OPTEEMAL: IT-SUPPORTED DESIGN TOOL FOR THE GENERATION OF OPTIMISED ENERGY RETROFITTING SCENARIOS AT DISTRICT LEVEL

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Abstract

The EU strategies to reduce the carbon emissions highlight the importance of renovating the existing building stock as one of the major contributing sectors to these undesired emissions to the atmosphere. The existing practices to design energy efficient retrofitting projects are still too time consuming, unprecise and provoke, therefore, a lack of trust within the sector; especially to investors. There is a need to improve these practices through reducing the errors and the time required to evaluate retrofitting alternatives in order to select those most appropriate according to the stakeholders' priorities. In order to give an answer to this challenge, the EU funded project OptEEmAL has designed and deployed an integrated platform that delivers automatically some of the steps that belong to this process reducing thus time, errors and therefore costs, which will lead to increasing efficiency and creating confidence among the stakeholders.

Introduction

The design of energy efficient retrofitting projects poses an elevated number of challenges when evaluating candidate retrofitting alternatives. Apart from the fragmentation of the retrofitting sector, with several stakeholders with different and sometimes conflicting interests, from the technical perspective the selection of indicators, generation of candidate retrofitting scenarios or the related simulation models are sometimes too time consuming and prone to human errors (Berkeley, et al., 2015). These problems, that are evident at building level, grow exponentially when tackling greater scales, as the district level, where new interactions and flows appear, as well as new potential technologies to be implemented.

Acknowledging all these issues, the OptEEmAL project has designed and developed a platform that implements a number of processes to support the design of energy efficient retrofitting projects at district scale (García-Fuentes, et al., 2016). The main functionalities offered by the platform are the integration of data and generation of baseline data models, the simulation of the baseline conditions, the generation of candidate retrofitting scenarios as a combination of Energy Conservation Measures (ECMs) – modelled and integrated within a digital catalogue –, and their evaluation and optimization against a set of District Performance Indicators (DPIs) that are weighted considering the users' preferences and conditions.

All these functionalities are delivered by a set of modules that have been deployed and connected through the appropriate interfaces to ensure the communication among them. With a distributed architecture, the OptEEmAL platform is able to interact with the users through a set of user-friendly Graphical Interfaces and to perform the steps that belong to the process of designing energy-efficient retrofitting projects. Thus, through delivering automatically processes that are manually performed in the Business-as-usual, this platform helps reducing errors, time and therefore costs to the stakeholders.

This paper presents the architecture of the OptEEmAL platform, describing its high-level architecture, functional modules and the testing activities that have been performed to ensure its functioning.

High-level architecture

Taking into account the main objective of the OptEEmAL solution, this section details a high-level overview of the specific functionality expected for all the key components associated with the OptEEmAL architecture. This architecture assumes a three-layer structure, i.e. the Data Layer, the Business Logic Layer and the Application Layer, which altogether offer a holistic service-oriented platform able to integrate interoperable modules/tools to generate optimized district retrofitting scenarios. On the other hand, the framework presented in this paper reinforces the commitment of all the involved stakeholders through an Integrated Project Delivery (IPD) approach in a collaborative and value-based process towards obtaining the most sustainable and efficient retrofitting solution for a refurbishment project.

In order to properly collect all these needs, a deeper analysis of the platform requirements is fundamental

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as the starting point to the design of the OptEEmAL architecture.

On the other hand, when interoperability is required in the definition of ICT solutions, it can be reached by making use of existing technologies and standards (well-known and well-stablished communication protocols, data models and interfaces standard definitions). In the context of the OptEEmAL solution the interoperability requirement is desirable taking into account that the OptEEmAL system needs to be interconnected to different internal and external services, data sources and tools. A common data representation, in the form of a District Data Model (DDM), is also needed to obtain a common way of interacting among all these different elements. All these needs are presented in the following subsections.

Analysis of functional requirements

The OptEEmAL solution aims to develop an optimized energy efficient design platform for refurbishment at a district level, which delivers an optimized, integrated and systemic design based on an Integrated Project Delivery approach for building and district retrofitting projects, reducing time delivery and uncertainties, resulting in improved solutions when compared to business-as-usual practices.

To be able to reach the previous objective, the OptEEmAL platform requires to integrate five main pillars:

1. An IPD-based retrofitting design approach, to facilitate communication, knowledge sharing and consensus among interested stakeholders as the Owner, Primer Designer or Prime Constructor
2. A BIM-based information exchange approach to enhance collaboration between stakeholders and improve information flows within the design process.
3. A catalogue of Energy Conservation Measures (ECMs) considering scale of implementation and providing all the needed data for the evaluation of the design alternatives.
4. A Multi-Criteria Decision Analysis (MCDA) approach for decision making integrating the interest of the stakeholders and making use of well-stablished indicators at different scales.
5. A semantic data model and data mapping process to ensure interoperability among the platform components and consistency of communications.

These five essential pillars have been covered in the OptEEmAL project in different work packages, identifying in each of them the main requirements for the indicated functionalities (OptEEmAL Consortium, 2016-D5.1).

From the **end-user** point of view, a set of requirements has been collected related to the input data process to evaluate users' objectives and initial conditions (OptEEmAL Consortium, 2016-D1.2) (OptEEmAL Consortium, 2016-D1.3). In that sense data needed to build the baseline model of the district and to compare district retrofit scenarios is required by the platform. To address the multiple objectives of the project, this data comes in four different forms: BIM models and CityGML models representing the district, contextual data (climate, energy prices, socio-economic data, etc.), and configuration data.

From the **data representation** point of view, requirements have been identified for the definition of the ontology used to generate the OptEEmAL District Data Model (OptEEmAL Consortium, 2016-D2.1). The DDM has to integrate all the data required to perform a refurbishment analysis of buildings within a district, including building data, district data, contextual data, District Performance Indicators (DPIs), intermediate results and targets, barriers and boundaries delimiting the project assessment.

Related to the **ECM catalogue**, a set of requirements have been defined (OptEEmAL Consortium, 2016-D3.1) to determine the kind of information the catalogue has to contain to feed properly the different steps of a project elaboration, the way the ECMs have to be store into the catalogue, and in which moments the catalogue is going to be queried to provide information to the modules/services of the OptEEmAL solution.

In the case of the **optimization process**, the specification of a set of parameters that adequately represent the refurbishment plan, the barriers and boundaries and the stakeholders' priorities with the aim to define the optimum scenarios have been stablished (OptEEmAL Consortium, 2016-D4.1).

From a **simulation** point of view, the tools and methodologies to evaluate the DPIs required by the process implemented in the OptEEmAL platform towards the identification of the best retrofitting scenarios according to stakeholders' priorities for each design project have been investigated (OptEEmAL Consortium, 2016-D4.4). As result, a set of requirements have been identified to guide the design of the OptEEmAL DPI calculation element of the platform, divided into two parts, building- and district-level calculation methodologies.

Finally, and in order to complete the analysis of requirements more related to the whole platform, different aspects have been analysed more deeply, comprising functional requirements and non-functional requirements such as performance, security, human-machine interaction, systems management (configuration and interoperability) and data management.

The translation of all these requirements into a set of Use Cases has been necessary to define the high-level architecture of the OptEEmAL solution presented in the following subsection.

High-level architecture of the OptEEmAL solution

With the aim of fulfilling the requirements and functionality expected for the whole OptEEmAL system, a three layer architecture is envisaged in Figure 1 (OptEEmAL Consortium, 2016-D5.2).

The **Application Layer** works as point of interaction between the OptEEmAL platform and the user. It is used for data insertion, showing results and providing outputs, as well as for other interactions (checking results, checking progress of the processes, etc.).

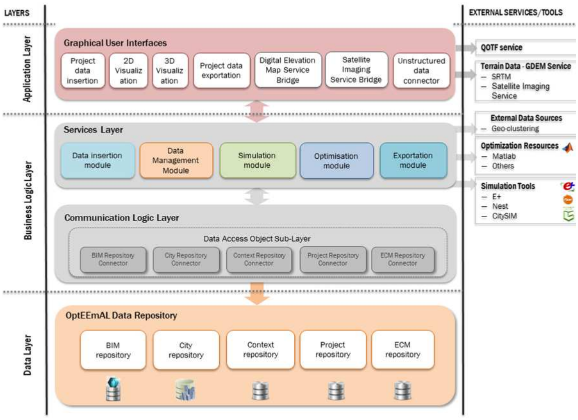


Figure 1: High-level architecture of the OptEEmAL platform

The **Business Logic Layer** contains the modules with major functionalities of the platform as the Data Insertion Module, the Data Management Module, the Simulation Module, the Optimisation Module and the Data Exportation Module. Moreover this layer contains the Communication Logic Layer that acts as the link of the different modules of the platform since it enables the communication between the Data Layer and the Services Layer.

Finally, the **Data Layer** represents the OptEEmAL Data Repository which is composed by five different repositories: the BIM, CityGML, Context, Project and ECM repositories. The Context, BIM and CityGML repositories store information about the districts to refurbish. On the other hand, the Project repository has information about the refurbishment projects (such as platform users and user's inputs, e.g., barriers, targets, boundaries, prioritisation criteria) and data generated within the platform such as District Performance Indicators, scenarios and simulation models (Energy, Economical, Environmental…) automatically generated. The ECM repository contains the Energy Conservation Measures (ECMs) used to generate the refurbishment scenarios to be optimized by the OptEEmAL platform, and also contains information about these ECMs to be exported in the final step.

In order to work properly, the OptEEmAL platform also needs to interoperate with other **external and existing services and tools** needed to support and enhance part of the expected functionality to be offered mainly by the simulation module. These external tools comprise:

- **EnergyPlus**: It is an energy analysis and thermal load simulation program. Based on a user's description of a building from the perspective of the building's physical make-up, associated mechanical systems, etc., EnergyPlus is able to calculate the heating and cooling loads necessary to maintain thermal control set-points, conditions throughout an secondary HVAC system and coil loads, and the energy consumption of primary plant equipment as well as many other simulation details that are necessary to verify that the simulation is performing as the actual building would.
- **NEST**: for life-cycle and social District Performance Indicators calculation. NEST is a plug-in for Sketch-Up. It allows, from 3D modelling of the area, impact assessment and comparison of development scenarios.
- **Matlab Runtime Compiler**: MATLAB Runtime Compiler lets developers to share MATLAB scripts into standalone applications. Using this solution, it is possible to package M-Files as Java libraries used by the DPI computation process. The M-Files are organized into Java classes and each MATLAB function is provided as Java method.
- **Terrain data access**: in order to provide the user with a user-friendly view of the district, it is shown the terrain geometry mapped with satellite images around the district location. These data are obtained from open source third party services such as ASTER DEM and SRTM for the terrain geometry, and from OpenStreetMap and/or similar satellite imaging services for the satellite images.

Other ad-hoc implementations have been developed to cover the calculation of specific DPIs, as for example the **ECO tool**, for the calculation of economic indicators, and the **HVAC tool** for the simulation of the active elements of the building/district.

District Data Model for data representation

As it was mentioned previously, the interoperability of an IT solution is gained by using well-known communication procedures, common data models and standardized interfaces definitions. In the case of the data models, OptEEmAL uses the **District Data Model** (DDM) as a means to represent, in a common manner, all the input data of the platform (BIM/GIS models, contextual data, inputs from the users, etc.), ensuring the interoperability and understanding in their exchange among modules, components, services and external tools. Therefore, the DDM contains the data resulting from the recovery, integration and transformation of the input data. These data are provided at each stage of the processes managed by the platform in the required representation.

In (OptEEmAL Consortium, 2016-D2.1), the DDM was described as an ontologies-based framework for district information representation. The DDM enables the intertwining of standardized data models (e.g., CityGML, IFC) with ontologies in domains related to building energy efficiency at the district level (energy, social, environment, comfort, urban morphology and economic). To be able to represent the data of all these domains, the DDM provides a semantically integrated data model including data about geometry, materials, equipment, and indicators, at the building and urban scales) that the platform needs to carry out the calculation of the optimized retrofitting scenarios.

More specifically, the data included in the DDM are represented according to the following six ontologies:

- **Urban Data Model**. This model represents the data about the relations between buildings, weather data, placement, population, total surface of buildings and relations to other data models (e.g. to which district energy system is a building connected).
- **Building Energy Data Model**. This model represents the data necessary to carry out energy simulations of buildings. It includes the geometry of the building, material properties, building energy systems, etc.
- **District Energy Data Model**. This model represents the data necessary to carry out energy simulations at district level. Basically, it includes the data of active systems.
- **Energy Carrier Data Model**. This model represents the data of energy carriers that can be selected for a project. Basically, it includes energy carrier costs.
- **Social Data Model**. This model represents the social data of a district. It includes number of inhabitants and their income.
- **ECM Data Model**. This model represents the data about the Energy Conservation Measures at building or district scale.

While the District Data Model assures the interoperability between the various data sources (BIM and GIS models, and contextual information), represented in different formats (IFC, CityGML), and a set of external tools used to perform building simulations, the **Data Management Module** (DMM) includes the necessary components to carry out the different stages required to transform and integrate the data to generate the District Data Model.

The DDM Manager, one of the two software components implemented in the Data Management Module, provides the necessary functionalities to carry out the corresponding data transformation and integration processes. These two processes are identified as ETL1 and ETL2. The ETL1 process transform the input data models (e.g., IFC, CityGML) into semantic data models (RDF models), represented according to different data schemas (e.g., ifcOWL ontology). The ETL2 process integrates the data resulting from the ETL1 process where semantic data models are transformed into Simulation Data Models (e.g., RDF models represented according to the OWL version of the SimModel data schema).

Finally, the Simulation Module (represented in Figure 1) invokes the model input file generator process to create instances of simulation models from the Simulation Data Models obtained in the ETL2 process. An instance of simulation model is a set of data that fulfils the input data requirements of a specific simulation tool (e.g., EnergyPlus requires the input data in IDF format).

Platform design, implementation and deployment

In the platform design stage, the high-level architecture has been taken into account and the modules have been finely described, explaining their main **components** with the functionalities related and the **processes schemes** that identify the workflow following in the platform and also the information interchanged between the components (OptEEmAL Consortium, 2016-D5.2).

Once the platform has been designed the next steps are the implementation and the deployment of the platform. All these steps are explained in the following subsections.

Component diagrams and processes schemes

According to the workflow generated as part of the requirements definition, the functionality of the platform can be divided into three main processes:

1. Data insertion and diagnosis process
2. Scenarios generation and optimisation process
3. Data exportation process

Each one of these processes involved a set of modules. The processes schemes show the different components that constitute each module and the relationship between these components. They are explained below.

Data insertion and diagnosis process

This process, represented in Figure 2, provides as an output all the data needed to be introduced into the Optimisation Module. To this end, through the data insertion module, the user is able to introduce all the required data (**input data connector** component), which is checked (**data checker** component) and complemented with information coming from external geo-clustering services (**geo-connector** component). All these data are stored in the corresponding repositories through the corresponding connector of the communication logic layer.

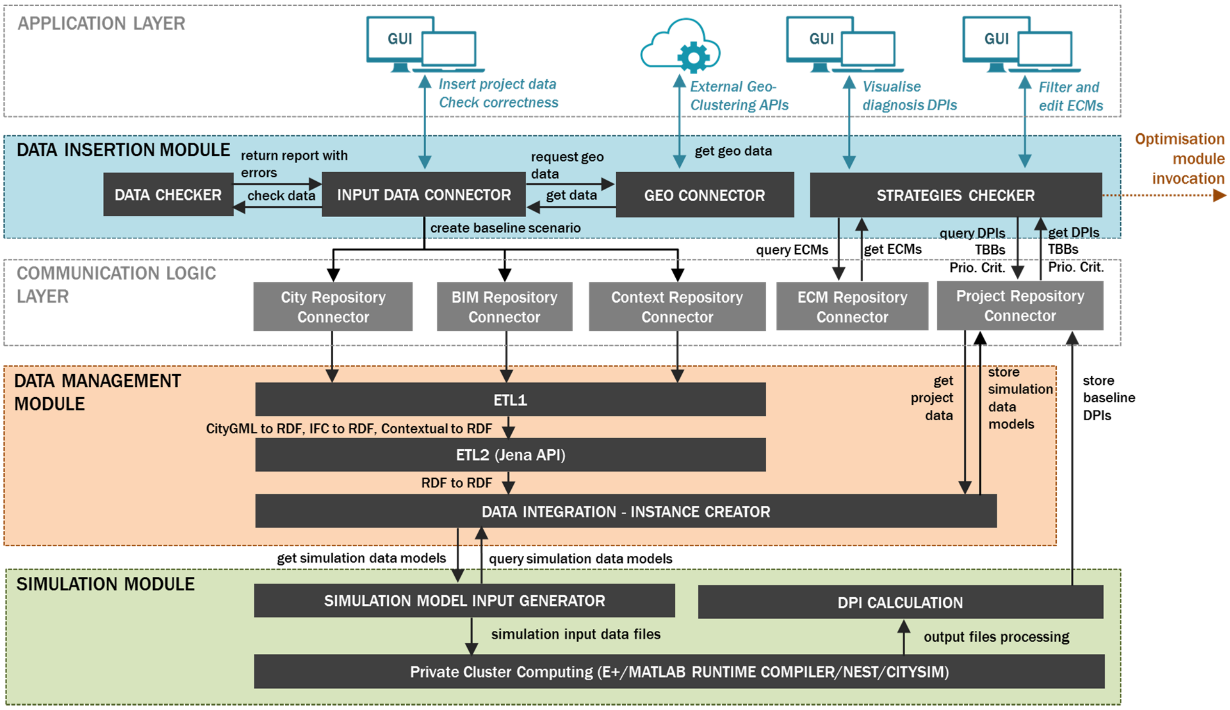


Figure 2: Data insertion and diagnosis process scheme

Once the information is stored in the repository, the Data Management Module (presented in the section District Data Model for data representation maps the information in order to create one instance of the baseline scenario. The simulation data models generated by the **data integration** component is stored in the project repository.

This information is retrieved later by the Simulation Module (simulation module input generator component), which will be in charge of configuring the simulation files and launching the simulation tools (private Cluster Computing component). With the result of this process the DPI calculation component calculates diagnosis DPIs, which are stored in the project repository.
The last step inside this process requires user interaction to validate the generated information. The results from the DPIs are extracted from the project repository and shown to the user along with the other information of the baseline scenario (data insertion module), who, taking into account these results, could reconsider the choices they have made with regards to their objectives. With these new list of targets, boundaries and barriers (or the same if the user has not changed their mind) the ECM catalogue is queried to provide the user with the list of applicable ECMs filtered according to their objectives. Through a specific GUI the user could discard the ECMs that they do not want to apply in their district or edit the applicable ones proposed by the platform (**strategies checker** component). This information will configure the optimiser input data to be used in the next process.

Scenarios generation and optimisation process

This process (see Figure 3) represents the core element of the platform, where scenarios are generated from different combinations of ECMs and the DPIs are calculated by launching simulations with external tools. These results are evaluated to be able to have as an outcome a series of optimised scenarios and the data generated along this process (García-Fuentes, et al., 2018) (Hernández, et al., 2017).

Optimiser input data generated in the previous process is introduced in the Optimisation Module (**scenario generator** component), which is in charge of generating scenarios by means of combining the applicable ECMs in the retrofitting project with a certain intelligence. It has as result a codification which generates a scenario vector that is mapped in the Data Management Module (**data integration – instance creator** component). This scenario vector is fed to this component with information coming from the ECMs data base to configure the simulation data models.

Once the simulation data models have been created the Simulation Module (**simulation module input generator** component), will launch the simulation tools (**private Cluster Computing** component) and the **DPIs calculation** component in order to calculate the simulation DPIs which will be directed to the data management module to be stored in the project repository.

Once the DPIs are stored, these can be retrieved by the Optimisation Module (**evaluator** component) in order to have one single, understandable and easy-to-handle

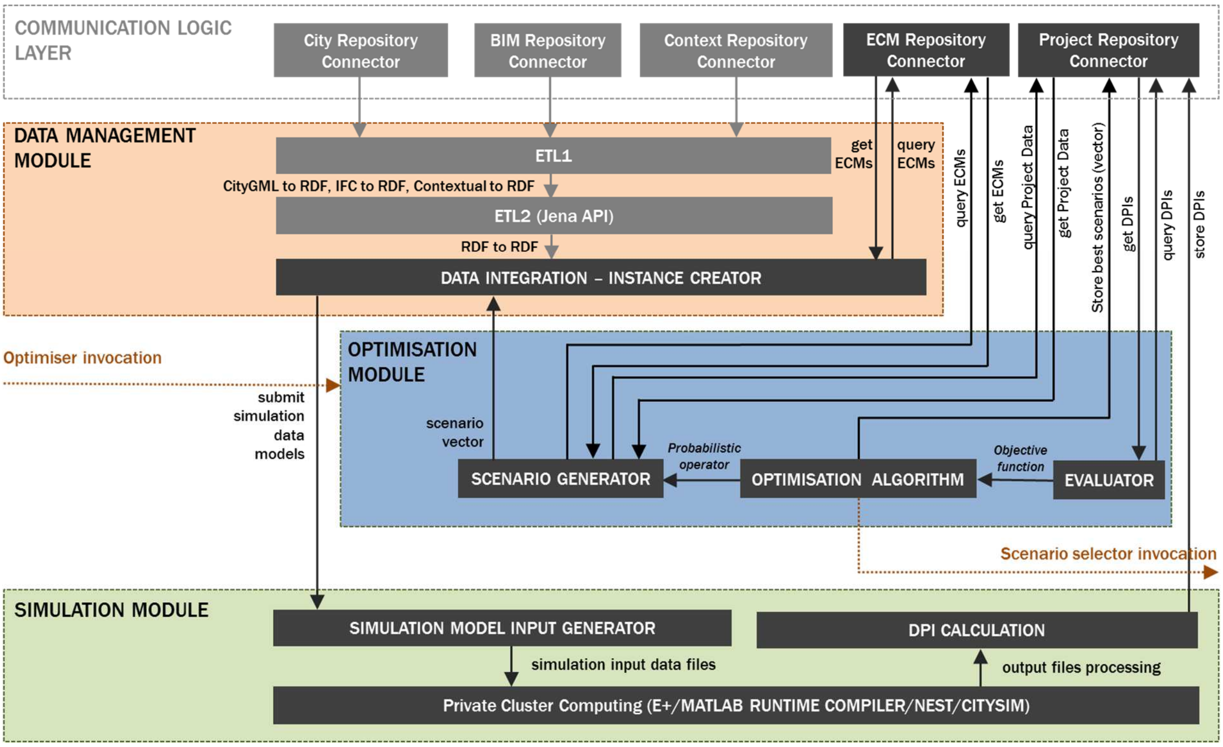


Figure 3: Scenarios generation and optimisation process scheme

value or grade for each scenario to be ranked in by the Optimisation Module. With the result of the objective function, the Optimisation Module (**optimisation algorithm** component) will either generate more combination rules and will continue the iterative process or the stopping criteria will be met and the optimiser output data will be generated and stored in OptEEmAL repositories.

<u>Data exportation process</u>

The last stage carried out in the platform is the data exportation process (see Figure 4), where the main objective is to process the information generated in the previous stage in order to generate exportable information that is relevant for the user to execute their retrofitting project.

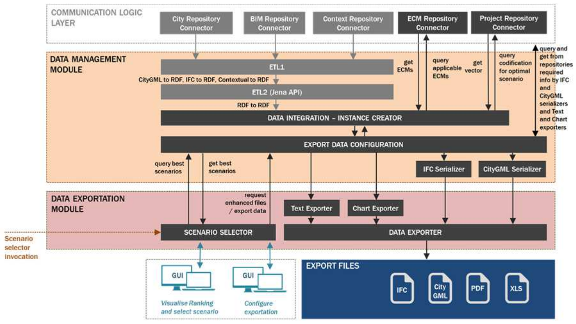


Figure 4: Data exportation process scheme

The process starts in the Data Exportation Module, where the user can visualise through a GUI the ranking of scenarios generated in the optimisation process. Afterwards, through a different GUI and another component (**scenario selector** component) they are able to select their desired scenario.

This selection will launch the **export data configurator** component (inside the data management module) which will be connected to the different repositories to extract the necessary information to be exported that has been indicated by the user. These data will be processed through several components (**IFC serializer, CityGML serializer** in the Data Management Module and **Text exporter and Charts exporter** in the Data Exportation Module) to end up in the **data exporter** component which will in the end enable the user to export the files with the information: IFC, CityGML and XLS.

Implementation and deployment

The OptEEmAL platform is composed by different modules and components described in the previous sections. In order to carry out their functionalities the modules need to communicate among them and with external tools and services. The module dependencies have been analysed and the logical interfaces between modules have been defined. It is important to highlight that the modules and the repositories of the platform have been developed by different companies, so the definition and development of the interfaces were essential steps in the implementation of the platform.

Red Hat JBoss Fuse has been used as an Enterprise Service Bus (OptEEmAL Consortium, 2018-D5.3), which role into the OptEEmAL platform is to synchronize different and asynchronous modules deployed on several environments and to have a base control of it. This is an open source integration framework based on Apache Camel and it is a distributed integration platform that allows the integration of services, microservices and application components. This allows us to delocalize the different modules and repositories of the platform.

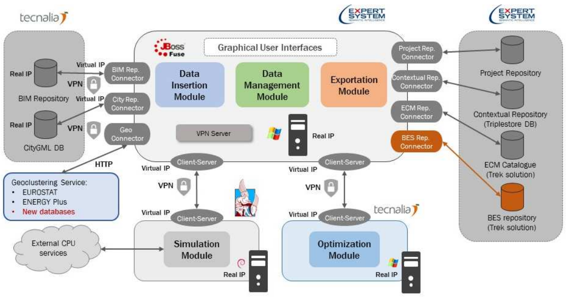


Figure 5: Deployment physical scheme

From a deployment point of view, Figure 5 shows the physical distribution of the different modules and repositories. As it is shown in the figure, the different modules and repositories are geographically distributed in three different premises and locations. In that sense, security and reliability in the communications is needed and guaranteed by the Enterprise Service Bus.

The repositories can be accessed through APIs in a remote way. Besides queues are used in order to send files that are too large to be managed by the APIs.

Graphical User Interfaces

For the OptEEmAL platform, the Graphical User Interface (GUI) is a web/browser-based solution that facilitates the human-machine interface with the functionality offered by the design tool. The canvas interface is a web site based on HTML5 and supported by a WebGL-based 3D visualization environment.

The GUI is composed of different components:

- **User data input module**: responsible of collecting data inputs from the users, for example: the login information, project data such as project name, description, CityGML and IFC files that will be used in the optimization phase.
- **2D visualization module**: this module will provide the user with all necessary data and interactive graphical interface such as web page in the forms of texts, charts, tables or similar representations.
- **3D visualization module**: a 3D representation of the district and buildings will be shown in this module.
- **Data communications module**: this module is responsible for data transport between the 2D and 3D visualization modules.
- **3rd party Digital Elevation Map service communications module**: this module acts as an interface that obtains from third-party services the information required by the 3D visualization module to visualize the terrain geometry around the district.
- **3rd party Satellite Imagery communications module**: this module will act as an interface between the 3D visualization module and the third-party satellite imaging services to obtain the district satellite images that will be shown on top of the terrain geometry.
- **Unstructured Data Connector module**: in this module the users can search in the web for useful information related to the district to support the evaluation of the current scenario and its objective setting.

Navigation scheme

In this subsection, the navigation scheme followed by the OptEEmAL GUI is presented in 15 different steps. Figure 6 shows the site map of the OptEEmAL platform *(OptEEmAL Consortium, 2016-D5.2)*.

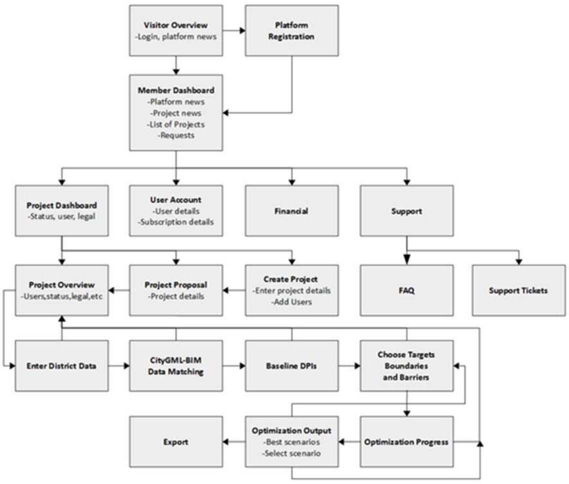


Figure 6: Site map of the OptEEmAL GUI as a web site

The first page shown in the platform is the Visitor Overview with the login page for the platform users. From this point the end-user interaction in the GUI is required in the next steps:

1. Create new project
2. Create new IPD Group
3. Insert CityGML and IFC files
4. CityGML-BIM Matching
5. Baseline Energy Systems
6. Insert contextual Data
7. Energy Conservation Measures
8. Check Strategies
9. Baseline Performance
10. Insert Targets and Boundaries
11. Prioritization Criteria
12. Problem Summary
13. Optimisation Process
14. Select optimal scenario
15. Configure and export data

The data inserted by the users are checked for integrity and correctness by the system with a specific checking tool developed. This tool has 3 different checking operations: Consistency check (IFC4 schema compatibility), Completeness check (the required input data for the Building Energy Performance Simulation model by checking rules) and Correctness check (geometric error detection) (Lilis, et al., 2018). After all the information required by the system is collected and verified, the necessary processes are launched to obtain the initial performance of the district. The results of the calculations are presented to the users which can modify the targets, boundaries, barriers and prioritization criteria taking into account the results of the baseline district evaluation. After ECMs are shown to the users and are then selected or discarded by them, the scenario generation and optimization phase takes place in the platform core. Finally, after the optimization phase is finished, a number of best optimized scenarios for the district are shown to the users to select and export the best scenario for them. The users can go back to the target, boundary and barrier selection phase in order to change or fine tune their choices.

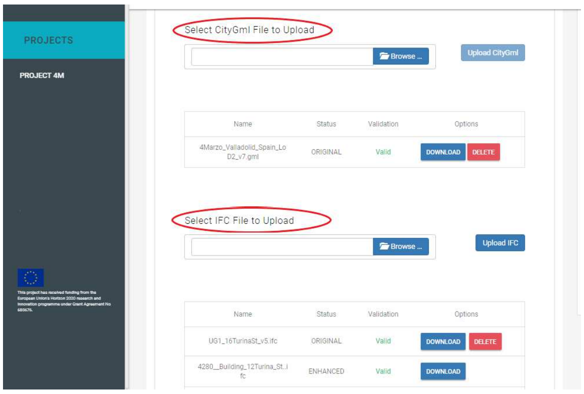
Example of use with a real case: Cuatro de Marzo district in Valladolid (Spain)

The platform has been tested and validated in different case studies or districts and in three different Technology Readiness Levels or TRLs, from TRL5 to TRL7. One of them is *Cuatro de Marzo* district located in Valladolid (Spain), demonstrated for TRL6 (platform prototype demonstration in relevant environment).

Figure 7: View of Cuatro de Marzo district
(Image ©2019 BingMaps)

For *Cuatro de Marzo* case study, five residential buildings (two towers and three individual blocks – see Figure 7) have been tested for the retrofitting project. In this district the information required and uploaded to the platform has been:

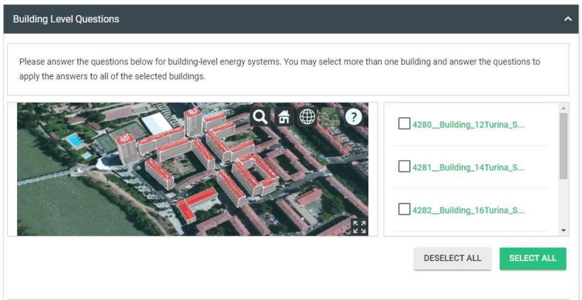
- Four IFC models (one IFC per block and one IFC for the two towers) and one CityGML model of the district. Figure 8 shows the interface where the user has to upload and check the models.
- Building Energy Systems related information (with a questionnaire), shown in Figure 9.
- Biomass prices. Figure 10 shows the climate, energy & Socio-Economic data included in the Contextual Data interface with the biomass price data for this project.
- Targets and boundaries. Figure 11 shows the information completed for the project *Cuatro de Marzo*.
- Prioritisation criteria. Figure 12 shows the options to choose for the Prioritisation Criteria.



Name	Status	Validation	Options
4Marzo_Valladolid_Spain_LoD2_v7.gml	ORIGINAL	Valid	DOWNLOAD DELETE

Name	Status	Validation	Options
UG1_16TurinaSt_v5.ifc	ORIGINAL	Valid	DOWNLOAD DELETE
4280__Building_12Turina_St..ifc	ENHANCED	Valid	DOWNLOAD

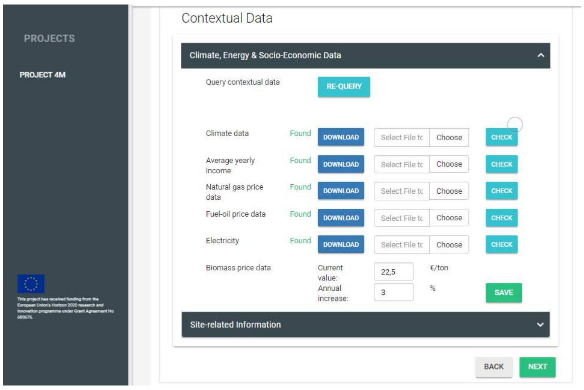
Figure 8: Insert CityGML and IFC files interface in the project Cuatro de Marzo with the user Data Input Module



Please answer the questions below for building-level energy systems. You may select more than one building and answer the questions to apply the answers to all of the selected buildings.

☐ 4280__Building_12Turina_S...
☐ 4281__Building_14Turina_S...
☐ 4282__Building_16Turina_S...

Figure 9: 3D representation of the Cuatro de Marzo district with the 3D visualization module



Query contextual data

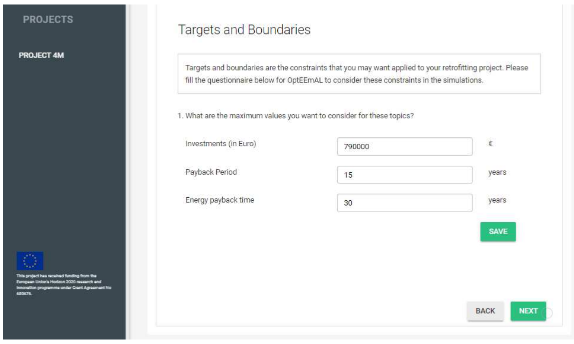
Climate data	Found	DOWNLOAD	Select File tc Choose	CHECK
Average yearly income	Found	DOWNLOAD	Select File tc Choose	CHECK
Natural gas price data	Found	DOWNLOAD	Select File tc Choose	CHECK
Fuel-oil price data	Found	DOWNLOAD	Select File tc Choose	CHECK
Electricity	Found	DOWNLOAD	Select File tc Choose	CHECK

Biomass price data
Current value: 22,5 €/ton
Annual increase: 3 %

Figure 10: Contextual data interface included in the user data input module

After the upload to the platform of all the information required, the optimization process is launched and the Pareto Front, shown in Figure 13, is been obtained with the execution of ten iterations and ten scenarios for each iteration. With this case study, a complete validation of the platform prototype is obtained.

Some results related to one of the chosen optimal scenario (Scenario1) are presented in Figure 14 in comparison with the results for the baseline condition of the district.



Targets and Boundaries

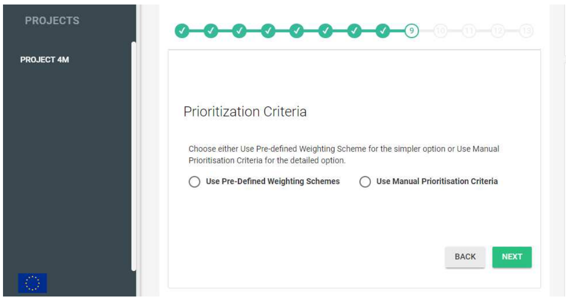
Targets and boundaries are the constraints that you may want applied to your retrofitting project. Please fill the questionnaire below for OptEEmAL to consider these constraints in the simulations.

1. What are the maximum values you want to consider for these topics?

Investments (in Euro)	790000	€
Payback Period	15	years
Energy payback time	30	years

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 680676.

Figure 11: Targets and boundaries interface.

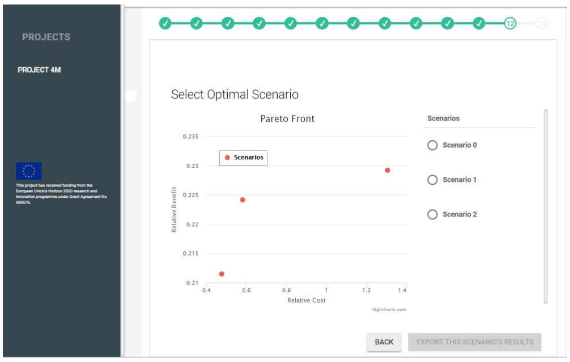


Prioritization Criteria

Choose either Use Pre-defined Weighting Scheme for the simpler option or Use Manual Prioritisation Criteria for the detailed option.

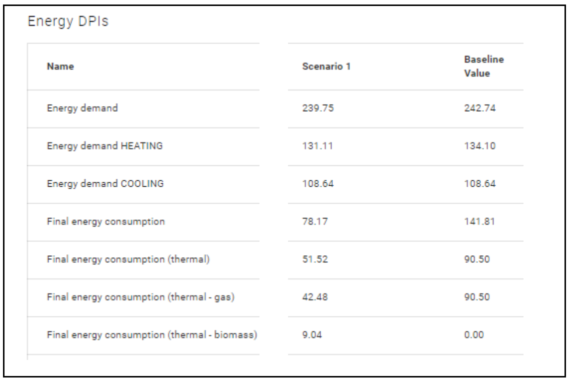
○ Use Pre-Defined Weighting Schemes ○ Use Manual Prioritisation Criteria

Figure 12: Prioritisation criteria interface.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 680676.

Figure 13: Select optimal scenario interface with the Pareto Front obtained in the project Cuatro de Marzo



Energy DPIs

Name	Scenario 1	Baseline Value
Energy demand	239.75	242.74
Energy demand HEATING	131.11	134.10
Energy demand COOLING	108.64	108.64
Final energy consumption	78.17	141.81
Final energy consumption (thermal)	51.52	90.50
Final energy consumption (thermal - gas)	42.48	90.50
Final energy consumption (thermal - biomass)	9.04	0.00

Figure 14: Energy DPIs for the optimal Scenario1

A deeper analysis of the results obtained for the *Cuatro de Marzo* district can be done by comparing the available information of the district coming from the R2Cities project and the proposal of ECMs provided by the OptEEmAL platform. This comparison is shown in Table 1 .

Comparing the results it is observed that OptEEmAL proposes similar ECMs than those actually implemented in the district. In the case of the OptEEmAL platform, internal roof and external façade insulations are proposed as well as monocrystalline photovoltaic panel connected to the grid instead of solar thermosiphon collectors for Domestic Hot Water (DHW). The total investment for the Scenario 1 would be of 453.592€ according to OptEEmAL calculations.

Table 1: ECMs comparison between actually implemented and proposed by OptEEmAL in Cuatro de Marzo district

Real ECM	**ECMs proposed by OptEEmAL**	
	Scenario 1	**Scenario 2**
Roof insulation below top slab (Rockwool 100mm)	Passive Roof Pitched Internal Insulation (Mineral wool 100mm)	Passive Roof Pitched Internal Insulation (Mineral wool 60mm)
Façade External Thermal Insulation Composite system (ETICs) EPS 120mm	Passive Façade External Thermal Composite System (EPS 150mm)	Passive Façade External Thermal Insulation Composite System (EPS 250mm)
Solar thermosiphon collectors for DHW	Monocrystalline photovoltaic panel connected to the grid, 320 W	Monocrystalline photovoltaic panel connected to the grid, 320 W
Efficient condensation low-temperature boiler for heating and support of DHW, 24kW	Condensing natural gas boiler with 24kW of nominal capacity	Condensing diesel boiler with 26kW of nominal capacity

Conclusions

This paper has presented the main objectives of the OptEEmAL platform and how the technical challenges to pursue these objectives have been tackled. Of particular relevance is the approach followed in the platform design, implementation and deployment, where a **SOA-EDA platform** using an Enterprise Service Bus to connect and synchronize different and asynchronous modules has been deployed on several environments. This connection and synchronization would not have been possible without relying on a **District Data Model** based on standards that can assure the interoperability among the modules of the platform. It enables to represent the baseline scenario and the different enriched models including a combination of Energy Conservation Measures. Moreover, to be able to support the design of energy retrofitting solutions, an important advancement proposed by the OptEEmAL platform is the **automatic generation of scenarios** based on the combination of **Energy Conservation Measures** and the optimization based on previously performed simulations of the behaviour of the district, as well as considering the objectives and barriers defined by the user.

All these requirements have been reflected in this paper in the form of a **high-level architecture** comprising a set of modules, services, external tools and the interfaces among them. The way these elements interact to fulfil the different OptEEmAL functionalities has been reflected in several **processes schemes** representing the three main actions: the data insertion and diagnosis process, scenarios generation and optimization, and the data exportation. Finally, the **Graphical User Interface** for accessing to these functionalities has been presented by showing real results when applying the tool in the *Cuatro de Marzo* district located in Valladolid (Spain).

The combination of all these innovations will allow reducing time, errors and inconsistencies in the design and refurbishment of district retrofitting projects, and thus, lead to increasing efficiency and generating confidence among stakeholders. This will result, as a consequence, in a greater number of retrofits, which will contribute to the reduction of carbon emissions.

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