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Specs of SEOR methodology and Enhanced Display Energy Certificates

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Lead beneficiary	**HYPERTECH**
Authors	**Tsatsakis Konstantinos (HYP), Tsitsanis Anastasios (HYP), Desislava Todorova (BAL), David Burke (BOC), Wilfrid Utz (BOC), Alexandar Vodenicharov (BAL), Christos Malavazos (GD)**
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Author(s)	Tsatsakis Konstantinos (HYP), Tsitsanis Anastasios (HYP), Desislava Todorova (BAL), David Burke (BOC), Wilfrid Utz (BOC), Alexandar Vodenicharov (BAL), Christos Malavazos (GD)					
Description of the related task and the deliverable in the DoA	The goal of the task is to define realistic specifications for the Systemic Enterprise OR framework & Enhanced DECs modelling framework. The generation of detailed specifications for SEOR & eDECs starts from the requirements documented during T1.1 and takes into account the constraints and methodological aspects of the proposed framework, such as the integration of information about business processes, building characteristics, behaviour of organizational actors and near real-time energy monitoring in order to produce the eDECs. This deliverable documents the overall SEOR model with the respective specifications for the provision of enhanced Display Energy Certificates.					
Comments						

V	Date	Authors	Description
0.1	2015-05-16	HYP	1st draft version of the deliverable focusing on ToC and SoTA Analysis
0.3	2015-05-20	HYP	2nd draft version of the deliverable providing the methodological framework for SEOR engine
0.3_BOC	2015-06-01	BOC	Contribution on BPM related modelling and KPIs definition
0.3_BAL	2015-06-25	BAL	Contributed on BIM related modelling and KPIs definition
0.3_GD	2015-07-01	GD	Contributed on HM modelling and KPIs definition
0.4	2015-08-31	HYP	3rd draft version addressing the comments from partners
0.4_COV	2015-09-30	COVUNI	Contributed on BCM modelling and KPIs definition
0.5	2015-10-15	HYP	Version ready for review
1	2015-10-31	COVUNI	Checked and released to the Coordinator for internal QA and subsequent submission to the EC.

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1. PUBLISHABLE EXECUTIVE SUMMARY

The main objective of Task 1.2 is to define a reference **Enterprise Operational Rating** (denoted SEOR) for buildings, to be further used by the subsequent work packages in the OrbEEt project. The proposed **Systemic Enterprise Operational Rating** extends and integrates existing Operational Rating Models (UK EPC Model) by incorporating and integrating several dimensions: the ***physical sub-system***, i.e. the buildings and their energy-consuming equipment; the ***human sub-system***, i.e. occupants and their activities in relation to the buildings and equipment; the ***business sub-system***, i.e. the business processes and the business objectives they support. The proposed framework selects from the existing modelling methodologies on energy performance certification (EPC) the parameters that are suitable for dynamic and situational energy management across business domains and their associated KPIs. In this way, OrbEEt extends the concept of existing DECs towards delivering certificates of significantly enhanced spatio-temporal granularity by establishing a dynamic model-based approach (models, methods & tools) for a continuous estimation of their constituent metrics and indicators.

This deliverable thoroughly describes the extended **Systemic Enterprise Operational Rating (SEOR)** method along with specific key performance indicators, and elaborates on the existing methods and indicators for constructing such a rating. We first explore the main dimensions and attributes of building performance and efficiency. We seek to identify the directly measurable attributes based on the building aspects typically available during design phase. Normalization of these performance aspects is a challenge in any effort to establish reusable building ratings and benchmarks. Building performance needs to be estimated given the parameters typically monitored in a building while the unit of measurement for the composite building operational rating is in tones of CO2 emissions per year, in line with the EU regulations, standards and practices for introducing a measure of the carbon footprint in the building sector. Our defined building performance rating (SEOR approach) is similar but complementary to existing energy rating methodologies.

The OrbEEt Enhanced DECs framework takes into account all major loads related to organizational activities and most importantly, establishes a direct link between energy performance and various elements of the organizational ecosystem (spaces/offices, teams & activities), allowing for a more systemic view (drill-down and drill-through) beyond typical DECs. Consequently, occupants will be provided with timely and concrete information on how their everyday actions influence building energy performance as well as how and how much they can actually improve their behaviour. A functional view of eDECs is provided as part of the deliverable in line with the requirements analysis.

Finally, this deliverable influences the functional specification of several modules, responsible for managing or presenting the performance indicators identified. Therefore, the model presented impacts to the future work to be done in work package WP2 (SEOR modelling phase) and WP3 (SEOR development phase).

2. INTRODUCTION

2.1 Purpose and target group

This deliverable defines the integrated **Systemic Enterprise Operational Rating framework** (denoted as **SEOR framework**) which extends existing Energy Performance Models for enterprise buildings. This is done by incorporating, extending and integrating several dimensions of the Building Eco-System: the so-called BIM Sub-System, i.e. the building construction and its energy-consuming equipment; the Occupants Sub-System, representing occupancy behavior patterns under different context conditions; and the Business Sub-System, representing the business processes and business goals, and their impact on human preferences and on energy aspects. By explicitly incorporating business processes and occupants preferences as main factors of this ecosystem, an enhanced building energy performance model is expected, which allows for a more accurate estimation of the operational rating of enterprise building.

It should be noted that this energy performance model does not focus on the structural aspects of buildings, but will only address those aspects which affect occupancy and the aspects of energy performance, business performance and individual comfort for its occupants. For example, it will not deal with the structural or mechanical characteristics of buildings, such as wall material, insulation, etc, but rather analyze how walls establish working areas and affect occupant presence and movement within the building. Also, it will not focus on the energy performance of a specific HVAC system, but on the estimation of the variability of the energy performance due to enterprise- and occupant-induced factors, e.g. due to business needs or due to occupancy preferences.

The enhanced **SEOR framework** incorporates several enterprise aspects of building use:

- **Operations and Management of the Building and ICT Infrastructure**, particularly the management of energy-related parameters and its related KPIs (such as energy consumption & CO2 emissions);
- **Business modelling of actors** to explore the ecosystem state space and determine the impact of enterprise workflows and occupancy patterns on the building performance KPIs.
- **Surrounding environment**, i.e. internal environmental conditions, such as temperature, humidity, air pressure, air flow.

Based upon this operational model, a holistic Systemic Enterprise Operational Rating Framework will be developed in another task of OrbEEt project, consisting of the building operational performance calculation method and the associated algorithms and tools, which exploits the measurements and observations of the enterprise state and its dynamics at various times and scales. This system can be extended in the future, for instance to set the reference tool for an enhanced operational rating on similar types of buildings.

2.2 Contributions of partners

The main goal of this task is to define the detailed specifications for SEOR & eDECs modelling, taking into consideration the integration of information about:

- business processes (BPM)
- building characteristics (BIM)

- behaviour of organizational actors (Human Preferences)
- real-time energy monitoring

By taking into account the different fields of analysis BOC will contribute on Organizational Related Aspects of SEOR (BPM) through the definition of enterprise business processes. BALKANIKA, the ESCO Company of the consortium will lead the definition of Building/Energy related aspects of SEOR (BIM) while Grindrop LTD will integrate Human Profiling related aspects in the proposed SEOR framework. HYPERTECH will lead the overall work and provide the integrated enhanced SEOR framework by taking into account the contribution from the partners involved.

2.3 Baseline

The deliverable is structured and organized in the following chapters:

- **Chapter 2** presents an overview of the terms related to the operational rating and the overall energy performance certifications. In addition, the current status on EPC framework in Europe is provided, with special focus on the status of the pilot site counties.
- **Chapter 3** details the proposed SEOR modelling framework of OrbEEt. This is the core part of the work on the deliverable, as the proposed model incorporates energy, business and user parameters under a common framework towards the provision of the innovative OrbEEt SEOR mechanism.
- Along with the modelling aspects of the SEOR framework, the OrbEEt Enhanced Display Energy Certificates will be defined as part of the work. To this direction, a list of specifications will be provided in **Chapter 4** addressing the end users requirements as expressed at the very early phase of the project.
- **Chapter 5** provides a summary of the Systemic Enterprise Operational Framework of OrbEEt Project along with the next steps of the work to facilitate the work on the development phase.

2.4 Relations to other activities

This deliverable is mainly based on the results from *T1.1 End User and Business Requirements*, provided at the very early phase of the project, highlighting user needs and business requirements to be addressed on the innovative operational framework proposed within OrbEEt Project. More specifically the focus is delivered on the coverage of energy, business and occupants needs that set the baseline for the extraction of the enhanced rating framework. Special interest is delivered also on the requirements related to the visualization of information through the respective user interfaces which set the specifications for the enhanced display energy certificates to be modeled in the project. In addition, and as the SEOR framework will set the indicators analysis for the Behavioural triggering framework, a close linking with T1.3 (Organization Behavioural Change Framework Design & Specifications) is considered.

As the proposed framework incorporates energy and business aspects, there is a high need to define the methodology for BIM (Building information Model) and BPM (Business Process Modelling) processes. The clear definition of the respective models will further set the baseline for the work in Task 2.1 through the definition of the energy and building characteristics that should be addressed on the proposed framework. Further, and by taking also into account the business processes modelling methodology , the definition of high level business processes at pilots will be defined in Task 2.2. Therefore, the work towards the definition of SEOR framework is delivered in parallel with the extraction of the characteristics from pilot sites (both energy related characteristics and business processes definition) towards the provision of the Enhanced SEOR framework fully focused on end users' needs.

The proposed Systemic Enterprise Operational Rating model will further trigger the extraction of the specifications, to be further defined as part of the overall technical architecture of OrbEEt software (Task 1.4) towards the actual development of the system component in WP3 (Task 3.3). In addition, the proposed framework will set the baseline for the Open Reference models (Open Reference Models for Systemic Enterprise Operational Rating and Enhanced Display Energy Certificates –Task 2.4) which will stimulate the collaboration between OrbEEt participants and the potential users of its outcomes.

Therefore a strong interconnection of Task 1.2 with different parts of the work within project reveals the impact of the SEOR model towards the final deployment of OrbEEt overall platform.

3. Current Status on Operational Ratings & Display Energy Certificates

3.1 Current Status in Europe

Energy Performance Certificates (EPCs) is an integral part of the Energy Performance of Buildings Directive (2002/31/EC1; 2010/91/EU2) [1], and stand as an important instrument to enhance the energy performance of buildings.

The main aim of the EPC is to serve as an information tool for building owners, occupiers and real estate actors. Therefore, EPCs can be a powerful market tool to create demand for energy efficiency in buildings by targeting such improvements as a decision-making criterion in real-estate transactions, and by providing recommendations for the cost-effective or cost-optimal upgrading of the energy performance. [2]

EPCs are currently among the most important sources of information on the energy performance of the EU's building stock. There are now between 5 and 12 years of experience in implementing the Energy Performance Certification in Europe and an important lesson has been learnt through the enforcement of the first EPBD. Towards this direction, the EPBD recast (2010) introduced a set of new requirements (i.e. quality controls, penalty system, promotion of the EPC in the retail market and advertisements, etc.) that, once fully implemented at national levels, may deliver a significant improvement. Additionally, EPCs have the potential to become even more effective instruments to track buildings' energy performance and the impact of building policies over time as well as to support the implementation of minimum energy requirements within the regulatory process. Europe's buildings are responsible for 38% of the total energy demand in EU-28. Therefore an improvement in energy efficiency in the building sector is among the key elements of the EU's climate and energy agenda. Based on the analysis of the current status of implementation of the Energy Performance Certification, a list of guidelines/needs already provided on the EPBC recast should be addressed by the national regulatory frameworks towards the enhancement of the role of EPC as a mechanism for the establishment of an energy efficient environment. A summary of the main guidelines is presented in order to set the boundaries for the proposed SEOR framework.

Need to improve enforcement of the EPC schemes in Member States and strengthen the monitoring of EPC scheme compliance both at Member State and European levels.

There is an urgent need to strengthen the monitoring of EPC scheme compliance (both at Member State and European level), especially in regard to independent control systems and enforcement of the penalties for non-compliance. Lack of understanding for the benefits of the EPCs is among the key challenges that need to be addressed in the future. Effective EPC schemes will support the improvement of the energy performance of the existing building stock at market level and provide very useful data for further monitoring and adjusting of buildings policies.

Therefore the main objective is to define an Operating Rating framework, which will provide useful data for monitoring of energy performance and will be easily adjustable on different countries, following the way for a common approach along Europe

Need to strengthen the role of EPCs in the context of national legislation, especially for renovation policies and programmes

EPCs are not only a valuable source of information for the building owner regarding cost-effective measures, they can also be an important tool to evaluate and monitor the renovation rate of the building stock. Moreover, EPCs should become a requirement for more effective financing of renovations, especially through Cohesion Policy Funds. Important steps in applying for funding shall be the identification of the energy saving potential (based on the best available building stock data) and the definition of eligible types of measures. The compulsory consideration of the energy label in projects financed with public funds has been already recognised across Europe.

The main objective is to define an Operating Rating framework, which will not provide a unique indicator for the whole building performance but will further incorporate additional measurements and indicators towards the extraction of enhanced DECs.

Need to introduce further quality assurance measures, especially during the early stage of the certification process.

There is a high need to address a high quality approach on the extraction of EPC framework. Towards this direction, a list of actions should be addressed in order to further enhance the overall methodology. Data gathering for EPCs for new buildings should be combined with an onsite inspection during construction phases. The quality of input data for the calculation has a major impact on the quality of results. In addition, intelligent tools for the quality check of the EPC data should be used, such as plausibility check in the calculation software and/or the EPC registers. With the use of digital solutions and tools it is possible to optimise the process of issuing, validating and verificating the EPC. Finally, there is a need for further harmonisation of the quality check of the EPCs, especially for random selection of the “statistically representative sample,” as well as including re-certification by an independent expert in the process of verification.

The main objective is to set a standardized auditing approach towards the extraction of the Operational Rating. To this end, standardized and open source tools should be used for the extraction of useful information

Need to promote the effective use of the EPC data

A well-functioning EPC system accompanied by an EPC database provides a ready-to-use source of information on the building stock. There is an increasing number of the best practices across Europe that demonstrate the added value of EPC data for policy making (e.g. to inform relevant renovation strategies) and monitoring, as well as market and research analysis. The European Commission should support Member States in the development and strengthening of central EPC registers, especially in the context of a solution to tackle the private data issues, and tools for data analysis. Standardized methodologies and formats of data gathering and sharing should be promoted. There is a need to further promote the EPC schemes as a tool for mapping and monitoring the national and European building stock. Once properly implemented, it will allow assessment of real market needs and the potential for energy efficiency improvements in the building sector.

The main objective is to further exploit building operational rating towards the establishment of an energy efficiency environment. To this end, the effort is delivered on the way to exploit Building Operational Rating results with the most beneficiary way.

The overall perspective of EPC approach in Europe seems to be beneficial for the member states towards the delivery of an energy efficiency environment on the basis of European Commission which has proposed binding targets to reduce energy consumed of at least 27% in 2030. Most of the actions mentioned on this section are focusing on activities towards the dissemination of EPC framework across Europe. Thus, and following a top down approach, there is a high need to address these specific guidelines of interest by further extending the existing status towards a more dynamic Operational Rating framework. To this end, the proposed enhanced operational rating framework should address the main requirements as expressed on EPBD recast [3]. Prior to the detailed analysis of the Systemic Enterprise Operational Rating, an overview on the current status on pilot countries is needed to define the common line specifications that will lead the modelling of the proposed framework.

3.1 Baseline Energy Performance Certificate

The baseline EPC approach is defined as the common baseline from the overall review on E.U. states and by taking into consideration the EPBD mandates. As a starting point on the EPC process, the distinction among asset rating and operational rating is considered. [4] [6].

The asset rating is a measure of building quality though it provides no information about how the building is operated in practice. An asset rating models the theoretical, as-designed energy efficiency of a particular building, based on the performance potential of the building itself (the fabric) and its services (such as heating, ventilation and lighting). On the other hand, the operational rating records the actual energy use in a building over the course of a year, and benchmarks it against buildings of similar type. To this end, in order to understand and manage the energy use in a building, both ratings are required as they show different aspects of a building's total energy performance. The building quality (provided by the asset rating) has a large impact on the total emissions, but does not explain all emissions. Other factors such as unregulated loads (e.g. IT, plug-in appliances) or building user behavior can also create emissions, which are reflected in the operational rating. Two offices with the same asset rating could have very different operational ratings – a building with a low rating is used well by its occupants, a building with a high rating is used badly. In the latter, measures to change the behavior of the end users will be the best option for reducing energy use and carbon emissions. [5] Towards this direction, operational rating approach is the preferable for the extraction of accurate EPCs as it incorporates occupants' processes as a critical parameter on energy performance evaluation. Operational rating is defined as a dynamically adjusted indicator, focusing on the operational characteristics of the building and not only on the static building elements that define the asset rating operation. To this end, and as OrbEEt project is focused on the way occupants interact with the building towards the definition of the energy performance, Operational rating methodology stands as the baseline for the proposed framework. By following UK regulation which has fully adopted Operational Rating as the methodology for EPC assessment [6]:

The *Operational Rating* (OR) shall be calculated as the relevant total carbon dioxide emissions of the building over an assessment period divided by the degree day and occupancy corrected CO2 density benchmark. In the case of a composite benchmark assessment, the relevant total carbon dioxide emissions of the building over the assessment period are divided by the overall Composite CO2 Benchmark (CB).

Thus the overall operational rating is expressed as:

$$OR = \frac{Building\ CO2emissions}{Building\ area} * \frac{100}{Typical\ CO2emissions\ per\ unit\ area}$$

In addition to the high level definition of Operation Rating indicator, the details of the baseline EPC framework are further provided in the next sections.

3.1.1 Defining the building characteristics

The baseline framework applies to buildings, or parts of buildings designed, or altered, to be used separately. In an ideal situation each building has its own energy meters or, where only part of a building is occupied, that part is metered separately. [9] [10] [11]

Where there is a group of buildings on a site that is metered only at site level, then each building should normally be assessed individually. The energy used by each building is determined from the site energy consumption on a simple area weighted basis. The process of disaggregating the energy on an area weighted basis means that the OR for each building will be the same and equivalent to the value that would have been obtained if a site based calculation had been carried out.

The building area measurement is the Total Usable Floor Area (TUFA) as the "total area of all enclosed spaces measured to the internal face of the external walls". Within the Total Usable Floor Area, some covered areas may be untreated (neither heated/cooled nor ventilated), and are termed accessible unconditioned areas (for example attics and basements). Although the calculation of the OR is not adjusted to take any account of these areas, these areas are recorded as part of the data entered into the calculation procedure. Note that where a benchmark is available for the accessible unconditioned space, then a composite benchmark approach should be adopted.

3.1.2 Determining energy consumption

The ultimate aim is that all energy flows into the building will be metered. It is necessary for 95 per cent or more of the energy consumption of the building to be metered or estimated within acceptable limits. Where insufficient metered or estimated energy consumption information is available to carry out the OR calculation, then a default high value is given to the OR. This indicates a rate of double the amount typical for the type of building, and is associated with a grade G (worst performer) label. This rule highlights the importance of measured data during the operational rating process. [8]

The aim of the OR is to compare the annual energy consumption of the building with that of a building typical of its type. In some cases, though, the building may include activities that consume energy and which are not considered typical of that building type. Including these activities could reduce the validity of the comparison, and so it may be reasonable to subtract these separable energy uses in certain circumstances.

In order to be able to isolate and remove the annual separable energy consumption from the total, any separable energy uses must be separately metered. This is to ensure that the adjustment is based on robust evidence and will also encourage the installation of sub-meters.

The calculation of the OR is based on annual energy consumption, which is defined as the energy consumed over the assessment period of 365 days. The ideal situation would be where all energies are metered over the same one-year period. [9] However it is recognised that, at least during the early years of carrying out the assessment, the different forms of energy consumed are likely to have been measured over different periods, and may be displaced in time from each other. Provided the differences in period length are within reasonable limits, the calculation must accommodate these by **extrapolating or interpolating** from shorter or longer measurement periods. The method of extrapolating or interpolating energy use from measurement periods that are not exactly one year **depends on the use of the energy**. The main heating energy needs to be treated differently to the energies used for other purposes. Uses of energy other than for space heating are considered to be relatively constant in use throughout the year, and so correction can be applied on a pro-rata basis according to the length of the measurement period. The main heating energy is considered to be at least partially weather dependent, and so the measured energy should be corrected in proportion to the number of heating degree days in the measured and in the 'extrapolation' or 'interpolation' periods.

3.1.3 Determining Carbon dioxide conversion factors

Buildings cause the emission of carbon dioxide (CO2) as a result of their consumption of energy in all its various forms. The factors of interest are therefore the annual energy consumptions of each form of energy, and the CO2 conversion factor associated with each. Standard values of CO2 conversion factor are needed for each form of energy used in buildings, and these have been determined for most fuels by government. [9]

The CO2 conversion factors used for EPC are intended be representative of the period for which the OR is to be calculated. The CO2 conversion factors are different per country depending on the type of energy mix. Where fuel consumption is measured in terms of mass or volume (e.g. for solid and liquid fuels) rather than in energy terms (e.g. kWh), the energy content of the measured fuel consumption should be derived using the Gross Calorific Value of the fuel under normal conditions. The energy content of the fuel consumed over the assessment period may then be converted to CO2 emissions by using the conversion factors specified.

3.1.4 Typical carbon emissions benchmarks [7]

Building performance can only usefully be compared with other buildings that carry out the same or similar functions. It is not helpful to compare, for example, an office with a hospital, and so different performance benchmarks are required for each type of building function.

The national legislation prepared operational benchmarks for main categories of building, and have listed together the different types of building and use that would be included within each of the general category descriptions. These benchmarks are expressed in terms of energy density (kWh/m2/yr), and are expressed separately as the electrical and non-electrical (fossil-thermal) components of the benchmark. Representative emissions densities (kgCO2/m2/yr) are also indicated, using representative CO2 emission factors, for information only and not for use in the calculation procedure. The benchmarks have been prepared to represent building use under a number of standardised conditions:

- The weather year is standardised at a specific number of heating days per year
- A defined occupancy period is noted for each category individually
- A standard proportion of the non-electrical energy density benchmark that is considered to be related to the heating demand is noted for each building category individually.

The purpose of these factors is to form part of the procedure of adjusting the benchmarks to better represent the characteristics of a building being assessed, where the basic benchmark should be adjusted to the location and use of that building.

More specifically, and what related to weather conditions, the category benchmark is always adjusted according to the 'history' of temperature in the building location, for the one-year assessment period over which the OR is to be calculated. The adjustment is based on the number of monthly degree days over the 12-month assessment period for the region in which the building is located. The adjustments are for heating degree days only, and no adjustment for cooling degree days is undertaken.

By analyzing occupancy factor, when the building is occupied for significantly longer periods than the standard hours quoted for in the benchmark category, the benchmark includes a numerical factor allowing correction for extended hours of use to be made.

In any way, to obtain the annual occupancy hours we must use the appropriate occupancy measurement systems as indicated for each benchmark category. The two systems of defining annual occupancy hours are:

- The number of hours per year that the number of recorded occupants exceeds 25 per cent of the nominal maximum occupancy, or
- The numbers of hours per year that the premises are fully open to the public according to published opening hours.

Where different parts of the building (falling within the same benchmark category) have different occupancies the lowest occupancy must be used, unless an assessment of occupancy in each part is made and the occupancies combined using the percentages of overall floor areas, i.e. using an area-weighted average.

Therefore, and following the steps of the proposed framework, the operational rating is defined as the ratio of the building to the corrected CO2 density benchmark. Then, and based on the operational rating, a display energy certificate is required to display the performance of the building as a label, which is determined to be displayed on an “A to G” scale, as this is a format easily accessible to the public. An indicative A to G banding of the Operational Rating is determined as the common baseline from the State of the Art Analysis and set the rating for the baseline EPC process.

Table 1 Operational Rating Levels

Operational Rating	“A to G” label
0 to 25	A
26 to 50	B
51 to 75	C
76 to 100	D
101 to 125	E
126 to 150	F
More than 150	G

The aforementioned framework is based on UK regulation, which has fully adopted the measured based approach for the extraction of Operational Rating of the buildings. The respective Display Energy Certificate [9] as extracted from operation evaluation process is further visualized, along with additional information as extracted from the auditing process.

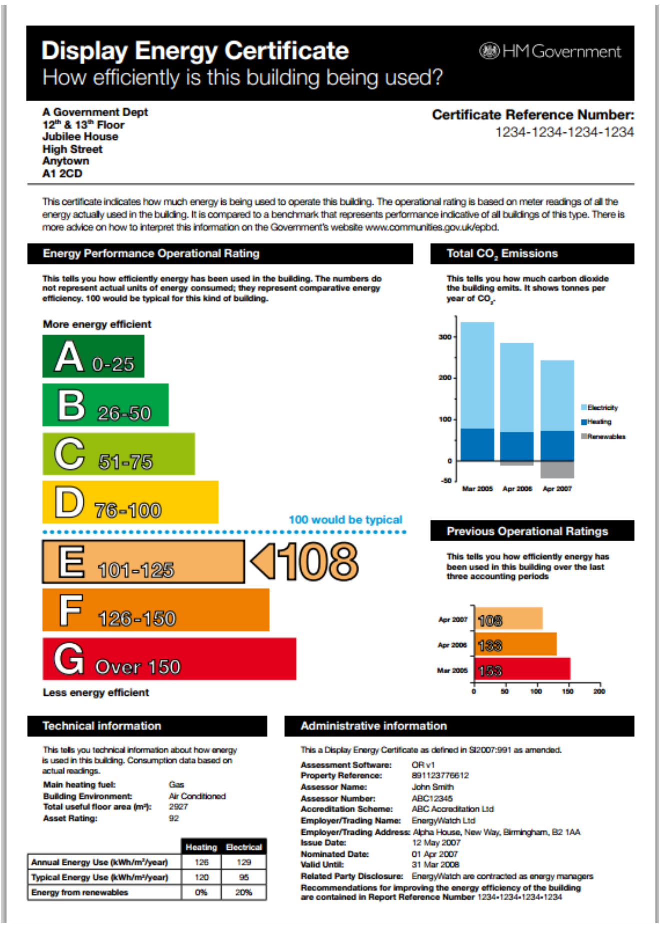


Figure 1 Typical Display Energy Certificate

Knowing how efficiently a building is used in practice, as opposed to a virtual simulation, is simpler, costs less, and allows for better tracking of progress over time. An important factor is also the use of CO2 density as the common ground indicator for the operational rating, addressing the different types of energy sources under a common representation.

Following the detailed analysis of baseline EPC framework and prior to the definition of OrbEEt Enhanced SEOR framework that fully covers users' needs and requirements we need to examine the status on Pilot counties, towards the transformation of current Energy Performance Certificates to the proposed SEOR framework.

3.2 Energy Performance Certificates in Pilot Sites

The OrbEEt proposed SEOR framework stands on top of the existing Operational Rating frameworks towards the extraction of dynamic Display Energy Certificates. Therefore, it is mandatory to summarize the status on energy performance regulation at pilot countries towards the definition of the common parameters to be addressed on the proposed framework. To this end, the main objective of this section is to provide a summary of the EPC models as adopted in Germany, Austria, Spain and Bulgaria. The goal of this section is not to steer present the framework for each country but to align the current approach with the main guidelines as adopted on the proposed SEOR methodological framework.

3.2.1 Energy Performance Certificates in Austria [12]

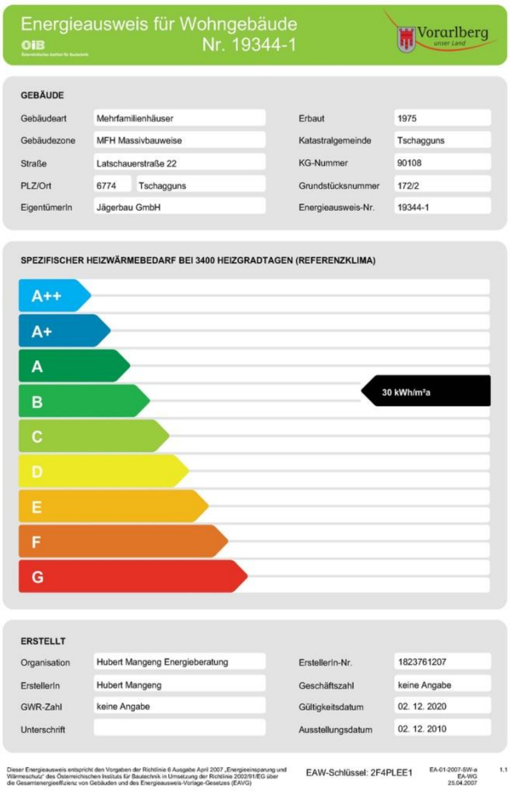
In Austria, the implementation of the EPBD (2002/91/EC) was completed in 2008, after a process of harmonization within the country – previously the nine "Länder" (provinces) had nine different building codes, including quite different regulations concerning energy. The process of harmonization and implementation was managed by the OIB (Austrian Institute of Construction Engineering). The regulations included all types of buildings, i.e., new buildings, major renovations, large non-residential buildings and all buildings when sold or rented. Based on the regulation, each building or building unit e.g. an apartment, is assigned an energy rating while the certificates can only be issued by qualified experts.

The energy certificate is based on ***calculated values only*** and assigns an energy performance label to residential and non-residential buildings or building units. The energy label classifies the buildings on an efficiency scale ranging from A++ (high energy efficiency) to G (poor efficiency). The following figure shows the general data of the building, of the qualified expert and the heat energy demand in kWh/m2 year as key factor for the labeling.

A++	≤ 10 kWh/(m²a)
A+	≤ 15 kWh/(m²a)
A	≤ 25 kWh/(m²a)
B	≤ 50 kWh/(m²a)
C	≤ 100 kWh/(m²a)
D	≤ 150 kWh/(m²a)
E	≤ 200 kWh/(m²a)
F	≤ 250 kWh/(m²a)
G	> 250 kWh/(m²a)

Figure 2 Efficiency Ranging in Austria

To implement the recast of the EPBD, there is a high need to show the primary energy demand and the respective CO2 emissions. Page 2 of the certificate shows detailed data concerning (final) energy demand of the envelope as well as of the HVAC systems, based on specific climate data of the site. The validity of energy certificates is 10 years.



Energieausweis für Wohngebäude
Nr. 19344-1
OIB
Vorarlberg unser Land

GEBÄUDE

Gebäudeart	Mehrfamilienhäuser	Erbaut	1975
Gebäudezone	MFH Massivbauweise	Katastralgemeinde	Tschagguns
Straße	Latschauerstraße 22	KG-Nummer	90108
PLZ/Ort	6774 Tschagguns	Grundstücksnummer	172/2
EigentümerIn	Jägerbau GmbH	Energieausweis-Nr.	19344-1

SPEZIFISCHER HEIZWÄRMEBEDARF BEI 3400 HEIZGRADTAGEN (REFERENZKLIMA)

A++
A+
A
B
C
D
E
F
G
30 kWh/m²a

ERSTELLT

Organisation	Hubert Mangeng Energieberatung	ErstellerIn-Nr.	1823761207
ErstellerIn	Hubert Mangeng	Geschäftszahl	keine Angabe
GWR-Zahl	keine Angabe	Gültigkeitsdatum	02. 12. 2020
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1.1

Figure 3 Energy Performance Certificate Austria

When preparing an energy certificate for a major renovation, **recommendations have to be given** to the building owner. These are listed on additional pages added to the energy certificate. Recommendations always have to be worked out for the specific building and usually include a detailed description, estimates of costs, savings and paybacks, as well as the impact on the energy rating if all measures are implemented.

The overall methodology was developed before 2008 including the existing CEN-standards at that time. It describes the whole building envelope as well as heating, cooling, ventilation and air conditioning, etc., needs in detail, expressed in terms of useful and final energy. For non-residential buildings, lighting is also included. All kinds of renewable energy systems are included (most new buildings use solar energy for supplying part of their domestic hot water preparation and some also for part of their space heating). Results and details of the calculation of the energy rating have to be uploaded to the central register of Statistics Austria; a web based central registration system. The next figures shows the main elements of the calculation methodology: starting from useful energy demand, including gains and losses, the efficiency of every technical device is defined and taken into account for the calculation of the final energy demand of heating, cooling etc.

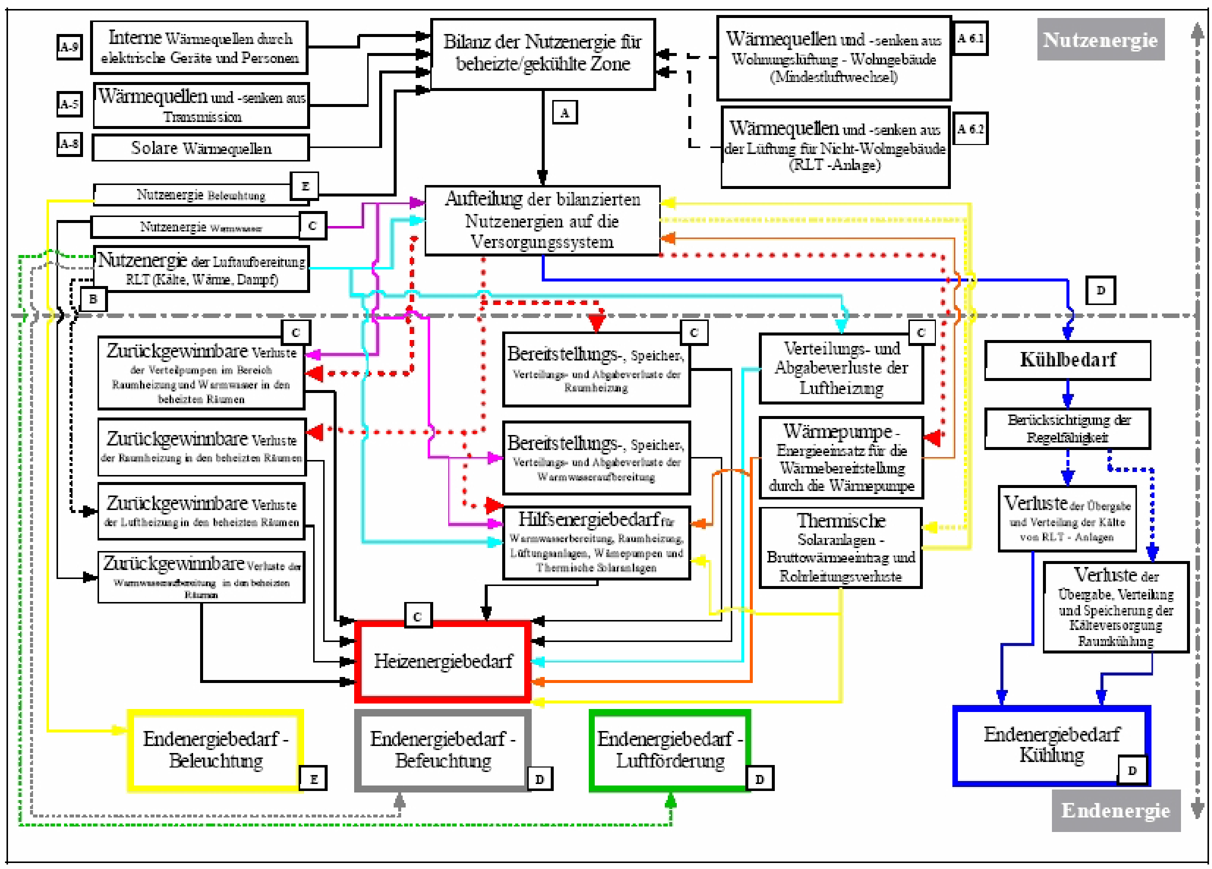

Figure 4 Main elements for EPC calculations

In Austria, according to regional regulations, every public building with a gross floor area larger than 1,000 m² is required to display energy certificate at the main entrance since 2008. The term ‘public building’ means frequently visited by the public, irrespective of whether owned by private or government bodies. By the end of 2010, only several hundred public buildings were certified, but the number increased considerably since then. Some of the ‘Länder’ developed ambitious programmes to certify their building stock faster than planned in the official time schedule for Austria. In accordance with the 2011 issue of the OIB guidelines, the new regional regulations in the nine ‘Länder’ implement now stricter rules.

This means that the threshold lowered to 500 m² gross floor area and to 250 m² by the 9th of July 2015 if the building is occupied by public authorities.

3.2.2 Energy Performance Certificates in Germany [13]

EPCs in Germany can be grouped into two categories according to the type of assessment method: certificates on the basis of ***calculated demand*** and certificates on the basis of ***metered consumption***. In doing so, all new buildings and cases of major renovation must have an EPC based on a calculation methodology. The simpler metered energy consumption method only applies for:

- existing residential buildings with at least 5 apartments, where the influence of individual user behaviour is statistically balanced by the large number of users
- smaller existing residential buildings, which at least conform to the first German Thermal Insulation Ordinance for thermal insulation (1977)
- all existing non-residential buildings

The mandatory standard form of the EPC consists of five pages plus an annexed 'template for the EPC display'. The EPC shows a continuous reference scale with a colour gradient from green to red. A benchmark indicates the average value of the building stock which defines the central point of the scale, according to the individual use. Since the first EPC was introduced in 2002, the EPC was modified a couple of times according to changing needs and advanced experience. Towards this direction, different sources of renewable energy and their particular share must be indicated for new buildings in accordance with the Renewable Energy Heat Act and the RES Directive. Recommendations shall always be given for the specific building. Formerly attached to the EPC, they will in the future form an integrated part of the standard forms.

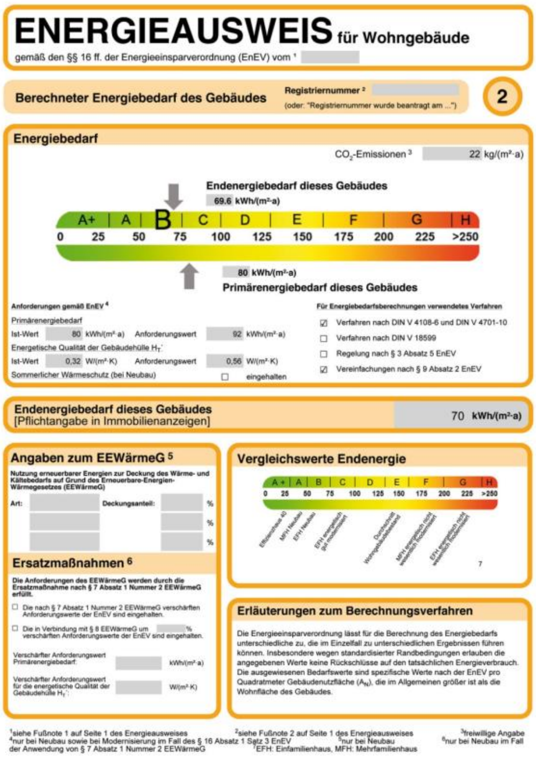

Figure 5 Energy Performance Certificate Germany

Depending on the type of EPC, scales with identical ranges are used to indicate the final and primary energy demand, or the final and — in the future — primary energy consumption.

This approach is in line with the EU regulation towards the extraction of primary energy based performance certificate.

For existing buildings, there is the possibility of **'simplified data recording'** to facilitate calculated rating. Simplifications allow the assessor to calculate with default values and to approximate the geometrical shape of the building. Energy consumption is determined on the basis of a record of heating costs, which must normally be made as part of consumption-based billing. A condition for the use of these data in EPCs is that a period of at least 36 consecutive months is recorded during the most recent months preceding the issue of the certificate. The proportion of heating energy has to be corrected from real local weather conditions during the recorded periods, to standard conditions using officially provided climate correction factors. A system for authorizing the issuing of energy certificates, which does not require any additional bureaucracy, was introduced in Germany in 2007. Authorization to issue certificates is based on the qualification of the persons concerned. For new buildings, the assessors' requirements are defined by regional law. These experts are also entitled to issue certificates for existing buildings of similar use and size. A person who issues an energy certificate and who is not entitled to do this breaches the regulations and can be punished by a fine.

In Germany there is no official software for energy certificates. Software developers are acting free on the market. The quality of software, i.e., the correct transfer of the technical rules into the software, is an important step regarding the quality of the results. Since there is also great interest by private sector software suppliers in guaranteeing the quality of their products, the great majority have joined together since April 2009 to form a 'Quality community 18599'.The quality community is organised as an association and contributes to further improvements in the products and greater clarity for the users. The liberal approach of an open market without official approval is an obstacle for the setup of the independent control system. Another important point while establishing the control system was to secure data privacy for property owners, which is held in high esteem in Germany. Therefore, the control system has to work without general data retention in a central database. A commissioned and authorised body ('Deutsches Institut für Bautechnik') holds a central EPC register without collecting the contents of the EPC. The register collects data from each assessor in relation to the number of EPCs issued per type and location of the building. Each certificate gets an individual registration number and can be part of the random quality check.

Despite numerous changes to the forms, all certificates issued in the past, either based on former regulations or following earlier programmes (and independent of the variations in layout due to transitional regulations) retain their validity of 10 years from the date of issue.

3.2.3 Energy Performance Certificates in Spain [14]

According to the Royal Decree 235/2013 on the Energy Certification of Buildings, the Autonomous Communities are in charge of the registration, inspection and control of the Energy Performance Certificates (EPCs).Though, the certificate for new buildings came into force in November 2007. CALENER is the name of the software that implements the official calculation methodology. The Royal Decree 235/2013 transposes the recast EPBD, in relation to the energy certification of existing buildings. This is a key point to reduce the energy consumption of the housing stock.

To support the technical certifying officers (Qualified Experts (QE) who must be architects or engineers authorized to sign building projects, responsible for the energy certification of existing buildings, IDAE has published two new procedures for the energy certification of existing buildings, establishing the official calculation methodology for EPCs (named CE3 and CE3X). The procedures for existing buildings account for the assessment of energy efficiency measures, both from technical and economical point of view. This analysis is stated in the final report issued by the software programme. The two software procedures, CE3 and CE3X, are already recognized as official documents, according to the procedure established by the Ministry of Industry, Energy and Tourism, and the Ministry of Public Works. Both include specific modules according to the type of the building:

- housing 'ViV';
- small and medium tertiary 'PYMT';
- great tertiary 'GT'.

Both procedures enable the energy certification of existing residential buildings, as well as of small and large tertiary buildings, establishing a degree of energy efficiency based on **CO2 emissions** and **primary energy consumption**, arising from consumption related to heating, cooling, water heating, ventilation and lighting needs. Though, the label is extracted based on calculated estimation and not based on the actual measurements about energy consumption. The energy label classifies the buildings on a scale from G (least efficient building) to A (most efficient building). Additionally, the auditing process provides energy efficiency improvement measures and enables the definition of sets of measures by the technical certifying officer, as well as the realisation of an economic analysis of these measures from the aspects of investment costs, energy savings achieved and actual building energy bills. With this information, the building owner can assess and voluntarily undertake actions of renovations in order to improve the building energy rating. Finally, the tools automatically generate a certificate that indicates the energy label, along with the new letter after applying the improvement measures.

The label of the official EPC that is currently approved for the energy certification of existing buildings may be seen in Figure 2.

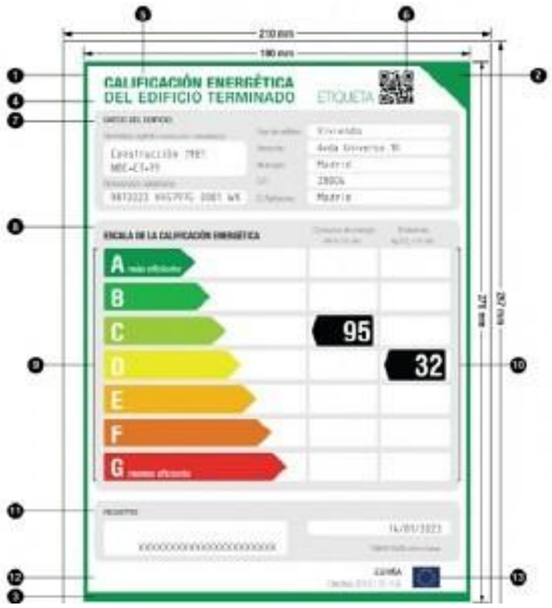

Figure 6 Energy Performance Certificate Spain

As stated, the global energy rating is assessed according to the CO2 emitted per unit floor area per year [kgCO2/m2.year], as well as the primary energy consumption [kWh/m2.year]. Moreover, there are partial ratings depending on the demand and energy consumption for the various energy-consuming services (heating, cooling, sanitary hot water and lighting for tertiary buildings). The calculated values are compared **with a series of reference values** that vary according to the local climate, and with a reference building of the same shape, which abides by the building energy regulations, depending on whether it is a new or existing building, or a residential or non-residential one.

The current legislation requires that public buildings must obtain a certificate of energy efficiency. Buildings or parts of buildings of a public authority, occupying a total useful floor area over 500 m^2 and frequently visited by the public, have currently the obligation to possess the EPC. If the floor area of the building exceeds 250 m^2, this obligation is mandatory from the 9th of July 2015. Moreover, all buildings occupied by public authorities, with a total useful floor area over 250 m^2, must **exhibit an EPC label in a prominent place**. In addition, all buildings frequently visited by the public, other than those owned or occupied by public authorities, with a total useful floor area greater than 500 m^2, must display an EPC label in a place clearly visible to the public.

The adoption of the Energy Performance of Buildings Directive (EPBD) has significantly increased the number of requirements that buildings in Spain must meet. The next logical step is to combine the subsidies of the Energy Saving and Efficiency Plan with the improvement of the building energy rating. In addition, given the compulsory consolidation of the recast EPBD, the Energy Performance (EP) requirements for buildings will have to be tightened in order to meet the cost-optimal requirements set forth therein.

The process of revision of the current regulations (RITE) and the rules concerning the Energy Performance Certificate (EPC) has already started. The Spanish normative will be tightened gradually, to achieve the NZEB objective by 2020.

3.2.4 Energy Performance Certificates in Bulgaria [15]

The building sector has a great potential for energy savings and thus a high interest is delivered on the establishment of a steady energy performance certificate programme. Certain provisions of the Directive 2002/91/EC on the Energy Performance of Buildings (EPBD) were introduced in the Bulgarian legislation in 2005. The development of the legal framework continued with the adoption of the new Energy Efficiency Act, promulgated in the State Gazette (SG) No. 98/14.11.2008. The next amendments after 2010 were promulgated in the SGs No. 35/3.05.2011 and No. 38/18.05.2012. The Sustainable Energy Development Agency (SEDA) has been created, replacing the Energy Efficiency Agency (AEE) as the agency responsible for the delivery of EPC programmes. The new Energy Efficiency Act was promulgated in the SG No. 24/12.03.2013, and came into force on the 12th of March 2013.

The new **Energy Efficiency Act** introduced obligations to owners of public service buildings with a built-up area of over 500 m^2. The same requirements have to be applied to all public service buildings with a built-up area of over 250 m^2 by the 9th of July 2015 following the European Directive about energy efficiency in public buildings. New and existing buildings have their own specific requirements for different types of use (residential, non-residential and public) and therefore different types of performance certificates are considered. An energy consumption scale consisting of classes from A to G is established following the BDS EN 15217. The Energy Efficiency Act further requires that the seller of a building provides the buyer with the **original EPC of the building**, and/or the **Energy Passport**.

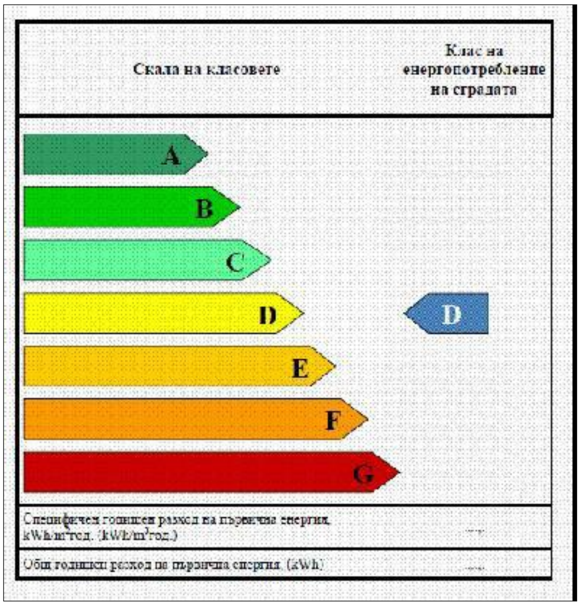

Figure 7 Energy Performance Labelling Bulgaria

The energy consumption class scale is composed on the basis of two values of the integrated EP characteristic:

- $EP_{max,r}$ → total specific energy consumption for heating, cooling, ventilation, DHW and lighting, corresponding to the current national norms.
- $EP_{max,s}$ → total specific energy consumption for heating, cooling, ventilation, DHW and lighting, corresponding to the norms in force when the building came into use.

The values of the thermal and technical performance of the **building envelope** and elements, as well as the efficiency of the **heating, cooling, ventilation and DHW systems**, are **calculated** under the legal acts in force when the building came into use.

A so-called 'Energy Passport' is required for a new building after the completion of the construction. It is issued by qualified construction consultants. The passport contains the EP parameters, corresponding to the normative and project requirements for the energy efficiency of the completed construction.

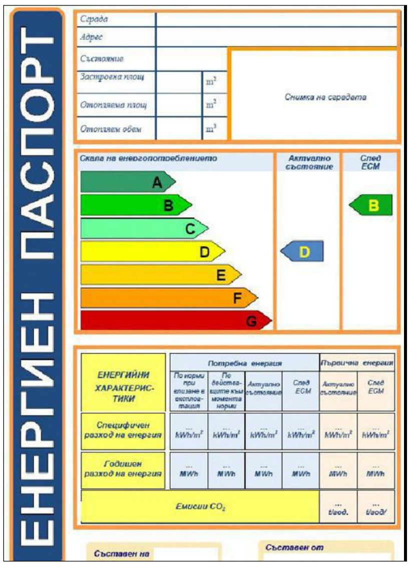

Figure 8 Energy Passport Certificate Bulgaria

On the other hand, the Energy Performance Certificate (EPC) is required for existing buildings. The EPC of the building shall be updated after major renovation leading to the improvement of the overall EP. The energy certification can only be conducted in no less than 3 years and in maximum 6 years after obtaining the building permit. All public buildings in operation with a floor area above 500 m^2 are subject to obligatory certification. The validity of the EPC for property tax reductions can be up to 10 years. This depends on the energy efficiency class of the building, and on whether RES are used for the reduction of the energy demands for purchased energy.

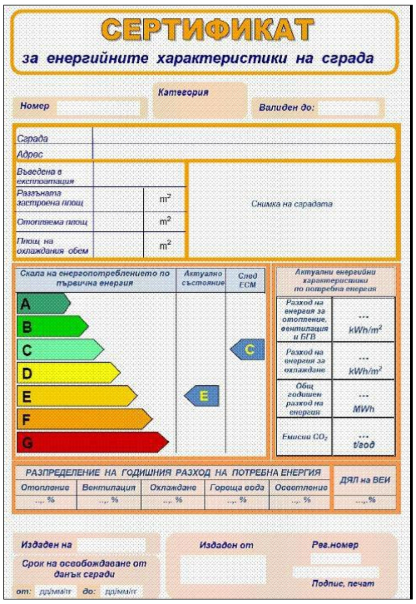

Figure 9 Energy Performance Certificate Bulgaria

The EPC contains the following information:

- The type of the building, the address, the year in which it was put into use, total floor area, heated area, cooled area, and pictures of the building.
- The values of the building's integrated EP according to the required energy: total **annual energy consumption** in MWh, **annual generated CO_2 emissions** in t/year, rating and class of the energy consumption according to the **primary energy** and **category of certificate**.
- The distribution of the annual energy consumption for heating, ventilation, cooling, DHW and lighting, expressed as a share of the total consumption.
- The name of the person who carried out the certification, and the number of their public registration certificate.
- Recommended groups of energy efficiency measures leading to the achievement of minimum requirements.

The Bulgarian legislation has introduced two categories of certification – 'A' and 'B' – for existing buildings constructed before 2005. This should not be confused with the building energy class. The certificate defining a category is issued to assist the building owner to get an exemption from property tax for the period of validity. This is done to promote the process of certification of existing buildings, and to improve the building EP.

Category A certificate – with validity from 7 to 10 years– is issued for:

- Buildings constructed between 1990–2005, with Energy Class B
- Buildings constructed before 1990, with Energy Class C

Category B certificate – with validity from 3 to 5 years– is issued for:

- Buildings constructed between 1990–2005, with Energy Class C
- Buildings constructed before 1990, with Energy Class D

Under the law, the EPC and/or the Energy Passport of a building should be displayed at a clearly visible place within the said building. Unfortunately, this requirement is not always met, and no fines or penalties are imposed for noncompliance.

The extensive survey on EU Member States reveals that the design and the implementation of the EPCs within their national legal frameworks encounter **several challenges** and **barriers** that lead to suboptimal solutions. For implementing an effective EPC scheme it is necessary a strong commitment and to develop appropriate measures in accordance to the national specificities. Significant attention must be paid in choosing the appropriate calculation methodology as this is vital for the credibility, success and effectiveness of the energy performance certificates. Therefore, it is important to consider from the early design stages issues such as reproducibility, accuracy, level of expertise and to elaborate the most appropriate methodology for the given market. Towards this direction, and prior to the proposed OrbEEt framework, a baseline EPC approach is defined as the common ground framework for the early auditing period within project.

3.3 Comparative Review of Current Status on EPC

The previous analysis was focused on the clear distinction among asset and operational framework, with an overview of the current status on pilot countries, always taking into account the mandates as defined by EPBD. The goal of this section is to highlight the difference among the cases examined on previous sections and how the proposed framework will further handle the conflicting approaches to the final OrbEEt SEOR to be defined at the next Chapter. To this end, a set of criteria have been defined in order to follow a standardized approach on the evaluation of the different EPC approaches. The evaluation criteria are defined in line with the mandates as expressed by EPBD. More specifically the evaluation criteria are summarized:

- To define an Energy Performance Rating framework, which will provide useful data for monitoring of energy performance and will be easily **adjustable on different countries**, following the way for a common approach along Europe
- To define an Energy Performance Rating framework, which **will not provide a unique indicator** for the whole building performance but will further incorporate additional measurements and indicators towards the extraction of enhanced DECs.
- To define an Energy Performance Rating framework, which will not only evaluate energy related factors but will also evaluate the societal impact (CO2 emissions).
- To define an Energy Performance Rating framework that is **fully dynamic**, adjusted on the **real time operational processes** of the building.
- To set a **standardized auditing approach** towards the extraction of the Operational Rating. To this end, standardized and **open source tools** should be used for the extraction of useful information
- To **further exploit building rating** towards the establishment of **an energy efficiency environment**. To this end, the effort is delivered on the way to exploit Building Operational Rating results with the most beneficiary way.

The next Table summarizes the level of fulfilment of the high level criteria for the aforementioned Energy Performance Certificates.

Table 2 Comparative analysis of EPC framework

	Baseline	Austria	Germany	Spain	Bulgaria
Easily Adjustable EPC framework	+	+	+	+	+
Multiple Indicators Analysis	-	-	-	-	-
CO2 emissions related rating	+	-	+	+	+
Real time EPC rating evaluation	+	-	+	-	-
Standardized Auditing process	+	+	+	+	+
Exploit EPC Rating to the establishment of an Energy Efficiency environment	-	-	-	-	-

The comparative analysis highlights the missing issues on the current EPC frameworks, setting the baselines for the added value concepts to be addressed on the proposed framework. More specifically OrbEEt will try to extend the concept of operational rating framework towards delivering certificates of significantly **enhanced spatio-temporal granularity** for a continuous estimation of **different metrics and indicators**. DECs will be **continuously updated using actual building measurements** and made available to occupants/visitors at almost real time. Consequently, occupants will be provided with timely and concrete information on how their everyday actions influence building energy performance as well as **how and how much they can actually improve their behaviour**. To this end, OrbEEt will establish an exhaustive list of well-defined performance metrics and indicators, directly linked to Building Operational Rating Certificates (Display Energy Certificates). The dynamic correlation of activity models with energy performance analytics practically enables the generation of enhanced DECs that fully incorporate energy performance rating at various organizational spatio-temporal levels, like individual spaces (since loads are space bound), organizational activities/processes and organizational units. The next section, describes the models of the proposed SEOR framework, taking into account the aforementioned mandates and requirements.

4. OrbEEt Enhanced SEOR Framework

4.1 Introduction

The building sector consumes approximately one third of the primary energy supply worldwide. In EU, the building sector accounts for over 40% of final energy and is responsible for more than 30% of the CO2 emissions. As the sector with the highest cost-effective energy savings potential, increased energy-efficiency of buildings is a key objective of EU energy and climate change policy (Commission of the European Communities, 2006). Towards this direction, operational ratings, as presented on the state of the art analysis, assess the actual performance of buildings based on actual measured energy consumption. These are useful for periodic monitoring of building day-to-day energy performance, because they allow the real performance of buildings' owner/operator to be measured over time, enabling continuous improvements. Display Energy Certificates (DECs) resulting from Operational Ratings are typically generated annually at the level of entire buildings to quantify the comparative energy efficiency of the organization operations independently of factors like building characteristics or weather conditions. According to common business practice, DECs are generated annually and in most cases do not differentiate between various plug loads, which according to recent statistics account for more than 30% of modern commercial buildings energy consumption. Though, the lack of detailed and timely information significantly hinders the effectiveness of DECs as a means of influencing occupant behaviour, since they fail to present in a concrete manner the impact of individual daily actions on the overall energy performance of an entire building.

Having as a starting point the existing DECs framework, OrbEEt tries to extend this concept towards delivering certificates of significantly enhanced spatio-temporal granularity by establishing a dynamic model-based approach (models, methods & tools) for a continuous estimation of their constituent metrics and indicators. DECs will be continuously updated using actual building measurements and made available to occupants/visitors at almost real time. On the other hand, enhanced DECs will take into account all major loads related to organizational activities and most importantly, they will establish a direct link between energy performance and various elements of the organizational ecosystem (spaces/offices, teams & activities), allowing for a more systemic view (drill-down and drill-through) beyond typical DECs.

Towards this direction, OrbEEt aims to establish a common set of reference building performance models for correlating the physical building elements (BIM) with enterprise processes (BPM) of the owner/hosting organization and tenants - organizations hosted in the building, and the dynamic usage of the building by its occupants (HP), which is captured and reflected by the equipment used. In parallel, a behavioural triggering model is defined to engage occupants towards a more energy efficient operation. These models form the basis of the proposed enhanced SEOR framework, which will be implemented in the project. The model is holistic, in the sense that it includes the main influencing factors of energy performance in a commercial building – the occupants, their enterprise-related activities and the surrounding environment, corresponding to the different sub-systems which make up the Building Eco-System (BES):

- The Physical Sub-System: buildings and their energy-consuming & context measuring equipment
- The Enterprise Sub-System: business processes & goals, impact on the human behavior, cost/benefit analysis and other drivers for commercial activity

- The Human Sub-System: occupants, with their occupancy and usage behavior

A set of Key Performance Indicators (KPIs) are defined, which measure the efficiency of the above-mentioned subsystems along four building performance axes (Energy Performance, Business Performance, Human Comfort, Users Engagement) irrespective of the enterprise and business domain served by the building. The next figure provides an overview of the overall SEOR framework. On the lower level we specify the modelling framework of the whole building ecosystem while on the upper level we define the core building ecosystem attributes with the associated KPIs that set the information model for the SEOR framework.

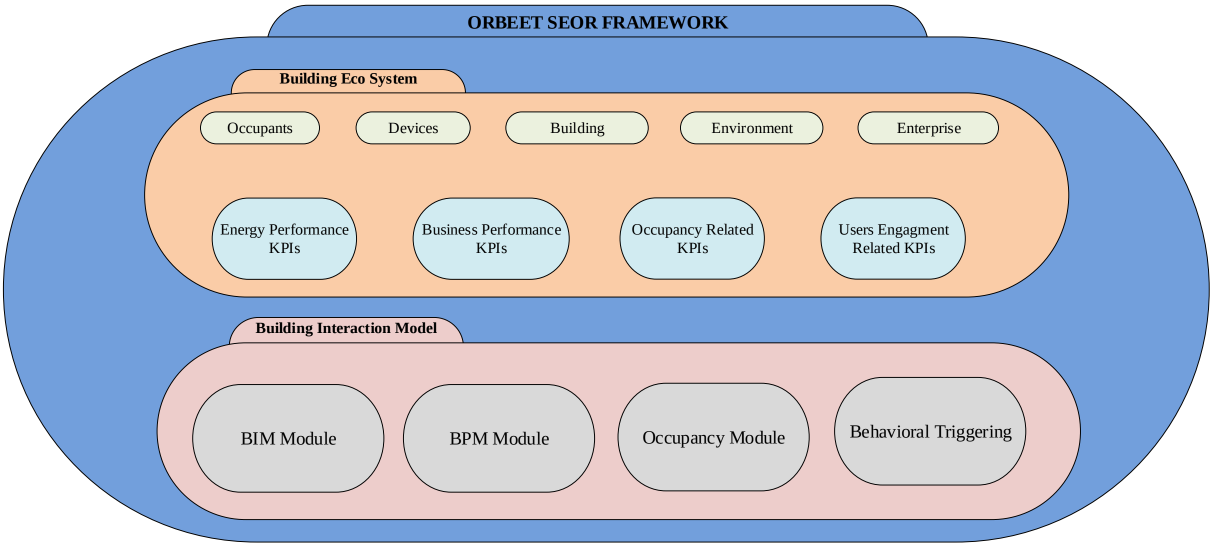

Figure 10 Overview of OrbEEt SEOR modelling framework

Based on the list of KPIs, the operational rating can be more accurately measured, compared and better handled. Though, prior to the analysis of the respective indicators, the review on the constituent modelling components (BIM, BPM, HP & Behavioural Triggering Models) of the proposed framework is provided.

4.1 Building Information Model (BIM)

4.1.1 Overview

The Building Information Model (BIM) is an abstract representation of the physical and environmental aspects of the Building Eco-System, incorporating architectural metadata and environmental parameters. This Section defines the requirements, the elements and the modelling approach for BIM. Examples of requirements for the Building Information Model are for instance:

- BIM needs to be compatible and to support existing architect’s tools to:
  - Allow input from multiple modelling programs
  - Support complex geometries
  - Allow change of building geometry without having to re-enter all simulation variables from scratch
- BIM needs to be able to integrate Facility Management information, i.e. details about facilities, occupancy load factor per room, devices per room, placement of sensors etc.
- BIM needs to support interoperability standards for building specification, such as gbXML. Engineering requirements:
  - Support one common language and open standard like gbXML
  - Needs to support seamless exchange of models and to facilitate the iterative process of optimizing the design

  - BIM should support linking of the building design with Geo-Information System (GIS) parameters such as latitude, longitude, altitude, to map building's position with related facilities and facilitate extended urban design

These high level requirements define the modelling framework for the needs of the project, what related to the definition of metrics and indicators about the building elements.

4.1.2 BIM Modelling Approach

Building Information Model (BIM) can be viewed as a key enabling technology to encompass all aspects of the design, construction, and operation of a building. BIM includes several elements of the building which play an important role in the building energy performance. For these elements, the number, the physical parameters and the geographical disposition needs to be known, e.g. the spaces, building structures and access points, i.e. doors, windows, stairs, corridors. The representation of BIM is based on the following elements:

- Facility = collection-of (Building)
- Building = collection-of (Floor; Spaces; Zones)
- Building_Element = one-of (Floor; Space; Zone)
- Floor = collection-of (Spaces; Zones)
- Component = one-of (Segment; Node); where Segment IN {Corridor; Stairs}
- Node = one-of (Entry; Room); where Entry IN {Door, Window, Wall}

These elements defined the building blocks of the BIM model towards the adaptation of the metrics and KPIs to the respective static points. Therefore and as part of the modelling approach, the correlation of dynamic energy data with the respective blocks set the modelling framework in OrbEEt. Each one of the elements of the BIM mentioned above is modelled as a resource of the building eco-system.

Within OrbEEt framework, all the static characteristics of the building, along with the respective energy loads and the sensors installed for monitoring purposes should be addressed on the detailed BIM of the building, in order to further proceed with the Operational Rating of premises.

4.2 Business Process Model (BPM)

4.2.1 Overview

The Business Process Model (BPM) [16] is an abstract representation of the functions and processes that an organisation performs to reach a defined business goal. In the context of SEOR framework, those processes and especially their design and structure influences the energy performance model and vice versa.

The enterprise processes that the building supports encode valuable information about the building usage. Depending on the method used to design the Business Process Model, it can graphically represent and document what is happening in business activities. A business process model typically contains:

- **Activity Objects:** Tasks, Activities and sub processes
- **Relations:** The objects that are used to represent the flow from the start to the end of the process.
- **Gateway objects:** Indicating branching points, for example through a decision during a process or at points where parallel sets of tasks are conducted.

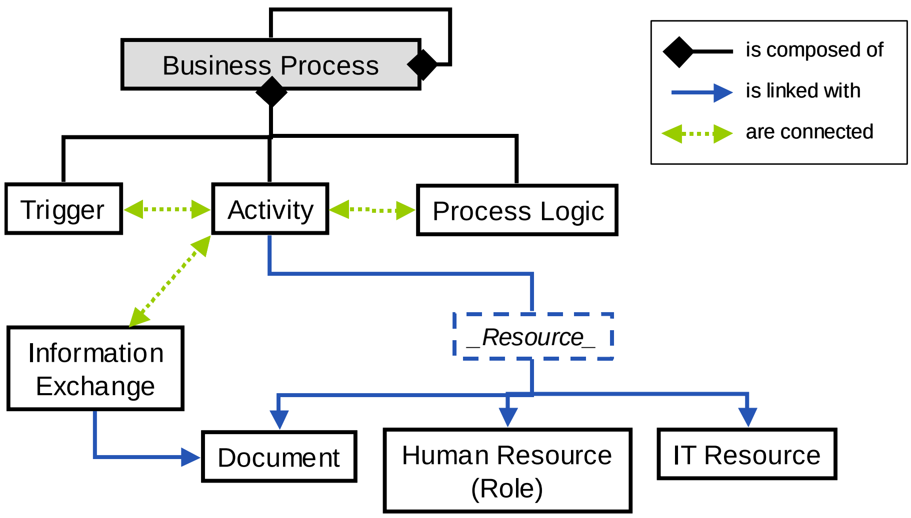

Figure 11 Typical Representation of Business Processes

A business process model is defined by the choice of a modelling method which is composed of the modelling language (through which the model is expressed), the modelling procedure (as the guiding element for the user consisting of steps and results) and mechanisms/algorithms (which offer functionality to operate on the model). [16]

Depending on the level of abstraction and the domain under investigation, different modelling approaches for BPM have been developed in the research community as well as from an industrial background. As shown in Figure 11, a business process is considered as a sequence of activities that are performed by actors utilizing diverse resources (e.g. documents, IT): the central element for capturing enterprise information on a business process is via the activity/task construct. All business processes should produce a specific product or service for an end customer (goal-driven). The business processes of any organization should be designed to add value for the customer to ensure competitiveness in the marketplace (external perspective).The basic characteristics of a business process are defined below as guiding principles of business process modelling initiatives:

- A business process has a defined and explicit *goal*,
- A business process uses specific *inputs* for execution
- A business process "produces" specific *outputs or products*
- A business process applies *resources* (in a general sense such as humans, IT, etc.)
- A business process has a number of activities that are performed in a logical/chronological sequence/order
- A business process can affect more than one organizational unit as a cross-organisational analysis means.
- A business process creates value for the process customer. The customer may be internal or external.

These characteristics establish the challenge for the modelling tasks related to business process as described in the following section.

4.2.2 BPM Modelling Approach

The enterprise that the business process models are representing typically consists of many individuals who have diverse roles and who belong to different organisation units. In trying to create a link between the actual buildings that house the enterprise, the business processes that are taking place and the resulting behaviour of the occupants will be highly dependent on their assigned roles, their individual preferences and other factors correlated with their social and physical needs. This will have a knock-on effect of the perceived energy performance of both the business processes, the resources used and the building envelope. Hence, the modelling of a given business process is often complemented by a model of the organisational structure and working environment within which the processes are conducted (organisational units, task performers, resources).

With regard to operational rating, the business process model needs to be able to document and measure the energy efficiency of its activities. This includes the ability to represent the relation between BPM elements and BIM elements, the cost of energy of a business processes (in terms of resources and particularly concerning energy consumption). All actor activities need to be divided into different categories so that we can measure both the primary activities which are part of the daily business workflow, and also any ad-hoc secondary activities which an actor can be involved in, such as taking a coffee break. Each business process should make explicit its goal(s), required information, the resources consumption (i.e. quantities of elements used: building elements, equipment, renewable materials, including energy and emissions quota), dependent activities, component activities (i.e., sub-processes) and their order, and performing and beneficiary actors (occupants, tenants etc.).

OrbEEt SEOR framework aims at integrating the models of the static nature (BIM), dynamic structural (BPM) and dynamic-occupant (HP) into a homogenous model for the evaluation process, a mapping of the different domains onto each other. From a conceptual perspective an annotation mechanism is foreseen that enables the mapping between an arbitrary BPM using a custom meta-model applying the hybrid approach to a BIM model on one hand and the HP model on the other. Towards this direction the mapping of BPM aspects to energy related parameters and occupancy preferences will enable us to extend the overall rating approach to SEOR framework.

From a technical point of view, a semantic data structure will be prepared and will be generalised for a broader usage in the future. Elements of BIM can be enriched and annotated with BIM-related contextual information (e.g., location of a process, participants/occupants involved) and indirectly allowing to show what kind of Energy Performance relevant data can be drawn based on this data aggregated at BIM level.

4.3 Human Preferences Model (HP)

4.3.1 Overview

The Human Preferences Model (HP) is a part of the building's Physical Sub-System and describes the contextual framework of the premises which is further aligned to occupants' preferences. For our scope, the HM captures the following aspects of the building ***context environmental conditions***, i.e. the building state being measured, e.g. temperature, humidity, luminance levels, and the ***occupancy model***, i.e. specific occupancy parameters, e.g. occupant density, presence/absence, number of active concurrent business activities; towards the extraction of levels of preference & non preference.

The HP should satisfy the following general requirements:

- HP should be able to express capabilities of sensor devices (e.g., measuring context conditions).
- Sensor devices in HM need to be linked with the BIM, e.g. the ability to specify the device placement to a particular room or office space in a building.
- HP need to be linked to business and energy performance characteristics of a class of devices.

Sensor devices (e.g. temperature sensors, humidity sensors, PIR sensors) are the elements to be modelled as part of the HP. These are further linked to specific business processes and therefore groups of occupants in order to further define the preferences/ non preferences of occupants.

The HP can also be seen as the projection of occupancy onto environmental parameters and energy and comfort KPIs, and can describe the context of use and the possible effects of equipment use by or on behalf of occupants. For example, an HVAC running in standby mode, with the normative set-point temperature in an empty room uses on average a certain amount of energy and has a certain effect on the temperature. In active mode and given full occupancy, HVAC operates in a different set-point, revealing the thermal preferences of the group of occupants. [17]

HP Model is an important component model of SEOR, as it captures the occupancy related parameters of the model. Each part of HP corresponds to an environmental sensor that is associated with the BIM & BPM elements of the building, towards the linking of energy consumption with occupancy preferences.

4.3.2 HP Modelling Approach

With regard to operational rating framework, the human preferences model needs to be able to document and measure the interaction of occupants with the devices, focusing on the preferences on different environmental conditions. To this end, and as the modelling framework incorporates both occupants and devices, a direct linking with BIM and BPM modules is considered. All actors (either groups of users or individuals) need to be defined and further correlated with the respective devices and spaces as defined through the business process modelling analysis. Then, by incorporating into the model the environmental measurement data as extracted from the Wireless Sensor Networks, we define the comfort and non-comfort boundaries for the building occupants. Different types of human preference models (thermal comfort/ visual comfort) are defined taking into account the existing sensors installations and the criticality of loads in building premises. More specifically:

- Thermal comfort/ non comfort settings are defined by taking into account the temperature (and humidity) measurement data and the operational status of HVAC devices
- Visual comfort/ non comfort settings are defined by taking into account luminance measurement data and the operational status of lighting devices

The representation of HP Modelling is based on the following elements:

- Individual Users= associated with (Business Processes)
- Groups of Users = associated with (Business Processes)
- Building_Element = one-of (Floor; Space; Zone) associated with (Business Processes)
- Environmental Sensors = associated with (Building_Element)

The association of occupants with environmental conditions set the baseline for the modelling framework towards the extraction of human preferences boundaries through the continuous monitoring of context (environmental and device operational) characteristics.

4.4 Behavioural Change Model (BCM)

4.4.1 Overview

The Behavioural Change Model (BCM) is an abstract representation of the functions and processes that are defined in order to further enable the implementation of OrbEEt

Behavioural Triggering framework. In the context of SEOR framework, those processes and especially their design and structure influences the performance model and vice versa as we need to define the KPIs that further enable the implementation of Behavioural Triggering framework.

4.4.2 Behavioural Change Modelling Approach

The BCM approach provides a theoretically and empirically driven guideline that will link the users associated with the Business Processes (Individuals and Groups) with contextual information available (e.g., thermal and visual comfort settings) and data derived from Sensors (e.g., locations of individuals and groups in the buildings, activities related to devices). The BCM approach is grounded in principles of using game mechanics and visual interfaces in order to promote users' engagement in behaviours that ultimately impact the major KPIs of the project. A key mechanism for change in the current approach is to use engaging 3D dashboard visualizations and injunctive agents (personas), at varying granularities (spatial, temporal, business, and organizational)to increase intuitiveness and transparency in energy performance measurement, assessment and awareness through real-time monitoring and continuous feedback provision. In line with this, energy behaviours represent a significant potential for the increase of end-use energy efficiency in buildings, although inherently neglected. There have been different modelling techniques to model energy behaviours with the most prevalent being qualitative approaches from the social sciences attempting to understand behavioural patterns and conceptions of, and approaches, to behaviour with the scope to design and implement energy behaviour frameworks. Quantitative studies from economics, engineering and business for devising measurable metrics as means to quantify energy behaviours result to energy behaviour modelling.

Different behaviour modelling architectures [18] make a substantial difference between energy efficiency [18] and energy conservation [19] which is key to understand for structuring OrbEEt's BCM approach. For example energy efficiency should not be used when referring to energy behaviours [20] as it refers to the adoption of specific technologies that reduce energy consumption without considering the change in relevant behaviours and exploiting the services (e.g. heating, cooling, and lighting at their maximum. Energy conservation on the other hand, is a change in consumers' behaviour (i.e. human conceptual change, combining past and new knowledge to achieve conceptual change) that is responsible for the energy savings. For OrbEEt, therefore, we are interested in designing a BCM architecture that it is not only influenced by the inclusion and exploitation of state-of-the-art technologies and smart, playful and immersive interfaces but also by the way they are conceptualised, experienced and used discerned from energy behaviours.

The BCM is grounded in behavioural change theories [18][19], utilising components that are directly and indirectly relevant for changing behaviours in similar contexts to the OrbEEt project. A factor that is key to engaging users in behaviour change is presenting the relationship between energy use information and behaviours in a way that makes the outcomes of behaviours transparent and meaningful. Information alone has not been efficient in the past to motivate behaviours, especially when the relationship between microbehaviours (e.g., turning off an electrical device when it is not in use and a rating on a Display Energy Certificate given annually) is perceived to have little relationship or impact 20]. Hence, the BCM leverages gamification principles to achieve effective and persistent organizational behaviour change. Gamification principles such as rewards, challenges and status [21] that trigger intrinsic and extrinsic employee motivators will be utilized, based on a comprehensive two-pronged framework of incentives. This two-pronged framework combines rewards for individual/team-level competitive achievements with social recognition derived from social collaboration endeavours that will yield benefits to the society at large. Gamification approaches will be implemented through intriguing eco-visualizations and dynamic interface modalities that will adapt to an individual user's preference and performance.

Essential to the application of these principles is an understanding of underlying social dynamics and individual responses. Attaching points to an undesired activity is unlikely to make it desirable in isolation [20]; similarly, feedback in the absence of reward has been shown to be inconsistent when seeking to achieve a tangible outcome [22,23]. Consequently, the behavioural framework within OrbEEt considers the individual interfaces available to the end-user, and how information from the platform can be used to drive change. Principally, it adopts methods that consider individual and group layers of motivation, structuring and scaffolding behaviours under the two-pronged approach above. This results in important considerations in how data is filtered and presented, as "raw" sensor data as outlined in Section 4.6.1 could lead to difficult scenarios. Consider, for example, a user seeking to reduce their consumption, only to see the energy consumption per occupant remain constant or increase due to their colleague's poor performance. Unless carefully handled, a result here could be the user disengaging from the OrbEEt platform, feeling their efforts were insignificant or against the peer-norm. This in turn could reduce their sense of self-efficacy, a fundamental component of behavioural intent [19].

Providing information on individual consumption ascertained through device ownership and use offers a means to support the individual, though despite potential issues such as that outline above, consideration of group behaviour and dynamics remains a powerful and essential tool when seeking to stimulate a change in behaviour [24]. Indeed, many behavioural change theories place social elements at their core. Therefore, a principal challenge addressed by the behavioural model within OrbEEt is to filter and present the data from the metrics defined in the subsequent sections to promote both a positive overall culture and peer-norm against which staff improve, whilst addressing the need for interfaces to act on both individual and group levels to sustain feedback.

Rewards under this approach are inherently intangible: a high-performer does not receive additional pay or gifts. However, approaching the social layer from competitive and collaborative viewpoints allows insight into how gamification can act to generate a perception of value through how feedback is translated and individualised. Returning to the example of the user viewing overall office consumption and feeling their impact is negligible, presenting this data instead in terms of their office's performance against other sites or baselines could reaffirm their belief they are part of a high-performing team25]. Similarly, the level of granularity with which performance is measured and reported on could be adjusted to make short-term impacts more immediately observable. As a user engaged with the OrbEEt system and seeking to make a change, the individual is also afforded through the intranet portal a means to informally - and potentially anonymously - communicate with colleagues to developer their identity as a leader of positive change. The reward in this example is thus ultimately social, scaffolded through the technologies at the core of OrbEEt.

Another objective of the gamification approach is to support the behavioural objectives by simplifying how KPIs are presented to the user. As such it layers visual representations, in concert with in-office displays and the intranet portal, with abstractions and metaphors. Within the game, for example, CO2output can instead be utilised as a variable and used to drive narratives or game mechanics, such as boosting the player's skills or abilities, or allowing them to "level up" as they reduce or maintain low consumption habits. Presenting KPIs in such a fashion allows them to become immediately relevant and useful to an OrbEEt user, avoiding common problems with consumption metrics related to their lack of immediately observable impact on the user [26]. As such, a behaviour may be triggered out of intent to progress within the game, or support the team's efforts, rather than directly from environmental or efficiency concerns. It is therefore important that KPIs can be related to a user's profile and referenced historically, to establish changes in these profiles over time and reward or incentivise the user accordingly.

Behavioural "triggers" target events identified by KPIs, as well as metrics of engagement with the platform. These platform engagement metrics consider individual usage times against

KPIs to categorise and target users and adapt accordingly. A loose categorisation can be provided as per Figure 12:

	High Usage	Low Usage
Good KPI performance	The user is using the OrbEEt services, but already has, or has developed, good energy habits	The user is not engaging with OrbEEt, but has good energy performance.
Poor KPI performance	The user has poor performance against KPIs but is engaging with OrbEEt	The user has poor energy performance, and is failing to engage with OrbEEt.

Figure 12 Target behavioural triggers (high-level)

Figure 12 assumes the capability to translate KPIs into consolidated "good" or "bad" performances, which could be based on either baselined targets, or peer and cross-site performance. The goal is to "nudge" the user between states towards the ultimate goal of them using the platform and retaining good energy habits beyond the lifecycle of OrbEEt's intervention. A user in each state requires different behavioural triggers: for a user with poor performance failing to engage with OrbEEt, social drivers and short-term goals are likely to be more valuable. This could be handled, for example, with a short team scenario within the game which seeks to quickly engage the user alongside their colleagues for a limited space of time and against a clearly-defined short term goal. For users transitioning their KPI performance whilst engaged with the platform, information-based approaches and profiling are likely to be more valuable.

The BCM approach hence provides guidelines, based on behavioural theories, for how to develop complex incentives to engage building occupants (HP) in modifying their behaviour to consistent with energy efficient operations based on information that relates the physical building elements (BIM) with business processes (BPM). In the ways outlined above, OrbEEt aims to increase a workforce’s extrinsic motivation by triggering their quest for social recognition resulting from improved performance, or their reluctance against criticism in cases of poor performance. This provides a first step towards engagement to action for energy efficiency, while involving public building visitors and their social pressure dynamics, as an additional motivational lever for engagement.

Such an integrated and sophisticated engagement environment is complemented by a general underlying framework for the BCM approach (D1.3). This is valuable especially where repeated interactions with the system are necessary, is the Social Engagement Loop [27]. The engagement loop comprises of three key elements and a fourth social element for the needs of gamification shown in Figure 13.

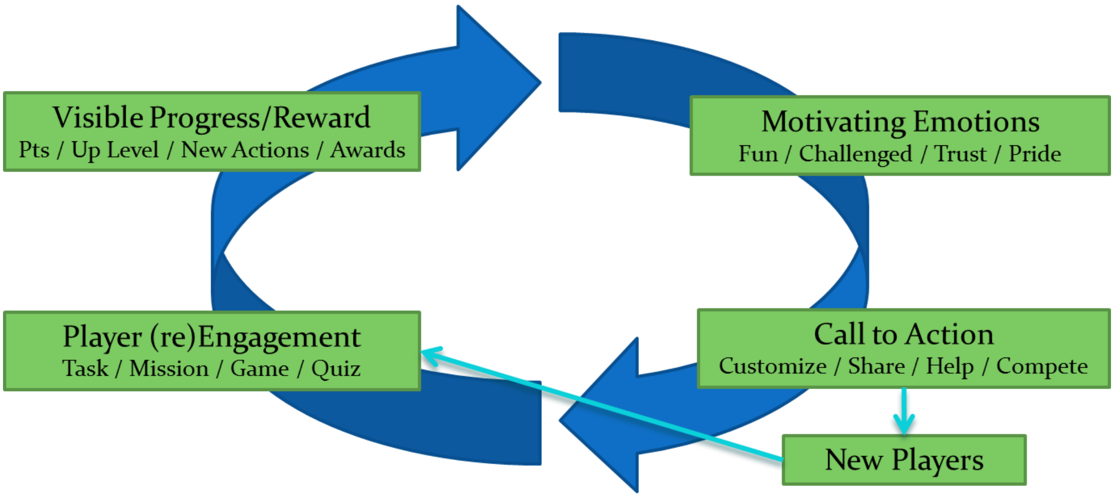

Figure 13 Social engagement loop [27]

With regards to SEOR, the business process model needs to be able to document and measure the energy efficiency of its activities. This includes the ability to represent the relation between BPM elements and BIM elements, the cost of energy of a business processes (in terms of resources and particularly concerning energy consumption). All actor activities need to be divided into different categories so that we can measure both the primary activities which are part of the daily business workflow, and also any ad-hoc secondary activities which an actor can be involved in, such as taking a coffee break. Each business process should make explicit its goal(s), required information, the resources consumption (i.e. quantities of elements used: building elements, equipment, renewable materials, including energy and emissions quota), dependent activities, component activities (i.e., sub-processes) and their order, and performing and beneficiary actors (occupants, tenants etc.).

4.5 Key Performance Indicators (KPIs)

Following the analysis of the components that set the engine for the calculation of the Operational Rating, the core part of this mechanism is provided with the analysis of the respective indicators that will further triggering the rating of the building and further the representation of the enhanced Display Energy Certificates (eDECs).

A Key Performance Indicator (KPI) is the measure of performance concerning one specific business aspect of an enterprise. It typically corresponds to business domain-specific aspects of an enterprise, i.e. measurable and quantifiable factors that help an organization to define and measure its progress towards achieving its business goals, such as efficiency and quality. KPIs use metrics, which are numeric values of measurable attributes, to characterize a particular aspect of the BES (or of any business system) as the distance above or below a pre-determined target value, i.e. they classify the metric with respect to the threshold(s).

Traditionally, performance ratings are calculated on the basis of on premises energy use, primary energy consumption or relatedCO2 emissions. OrbEEt SEOR aims to support an operational energy rating oriented on carbon emissions and ecological footprint, but also taking into account occupancy and the effects of enterprise activities on environmental conditions. Therefore, we are interested in KPIs and related metrics which can be easily quantified and measured, to give an indication of the operational rating of a building with respect to energy performance (efficiency), business performance, and occupant comfort. The following types of KPIs are distinguished:

- **KPIs describing Energy Performance aspects**, e.g. energy consumption, CO2 emissions

- **KPIs describing Business Performance aspects**, e.g. total execution time of a business process, total activity time per room, etc.
- **KPIs describing Human Comfort aspects**, e.g. temperature, humidity, luminance level variability, etc.
- **KPIs triggering Behavioural triggering framework** e.g. level of participation, level of triggering etc..

For each of the categories above, we compiled a list of the most relevant attributes available, which form a KPI parameters library. Towards this direction, the analysis of the respective KPIs is provided to set the SEOR framework of the project. In addition, a tabular based description of OrbEEt KPIs is provided as an Annex 1

4.5.1 Energy Performance Indicators

The energy performance of a building has been defined (in [1]) as "the amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building, which may include, heating, hot water heating, cooling, ventilation and lighting". Therefore we define Energy Performance (EP) KPIs as measurable attributes that characterize the building energy performance with respect to its demand for power and electricity consumed and its effect on its local environment: energy consumption, and sustainability parameters, e.g. GHG emissions. They can be defined for the building as a whole, for individual building elements (e.g., office spaces, public spaces, corridors) or for groups or zones of a building. These indicators can be measured directly, based on readings of smart electricity, gas, fuel, or power consumption meters, or can be calculated for specific configurations of the building eco-system, including a particular building design, a given level of power consumption of its equipment, a given set of enterprise processes and the level of activity of the occupants.

Within OrbEEt, a sub metering process is adopted in order to clearly define the actual energy consumption on the minimum of granularity. This is an extension to the current operational rating, where only the total energy consumption is measured, while the extrapolation on specific device types is based on a simulated process.

Without emphasizing solely the energy consumption, we define also indicators that can capture several aspects of the ecological footprint of a building, and can be used as input coefficients for energy performance calculations, together with the building eco-system configuration. Thus, the indicators measured can be divided based on the type of analysis we want to make:

- **Energy Consumption per m^2 (EC_A)** – this measures building energy consumption (for a specific reporting period, e.g. annual, hourly) related to the total floor space. It provides a simple measure of the energy performance of a building, which can be compared to a reference building. In addition, the distinction of type of building zones can be provided, by taking into account the attributes addressed in the BIM of the building. *(measured in kWh/m^2)*
- **Energy Consumption per device (EC_D)** – this metric tells us the total contribution of specific device to the overall consumption of the building. *(measured in kWh)*
- **Energy Consumption per Business Process (EC_BP) –** by addressing also the BPM elements as part of the BIM model, a detailed alignment of energy consumption with main business processes is revealed. Therefore, this indicator defines the cost of energy per business process in premises. *(measured in kWh)*

- **Energy Consumption per role (EC_O) –** usually there is not a linear relation between the number of occupants of a space and the total use of energy. By linking the OM & BPM parameters in BIM model, a calculation of Energy Consumption per occupant is provided, towards the direct comparative analysis of end users. *(measured in kWh)*

The transformation on **primary energy** *(measured in kWh)* is considered on the analysis though a distinction among "fuel and heat" and electricity consumption is considered on the SEOR framework. Therefore we have:

- **Primary Energy Consumption per m^2 (PEC_A)** *(measured in kWh)*
- **Primary Energy Consumption per device (PEC_D)** *(measured in kWh)*
- **Primary Energy Consumption per Business Process (PEC_BP)** *(measured in kWh)*
- **Primary Energy Consumption per role (PEC_O)** *(measured in kWh)*

Based on recent EU regulations, it is preferable to calculate and compare the building energy performance based on the measure of the annual **CO_2 emission per unit** of area of the building caused by its consumption of energy. The factors that contribute to this energy performance of a building include:

- Reference values and Actual/calculated values for "fuel and heat", electrical and CO_2 performance indicators(kWh/m^2) and (kg CO_2/KWh) respectively
- **Benchmark ratios for "fuel and heat",** electrical energy performance and CO_2 performance

The quantity of CO2 emissions of the entire building site is measured in kg CO2e/year. To factor in the actual volume and shape of the building, the total CO2 emissions per volume unit is computed by dividing total CO2 emissions by the total volume of the building, measured in kg CO2e/m3. To factor in the energy intensity and the building equipment efficiency, the total CO2 emissions of the entire building in one reporting period (year, month, week, day) is divided by the total energy consumption of the entire building (this is measured in kg CO2e/KWh). The list of indicators is further provided:

- **CO2 Emissions per m^2 (EC_A)** – this measures building energy emissions (for a specific reporting period, e.g. annual, hourly) related to the total floor space. It provides a simple measure of the energy performance of a building, which can be compared to a reference building. *(measured in kg CO_2/m^2)*
- **CO2 Emissions per device (AEC_D)** – this metric tells us the total energy emissions of specific device to the overall emissions of the building.(*measured in kg CO_2*)
- **CO2 Emissions per Business Process (EC_BP) –** by addressing also the BPM elements as part of the BIM model, a detailed alignment of CO2 Emissions with main business processes is revealed. (*measured in kg CO_2*)
- **CO2 Emissions per role (EC_O)** By linking the OM & BPM parameters in BIM model, a calculation of energy emissions per occupant is provided, towards the direct comparative analysis of end users. (*measured in kg CO_2*)

Further, and taking into account the CO2 emissions values and the baseline definition, **benchmark ratios** (per granularity level as addressed on the aforementioned key performance indicators) are defined on the granularity expressed above. In some cases, these values can be computed per room or building segment, based on the readings of CO2 emissions percentage per room.

Metrics classification

Following the detailed analysis of Energy Related KPIs, we present the metrics classification. The metrics can be grouped based on their specific calculation time granularity, building area levels and other occupancy related factors of energy consumption.

- Spatial Analysis metrics: the measurement can be done at several levels:
  - Per area (m2); Per room or room type (e.g. 2-persons offices, corridors)
  - Per building or building zone/segment (e.g. entire ground floor)
- Temporal Analysis metrics: different time scales are supported: per hour; per day; per week; per month; per season; per year; multi-year (year-on-year)
- Occupancy-related metrics: metrics that report KPIs per occupant or occupant group
  - Per occupant/per capita
  - Per type of actor or role: doctor, patient, office occupant, catering employee
  - Per business process
- Energy-related metrics: report usage level of specific resources or BES objects:
  - Per Device / Per Device Category

To be able to provide a benchmark estimation between alternative building designs, we need to proceed with the normalization of measurements. The factors that we need to take into consideration when normalizing the values of KPI and metrics are:

- Occupancy: total number of occupants per business process
- Geographical Area: floors or room area affected by an occupant, occupant group or workflow;
- Period of the year: different seasons have other sunlight, average indoor temperature and temperature day-night variation, different weather conditions, different business utilization in connection to seasonal holidays, etc.

For normalization of energy efficiency measures, we identify the main factors and coefficients for transforming energy consumption into primary energy production and into total CO2 emissions, and the respective savings thereof. This requires definition of a more detailed set of energy coefficients, such as energy mix. In addition and as already stated on the literature review typical benchmarking points are considered on the analysis towards the provision of a comparative operational rating. These benchmarks, typically defined in national legislation, are provided as part of Annex 1.

4.5.2 Business Performance Indicators

Based on the terminology, business performance KPIs must be able to reflect the achievement of the business goals and objectives and they must be quantifiable and measurable. For instance, the building is designed to be utilized at maximum levels, but also its use must obey certain rules and regulations concerning maximum levels of occupancy per m2. Each individual business process is typically composed of a sequence of tasks. Hence, there are two perspectives on extracting business processes related metrics.

a) The process level. That is to say, viewing the business process (as a whole. While knowledge of KPIs for a process can be extracted from a finer grained detail of BPs (i.e. on a task level) they should also be defined for a process as a whole as far as possible. It is important to establish the selection of concrete business processes that these may extend beyond spatial-temporal boundaries. That is to say, processes can be carried out between defined spaces. This can and should also be reflected in the annotated BIM that is constructed.

b) The individual task level, for each task involved in the overall process. Each task that composes a business process may directly involve the utilisation of an energy consuming device or system. In this respect, we make contact at a resource level, which facilitates the integration with energy related indicators attached to particular resource. This process is dependent on the performance indicators defined for nodes of the sensor network.

Taking into account the different views, a list of business indicators is defined. Examples of such indicators used under OrbEEt framework:

- **Building Utilization Level (BUL) per Year**. This is a complex measure, which has several components and measurement parameters. We propose a simplified approach to quantify this indicator based on:
    - Cumulated Activity Time (CAT): the cumulated activity time (total execution of business processes); this is expressed per each department of the building (expressed in number of total hours served) by taking also into account the total operational period of the building. *(measured as% = total hours served/ total operational period)*
- **Business Process Cycle time:** is related to the time period needed to perform a specific process. This indicator is not directly aligned to energy measurement data, but it is linked to the typical timeperiod needed for a process and therefore affects the usage of specific devices within this timeframe. *(measured in seconds/minutes etc…).*As meta indicators related to process cycle period we can further define:
    - **Active Process Time:** This is the Process Cycle Time minus any time due to idle/waiting/resting/transfer/down time.
    - **Process Waiting Time:** The total time during the process cycle time where the processed item is waiting to be processed, either initially or during intermediate steps (awaiting further input or approval, for example)
    - **Process Transport Time:** The total time during the process cycle time where the processed item is being transported (to another department for further processing, for example). Can be seen as a sub item of Process Waiting Time
    - **Minimum quota of presence:** The minimum percentage of the cycle time that personnel need to be present for the process
- **Business Processes Utilization (BPU):** the overall building ecosystem consists of different business processes. This indicator reveals the level of alignment between measured business processes and typical business processes. The calculation of this indicator is not a straightforward process and thus a simplified approach is considered, taking into consideration the average business process cycle time as expressed on previous indicator. *(measured in % as the deviation from the typical time_period needed for a specific process)*
- **Number of participants:** The number of participants directly engaged in a particular process; as max, min and mean values as extracted by the business process modelling delivered in pilot sites. *(number of occupants)*

The same approach is delivered towards the extraction of **Devices/Equipment utilization level** per time period. More specifically the

- **Percentage Building Used (PBU):** the percentage of building utilization by a specific business process. *(taxonomy per business process – percentage estimation).* In addition to this indicator, the meta indicator **Common Resource Space Used** (The percentage of floor space used by a process relative to the space covered by a given common energy expenditure (heating/cooling for entire floor, common luminescence source) is estimated.
- **Device Utilization Level (BUL) per Time period** is defined through the overall time period of device usage by taking also into account the overall operational period of the building. *(measured in minutes/hours).* In addition, and taking into account information on the resources of Business Processes, the utilisation Level can be provided per business process.
- **Process Resource Use (PRU):** the percentage of device utilization by a specific business process *(Based on the mapping of the devices to specific business processes→ Estimation of device usage for a specific business process→ taxonomy based on business processes).*

Furthermore, and as the goal of the project is the alignment of Business processes with energy related parameters, additional indicators are provided. We have already highlighted **"Energy Consumption per Process"** as an energy related indicator and towards this direction we further define:

- **Active Energy Resource Usage:** As a percentage of the process cycle time, the amount of time an energy consuming resource is being actively used in conducting the process *(measured in minutes/hours).*
- **Passive Energy Resource Usage:** As a percentage of the process cycle time, the amount of time an energy consuming resource which is used in a process is in a passive or standby state but still consuming energy *(measured in minutes/hours).*

These indicators highlight the impact of occupants, through business processes, on energy consumption. This information can be further utilized to trigger the appropriate energy efficiency strategies via the OrbEEt Behavioural Change framework.

The main objective of the OrbEEt SEOR framework is to provide a detailed view on energy performance aspects. The scope of the Business related KPIs is to act as meta-indicators that will further provide insights on Energy Performance Indicators. OrbEEt Business Performance Indicators will act as the forcing element towards the delivery of an energy efficient environment within premises through the utilization of these indicators on OrbEEt behavioral triggering framework. A detailed presentation of Business Related KPIs is provided in Annex 1.

Metrics classification

Following the detailed analysis of Business Related KPIs, we present the metrics classification. The metrics can be grouped based on their specific granularity while the main focus is considered on the business process classification.

- Device-related metrics: metrics that report KPIs per equipment
  - Per device/ equipment (for devices utilization)
- Business-related metrics: metrics that report KPIs per occupant or occupant group
  - Per Business Activity/ Process

In addition, classification based on temporal and spatial parameters should be considered through the association of business processes examined in premises. These are the main building elements, setting the guidelines for the classification of Business Related parameters, already addressed on the taxonomy of the list of provided indicators.

4.5.3 Human Preferences Related Indicators

A specific class of Key Performance Indicators (KPIs) – the human preferences indicators - describes the level of comfort provided by the building (and its services) to its occupants. Several environmental conditions and individual attributes are measured and reported, mainly per BIM element - room, public space, etc, and sometimes per BPM element - enterprise process.

Prescriptive or normative values for the levels of comfort are established through international, national, regional, local and property-specific norms. These values can be specified for a limited category or group of occupants as the case examined within the project. Again to point out that the Occupancy Related Indicators are not defined as indicators of the proposed SEOR framework, rather act as enablers for the comprehensive analysis of energy performance indicators. In other words, occupancy related indicators act as meta-indicators towards the provision of **eDECs framework**. In addition, these indicators can be further utilized as input features of the behavioural triggering framework.

In the proposed framework, environmental measurements are used to estimate several KPIs concerning occupants' comfort mentioned in the related literature. These indicators are summarized.

- **Thermal Comfort (TC)** the level and variation of temperature by taking into account temperature measurement data. In addition, and by taking into account the humidity measurement data, the estimation of PMV value is provided, following a standardized approach on thermal comfort level evaluation. The equation of the PMV index is provided. [17]

$$
\begin{aligned}
PMV = {} & (0.303\, e^{-0.036M} + 0.028)\cdot \\
& \{(M-W) - 3.05\cdot 10^{-3}\cdot[5733 - 6.99\cdot(M-W) - p_a] \\
& -0.42\,[(M-W) - 58.15] - 1.7\cdot 10^{-5} M(5867 - p_a) - 0.0014M(34 - t_a) \\
& -3.96\cdot 10^{-8} f_{cl}[(t_{cl} + 273)^4 - (t_r + 273)^4] - f_{cl} h_c (t_{cl} - t_a)\}
\end{aligned}
$$

Where,

1. $t_{cl} = 35.7 - 0.028(M - W) - I_{cl}\{3.96 \cdot 10^{-8}\,[(t_{cl} + 273)^4 - (t_r + 273)^4] + f_{cl} h_c (t_{cl} - t_a)\}$
2. $hc = \max\,(2.38\,|t_{cl} - t_a|^{0.25}\,,\ 12.1\sqrt{v_{ar}})$
3. $f_{cl} = \begin{matrix} 1.00 + 1.290 I_{cl} \text{ for } I_{cl} < 0.078 m^2K/W \\ 1.05 + 0.0645 I_{cl} \text{ for } I_{cl} > 0.078 m^2k/W \end{matrix}$

Therefore the parameters examined are:

- M is the metabolic rate
- W is the effective mechanical power
- I_{cl} is the clothing insulation
- f_{cl} is the clothing surface area factor
- p_a is the water vapour partial pressure *(humidity)*
- t_a is the *air temperature*
- t_r is the mean radiant temperature
- v_{ar} is the relative air velocity.

As this is a complex equitation, the usage of **temperature level** for thermal comfort evaluation is considered as an option for the project. Therefore, by monitoring temperature conditions under specific business processes, the extraction of the comfort related indicator is foreseen. *(Dimensionless)*

- **Visual Comfort (VC):** expressed by Lighting Levels as the level and variation of light. The overall estimation is based on the luminance data coming from luminance sensors installed within premises.*(Dimensionless)*

These are measurable elements reflecting the internal environmental conditions of the building, and inherently influencing occupants' behavior. As these indicators are aligned with specific occupants, they can further map to specific business processes, through the interconnection of BPM and HP parameters. To this end, these indicators are indirectly related to specific devices operation (namely HVAC and Lighting devices) and therefore the main objective within the SEOR framework is to set them as the enablers towards an energy efficient management of the specific devices.

Metrics classification

Following the detailed analysis of Occupancy Related KPIs, we present the metrics classification based on the modelling characteristics as defined on the previous section. The metrics (sensor data) can be grouped based on their specific calculation time granularity, building area levels and the occupancy related factors defined. More specifically:

- Spatial Analysis metrics: the measurement can be done at several levels:
    - Per area (m2); Per room or room type (e.g. 2-persons offices, corridors)
- Temporal Analysis metrics: different time scales are supported: per day; per week; per month; per season; per year; multi-year (year-on-year)
- Occupancy-related metrics: metrics that report KPIs per occupant or occupant group
    - Per occupant/per group of occupants
    - Per type of actor or role: doctor, patient, office occupant, catering employee

4.5.4 Behavioural Change Related Indicators

The aforementioned layers set the core OrbEEt models towards the extraction of Key performance indicators, to be further utilized through eDECs visualization and behavioural triggering framework. To this end, BCM's role on SEOR engine definition is dual:

a. To identify the already defined KPIs that are essential for BCM framework
b. The BCM framework is further characterized by a list of internal indicators to further evaluate the impact of OrbEEt BCM. Towards the definition of a fully-fledged SEOR model (that also takes into account evaluation parameters), a list of indicators related to OrbEEt BCM are further presented.

The framework towards the definition of OrbEEt BCM related indicators is provided:

- Identifying the behavioural technique to adaptively employ requires an understanding of the performance of a user against their engagement with the platform (Figure 12). Engagement with the platform can be measured quantitatively at the high-level in terms of the **time spent using the intranet services and game** *(minutes)*, and at the lower-level in terms of **actions** *(Dimensionless)* **and performance** *(percentage)* within these interfaces. This ultimately needs to be linked to KPIs to categorise users and trigger behavioural strategies accordingly, as well as to validate the platform as a whole.
- Identify the qualitatively different ways that people change their bevaviour for encouraging more efficient energy behaviours and thereby making informed decisions on

what influences people to make rationale decisons and actions with regards to their energy consumption. It is key here to explore not only the energy demand originated by the individual but also the collective actions as a result of a social construct such as **collective actions** *(Dimensionless)*, **public participation strategies for gaining people's commitment** *(percentage)*. It is essential that OrbEEt's interventions are designed according to consumer's profiles and target the easiest behaviours to change with the greatest impact.

- To individualise and personalise feedback, KPIs of, for example, device use, ideally need to be tied to the business role responsible for the device. Understanding the individual as well as group performance is highly valuable in enabling a sense of self-efficacy in the user and therefore high-level performance metrics should link KPIs to both the individual and group (office).
- Behavioural Change Related Indictors are also tied to the business performance KPIs. The gamification platform will automatically log user interactions with the platform, especially the visual and feedback parameters that represent engagement mechanisms such as rankings, pledge settings, score history in relation to the business performance KPIs.
- Indicators of interest that would help to test the validity of the gamification approach include measures of energy hungry business activities and their respective energy consumption constituents and activities (e.g., leaving to go to lunch, opening window to cool down a room) that correlate with variations in energy consumption.
- In addition, the BCM depends on the availability of indicators of business activities', spaces' or departments' energy footprints that will triggering building occupants to focus on activities that can bring sizeable energy reduction. Data on these activities should be in form so that the gamified platform will enable users to rank their performance (at unit, activity or space levels) among "peer" or similar entities. Initially the granularity of the data will be adjusted at different levels and the indicators should be examined to maximize users' meaningful interactions with the system that impact their behaviour.

We have initially defined a list of KPIs related to the evaluation of BCM framework, while the rest of the points highlight the main SEOR engine related requirements towards the prompt implementation of a gamification framework. It is obvious that the correlation of energy, business and human related parameters is mandatory towards the definition of a concrete BCM framework.

4.6 Collecting Data for SEOR framework

The overall analysis over different indicators set the basis for the Systemic Enterprise Operational Rating framework proposed in OrbEEt Project. The overall objective is not to provide a monolithic approach, by adopting a single rating, rather to proceed with the development of a dynamic approach towards a more accurate estimation of building energy performance. By addressing the already defined Key Performance Indicators and the users' requirements as expressed at the very early phase of the work (Deliverable 1.1), the form of OrbEEt enhanced Display Energy Certificates is presented in the next section.

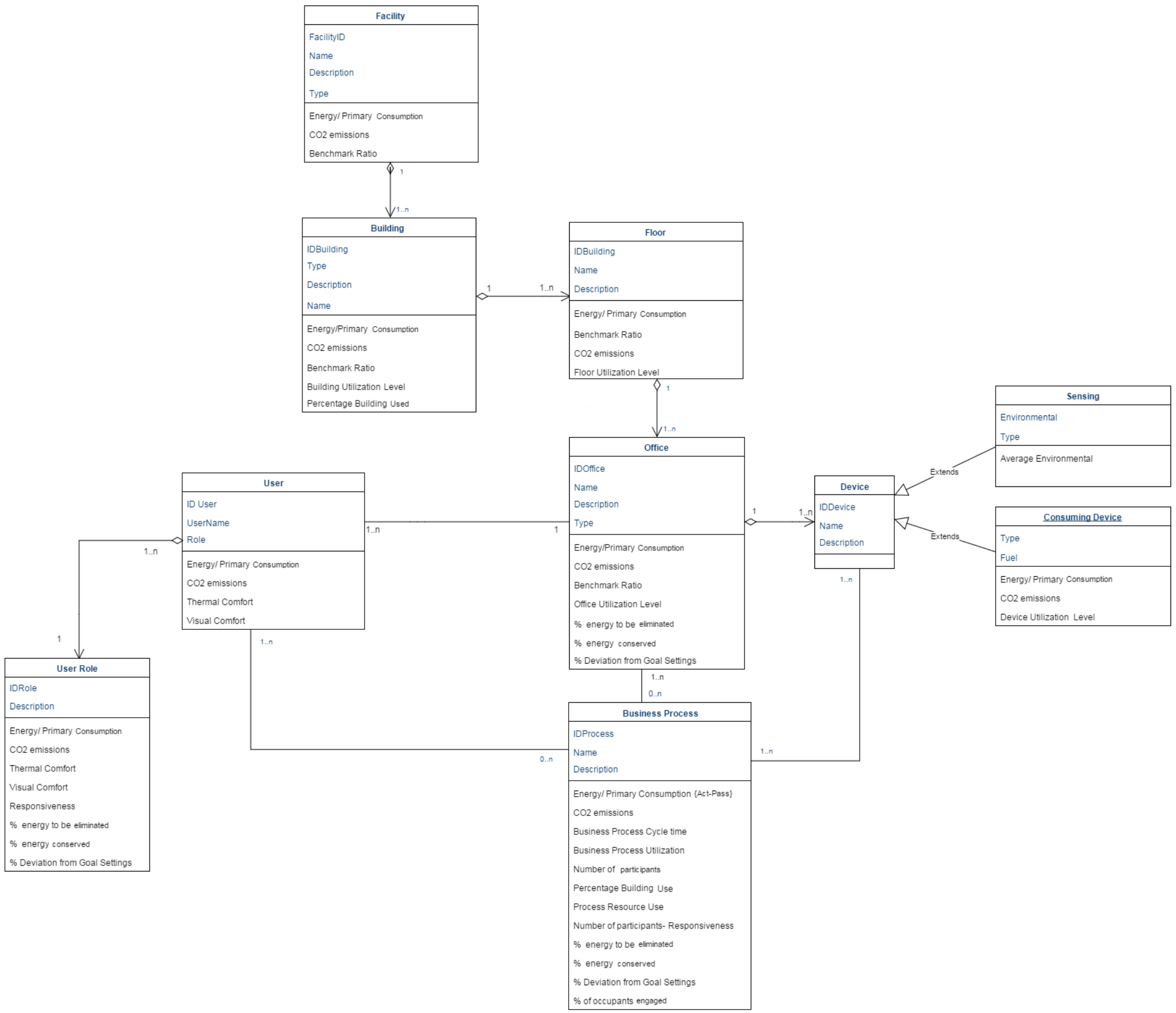

Figure 14 Key Performance Indicators Hierarchy

We have to point out that the hierarchy on KPI values is one of the main objectives of the project. As the goal of OrbEEt is to provide insights on KPIs for the different stakeholders of the project, the definition of BIM and BPM parameters is a critical aspect of the project. Through this hierarchy, the adaptation of metrics and KPIs on the specific static elements that set the core model of the project, provides the high level view of the functionalities to be developed in the project. This high level mapping of KPIs, as part of the project data model, set the guidelines for the development of SEOR and gamification components during the implementation phase of the project.

5. OrbEEt Enhanced Display Energy Certificates

5.1 End Users Requirements Analysis

Following the definition of the key performance indicators that further impart a dynamic character at the proposed SEOR approach, a detailed presentation of the OrbEEt enhanced Display Energy Certificates framework is provided. Prior to eDECs specifications overview, an analysis over the list of end users requirements is provided to set the limitations on the proposed framework. Therefore, the list of requirements that are closely related to eDECs definition is provided to set the basis for the proposed framework.

Table 3 eDECs functional requirements

Number	Requirement	Obligation level	Relevant to UC
ID_1	The system should extend the concept of DECs towards delivering certificates of significantly enhanced **spatial granularity** by establishing a dynamic approach	High	UC1
ID_2	The system should extend the concept of DECs towards delivering certificates of significantly enhanced **temporal granularity** by establishing a dynamic approach	High	UC1
ID_3	The system should extend the concept of DECs addressing also the **operational granularity (different business roles)**by establishing a dynamic approach	Medium	UC2
ID_4	The system should extend the concept of DECs by providing a **real time or near real time calculation** of Operational Rating Indicators	High	UC1
ID_5	The system should extend the concept of DECs by addressing not only **energy** but also **business and comfort** related indicators	High	UC2
ID_6	The system should ensure the calculation of indicators that are essential for the **visualization of energy & organizational information (eDECs) and the gamification framework** (along with the respective interfaces)	High	UC1, UC2, UC3

Therefore, the overall analysis will be performed in order to address these requirements as part of the provided model. The respective specifications will further trigger the definition of SEOR Reference Architecture, to be documented at the respective Deliverable (D1.4) as part of overall OrbEEt Technical Architecture.

5.2 OrbEEt Enhanced DECs

The main goal of this section is to provide the OrbEEt approach for Enhanced Display Energy Certificates. Towards this direction, we take into account the SEOR framework, as presented in previous section, in order to define the KPIs to be visualized through the eDECs. The perspective of this GUI should not be confused with the behavioural triggering engine, to be presented in T1.3.The focus is on the visualization of dynamic display energy certificates, replacing the static and monolithic representation of current DECs. Therefore, this UI addresses the role of the Facility Manager, though specific views should be available for building occupants.

As extracted by the requirements analysis, the respective service should incorporate apart from typical benchmarking ratios, business processes, building characteristics, behaviour of organizational actors and near real-time energy monitoring in order to produce the eDECs. The next section provides the representation of eDECs service component (to be further integrated in the holistic OrbEEt framework in T1.4) and further some mock up views of the system are provided to highlight the main functionalities provided by the tool.

5.2.1 OrbEEt eDECs Engine Architecture

The detailed architecture of OrbEEt eDECs Engine is provided in the next figure, highlighting the interfaces and the core elements of the application.

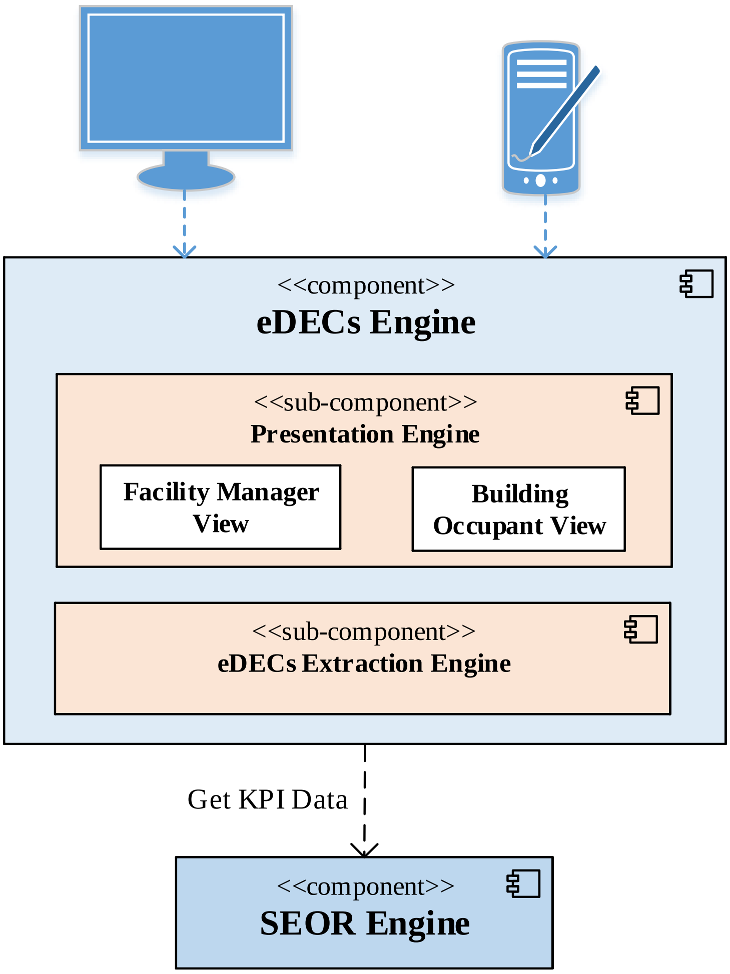

Figure 15 eDECs Engine – Internal components & Dependencies to other components

Main Functionalities

The core functionalities of the eDECs Component are divided on the different types of the end users and are presented:

- To provide the Facility Manager with a web user interfaces, in order to:

  - visualise real-time (aggregated and correlated) information on the energy consumption, CO2 emissions and benchmark point of the building
  - Spatiotemporal filters for the extraction of energy consumption, CO2 emissions and benchmark point of the building at any structural level.
  - Visualize main business processes and further information about business processes for a better understanding of energy consumption parameters
  - Visualize Human preferences related indicators for a better understanding of energy consumption parameters
  - Real time or near real time updates of the KPI values for a better view on whole building performance

- To provide user interfaces to building occupants, either web-based or through smartphone mobile applications, in order to allow them to:
  - provide real-time information concerning the energy consumption and the operational status of each sub area, towards the visualization of personalised information
  - User specific spatiotemporal filters for the customized extraction of energy consumption, CO2 emissions and benchmark point data.

Internal Components

The figure above presents the main internal parts of OrbEEt eDECs Interface component, which are described below:

- **eDECs extraction engine:** will retrieve the total information from underlying Systemic Enterprise Operational Rating framework, in order to provide the additional personalized information for the different User Interfaces. More specifically, and taking into account the filtering settings by the end users of the tool, customized eDECs views are delivered.
- **Presentation engine:** The content received will be properly transformed and formatted based on the needs of corresponding Views, to be presented to the end-users trough web/mobile user interfaces. Therefore this part of the system sets the front end of the application for visualization of eDECs.

External Interfaces

The external interfaces of the component are with the following components:

- **Systemic Enterprise Operational Rating:** The goal of the engine, as presented in previous section of this deliverable, is to set the KPI Library of the project. Towards this direction raw data are further transformed to KPI values for further exploitation by eDECs extraction engine

Inputs/Outputs

The eDECs Interface component will require a set of different inputs, in order to create appropriate views for respective end-users. These data will comprise of energy, business and human preference related data towards the provision of customized views (based on filter settings) to the end users of the system.

Following the detailed analysis of the system, along with the definition of the main functionalities of the tool, some indicative mock ups of the system are presented in the next section. These mock ups cover the system functionality; thought slight modifications are expected during the development phase of the project.

5.2.2 Facility Manager eDECs view

This is the core application of the system, customized for facility managers. We have adopted a top-down design framework, addressing the hierarchy of building premises. Therefore, as the main screen of the system, the technical and business indicators for each pilot site are presented:

Figure 16 eDECs Engine – Home View

The energy performance ratio (benchmark ratio) is provided for a specific time period. The user is able to select from a tab, the timeperiod for the analysis. In addition, detailed diagrams about CO2 emissions and previous operational rating are provided by comparing the current status with previous periods. Thus, the diagrams are considered as fully dynamic, dependent on the selected timeperiod value.

In addition, information about real time conditions in premises, and some technical information are provided through the main screen of the system. A map view is provided where the users is able to select a space to further drill in on a zone based analysis. This option is also available from the top menu, by selecting the zone button.

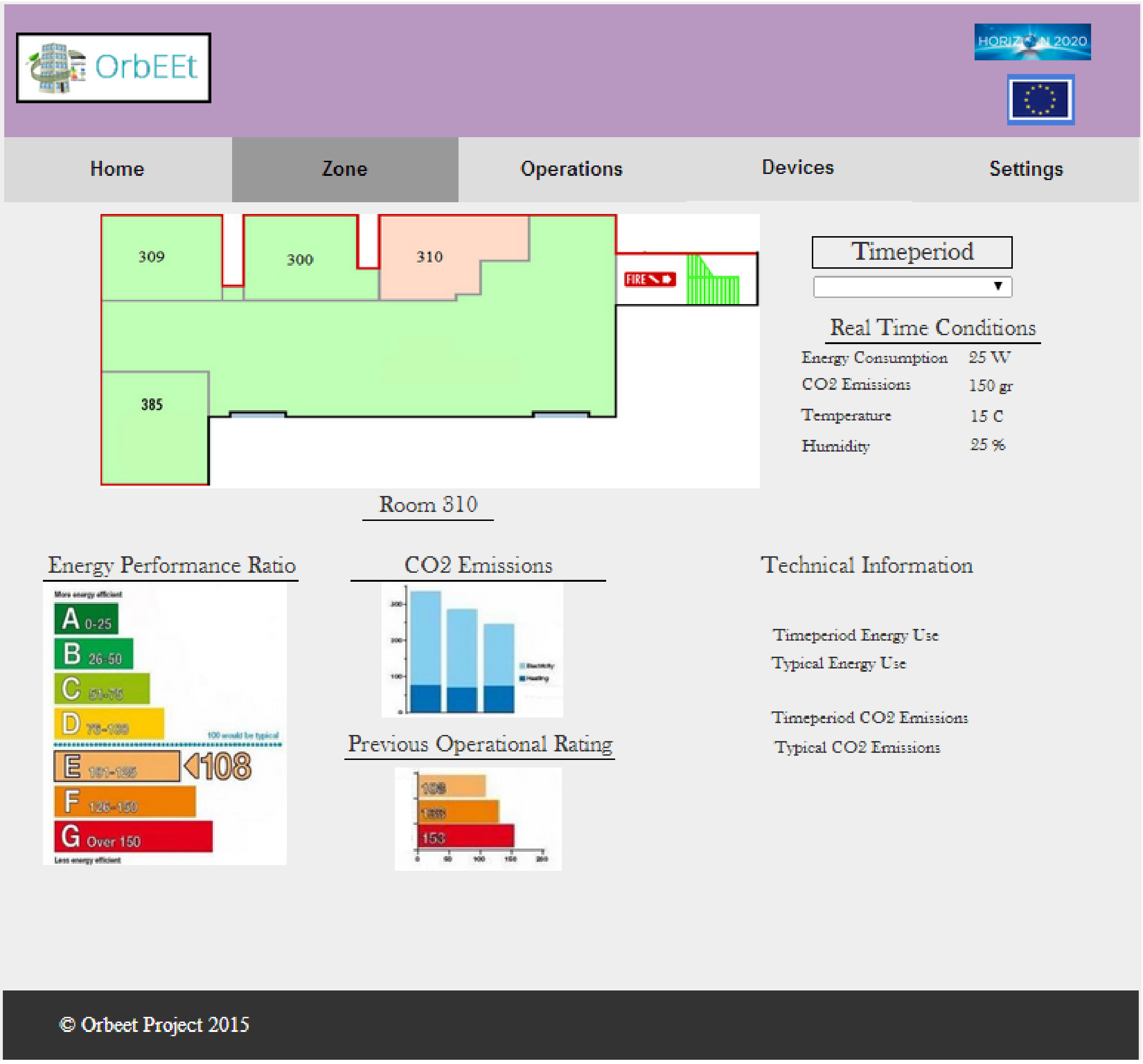

Figure 17 eDECs Engine – Zone View

The selected zone is highlighted while the diagram values fit on user settings. The user experience remains the same, as the user is able to select the timeperiod for the analysis. Again real time conditions and statistical information is provided through the respective UI.

Along with spatiotemporal analysis, the focus of OrbEEt eDECs is on business processes. Thus, through the top menu, the end user may also select the “Operation” tab for a detailed view on business processes. Again the UX remains the same, though the user is able to select a business process from the list

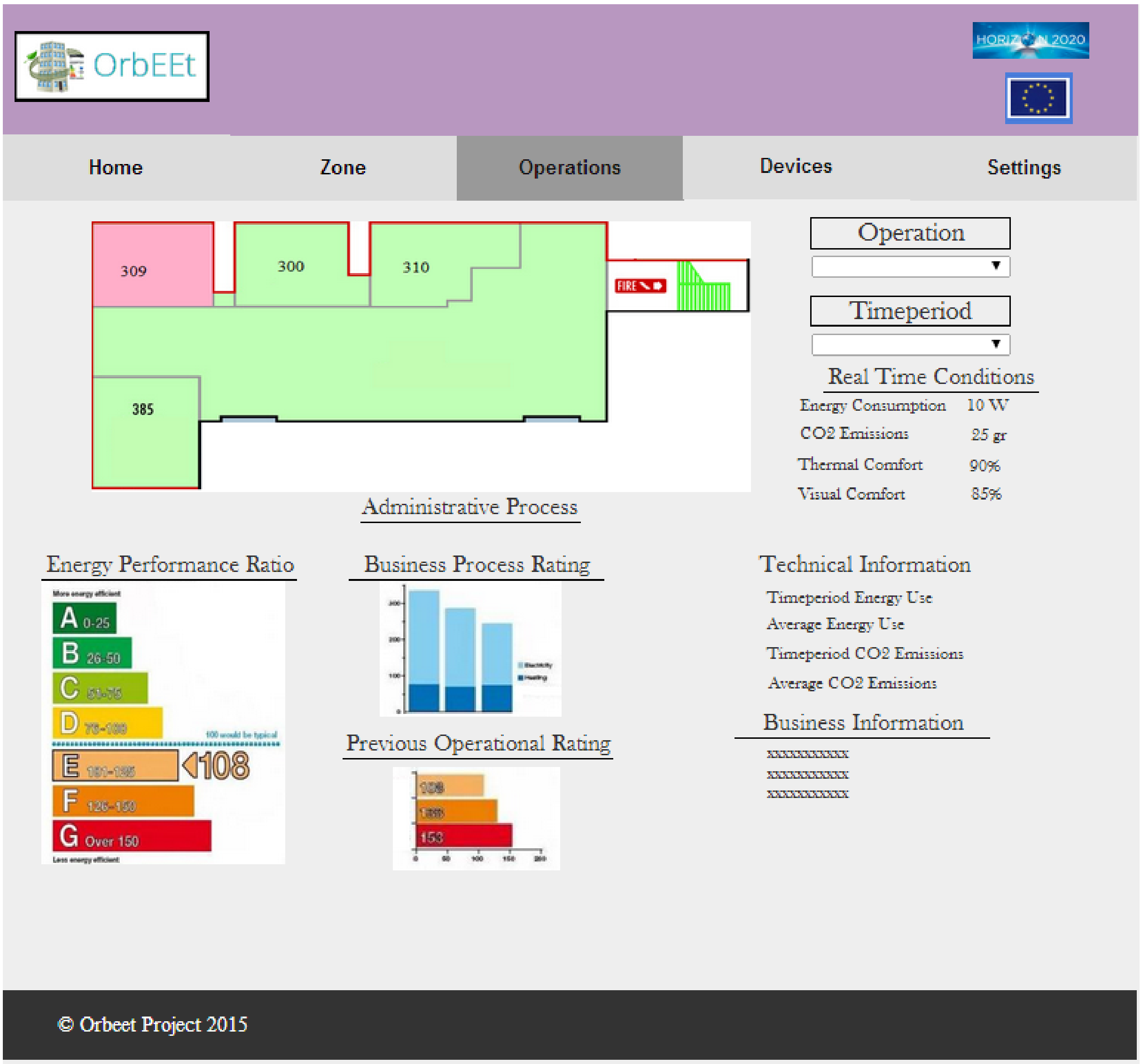

Figure 18 eDECs Engine – Business Processes View

Apart from performance rating graphs, KPIs about the performance of business processes are visualized. In addition, the map graph highlights the zones associated to the selected business process, information available through the enhanced BIM of the project. We have to point out, that KPIs related to human preferences are also visualized, addressing the main objective of the project for analysis of behaviour of organizational actors.

By selecting the Devices tab from the top menu, the users gets insights about the operation of device types. The placement of the devices in premises is based on the BIM model, while the user is able to select the device type by a drop down menu.

Figure 19 eDECs Engine – Device Types View

Again, the timeperiod filter remains the same, along with real time metric values and indicators, the associated performance graphs and technical information.

As the main innovation of OrbEEt eDECs is the customization of the tool, a "settings' button is also available on the top menu. The user, by selecting this view is able to set customized preferences on the views of the tool. Therefore, and taking into account the specific characteristics of each building or zone addressed, the user is able to select the parameters that best fit in each case.

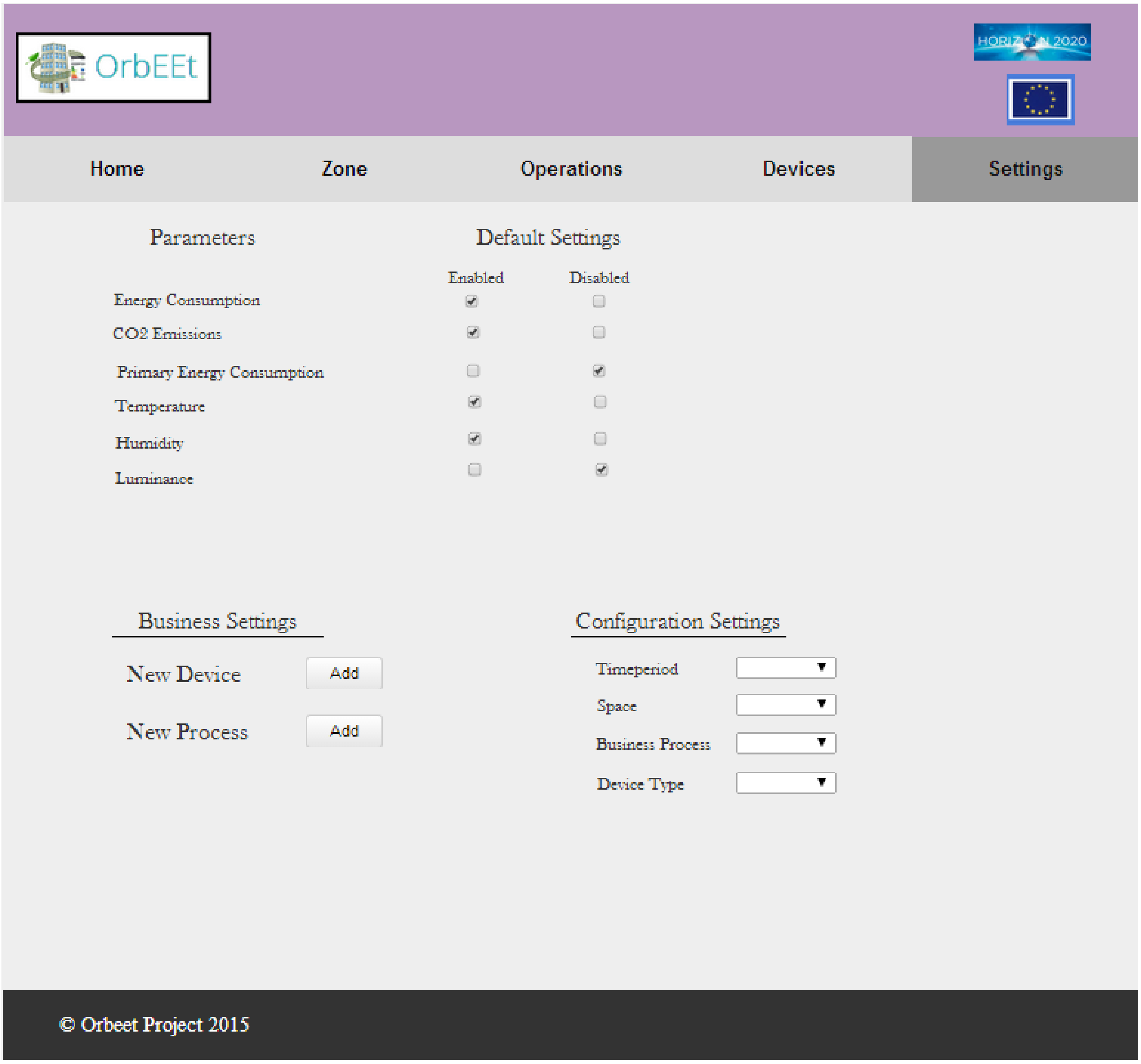

Figure 20 eDECs Engine – Settings View

A detailed functional view of the applications is provided, in the way to provide a manual/handbook for OrbEEt eDECs User Interfaces of OrbEEt project. A "drill - in methodology" is considered for the prompt description of the applications functionality. The selection of this methodology is considered in order to describe the different views in a comprehensible way. Following the description of the view for facility managers and energy experts, the next section provides the customized to building occupants views.

5.2.3 Building Occupants eDECs view

The focus of this section is not on the technical implementation of the mobile view rather on the functional description. A welcome page, allows the user to authenticate him in the system inserting its own credential (login and password). In case of error the user will be prompted to verify its data and reinsert it in the correct fields. Also the name/logo of the project are mentioned at the upper level part of the application.

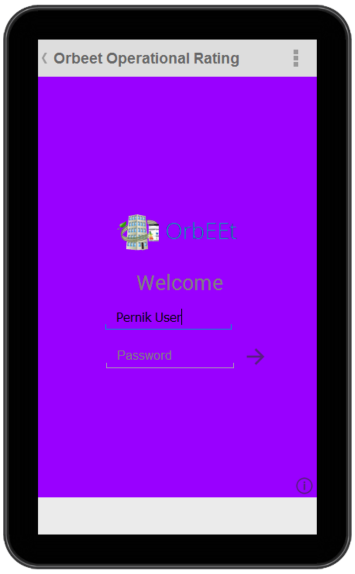

Figure 21 eDECs Mobile Version – Intro Screen

The homepage is a domestic environment overview that is made of three elements that helps the user viewing OrbEEt system parameters:

- Operation tab for monitoring associated business processes.
- Zone tab for monitoring associated building zones
- Device tab for monitoring associated devices

Therefore customized information is available through a tab menu. The user is able to customize the initial screen of the application, though "operation" tab is by default the initial view.

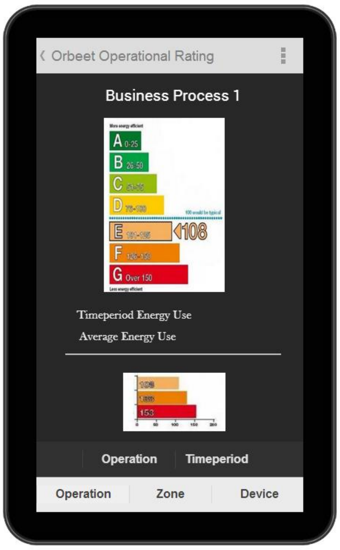

Figure 22 eDECs Mobile Version – Business Process Screen

Along with business process based operational rating, the user get an overview of technical information, while also comparative analysis through time is provided. Therefore, the available information is a subset of the information provided through Facility manager web interface. The end user, associated to more than one business processes, is able to filter operational processes and further set the timeperiod for analysis.

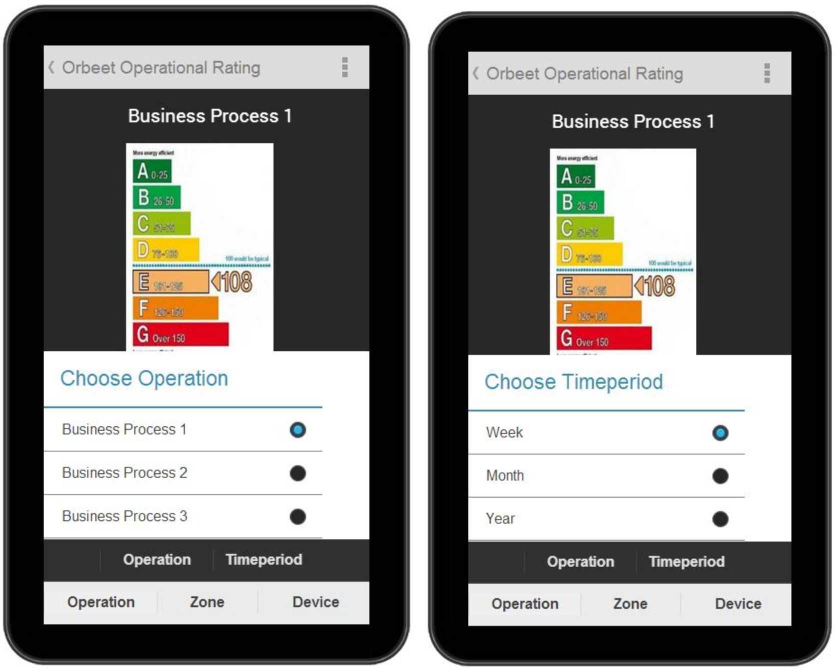

Figure 23 eDECs Mobile Version – Operation and timeperiod filters

Then, by selecting the "zone" or "device" button from the bottom menu, customized views are provided to the end users, focusing on these perspectives. Again, to point out that each user has access only at information, as associated by the BIM model of. Therefore, the user is eligible to select from associated zones and device types. The next diagram provides the respective screenshots for selection criteria.

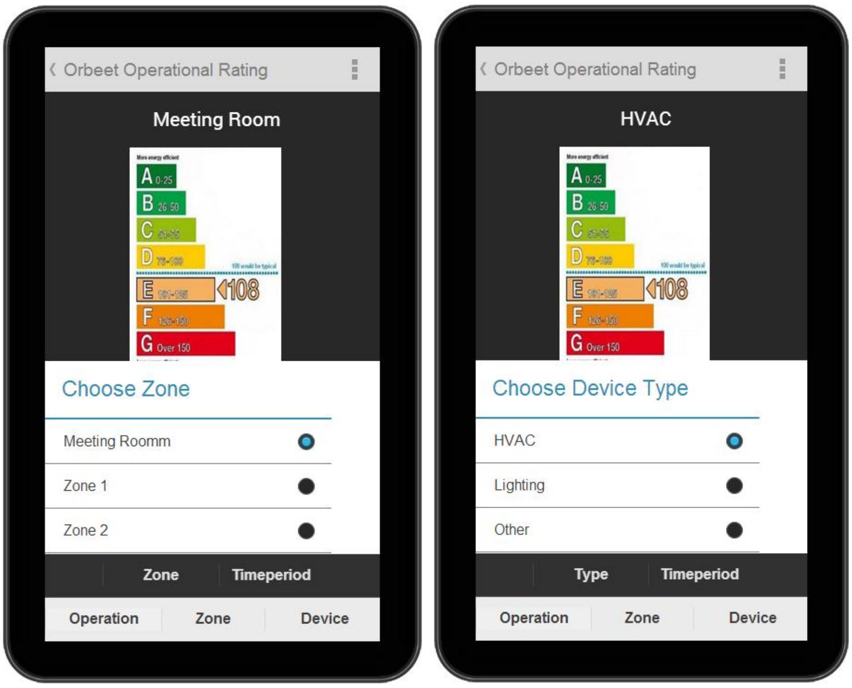

Figure 24 eDECs Mobile Version – Zone and Device filters

The previous analysis was delivered in order to have a detailed view on the role and the scope of the respective user interfaces taking into account the main entities of OrbEEt project:

spaces, devices, business processes. User interfaces play a pivotal role in acceptance and rejection of each application by the users. An application that is difficult to use will not be used by its stakeholders. It is important to have a set of user interface guidelines in place that ensures easy, intuitive and meaningful interaction with the system. In this deliverable, we have identified a list of good practices for designing UI for OrbEEt enhanced Display Energy Certificates. Though, and as these views are provided as mock-ups a definition of the detailed functionalities will be defined during the development phase in D3.3.

6. Conclusions

6.1 Summary of achievements

The proposed Systemic Operational Rating Framework (SEOR) is the main mechanism towards the achievement of the goal of efficient building operation in modern enterprises. SEOR is a performance model consisting of several component models, which describe the main functional, physical, environmental and organizational dimensions of a building.

In this document, we have explored the possibilities to extend the existing Operational Rating framework for enterprise buildings in several directions, to include the ***Physical Sub-System***, i.e. the building and its support equipment; the ***Human*** occupancy-related aspects, including ***Enterprise***-related processes and business goals that impact occupants' behaviours; and elements of the ***Surrounding Environment***, i.e. the indoor environmental conditions (temperature, humidity, luminance etc.).

The main objectives of this extended model are to capture and connect the key elements of the building infrastructure with the active usage of the building by its occupants through their business activities, and to create a building operational rating analysis model which is occupancy-centred and enterprise-aware and allows a more precise view on the energy related aspects of the building. Towards this direction, and by addressing specific indicators to set the enriched Operational Rating framework, we further provide enhanced Display Energy Certificates, dynamically updated, towards the establishment of an energy efficient operation in enterprises level.

The document defines the models and specifications of OrbEEt Systemic Operational Rating Framework (SEOR) framework along with the definition of enhanced Display Energy Certificates (eDECs) models. By starting from the current status we have extended the established operational rating framework to SEOR framework, by identifying the list of KPIs that can further trigger the behavioural change framework and further define the OrbEEt eDECs framework.

7. ACRONYMS AND TERMS

Acronym	Definition
SEOR	Systemic Enterprise Operational Rating
eDECs	enhanced Display Energy Certificates
EPC	Energy Performance Certificates
KPIs	Key Performance Indicators
BIM	Building information Model
ICT	Information and communications technology
HVAC	Heating, ventilating, and air conditioning
BPM	Business Process Modelling
ESCO	Energy service company
EPBD	Energy Performance of Buildings Directive
OR	Operating Rating
TUFA	Total Usable Floor Area
QE	Qualified Experts
EP	Energy Performance
NZEB	Nearly Zero-Energy Buildings
DHW	Domestic Hot Water
HP	Human Preferences
GIS	Geo-Information System
BCM	Behavioural Change Model
GHG	Greenhouse Gas
BES	Building energy systems
GUI	Graphical User Interface
UI/UX	User Interface (UI) & User Experience (UX)

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9. APPENDICES

Further information is described in related background documents:

9.1 Appendix 1: List of Orbeet Indicators

For the performance indicator presentation, a common pattern illustrated in Table 4 Detailed format for KPI definition will be used. These details will be examined in order to have a concrete view of the OrbEEt Key Performance Indicators.

Table 4 Detailed format for KPI definition

KPI details	Descriptions
Name	Name of the Performance Indicator. A KPI is associated with a specific process and is generally represented by a numeric value.
Id	KPI Id
Description	A short description of KPI presented
KPI calculation	The mathematical model for the extraction of KPI value
Metrics	Metrics are referred to a direct numerical measure that represents a piece of data in the relationship of one or more dimensions.
Input Parameters	Values that should be ALWAYS AND DIRECTLY available during the calibration as well as during the simulation and be reflected in the OrbEEt Data Model

Based on the aforementioned introduction, the list of energy consumption related aspects are further examined. As the scope of OrbEEt project is to examine different aspects on the flow, the extrapolation of the energy consumption measurements to the respective entities is considered on the analysis

Energy Related KPIs

KPI Name	**Energy Consumption (Monthly, Daily, Time-period)**
ID	E.01
Description	Total energy consumption is the sum of electrical energy, over a given time period T
Formula	$EnerConsum = \int_{Timeref} Elec\_measured$ (kWh)
Metrics/Input Parameters	Energy Consumption metrics: (Sensor Measurement Data)

KPI Name	**Primary Energy Consumption (Monthly, Daily, Time-period)**
ID	E.02

Description	Total primary energy consumption taking into account the source of energy
Formula	Energy Consumption * Primary Energy Indicator
Metrics/Input Parameters	Energy Consumption metrics: (Sensor Measurement Data) Primary Energy Indicator: Static Values

KPI Name	**CO2 emissions (Monthly, Daily, Time-period)**
ID	E.03
Description	Total CO2 emissions taking into account the CO2 emissions ratio and energy consumption
Formula	Energy Consumption * CO2 emissions ratio
Metrics/Input Parameters	Energy Consumption metrics: (Sensor Measurement Data) C02 Emissions ratio: Static Values

KPI Name	**Benchmark ratio (Time-period)**
ID	E.03
Description	The ratio of Energy Consumption (or primary energy consumption) to the benchmark point as defined by energy policies (per pilot site area)
Formula	Energy Consumption[1] / Benchmark Building Energy Consumption
Metrics/Input Parameters	Energy Consumption metrics: (Sensor Measurement Data) Benchmark Building Energy: Pilot audit phase taking into consideration the typical DECs

The overall definition of KPIs is delivered taking into account the availability of data as captured by the WSN installed in premises.

Business related KPIs

Based on the terminology, business performance KPIs must be able to reflect the achievement of the business goals and objectives and they must be quantifiable and measurable. Examples of such indicators used under OrbEEt framework:

KPI Name	**Process Cycle Time**
KPI Id	B.01
Description	The time interval between the start of a process and the start of the next process following the successful completion of the previous one.

[1] In addition to energy consumption, CO2 emissions can be considered as the metric for Benchmark ratio evaluation.

Formula	Time when ready for next process (t2) minus time for starting of the process (t1): t2 - t1
Metrics/Input Parameters	Process dependent: BPM Model

KPI Name	**Active Process Time**
KPI Id	B.02
Description	This is the Process Cycle Time minus any time due to idle/waiting/resting/transfer/down time.
Formula	Cycle Time - Waiting Time - Transport Time - Other inactive time periods
Metrics/Input Parameters	Process dependent: BPM Model

KPI Name	**Cumulated Activity Time**
KPI Id	B.03
Description	The total hours that the process is used as a percentage of the building operational time (for example, over a year)
Formula	(total process usage hours)/(building operational hours) x 100
Metrics/Input Parameters	Process dependent: BPM Model building operational hours: Pilot audit

KPI Name	**Process Waiting Time**
KPI Id	B.04
Description	The total time during the process cycle time where the processed item is waiting to be processed, either initially or during intermediate steps (awaiting further input or approval, for example)
Formula	Sum of time periods during which the process is waiting
Metrics/Input Parameters	Process dependent: BPM Model

KPI Name	**Process Transport Time**
KPI Id	B.05
Description	The total time during the process cycle time where the processed item is being transported (to another department for further processing, for example). Can be seen as a sub item of Process Waiting Time
Formula	Sum of time periods during which the processed items are being transported
Metrics/Input Parameters	Process dependent: BPM Model

KPI Name	**Percentage Building Used**
KPI Id	B.06

Description	The percentage of the building floor space used by a given process
Formula	[(Floor space used by process)/(total building floor space)] x 100
Metrics/Input Parameters	Floor space used by process: BPM Model total building floor space : Static Parameter

KPI Name	**Common Resource Space Used**
KPI Id	B.07
Description	The percentage of floor space used by a process relative to the space covered by a given common energy expenditure (heating/cooling for entire floor, common luminescence source). Defined for each common energy source.
Formula	[(Floor space used by process)/(Floor space covered by common energy expenditure)] x 10
Metrics/Input Parameters	Floor space used by process: BPM Model Floor space covered by common energy expenditure: BPM Model

KPI Name	**Business Process Utilisation**
KPI Id	B.08
Description	The overall building ecosystem consists of different business processes. This indicator reveals the level of alignment between measured business processes and typical business processes.
Formula	Measured in percentage as the deviation from the typical time period needed for a specific process
Metrics/Input Parameters	Time, represented as percentage Typical business process: BPM Model

KPI Name	**Number of participants**
KPI Id	B.09
Description	The number of participants directly engaged in a particular process; as max, min and mean values
Formula	Sum of all direct participants in all activities of a particular process
Metrics/Input Parameters	Persons: BPM Model

KPI Name	**Process Resource Utilisation**
KPI Id	B.10
Description	The time a resource or device (computer etc.) is used during a process as a percentage of the process cycle time. Defined one

	per resource used during the process (task level) and as a sum for a given process
Formula	(Sum of time periods during which the resource is used)/(Process Cycle Time) x 100
Metrics/Input Parameters	Sum of time periods during which the resource is used: Measured data Process Cycle Time: BPM Model

KPI Name	**Device Utilization Level (BUL) per Time period**
KPI Id	B.11
Description	The overall time period of device usage by taking also into account the overall operational period of the building.
Formula	Sum of time periods during which the resource is used
Metrics/Input Parameters	Sum of time periods during which the resource is used: Measured data, measured in minutes/hours

KPI Name	**Active Energy Resource Usage**
KPI Id	B.11
Description	As a percentage of the process cycle time, the amount of time an energy consuming resource is being actively used in conducting the process
Formula	[(Time of active resource usage)/(cycle time)] x 100
Metrics/Input Parameters	Time of active resource usage: Timeperiod measured cycle time: BPM Model

KPI Name	**Passive Energy Resource Usage**
KPI Id	B.12
Description	As a percentage of the process cycle time, the amount of time an energy consuming resource which is used in a process is in a passive or standby state but still consuming energy
Formula	[(Time of passive resource usage)/(cycle time)] x 100
Metrics/Input Parameters	Time of passive resource usage: Timeperiod measured cycle time: BPM Model

The BPM related indicators are defined based on the BPM Modelling as provided in premises. Though, there is a need for continuous adjustment of KPI values, addressing the dynamic characters of some metrics as described in the previous analysis.

Human Related KPIs

Finally a set of Comfort Related KPIs are defined towards the definition of occupancy related parameters in the model. The analysis is delivered based on the available context conditions captured by the environmental sensors.
Within OrbEEt, visual and thermal aspects will be further examined, and thus a list of KPIs is provided as part of the holistic evaluation framework.

KPI Name	**Thermal Discomfort Factor**
KPI Id	C.01
Description	This Indicator defines the Thermal User Preferences as examined within the Project. A scale of [0..1] is considered.
Formula	*Model based estimation : User Thermal Profiling model*
Metrics/Input Parameters	PMV (Temperature, Humidity,...) & Temperature

KPI Name	**Visual Discomfort Factor**
KPI Id	C.02
Description	This Indicator defines the Visual User Preferences as examined within the Project. A scale of [0..1] is considered.
Formula	*Model based estimation : User Visual Profiling model*
Metrics/Input Parameters	Luminance metric values

Human preferences analysis is one of the main innovations of the proposed SEOR framework and the analysis is based on the captured data from the environmental sensors installed in premises.

<u>Behavioural Change Model KPIs</u>

As mentioned in the deliverable, the role of this section is dual: to define the list of aforementioned KPIs needed for BCM framework, and further to define additional KPIs needed mainly for the evaluation of the proposed framework. These are further presented:

KPI Name	**Time spent using the intranet services and game**
KPI Id	G.01
Description	This Indicator defines the time spent using the intranet services and game for BCM
Formula	Sum of timeperiod addressed per application
Metrics/Input Parameters	Measurement of usage of applications: BCM Model

KPI Name	**% of occupants engaged**
KPI Id	G.02
Description	This Indicator defines the percentage of occupants participated on BCM framework
Formula	Number of occupants participated/ Total number of occupants

Metrics/Input Parameters	Number of occupants participated: BCM Model Total number of occupants: Static Parameter

KPI Name	Number of actions accepted
KPI Id	G.03
Description	This Indicator defines the number of actions accepted on BCM framework
Formula	Number of actions accepted
Metrics/Input Parameters	Number of actions accepted: BCM framework

KPI Name	**Responsiveness**
KPI Id	G.04
Description	This Indicator defines the percentage of active participation on BCM framework
Formula	Number of actions accepted / Number of occupants proposed
Metrics/Input Parameters	Number of actions accepted: BCM framework Number of occupants proposed: BCM framework

KPI Name	**% energy to be eliminated**
KPI Id	G.05
Description	This Indicator defines the % energy to be eliminated by BCM framework
Formula	Energy to be eliminated / Total energy planned
Metrics/Input Parameters	Energy to be eliminated: BCM framework Total energy planned: BCM framework

KPI Name	**% energy conserved**
KPI Id	G.06
Description	This Indicator defines the % energy conserved due to BCM framework
Formula	Energy conserved / Total energy planned
Metrics/Input Parameters	Energy conserved : BCM framework Total energy planned: BCM framework

KPI Name	**% Deviation from Goal Setting**
KPI Id	G.07

Description	This Indicator defines the % deviation from Goal Setting
Formula	(Total energy planned - energy conserved)/ Total energy planned
Metrics/Input Parameters	Energy conserved : BCM framework Total energy planned: BCM framework

The analysis shows that these indicators are calculated internally. Therefore these are not part of the core functions of SEOR engine, though we have modelled them in the deliverable as part of the work for the definition of Key Performance Indicators of OrbEEt Project.