing was added in

1974. It comprises 186 rooms, 14 suites, 12 meeting rooms and 1 concierge level. The building has 6 stories. It relies purely on electricity energy and it consumes about 1.300 MWh annually.

Figure 3. London Marriott county hall hotel

2. A retail store building located in central London. The building was erected in the 1960s and has 5 stories, and consumes about 850 MWh of electricity annually.

Figure 4. Building housing retail stores

3. A retail store building located in central London. It was originally built in 1920 and completely refurbished in 2014. The building has 7 stories and consumes about 900 MWh of electricity annually.

Figure 5. Building housing retail stores

4. A 5-story apartment building in central London. The floors above ground are 4 flats of about 70sq.m. each. The building was constructed in 1920 and refurbished in 1990. It mainly relies on electricity and gas, and its average annual consumption per flat is about 4MWh for electricity and 16MWh for natural gas.

Figure 6. Apartment building

4.1.2 Portugal pilot site

The buildings span a built area of about 8.000 sq.m. that have an annual consumption of 535 MWh of electricity and 760 MWh of natural gas. All buildings share their HVAC system which is based on district solution, natural gas-fired boilers to heat water. About 800 people occupy these buildings in a variety of roles that provide diversity in the occupant profiles. Sports facilities and the town hall host visitors as well as employees, while schools host students and employees. This diversity will also enable a thorough evaluation of the MOEEBIUS framework for varying occupancy profiles.

The pilot site comprises:

1. A complex of two educational/recreational buildings called "Complexo escolar de JI/EB da Venda do Pinheiro" built on 2005. The two buildings house a school, a swimming pool and multi-sports hall (for use by students and citizens). It has two stories and more than 550 visits per day from students/employees or visitors of the sports complex. The second building house a kindergarten and is also a two story building, hosting about 20 students and about 100 staff and visitors daily. The two buildings are interconnected with heating generation and distribution system. This building complex mainly consumes electricity and gas, with annual electricity consumption of about 257MWh, and 760MWh of natural gas.

Figure 7. Primary school, swimming pool, multi-sport hall

Figure 8. Kindergarten

2. The MAFRA city hall building. This building houses about 200 permanent staff and about 50 visitors on a daily basis. It is spread over four stories, each of them has 15 rooms. The building houses the mayor’s office and offices for the necessary supportive staff. Apart from HVAC, all other amenities run purely with electricity and the building consumes about 277MWh annually on average.

Figure 9. MAFRA city hall building

4.1.3 Serbia pilot site

It is an entire district comprises 48 diverse - functionally and operationally – buildings and has a built area of 434.000 sq.m, with an annual electricity consumption of about 12.400 MWh. All buildings share a central district heating infrastructure which is collectively managed by BEOELEK. The buildings house almost 12.000 occupants making this pilot site the largest one in MOEEBIUS project and a convincing platform for the demonstration of the framework's value.

1. Most buildings of the pilot site form a residential building group comprising 44 buildings with 64 flats each in five stories and is situated in the "Stepa Stepanovic" neighbourhood of the city of Belgrade. The main usage of space on floors from ground floor to the attic floor is residential, and the basement is a garage with 24 units. The ground floor level houses to flats and tenant storage spaces. The building houses 201 tenants in total with 3.790 sq.m of heated space. The heat installation capacity (calculated in the outside design temperature -18°C) is 307 kW. A district heating substation is situated in the basement of the building and supplies heat energy for this building exclusively. Individual thermostats for controlling heating loads are installed in each flat.

Figure 10. Residential building "Stepa Stepanovic"

2. Additionally, the pilot includes four other buildings for educational, recreational or commercial usage. The first educational building is the primary school "Dragan Lukic", situated in the "Bezanijska Kosa" neighbourhood in the city of Belgrade. It was constructed in 2011 and started functioning from September 2011. The building has 3 floors, including the ground floor, and its total area is 7.242,60 sq.m. 108 people are employed by the school and work daily in the building, which also accommodates about 1.500 pupils every day. The installed heat capacity (calculated in the outside design temperature - 18°C) is 393,4 kW (292 kW for radiator heating, 29,5 kW for floor heating, 72,3 kW for ventilation).

There are two district heating substations, one for radiator and floor heating, and another for ventilation chambers.

Figure 11. Primary school "Dragan Lukic"

3. Another educational & recreational building is the primary school "Danilo Kis", situated in the "Stepa Stepanovic" neighbourhood in the city of Belgrade. The school was constructed in 2014 and started working from September 2014. It is designed for 720 pupils in one shift with 25 general purpose classrooms, 8 specialized classrooms and one faculty room, administrative block, dining room with 88 seats, gym and auditorium with 90 seats. The school employs 50 individuals. Its structure is designed as one unit with basement, ground floor and 2 stories; the gym hall with dressing rooms, and an exercise equipment area. The installed heat capacity (calculated in the outside design temperature -18°C) is 369,8 kW (251,8 kW for radiator heating, 29,8 kW for floor heating, 88,2 kW for ventilation). There are wo district heating substations, one for radiator and floor heating, and another for ventilation chambers.

Figure 12. Primary school "Danilo Kis"

4. The last educational building is the combined children facility "Mala Sirena", situated in the "Stepa Stepanovic" neighbourhood of the city of Belgrade. The facility is designed to accommodate 270 preschool children in 14 groups. The total built area is 2.468,23 sq.m. distributed in two floors. It

was constructed in 2014 and started operation in January 2015. The installed heat capacity (calculated in the outside design temperature -18°C) is 94,2 kW for radiator heating and 42,4 kW for ventilation. There are also two district heating substations: one for radiator and floor heating, and another one for ventilation chambers.

Figure 13. Kindergarten/Children facility "Mala Sirena"

5. Finally, the commercial building is the administrative building of BEOELEK which is located in the Novi Beograd part of the capital of Serbia. It was constructed in 2010 and comprises two separate buildings, a two story building and a three story building. The total area of the buildings is 2.700 sq.m. and it houses about 210 personnel of BEOELEK and about 400 visitors per day on average. It relies solely on electricity in energy consumption. The installed heat capacity (calculated in the outside design temperature -18°C) is 166 kW.

Figure 14. Administrative buildings of BEOELEK

4.2 Validation scenarios

In the first stage the list of stakeholders and the associated Business Scenarios in the project is defined. Following the selection of the Business Scenarios, a list of technical use cases, which highlight the principles of MOEEBIUS framework, is extracted. Each business scenario is associated with 1 or more use cases that define the technical perspective of the respective business needs. The Business

Scenarios and Use Cases will be evaluated and assessed in order to ensure the fulfilment of the requirements and project objectives during the MOEEBIUS framework roll-out phase.

The following figure extracted from D2.1 shows MOEEBIUS Business Scenarios and Use Cases and Table 1 resumes the links between both explicitly:

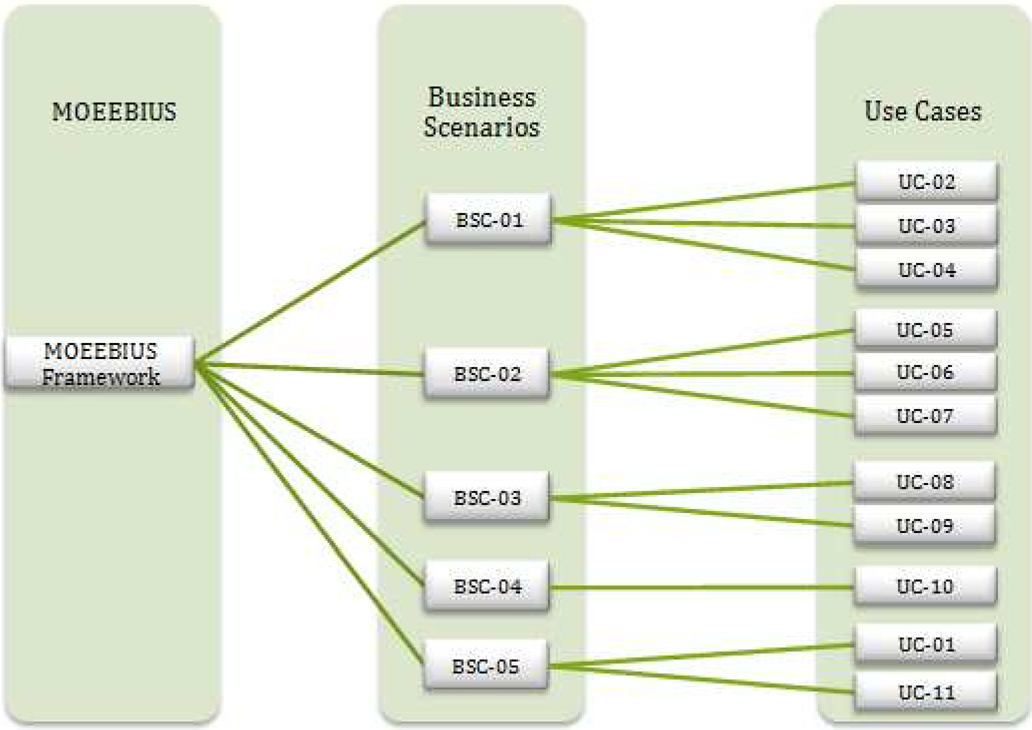

Figure 15. Graphic representation of MOEEBIUS Business Scenarios and Use Cases [1]

	Business Scenarios		Use Cases
BSC-01	Real-time building performance optimization towards the establishment of a sustainable environment	UC-02	Real-time Building Optimization through Simulation-based Automation
		UC-03	Building Energy Performance Assessment on the basis of enhanced BEPS models
		UC-04	Addressing the role of occupants as a main parameter on buildings operation
BSC-02	Active Participation in Demand Response Schemas through the optimal management of buildings' portfolio	UC-05	Visual Analytics over consumers' historical data
		UC-06	Hypothesis analysis for the optimal management of consumers on DSM strategies
		UC-07	District level dynamic assessment framework for energy performance optimization
BSC-03	Optimized Predictive maintenance	UC-08	Building performance optimization through the selection of predictive

	diagnostics and decision making tool to ensure high levels of business performance		maintenance strategies
		UC-09	Establishment of a Virtual Reality environment for Predictive Maintenance support
BSC-04	Optimized retrofitting decision making on the basis of improved and accurate LCA/ LCC-based performance predictions	UC-10	Supporting retrofitting decision-making by addressing real time building operation
BSC-05	Holistic DSS towards the establishment of a sustainable building level and district level environment	UC-01	Real Time Monitoring of Building Operation
		UC-11	Holistic DSS addressing real time building and district operation, predictive maintenance and retrofitting strategies

Table 1. MOEEBIUS Business Scenarios and Use Cases

4.3 End user requirements

A set of questionnaires was prepared and circulated to the main system stakeholders (ESCOs, Aggregators, building occupants), including participants of MOEEBIUS Living Lab, to address users' specific requirements. The goal of these questionnaires is to engage system stakeholders in project activities and further retrieve their valuable feedback towards the extraction of specific needs and requirements related to MOEEBIUS concept. Then the questionnaires analysis results are transformed to MOEEBIUS End users and Business Requirements, developed in D2.1 "End-user & business requirements". These requirements are also complemented with additional requirements as defined by the business partners of the consortium.

The building occupants, who set context preferences and further define the operational parameters for building conditions, are envisioned as major stakeholders in the project and thus are considered as active elements of the proposed framework, directly interacting with the MOEEBIUS tools and services.

Common patterns on the usage of devices, time spent in each building zone, main devices used and the preferred set points of operation have been collected from the MOEEBIUS Living Lab participants. Since the users´ behavior and their interaction are a key parameter in the operation of the system, users were also requested to express their preferences in the future user interface that will present directly the key energy performance information and will be highly related with the user experience toward the final products.

4.4 Ex-ante evaluation in the project pilot sites

To enable the thorough validation of the MOEEBIUS framework, an ex-ante evaluation of the project pilot sites will take place before deployment to create a realistic and reliable performance baseline (considering the modelled parameters of the MOEEBIUS framework and the methodology specified in Task T2.3), which will also be used as a reference during the impact assessment phase (Task T7.6). As part of the ex-ante evaluation, the Building Information Models of the pilot areas will be prepared to serve as the basis for the simulations to be performed through the BEPS.

To address the pilot sites diversity, the validation framework will be based upon the methodology specified in Task T2.3 and instantiate specific validation scenarios, associating them to sub-groups of Key Performance Indicators (KPIs) defined in T2.3, not only to properly address singularity of each pilot case, but also retain a uniform (and comparative) evaluation of the project results. For some Validation Scenarios, specific KPIs will be introduced to address unique characteristics. Therefore, the KPIs will be linked with specific Validation Scenarios and specific Pilot sites configuration, with a direct influence over the deployment plan in the three demo-sites of MOEEBIUS project.

4.4.1 Methodology

As mentioned above, the methodology for the ex-ante evaluation will be completely defined in T2.3 "Building and District performance assessment specifications and Key Performance Indicators". For the analysis of the energy performance of a building with specific configuration, users behavior and equipment operation, it is needed a proper collection of data and an thorough analysis of this data to get a full characterization of the energy performance of the building. Therefore, this methodology will be developed based on two main steps: data collection and analysis.

Data collection

The first step for the performace analysis consists of collection of necessary data to completely characterize the energy performance of the building. It is known that only a good characterization of the performance would enable the identification of deficiences, performances comparison among different configurations and analysis of the effect of the actuations over the energy performance and quantification of improvements. In that way it is necessary to:

- Define the type of measurement and data requirements.
- Collect and validate the baseline energy consumption data.
- Prepare a Measurement and Verification (M&V) plan.
- Identify measurement and metering points.

- Identify significant energy uses: the loads, plant and equipment that account for a significant proportion of energy consumption. A full inventory of energy uses is required to fix the baseline conditions and to establish an estimated breakdown in energy consumption.

Measurement and Verification (M&V), included in Task T2.3, is a process of using measurement to reliably determine actual savings created within an individual facility by an energy management program. Savings cannot be directly measured, since they represent the absence of Energy use. Instead, savings are determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in conditions.

M&V activities consist of the following:

- Meter installation calibration and maintenance
- Data gathering and filtering
- Development of a computation method and acceptable estimates
- Computations with measured data
- Reporting, quality assurance, and third party verification of reports

The main aim of the Task T2.3 will be then to provide the basis for the MOEEBIUS Measurement and Verification Protocol that will consist in a novel methodology, combining and extending existing methodologies and protocols (IPMVP [4], LEED [5], BREEAM [6]) to meet the requirements of EU-based stakeholders. The MOEEBIUS M&V protocol will enable more accurate energy consumption baseline adjustment, joint target setting and energy performance levels agreements, LCA/LCC-based measurement and verification of the achieved savings. The MOEEBIUS M&V Framework will set the principles for the holistic modelling activities of WP3 and the definition of the MOEEBIUS local and global energy performance models (building and district level).

Analysis and review

With all the necessary data collected, an thorough analysis can be done to characterize the building performance and enable the comparision of different configurations with suitable indicators.

To that purpose, a simulation model will be developed considering the influence of different Key Performance Indicators in energy consumption. These KPIs will form the basis for routine comparison against the energy baseline [2]

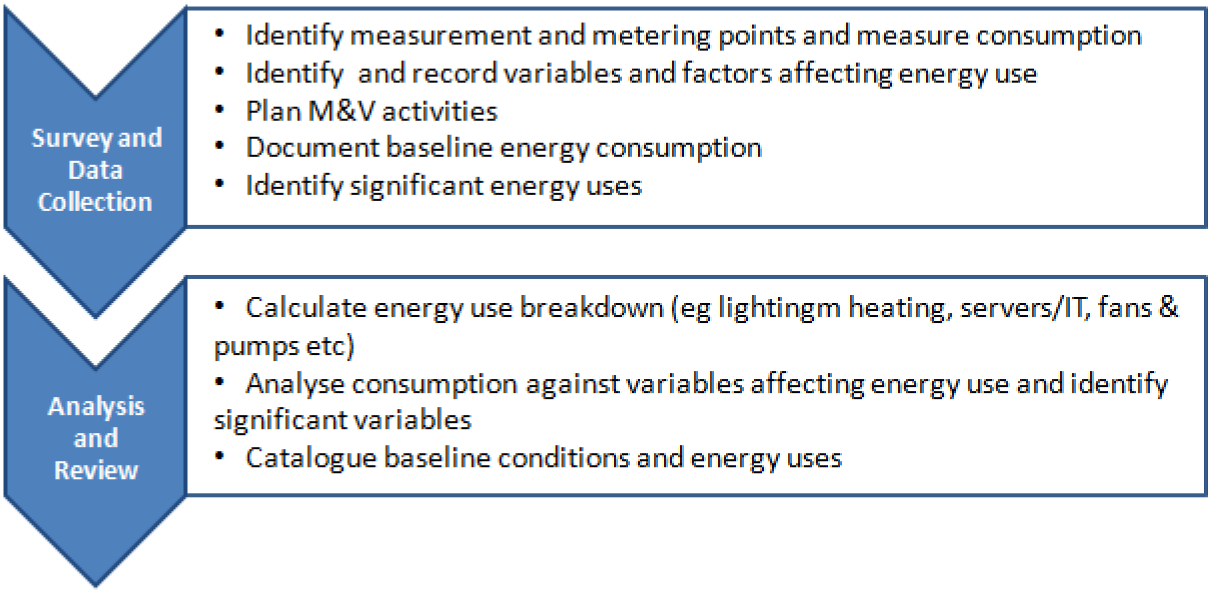

Figure 16. Stages of the ex-ante evaluation methodology

The Baseline, obtained before any intervention from MOEEBIUS with current building state and configuration and energy performance, will be used reference data for comparing the final results after implementing MOEEBIUS framework in the pilot sites.

The energy baseline characterization will include the following elements:

- Historical energy consumption over a sufficient period of time (about one year) and with sufficient resolution (hourly if possible) to identify variations in consumption.
- Inventory of energy uses and an estimated breakdown in energy consumption according to use (eg lighting, heating office equipment, servers, etc).
- Independent and fixed variables that affect the energy consumption and the relevant values (i.e. degree days for heating or cooling, floor area for lighting, building opening hours, metering period length, etc.). This data should be measured at the same time as, and correspond to, the energy consumption data.

4.4.2 KEY PERFORMANCE INDICATORS

The KPIs will be defined in Task T2.3 "Building and District performance assessment specifications and Key Performance Indicators", which main aim is to provide the basis for the MOEEBIUS Measurement and Verification Protocol.

Within the MOEEBIUS M&V framework, it is necessary to determine adequate Key Performance Indicators that reflect parameters needed to be considered for the assessment of the energy performance at buildings and districts level. Considering existing assessment methodologies for sustainable buildings (IPMVP, BREEAM, LEED), other EU projects (recent or on-going), and also standardization or harmonization works, a set of representative indicators will be delivered based on the existing ones, or even by developing additional indicators needed to fulfill the requirements of the MOEEBIUS end-users. The definition of determined values, thresholds or constraints of the indicators will be considered and incorporated especially in cases where mandatory limits are set by the European or national legislations (Cross-regulation approach).

It is known that the data availability and quality for existing buildings and districts is generally poor. Hence, many parameters for the calculation of the indicators are missing or the effort for the data collection for whole urban districts is too expensive. Therefore, analysis oriented to the missing parameters and required effort to access the needed data of existing buildings will be done, and then information from existing methodologies, R&D projects and standards of building and neighbourhood-level will be used to cover the project goals on the M&V aspect.

To make results comparable, buildings and districts energy performance values are usually referred to different basis or indicators, hence, the key performance indicators related to buildings energy use will be a yearly basis.

The main KPI typologies to be considered in the M&V are:

- Occupants Comfort
    - Thermal Comfort
    - Visual Comfort
- Indoor Air Quality
    - Selected pollutants
    - Humidity
- Operations and maintenance metrics
- Energy metrics (energy use and costs)
    - Buildings
    - Districts
- Demand Response

Along with the definition of energy KPIs, the project also intends to address the role of building occupants which are active element in building energy consumption. Therefore, one of the main objectives is to enhance the MOEEBIUS performance evaluation framework with KPIs of Occupants' preferences and non-preferences. MOEEBIUS targets as well the incorporation of HVAC and Lighting devices, hence, special interest will be given to the definition of the thermal comfort KPIs related to HVAC operation and the visual comfort KPIs related to lighting devices operation.

4.4.3 Building Information Models

The Building Information Models of the pilot areas will be prepared to serve as the basis for the simulations to be performed through the BEPS.

MOEEBIUS will use dynamic modelling approaches, proven technological components and novel performance assessment and verification protocols towards enabling the alignment between predicted and actual building performance and the establishment of business friendly environments for ESCO market growth. This will be realized through the fusion of two (currently disjoint) worlds: the Building Information Modelling (BIM) and the Occupants' Behaviour Modelling.

MOEEBIUS will adopt a hybrid approach that combines White-Box modelling techniques (at the level of BIM and District Modelling) with Black-Box modelling approaches (focusing on occupants' behaviour) to deliver an innovative system that captures the real complexities of actual buildings and districts and allows for the correct understanding of user behaviour´s impact. Enhanced, accurate and dynamic behavioural (individual and/or group) profiles will complement improved static BIM models (with reduced simplifications and able to accommodate LCA-LCC parameters) to enable advanced and optimized predictions through, the appropriately configured, MOEEBIUS Building Performance Simulation Engine.

In Task T3.6 "Local and Global Energy Performance Modelling", energy performance models (at both the building and district level) will be developed allowing the Enhanced BEPS (T5.1), the Dynamic Assessment Engines (T5.3, T5.4) and ultimately the Integrated MOEEBIUS DSS (T6.4) to represent, simulate and assess the energy performance of buildings and whole districts based on the Building and District performance assessment methodology and respective Key Performance Indicators specified in Task T2.3.

The resulting models will integrate the whole modelling work performed in T3.3, T3.4 and T3.5, while also focusing on enhancing static BIM models to give them the ability to exactly represent complexities of the actual building by addressing areas and aspects that are dominated by assumptions (e.g. thermal modelling and dynamic heat transfer). In this way, MOEEBIUS will ensure the delivery of more dynamic and representative holistic models (without increasing significantly the complexity introduced) which stands as the project's flagship towards holistically diminishing deviations between predicted and actual performance in buildings.

5 Installation, calibration, evaluation and optimization

This section summarizes the plan of activities to be conducted in MOEEBIUS pilots, including pilots adaptation, equipment installation and operation.

The activities will be distributed over the following consecutive tasks to be developed between the months 21 and 40 of the MOEEBIUS project:

- Installation of the required equipment
- Initial calibration of MOEEBIUS models and profiles
- First real-life trial of the MOEEBIUS framework and evaluation of gap reduction
- Optimization of DR and EE strategies, further calibration of models and roll out of the second trial phase

5.1 Installation of the required equipment

MOEEBIUS will develop a new innovative non-intrusive, low-cost, plug & play and self-configurable sensor/ actuator wireless device (integrating a wide range of sensors, such as luminance, occupancy, temperature, humidity and control interfaces) with enhanced communication capabilities and energy autonomy (MOEEBIUS NOD), to complement existing monitoring infrastructures in buildings and ensure the collection of all required information for the holistic energy performance assessment and optimization of the building environment.

MOEEBIUS NOD will represent the system front-end towards appropriately understanding occupant behaviour in the built environment. Its main purposes are:

- To gather information about perceived ambient conditions (with the integration of a variety of the mentioned sensors at individual spaces
- To collect user responses to these conditions (through e.g. gesture-enabled control actions over lighting and HVAC loads). In cases that optimized sensing capabilities are required, the adoption of a sentinel-based topology will be followed to significantly reduce the infrastructure cost and enable a direct point-to-point communication link with the "Sentinels".

From a computational point of view, a gateway will be designed around a future proof processor with adaptive performance (e.g. ARM Cortex series). The gateway will ensure smooth multi-radio point-to-point communication with low-power sentinels (MOEEBIUS NODS) reducing the impact on deployment issues compared to dynamic routing strategies between each node. The low-power nature of MOEEBIUS NOD will ensure that no additional consumption is caused, affecting building energy performance.

This activity will start in July 2017 (M21) and will end in September 2017 (M23).

5.2 Initial calibration of MOEEBIUS models and profiles

Modelling of the dynamic aspects (occupants, weather), which affect energy performance, will be a continuous process within MOEEBIUS, enabling successive calibration, updating and fine-tuning on the basis of real-life measurements.

Therefore, a calibration of the simulation models will be carried out, during which the MOEEBIUS individual modules and integrated framework will be trained and fine-tuned based on real-life data.

The dynamic visual and thermal comfort models (developed in T3.4), which facilitate the definition of accurate comfort profiles of occupants within buildings and that are integrated to the overall MOEEBIUS framework, will consider occupants as dynamically interacting entities within their environment through appropriately controlling their HVAC operations and luminance conditions. These Models will be created and calibrated with the aim to enable dynamic user profiles that reflect and more specifically quantify the discomfort of occupants based on the analysis of evidence captured exclusively from the observation of users' control actions under specific conditions.

In the same way, the enhanced Indoor Air Quality Models (created in T3.5) that are able to evaluate indoor hygienic and health/well-being conditions through identifying contamination of the air with various chemical compounds will be also calibrated in this stage at the Living Labs.

This activity will start in October 2017 (M24) and will end in January 2018 (M27).

5.3 First real-life trial

A first real-life trial of the MOEEBIUS framework will be done in order to fine-tune the MOEEBIUS platform and evaluate the gap reduction between the actual performance of the buildings and the performance predicted by the BEPS.

This first trial will allow an overall analysis and evaluation of the pilot operation phase of the project across the pilot sites of MOEEBIUS. To this end a consolidated evaluation will take place for providing individual, aggregated and comparative assessments of pilot results, considering energy efficiency, peak-load management, user acceptance and overall ICT framework performance, along with its cost-efficiency (savings vs costs), while defining further improvement actions, interventions and measures to be applied towards successfully exploiting MOEEBIUS components as commercial products that address real market and user needs. Evaluation will involve all stakeholders of the MOEEBIUS Living Lab, so as to achieve the holistic assessment and collaborative devising of the MOEEBIUS Framework.

During the project pilot trials, a Dynamic Price Simulation Engine will be used to generate variable pricing data, which in combination with demand elasticity data (as acquired from the MOEEBIUS pilot sites) will be analysed through the tool designed in T6.1: the Visual Analytics platform for the Aggregator.

Overall, the MOEEBIUS project relies on a well established validation process, which means that no further steps are carried out before prior steps have been successfully concluded. Once the first real-life trial is correctly finished, the last step "Optimization" starts.

This activity will start in February 2018 (M28) and will end in May 2018 (M31).

5.4 Optimization

On the basis of accurate, realistic and robust occupant behavioral models and DER flexibility models calibrated since the first results obtained in the first trial phase, Demand Response strategies will be formulated to offer fine control optimizing the operation in the framework of energy efficiency-driven or demand response-driven strategies.

The load models will provide flexibility and support the indoor environment optimization in terms of comfort and health preservation. In this terms, HVAC and lighting appear more appropriate and more favourable to this end.

At a neighbourhood level demand-response capacity and flexibility considerations will influence the operation of the buildings and district-energy systems forming part of a wider entity and enabling the simulation and assessment of alternative demand response scenarios and automated control strategies for the continuous optimization of the district's aggregated consumption/demand curves satisfying both demand response and energy efficiency requirements. This will allow the creation of high-level demand flexibility profiles illustrating the response capacity of demand in price-based control strategies for peak-load management optimization.

Finally, further calibration and a roll-out of a second trial phase will be carried out to test again at the Living Labs the deployment of the optimized operation through the MOEEBIUS framework.

This activity will start in June 2018 (M32) and will end in February 2019 (M40).

6 Results validation, impact assessment and Cost-Benefit

This section describes the proposed roadmap for MOEEBIUS consolidation and final evaluation of project outcomes in technical aspects, user experience, impact realization and cost-effectiveness validation.

Three main pillars of the results validation are defined in order to evaluate the fulfilment of the project objectives regarding the user and business requirements, explained in D2.1 "End-user and business requirements":

- **Technical assessment of the MOEEBIUS framework**

MOEEBIUS will provide precise allocation and real-time assessment of detailed performance contributions of individual critical building components and real-time building performance optimization through control and maintenance. This information will be continuously updated at real time to allow MOEEBIUS end users with an enhanced Simulation tool that enables accurate predictions through addressing M&V inefficiencies.

The information provided by the MOEEBIUS framework to the end users (ESCOs, Aggregators, Maintenance Companies and Facility Managers) is a detailed set of information addressing the identification of maintenance needs and defining alternative maintenance schedules.

- **Impact analysis assessment of the MOEEBIUS framework**

This analysis aims to identify the evaluation criteria based on which the impact analysis of the MOEEBIUS framework will be evaluated towards its objectives and under different evaluation scenarios. The impact analysis should be defined so that all the critical aspects of the MOEEBIUS framework performance reflect the different stakeholder needs and requirements are examined. For each of the evaluation domain a number of key performance indicators will be identified in order to evaluate the MOEEBIUS framework considering all functional and non-functional aspects.

The ultimate impact of the MOEEBIUS framework is the cost-efficiency analysis (savings vs costs) which will enable the establishment of novel, more robust and attractive business models, characterized by attractive payback periods and increased utility for all stakeholders involved (ESCOs, Aggregators, Maintenance Companies, Facility Managers, Building owners).

- **User acceptance assessment of the MOEEBIUS framework**

The MOEEBIUS evaluation framework will be complemented by means of the user acceptance assessment. This evaluation refers to the acceptability, reliability, easiness to use and attractiveness offered by the MOEEBIUS framework to its users and to other people affected by its use, aiming to examine the impact of the MOEEBIUS framework to the end stakeholders of the system.

For this purpose, besides the monitoring and assessment of some quantifiable indicators, a questionnaire will be done to the Living Lab participants (building occupants and facility managers) to have their feedback concerning MOEEBIUS system based on their experiences during pilot realization.

Questionnaires will be distributed to the involved pilot sites´ end users and will be collected in order to analyse the results towards the evaluation of system performance and project outcomes and to have final results from the user acceptance evaluation. The questionnaires will be delivered to the end users in last months of the MOEEBIUS framework validation during the organization of workshops and through e-mailing. A number of appropriate and relevant questions will be incorporated in the respective questionnaires to properly guide the end users to provide their answers through closed questions, while also allowing for feedback and comments provision in short text format.

The questionnaires for the Building Occupants will be important to address various aspects including [7]:

- MOEEBIUS system, in terms of comfort improvement/restrictions, usefulness, usability, reliability, system failures, energy savings.
- Level of Satisfaction and Obtrusiveness with regard to the continuous monitoring.
- User Interfaces of the MOEEBIUS system. Easiness, aesthetic, variety and usefulness of data.

The questionnaires for the Facility Manager will address various aspects including:

- MOEEBIUS system, in terms of usefulness, usability, reliability, improvement of building energy performance management, system´s failures.
- User Interfaces of the MOEEBIUS system. Easiness in use, attractiveness, variety of data and visualizations of the results, usefulness for defining the optimal strategy.

7 Living Lab Dissemination and Communication Plan

The major focus of the MOEEBIUS dissemination framework is to ensure that the project's outcomes (scientific results, tools and methodologies developed, validation results, etc.) are widely disseminated to the appropriate target communities, at appropriate times and via appropriate methods. To this end, the MOEEBIUS Living Lab is expected to play a significant role, by supporting, among others, knowledge transfer and experience sharing within an Open Innovation and EU Competitiveness Reinforcement Ecosystem.

The Living Labs will be an important means as demos to show the product developed, its deployment and application and the results obtained with the organisation of workshops and activities for the knowledge replication, the transfer of results and the promotion of open innovation, activities that will be developed in Task T8.3.

One of the major objectives of Task T8.3 is to take advantage of the pilot sites potential to maximise dissemination and exploitation. Three living lab dissemination and training workshops will be performed at each of the pilot sites in order to:

- Raise awareness, engagement and acceptance of pilot site occupants and stakeholders, including also the preparation and distribution of appropriate material.
- Involve end users in the requirements definition activities of the project.
- Training users and contributing to the adoption of the MOEEBIUS concept and operation in the pilot sites of the project.
- Involving all stakeholders in the evaluation of MOEEBIUS results. All living lab activities relevant to the engagement of stakeholders in all project phases will be designed under WP7 (T7.3 for UK Pilot, T7.4 for Portuguese Pilot and T7.5 for Serbian Pilot) and WP8 (T8.1 "Dissemination & Communication Plan" along with T8.3 "Living Lab Workshops and Activities for Knowledge Replication, Transfer of Results and Promotion of Open Innovation").

The training activities to be held within the context of MOEEBIUS play a crucial role in the overall dissemination and exploitation efforts of the project. The Training Activities Strategy of the project aims to reach the targeted stakeholders through a series of training programs. These may combine different training methodologies, while their contents will be specified according to the stakeholders' types, roles and knowledge levels.

The effectiveness of the workshops will be measured by the number of attendees and the number of Follow-up activities resulting from the workshops.

It should be also mentioned that the objectives of MOEEBIUS Dissemination are not limited to passive, a posteriori awareness and acceptance. Instead, dissemination is inherently embedded on many MOEEBIUS activities, from requirements definition to final evaluation, through the utilization of the Living Lab of the project as a means to involve end-users and stakeholders of the project developments in all phases of the project implementation.

To this end, awareness and social engagement activities towards end-users and occupants in the project's pilot sites, as well as, towards ESCOs and aggregators all around the EU (with emphasis given on the countries participating in the consortium), will comprise a fundamental element of the MOEEBIUS Living Lab.

Due to the great importance of the pilot sites stakeholder's participation in project activities, specific dissemination means have been designed to reach them and foster awareness and acceptance of pilot activities. This target group presents considerable differences to other groups, due to:

- The lack of technical background in the topics addressed by MOEEBIUS
- Possible difficulties with English-written promotional materials
- Possible concerns about personal privacy and disturbance of normal business activities and performance, during the execution of the pilots
- Dependence of the MOEEBIUS project success on their explicit consent and/or active participation

Dissemination goals toward this group are very specific and critical to the success of the project. These goals include:

- The promotion of project awareness among the pilot actors
- The fostering of active acceptance of the pilot activities impacting the actors, including:
    - Obtaining legal authorizations
    - Collecting necessary information
    - The physical deployment of the pilot
    - The pilot realization
- Establishment and maintenance of adequate communication channels with all types of pilot actors

For the involved end users apart from the building occupants, as the regulators, policy makers, buildings/ business managers and staff, short executive summaries of the project will be created, including the following items:

- Brief background (European project focused on energy efficiency and greener buildings, very high-level overview of the project objectives)
- Reasons for the actor to get actively involved/authorize in the pilot and what is specifically expected from him
- Targeted information (what the actor needs/wants to know about the pilot)

It will be convenient to reinforce the formal dissemination with previous or parallel informal contacts and face-to-face meetings or presentations, in order to create empathy, fight bureaucracy, proactively clarify questions and establish direct contact points (phone, email).

The approach to occupants must be different. It is necessary, for each Pilot, to identify the key groups of occupants and what is needed from them (it could be for example passive acceptance, explicit consent or active participation) and how it is needed. Direct contacts and follow ups with occupants will be prepared in coordination with pilot partners to avoid any conflicts of interest. Specific dissemination materials, one kit with training material prepared before month 18, will support these activities.

8 Conclusions

This document outlined the activities to be developed at the Living Labs. All activities were described and organized in groups following the sequence of development, respecting the dependencies existing among activities.

Four groups of activities have been developed. The first group comprises the activities to be done before any intervention to the pilot sites from MOEEBIUS framework, like the pilot sites analysis, the baseline definition, the end-user requirements collection and the definition of the scenarios to study. The second group comprises the activities that imply changes of the current state of the pilot sites (equipment installation and calibration) and the roll-out period with the first trials developed at the sites. The last group comprises the results validation and the impact and cost- benefit analysis.

In parallel with this sequence of activities, the fourth group of activities aims to disseminate the project and its results and to establish efficient and smooth communication during the project, awareness and engagement framework involving all the MOEEBIUS living labs´ stakeholders. These dissemination activities start at the first month of the project and will be developed along the project duration.

This document will serve as a guideline for the responsible stakeholders in developing activities in the Living Labs, showing "What to do", "When to do", the logics among different activities and their dependencies, the required data and materials.

9 References

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