OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

Optimised Energy Efficient Design Platform for Refurbishment at District Level

H2020-WORK PROGRAMME 2014-2015 – 5. Leadership in enabling and industrial technologies

H2020-EeB-05-2015: Innovative design tools for refurbishment at building and district level

D1.2: Requirements and specification of input data process to evaluate user objectives and current conditions

WP1, Task 1.2

February 2016 (m6)

Deliverable version: D1.2, v1.2

Dissemination level: Public

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

Document History

Project Acronym	OptEEmAL		
Project Title	Optimised Energy Efficient Design Platform for Refurbishment at District Level		
Project Coordinator	Miguel Á. GARCÍA-FUENTES (miggar@cartif.es) Fundación CARTIF		
Project Duration	1st September 2015 – 28th February 2019 (42 Months)		
Deliverable No.	D1.2. Requirements and specification of input data process to evaluate users' objectives and current conditions		
Dissemination Level	PU		
Status		Working	
		Verified by other WPs	
	■	Final version	
Due date	29/02/2016		
Work Package	WP1 – Stakeholders' involvement through IPD Design strategy and input data process		
Lead beneficiary	UTRC-I		
Contributing beneficiary(ies)	ACC, NBK, TEC, FUNITEC, TUC		
DoA	Task 1.2 – Definition of required input data to evaluate users objectives and current conditions		

Date	Version	Author	Comment
02/12/2015	0.1	Abhi Miranda & Hassan Ridouane (UTRC-I)	Initial draft with document structure
15/12/2015	0.2	TEC/NBK	Added contents
18/12/2015	0.3	Álvaro Sicilia (FUNITEC)	Added contents
13/01/2016	0.4	UTRC-I	Updated structure with feedback from partners
18/01/2016	0.5	Abhi Miranda (UTRC-I)	Added 6.1.5 and 6.1.6
20/01/2016	0.6	Miguel García (CAR)	Review of ToC and added contents
22/01/2016	0.7	UTRC-I	Final structure with feedback from partners
09/02/2016	0.8	UTRC-I, ACC, NBK, TEC, FUNITEC, TUC	First draft of various sections of the document
11/02/2016	0.9	UTRC-I, ACC, NBK, TEC,	Revised versions of various sections of the

		FUNITEC, TUC	document
15/02/2016	1.0	UTRC-I	Conclusions, edits and proof reading
24/02/2006	1.1	Leandro Madrazo (FUNITEC), Xabat Isasa (TEC)	Peer Review Comments and suggestions
26/02/2016	1.2	UTRC-I, ACC, NBK	Revision following review comments
29/02/2016	1.3	CAR	Final revision

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Abbreviations and Acronyms

Acronym	Description
AHU	Air Handling Unit
BAS	Building Automation System
BEMS	Building Energy Management System
BIM	Building Information Model
BMS	Building Management System

DDM	District Data Model
DPI	District Performance Indicator
ECM	Energy Conservation Measure
ESCO	Energy Service Company
FCU	Fan Coil Unit
HP	Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning
IPC	Integrated Project Coordinator
IPD	Integrated Project Delivery
OptEEmAL	Optimised Energy Efficient Design Platform for Refurbishment at District Level.
OW	Owner
PC	Prime Constructor
PD	Prime Designer
TRL	Technology Readiness Level
VAV	Variable Air Volume

Executive Summary

The objective of OptEEmAL is to develop an Optimised Energy Efficient Design Platform for refurbishment at district level. The platform will deliver an optimised, integrated and systematic design based on an Integrated Project Delivery (IPD) approach for building and district retrofitting projects. This will be achieved through development of holistic and effective services platform that involves stakeholders at various stages of the design while assuring interoperability through an integrated ontology-based District Data Model.

This deliverable is the outcome of Task 1.2 "Definition of required input data to evaluate users' objectives and current conditions" and specifies the data necessary to build the baseline model of the district and to compare district retrofit scenarios. This process is based on a precise definition of all required data to integrate users/stakeholders targets and to evaluate the current conditions of the district (climate, use, energy performance, socio-economic profile, built environment characteristics…). To address the multiple objectives of the project, this data will come in four different forms: BIM models, CityGML models, contextual data, and configuration data. BIM and CityGML models will be provided to the platform by the user. Contextual data will be provided through geo-clustering of relevant data sources. However, users can also choose to provide contextual data directly to the platform. Configuration data is project-specific data such as users and their objectives, and barriers. This data will be provided to the platform through geo-clustering/data-harvesting techniques and also by IPD users, in particular, by the owners.

The deliverable is structured as follows: Section 2 describes the IPD based profiles developed focussing on various actors and their possible interactions/responsibilities during the design phase. This is followed by the platform general work flow in section 3 highlighting input data required at each step of the design. Section 4 introduces OptEEmAL case studies and describes the template of the available and required data, IPD actors involved, and DPIs to be evaluated. Selected DPIs and how they are going to be evaluated to assess the district current conditions is depicted in section 5.

Four types of input data were identified as required to build the baseline energy model of the district and to compare district retrofit scenarios. These are detailed in section 6 as BIM related data, CityGML related data, contextual data, and configuration data. To ensure that the input data provided in section 6 complies with the platform requirements, in particular with those of the District Data Model, section 7 introduces guidelines for input data quality check and access control requirements.

The outcomes of this task (Task 1.2) will provide the basis for other tasks in WP1 including the district diagnosis scope. These outcomes will also contribute to the work in WP2 as they will be used to define the parameters and boundaries related to the District Sustainability Indicators and contribute to WP4 by providing input to the model generator for optimisation.

1 Introduction

1.1 Purpose and target group

The purpose of this task was to define and specify required input data needed to support development of various OptEEmAL modules. The modules that are directly related to the work in this task are "Calculation of DPI for current state module", "Boundaries, targets, and barriers module", "set of applicable ECMs module", and "Formulation of scenarios module". In particular, input data specified here will be used to evaluate:

- Platform users' objectives, which are the end goal of the design process. The user will have the flexibility to set the refurbishment objectives by choosing from a list of objectives supported by the platform. These objectives can be a single or combination of the following categories: energy, comfort, environmental, economic, social, and urban.
- Current conditions of the district before refurbishment (baseline). Establishing the baseline of the district is very important to understand the district performance before and after the implementation of OptEEmAL design for refurbishment. In addition, the baseline specification is fundamental to informing more detailed understanding that is necessary for the formulation of retrofit scenarios.

The results of this task are the identification and specification of the input data mentioned above. This data was identified and categorized under four types:

- BIM related data – buildings related information
- CityGML related data – district level related information
- Contextual data – weather data, monitoring (when available and always as static information), energy prices, socio-economic data, etc.
- Configuration related data – project-specific data such as users and their objectives, and barriers.

A general introduction on how the input data is requested within OptEEmAL and the relationship between this deliverable and other deliverables is illustrated in Figure 1.

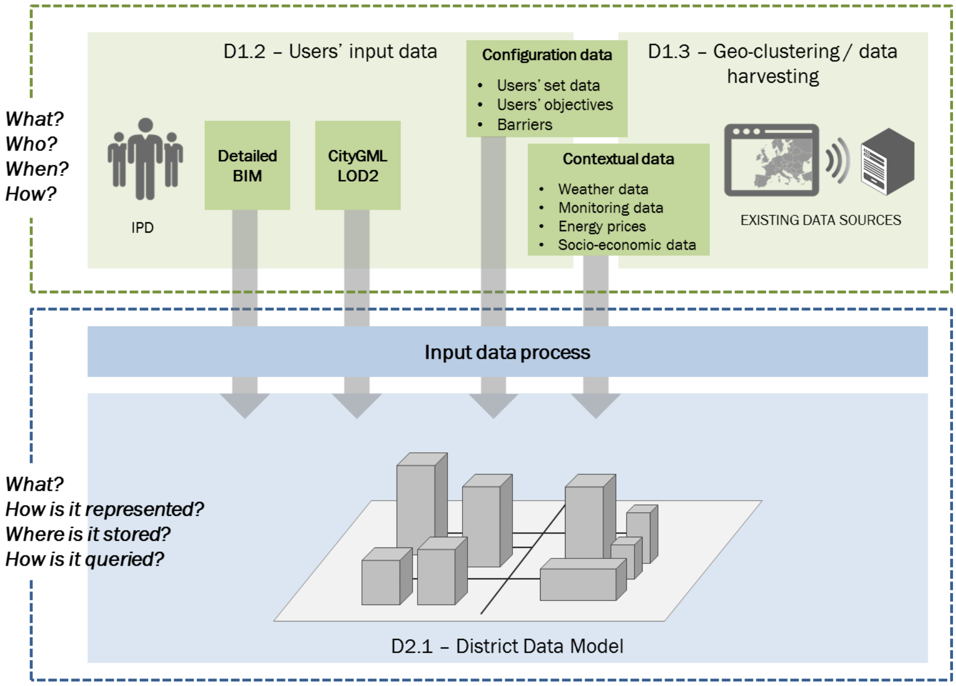


Figure 1: Input data into the OptEEmAL platform

1.2 Contributions of partners

Completion of this report was a collaborative effort of six partners (UTRC-I, ACC, NBK, TEC, FUNITEC and TUC) supported by CAR. The following Table 1: depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
UTRC-I	Deliverable leader responsible for overall content and quality of material included. UTRC completed the following section: Executive summary; Introduction; district current conditions; required input BIM related data including requirements for HVAC equipment and control strategies; and conclusions
ACC	Completed the IPD based profiles needed to provide input data; OptEEmAL general workflow and input data steps; requirements for construction elements; user set data and user identified barriers
NBK	Completed the OptEEmAL cases studies; District Performance Indicators; requirements for renewables, local generation and storage; and requirements for socio-economic data
TEC	Completed the sections on requirements for building use and schedules; internal gains; and user objectives
FUNITEC	Completed the sections on CityGML related data; contextual data; and input data quality and access control requirements
TUC	Completed the sections on requirements for internal gains; location and weather data; and monitored or metered data

1.3 Relation to other activities in the project

Input data requirements specified in this deliverable are key to design and development of various modules of the OptEEmAL platform, some of which are mentioned in section 1.1. The input data will be used to (a) generate the district baseline model to evaluate user objectives and current conditions (D1.6), (b) define targets and barriers, (c) generate models for retrofit scenarios evaluations (D4.3, D4.5, D4.6). Table 2 summarizes the main relationships of this deliverable to other activities (or deliverables) developed within the OptEEmAL Project.

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D1.3	D1.2 provides high level requirements for contextual and configuration data. Detailed requirements will be specified in D1.3.
D1.4	D1.2 provides high level requirements for contextual and configuration data. D1.4 is about implementation of contextual data access module.
D1.6	D1.2 lays the foundation for the “Diagnosis module” in D1.6 by specifying input data needed to build the baseline model of the district.

D2.1	D1.2 lists requirements for input data insertion into the DDM, data quality and access controls. All of these are highly related to D2.1 on requirements for DDM.
D3.1	D3.1 builds on D1.2 and provides requirements for the ECM catalogue
D4.3, D4.5, D4.6	D1.2 defines requirements to generate models for retrofit scenarios evaluations carried out by the optimization module documented in D4.3, D4.5 and D4.6.

2 IPD based profiles to provide needed input data

The IPD-based design strategy concept will be used for elaborating a collaborative, value-based process (as it is stated in the description of actions). To achieve this goal, the platform will be used by a set of IPD actors that will be named as users.

As stated in the Integrated Project Delivery Guide (American Institute of Architects -AIA, 2014 [1]), the two most important principles to implement an effective IPD strategy are the collaboration between the different actors of the project as well as the early implication of the main actors. As AIA describes, in IPD there are principal and secondary actors who have to collaborate assuming different roles, responsibilities and individual objectives that should be aligned with the principal project objective which is determined between the principal actors.

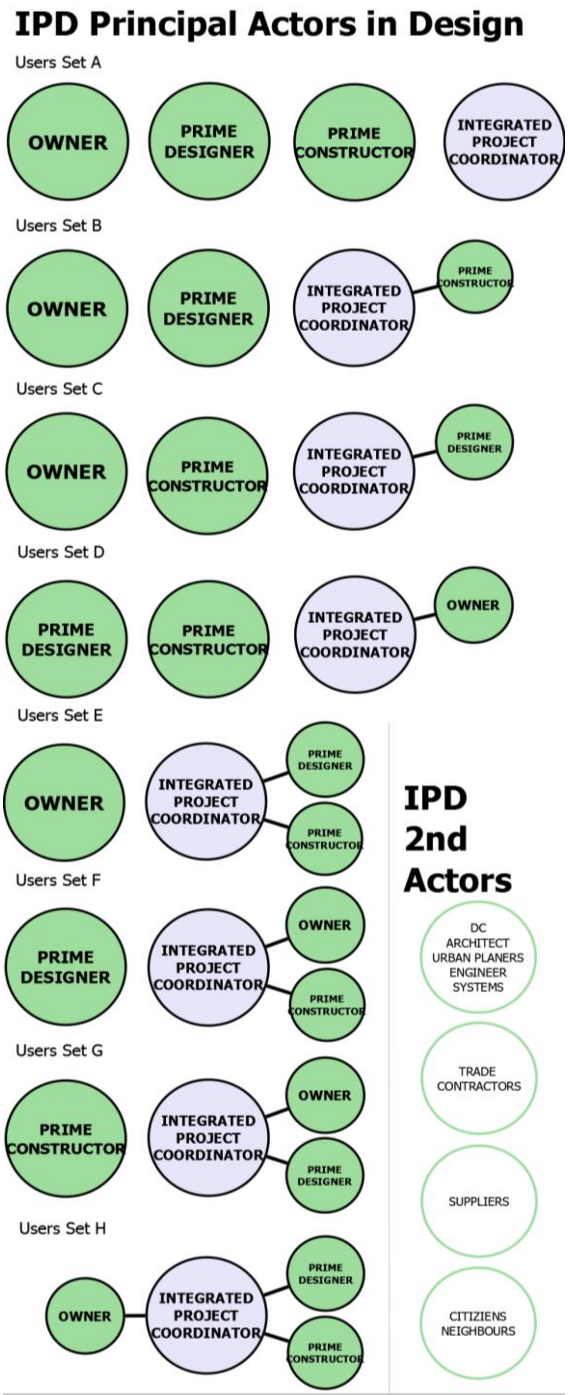


Figure 2: IPD actors

2.1 Approach followed in the platform

In the IPD guide [1] it is stated that *"[…] The primary participants are those participants that have substantial involvement and responsibilities throughout project, from beginning to end. […]"*. Given the objective of the OptEEmAL platform, it is clear that there is one user set that has to be present in the system. This set consists of; "The Owner", "The Prime Designer", "The Prime Constructor". This is going to be the minimum user set to be taken into account in the OptEEmAL platform.

In case that any of the members of the minimum set is missing, the "Integrated Project Coordinator" will play the missing roles as described in the annex of [1]. The proposed roles have been confirmed with the OptEEmAL "Case Studies".

2.2 Principal actors

To support the IPD approach, the OptEEmAL platform must comply with different GUIs (Graphical Users Interfaces) associated with different platform users. From an IPD point of view there should be at least three main actors who will act as Platform Users. These actors are defined in the AIA IPD Guide as the necessary ones to implement an IPD approach.

These are the owner, prime designer and prime constructor. These principal actors have to collaborate in high level for complying with the main objective.

Also, refer to the Appendix for further information regarding responsibilities of other actors that might be present in the IPD approach.

2.2.1 Owner

It is stated in the IPD Guide [1] that: "*In IPD, the Owner takes on a substantially greater and more active role in evaluating and influencing design options. Additionally, the Owner is required to participate in establishing project metrics at an earlier stage than is typical in a traditional project. In light of the fluid operation IPD requires, the Owner will also be called on more often to assist in resolving issues that arise on the project. As member of the decision making body, the owner will be involved on more project-related specifics and be required to act quickly in this regard to allow the project to continue efficiently.*"

Among the responsibilities that the Owner has regarding the phases considered for the platform (conceptualization, criteria design and detailed design) are:

- Establishing goals regarding the function and performance of the building, schedule, and budget based on organization's business case.
- Providing site data such as topography, utility locations, soils condition, environmental impact studies and reports, Phase I mitigation reports.
- Taking decisions based on consultations regarding project goals and standards.
- Facilitating site specific/user input and coordinating it with the team.

2.2.2 Prime Designer

In the IPD Guide [1] it is stated that "*IPD relies heavily on an extensive and thorough design process that incorporates input and involvement of other team members, including constructors, during the design phase.*"

This type of user has also the following responsibilities:

- Validation of opportunities and options of the business proposition to the physical outcome of the project.
- Visualization of neighbouring buildings
- Form, adjacencies and spatial relationships of the project.
- Regulatory requirements for the building (i.e. fire/life safety plan).

2.2.3 Prime constructor

Again from [1] we can extract, for the primal constructor that: "*The integrated delivery process allows constructors to contribute their expertise in construction techniques early in the design process resulting in improved project quality and financial performance during the construction phase. The constructor's participation during the design phase provides the opportunity for strong pre-construction planning, more timely and informed understanding of the design, anticipating and resolving design-related issues, visualizing construction sequencing prior to construction start, and improving cost control and budget management, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability, will be achieved.*"

Among the responsibilities of the prime constructor in the design phase, we can mention:

- Constructability
- Initial procurement and construction schedule, including integration into model
- Continuous cost feedback using information extracted from the model. At this phase many items may be conceptual, i.e., based on floor area or unit cost
- Validation of target cost

2.3 Formation of Users Set

For interacting with the platform it is required that a user set is formed. The following section is an extraction of the annex of a user set that is going to be the most relevant since it includes the minimum whole set of users to implement an IPD approach.

2.3.1 Users Set A

OW – PD – PC – IPC

The set labelled as “A” is the one in which all the IPD actors are included. The rest of the user sets have to use the Integrated Project Coordinator role to be able to use the platform.

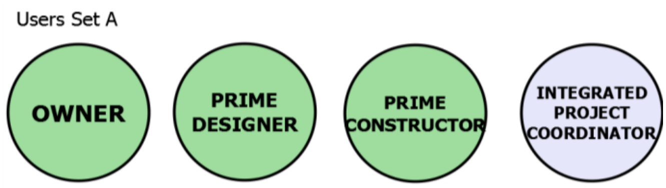


Figure 3: User Set A

3 OptEEmAL general workflow and input data steps

Defining the flow of information between the platform and the various actors defined in section 2 above can seem overwhelming. Even for individuals familiar with software processes considering the various levels of involvement from one actor to another and the new elements presented by the platform modules may be bewildering. The purpose of this section is to introduce a workflow that depicts a series of actions needed to execute the platform functionalities. The workflow diagram also describes a logical flow of information to achieve the optimal design of a district refurbishment project.

3.1 Sequence Diagram

As the design of the OptEEmAL platform progresses, the following diagram shows the structure of the successive input data steps and the different interactions between the main platform users (Owner, Prime Design, and Prime Constructor) and the platform. Updates to this sequence diagram will follow in future deliverables of the project.

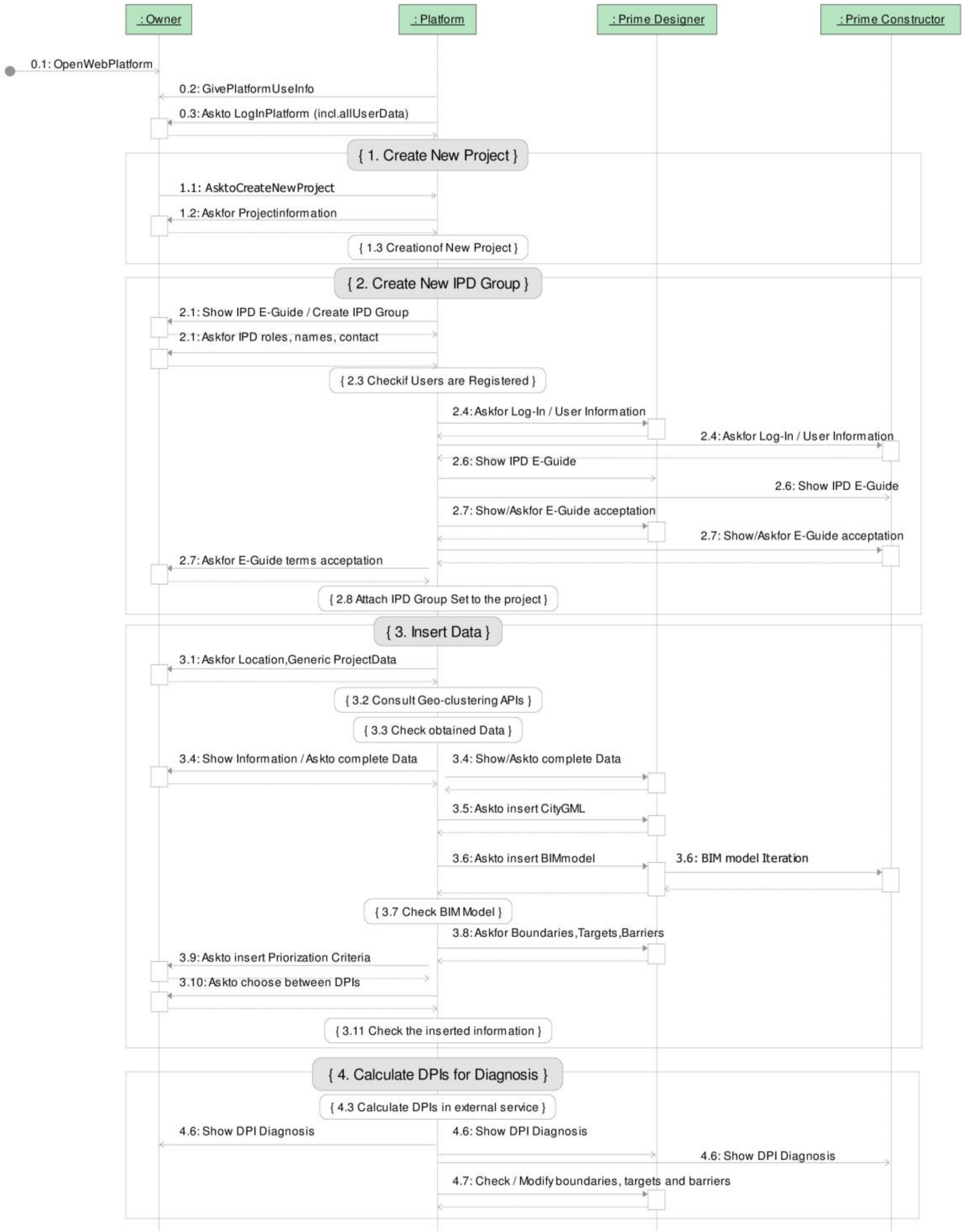


Figure 4: The OptEEmAL sequence diagram shows the interaction between the various actors and their actions (continued in the next diagram)

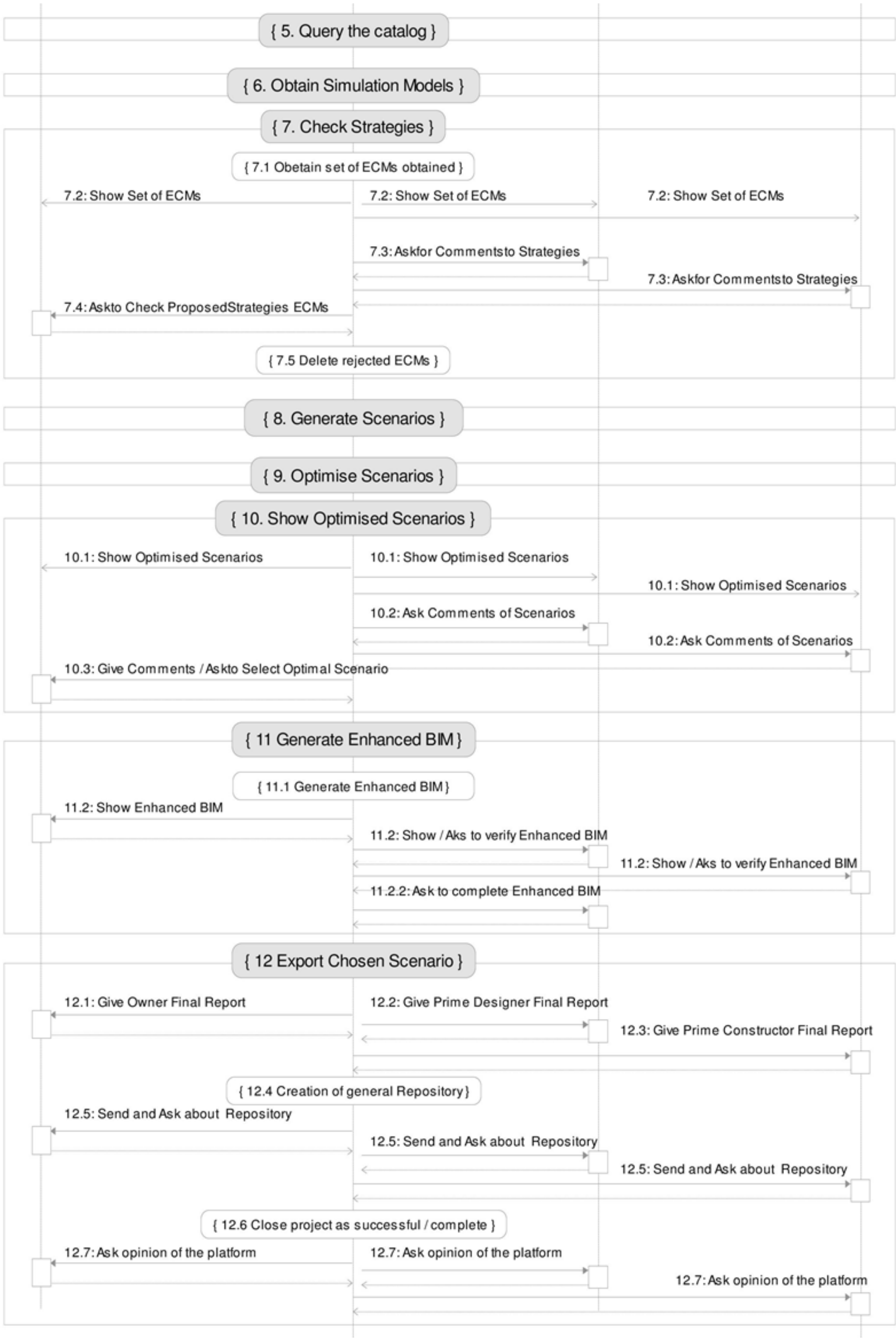


Figure 5: The OptEEmAL sequence diagram shows the interaction between the various actors and their actions (continued from the previous diagram)

3.2 Description of Workflow

The detailed description of the sequence diagram outlined in Figures 4 and 5 is provided here. It analyses the detailed interactions between various actors and the platform. This analysis will, later on, guide the development of different Use Cases.

This is the foreseen sequence of actions that the platform will undertake:

0. Start the platform

0.1 The OWNER accesses the web platform.

0.2 The platform provides information on how it can be used (How to use the platform guide)

0.3 The platform asks the user (OWNER) to log-in and give some information (User data): i.e., user name (Company name), contact details, role to use, interest in the platform...

R: The OWNER gives information to log-in to the platform.

1. Create New Project

1.1 The OWNER asks to create a new project

1.2 The platform responds and asks for information to create the project: i.e. project name, informative text, objective, place, etc.

R: The OWNER gives the general project information.

1.3 [The platform creates the new project, and it analyses if it is correctly created]:

1.3.1 If **yes**: the platform starts the point **2.1.**

1.3.2 If **not**: the platform re-starts point **1.2.**

2. Create New IPD Group Set

2.1 The platform shows the IPD E-Guide to the OWNER and asks to create a new IPD group related to the project.

R: The OWNER creates a new IPD group related to the project.

2.2 The platform asks for the IPD roles to be involved in the project, their names, and contact details of the users that are going to cover the different IPD roles.

R: The OWNER gives the IPD users, roles, names and contact details.

2.3 [The platform checks if these users are already registered into the platform]:

2.3.1 If **yes**: the platform creates the new IPD group and sends an email to all actors involved in the project notifying that a new project has been created.

2.3.2 If **not**: the platform sends an email asking for registration.

2.4 The platform asks all registered USERS to start / log-in to the platform. Also with the registration form the USERS have to give information related to the role (name, company, roles, interests, experience, contact, people involved...).

R: The different USERS start / log-in to the platform and also give the needed information requested by the platform.

2.5 The platform shows the IPD E-Guide to all new registered USERS (PRIME DESIGNER, PRIME CONSTRUCTOR) in the project.

2.6 The platform asks for the IPD E-guide terms acceptation.

R: USERS accept the IPD E-guide terms.

2.7 The platform gives the complete IPD E-guide with different proposed contracts to fulfil with the IPD objective within the project.

2.8 [After the acceptation the platform attaches the IPD group set with the USERS to the project (i.e. OWNER, PRIME DESIGNER, PRIME CONSTRUCTOR)]

3. Insert Data

3.1 The platform asks the OWNER to insert general information about the project and urban data to be able to consult the pre-configured list of geo-clustering APIs that are available.

R: The OWNER indicates the coordinates and generic urban data.

3.2 [The platform consults the geo-clustering APIs and obtains available information of the district (location data, urban data, climatic data, energy and environment data, social data, etc.)]

3.3 [The platform checks if the obtained information covers all the fields for the contextual data].

3.4 The platform shows this information to the OWNER and asks to insert manually the missing information. Then, the platform asks the PRIME DESIGNER to complete the pending information that the OWNER could not complete.

R: The OWNER provides the pending information required by the platform.

R: The PRIME DESIGNER provides the rest of the pending information required.

3.5 The platform asks the PRIME DESIGNER to insert the CityGML model:

R: The PRIME DESIGNER inserts the CityGML model.

3.6 The platform asks the PRIME DESIGNER to insert the BIM model after iterating it with the PRIME CONSTRUCTOR to achieve the better BIM performance.

R: The PRIME DESIGNER inserts the BIM model.

3.7 [The platform checks if the inserted BIM model is complete. Otherwise it informs the PRIME DESIGNER about the situation]

3.8 The platform asks the PRIMER DESIGNER to insert the known boundaries, targets and barriers for the refurbishment of the case study.

R: The PRIME DESIGNER specifies the boundaries, targets and barriers.

3.9 The platform asks the PRIME DESIGNER to introduce the prioritization criteria for qualifying the scenarios:

R: The OWNER inserts the prioritization criteria.

3.10 The platform asks the OWNER to choose from a list of pre-configured District Performance Indicators (DPIs) of interest for the new project:

R: The OWNER selects the appropriate DPIs

3.11 [The platform checks if the inserted information is consistent].

3.11.1 If **yes**: The platform continues to the next point **4.1** once data insertion by the user is complete.

3.11.2 If **not**: It informs about the situation and re-starts the points in which the incorrect information was submitted, showing it to the USER.

4. Calculate DPIs for Diagnosis

4.6 The platform shows the DPI Diagnosis to all the USERS.

4.7 The platform asks the PRIME DESIGNER to check if the calculated DPIs are correct.

4.7.1 If **yes**: The platform shows the results of the DPI diagnosis to the OWNER and continues to step **5.1**.

4.7.2 If **not**: The PRIME DESIGNER can modify boundaries, targets and barriers with the owner's consent. Then, re-start point **4.**

5. Query the catalogue

In this phase there is no interaction with the user, therefore there is no explicit relation to the IPD approach.

6. Obtain Simulation Models

In this phase there is no interaction with the user, therefore there is no explicit relation to the IPD approach.

7. Check strategies

7.1 [The platform consults the data repository to obtain a set of ECM measurements relevant for the project.]

7.2 The platform shows the set of ECM measurements (through the GUI) to the all USERS.

7.3 The platform asks the technical USERS (PRIME DESIGNER, PRIME CONSTRUCTOR) to give comments to the strategies that the platform will show directly to the OWNER.

R: The PRIME DESIGNER and PRIME CONSTRUCTOR give comments to the strategies selected by the platform.

7.4 The platform prompts the OWNER to check (accept or reject) the proposed strategies (ECM measurements) with the comments given by the PRIME DESIGNER and PRIME CONSTRUCTOR.

R: The OWNER accepts or rejects the proposed strategies (ECM measurements).

7.5 [The platform deletes those rejected ECM measurements from the data repository].

7.6 The platform asks the OWNER to define the objectives related to two DPIs

8. Generate Scenarios

8.1 In the case that no scenario meets the objectives set by the owner, the platform will return to the point 7.6 and the owner can edit the initial objectives

9. Optimise Scenarios

In this phase there is no interaction with the user, therefore there is no explicit relation to the IPD approach.

10. Show Optimised Scenario

10.1 The platform shows the selected scenarios proposed to the USERS.

10.2 The platform asks the technical USERS (PRIME DESIGNER, PRIME CONSTRUCTOR) to provide comments regarding the selected scenarios that the platform will show directly to the OWNER.

R: The PRIME DESIGNER and PRIME CONSTRUCTOR give comments to the selected scenarios proposed by the platform.

10.3 The platform asks the OWNER to select the optimal scenario from optimised taking into account the comments given by the PRIME DESIGNER and PRIME CONSTRUCTOR.

R: The OWNER selects the optimal scenario.

11. Generate Enhanced BIM

11.1 [The platform generates an enhanced BIM with the information of the optimal scenario].

11.2 The platform shows the generated enhanced BIM and prompts the PRIME DESIGNER and PRIME CONTRUCTOR to verify if it is correctly generated.

11.2.1 If **yes**: The platform continues to point **12.**

11.2.2 If **not**: The platform asks the PRIME DESIGNER to iterate with the PRIME CONSTRUCTOR in order to complete/modify the enhanced BIM.

R: The PRIME DESIGNER gives the modified enhanced BIM to the platform. After this response the platform goes to point **12.**

12. Export Chosen Scenario

12.1 The platform gives the OWNER a final complete report with the project coordination information, objectives achieved within the project, maintenance information, etc.

R: The OWNER confirms the reception, if not it has to be re-sent.

12.2 The platform gives the PRIME DESIGNER a final complete technical report with the project technical issues, methodology and procedures as well as the BIM Design archive.

R: The PRIME DESIGNER confirms the reception, if not it has to be re-sent.

12.3 The platform gives the PRIME CONSTRUCTOR a final complete constructive report with the project construction issues, procedures for the construction methods and the BIM Construction archive.

R: The PRIME CONSTRUCTOR confirms the reception, if not it has to be re-sent.

12.4 [The platform creates a general final repository where all the information of the project is exported and divided in different folders (per user)]

12.5 The platform sends the link/place of this repository and the access to it to all USERS and asks if the repository, information and scenario are correct.

12.5.1 If **yes**: The platform go to the next point **12.6**

12.5.2 If **not**: The platform asks all USERS if they want to calculate another scenario or specify what the problem is. (re-directing to another point is an option)

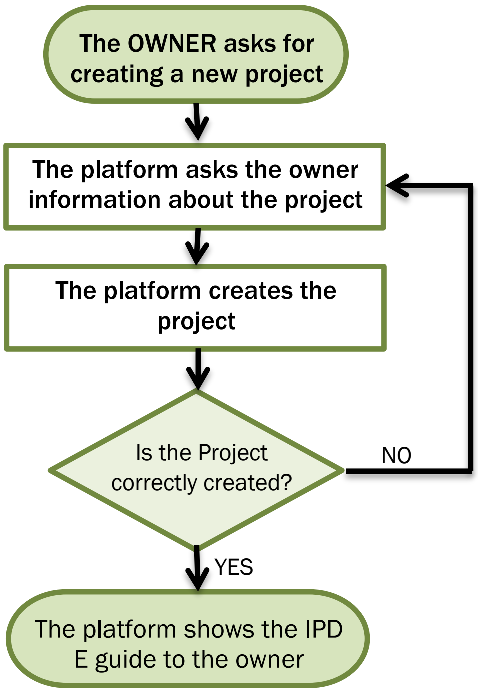
12.6 [The platform closes the project as successful / complete].

12.7 The platform asks all USERS to give their feedback/survey about the platform and its processes.

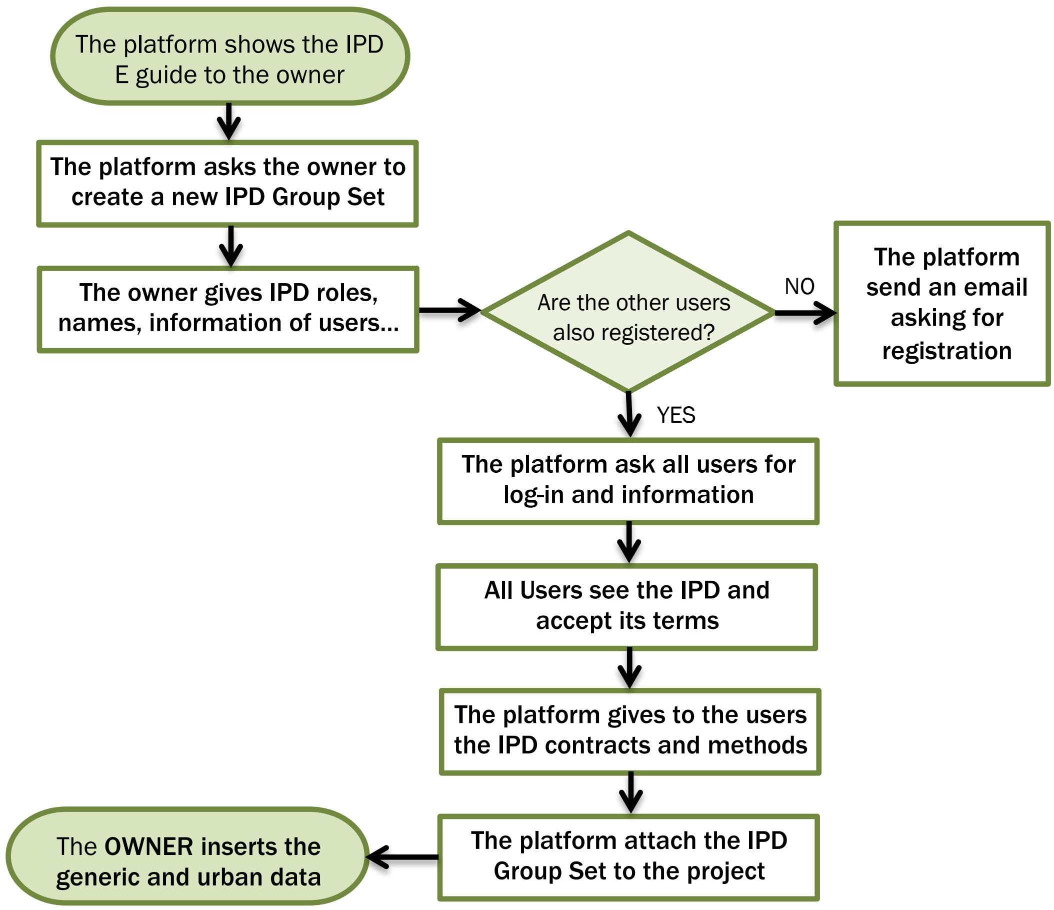
R: USERS choose to answer the questions (optional).

3.3 Workflow Diagrams

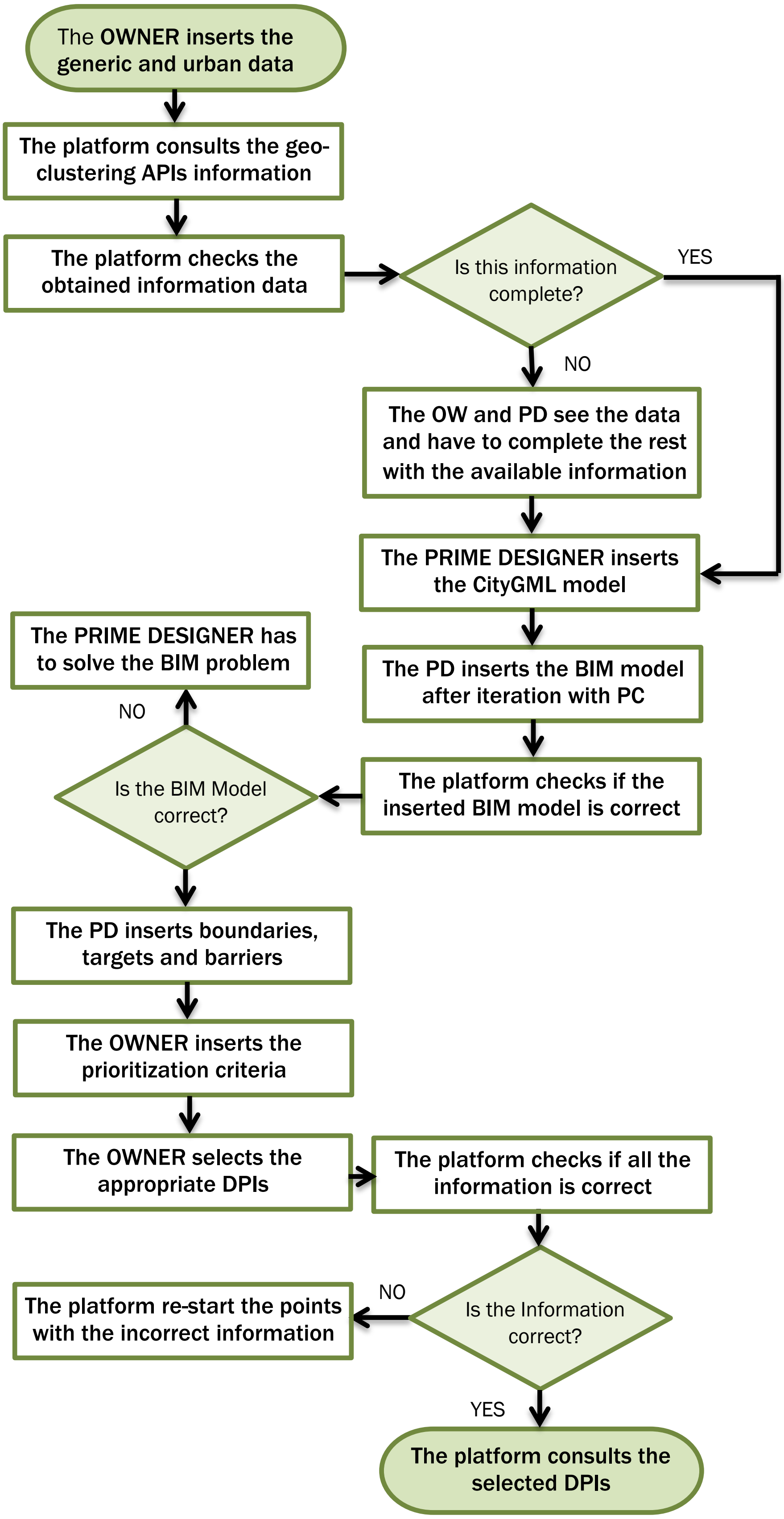
1. Create New Project



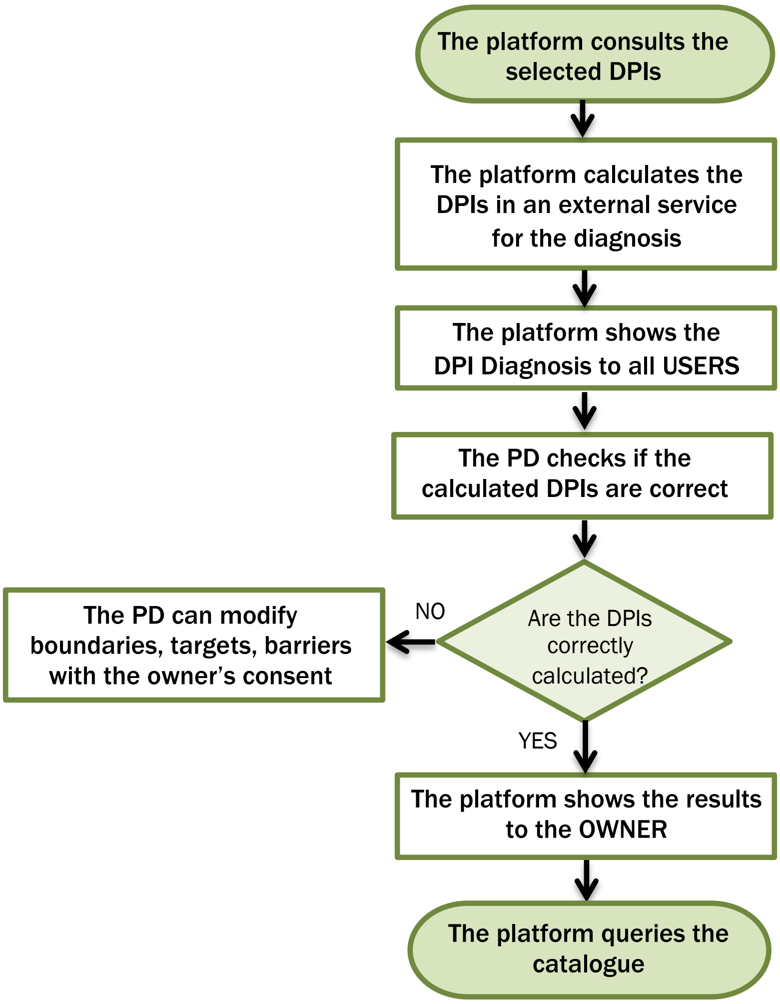
2. Create New IPD Group Set



3. Insert Data



4. Calculate DPIs for Diagnosis



The above workflow diagrams show the interaction between various actors and the platform in a standardized sequence. Steps 5 – 12 are yet to be analysed as the OptEEmAL project progresses. These steps define how the platform is going to be implemented from a software point of view.

4 OptEEmAL Case Studies

This section introduces the nine case studies considered in the project, including existing data and IPD roles and structures.

In OptEEmAL a **case study** is a decision-making scenario in which the platform to be developed in the project will, from a general perspective, aim at easing the decision-making process by providing an optimised building retrofitting scenario at district level and all associated information (from building design to building delivery). This optimised scenario will be generated from the initial situation characteristics (before refurbishment) and a set of retrofitting solutions (scenarios) involving project actors and using boundary conditions, targets, and prioritisation criteria.

All case studies presented in this section have been selected to validate the OptEEmAL platform. Two categories of case studies are considered, according to the level of development of the platform, which will evolve over overtime and is reflected by TRL levels. Refurbishment projects in these case studies are positioned at various stages. Some are finished, some are on-going and others are planned. This is explained in detail in the following paragraphs.

Among the nine case studies detailed in the following parts, six are considered as case studies for TRL6 validation activities which will be performed in WP6. Those case studies are existing retrofit actions that are were initiated by other EU projects performed by the OptEEmAL partners. They will be used to validate the platform prototype and associated functionalities. The aim of this validation step is to ensure all system specifications work as required under a semi-controlled domain (the final design and retrofitting measures are known, as well as the decisions taken during the process). They are classified below as “case studies”. These case studies are:

- Case study 1 – Cuatro de Marzo District, Valladolid (Spain)
- Case study 2 – Manise Province District, Soma (Turkey)
- Case study 3 – Historic city District, Santiago de Compostela (Spain)
- Case study 4 – Linero District, Lund (Sweden)
- Case study 5 – Mogel District, Eibar (Spain)
- Case study 6 – Sneinton District, Nottingham (UK)

The three remaining case studies will be used to demonstrate the TRL7 level of the OptEEmAL platform at the end of the project (within WP6). The main objectives of these demo cases will be to test the platform in a “real” environment to demonstrate its performance, usefulness and user-friendliness for developing integrated district retrofitting plans. They are classified below as “demo cases” and are the following:

- Demo case 1 – San Bartolomeo District, Trento (Italia)
- Demo case 2 – Txomin Enea District, San Sebastián (Spain)
- Demo case 3 – Möllevangen District, Lund (Sweden)

Although having different status as finished/on-going or planned, these nine case studies reflect a decision-making scenario into which the OptEEmAL platform can be used to ease decision making. In this early phase of the project, and in order to define the platform main characteristics, it was necessary to gather information about all the case studies regarding the initial situation of the district, the goal of future platform users, all available data, etc.. Case study information has been structured in the following manner:

- General presentation
- Goal
- Available data
- Needed data
- Workflow and project actors organisation (where possible, in line with section 2)
- Relevant indicators

- Legal/Technical constraints

The type of information collected from the different scenarios is shown in Table 3, the template used for the data gathering. This information have been completed by the different partners responsible for the different case studies

Geographical locations of these case study locations are presented in Figure 6.

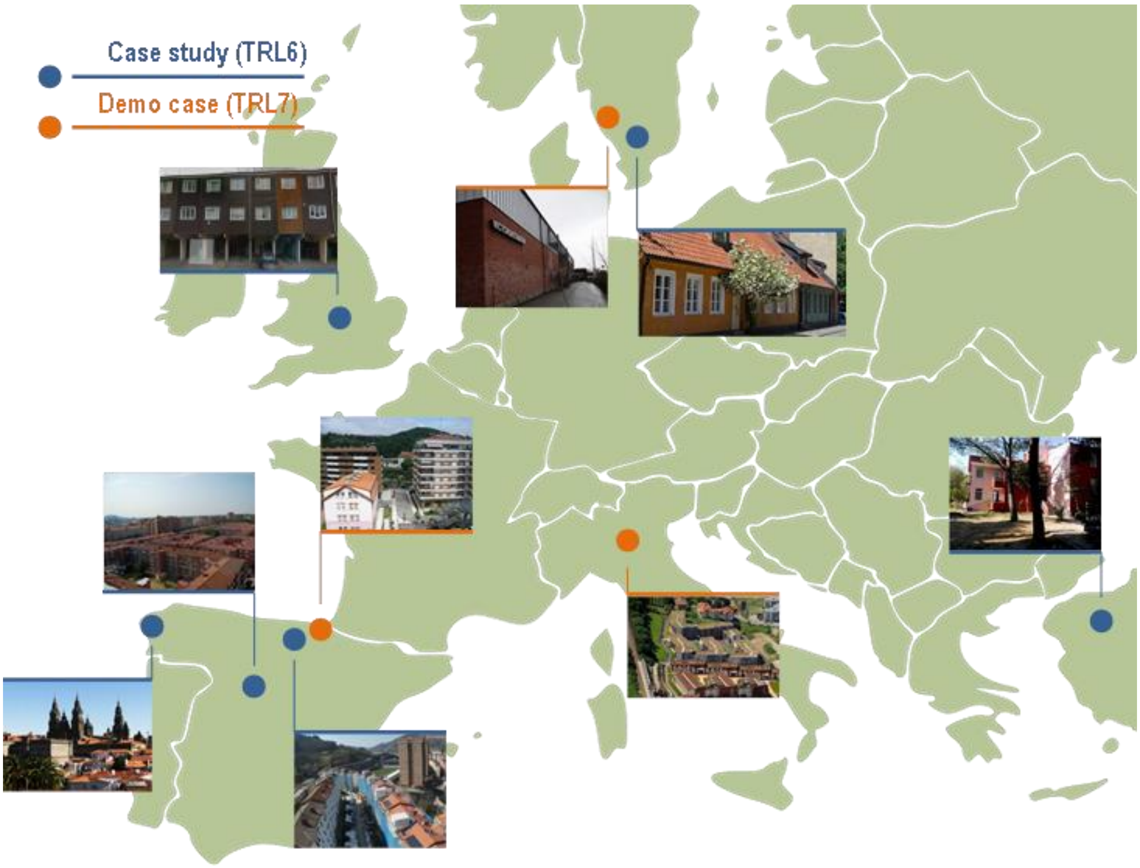


Figure 6: Case studies and demo cases in OptEEmAL

Table 3: Case study information template

<table>
<tr><td>Case study Name</td><td colspan="2"></td><td rowspan="3">PICTURE</td></tr>
<tr><td>Location</td><td colspan="2"></td></tr>
<tr><td>Partner in charge</td><td colspan="2"></td></tr>
<tr><td>Goal</td><td colspan="3"></td></tr>
<tr><td rowspan="23">Data available</td><td rowspan="10">Urban data</td><td>Year of construction</td><td></td></tr>
<tr><td>District surface [m²]</td><td></td></tr>
<tr><td>Site coverage ratio [%]</td><td></td></tr>
<tr><td>District morphology</td><td></td></tr>
<tr><td>Uses classification (*)</td><td></td></tr>
<tr><td>Number of buildings</td><td></td></tr>
<tr><td>Building typologies</td><td></td></tr>
<tr><td>Net built area of buildings [m²]</td><td></td></tr>
<tr><td>Net usable area of buildings [m²]</td><td></td></tr>
<tr><td>Number of dwellings</td><td></td></tr>
<tr><td rowspan="8">Climatic data</td><td>Climate zone (*)</td><td></td></tr>
<tr><td>Heating degree day (HDD)</td><td></td></tr>
<tr><td>Cooling degree day (CDD)</td><td></td></tr>
<tr><td>Average winter temperature [°C]</td><td></td></tr>
<tr><td>Average summer temperature [°C]</td><td></td></tr>
<tr><td>Global solar radiation [kWh/m²yr]</td><td></td></tr>
<tr><td>Average wind speed [m/s]</td><td></td></tr>
<tr><td>Average precipitation [mm/year]</td><td></td></tr>
<tr><td rowspan="5">Energy and environment</td><td>Thermal gross area of district [m²]</td><td></td></tr>
<tr><td>Thermal gross volume of district [m³]</td><td></td></tr>
<tr><td>Existing thermal systems (HVAC)</td><td></td></tr>
<tr><td>Existing energy sources (gas, oil, biomass, electricity, etc.)</td><td></td></tr>
<tr><td>Degree of energetic self-supply [%]</td><td></td></tr>
</table>

		Degree of accordance with national laws and standards (*) [%]	
		Estimated average final energy demand per building typology [kWh/m²yr]	
		Estimated average final energy consumption per building typology [kWh/m²yr]	
		Average energetic class of buildings	
		Net fossil energy consumption [kWh/m²yr]	
		Greenhouse gas emissions [kgCO_2/m²yr]	
	Social data	Number of inhabitants Board	
		Population density of district [inhab/m²]	
		Property structure	
		Average income of inhabitants	
		Other Information	
Data needed			
Work process			
Actors / IPD			
Platform Users			
DPIs			
Related national/local policy framework			
Others			

5 District current conditions and DPIs

In order to aid the accurate generation and optimization of the retrofit scenarios, a reliable estimate of the current conditions of the district is necessary. The current conditions will be determined from the District Performance Indicators (DPI) that will be computed for each case-study, c.f. sub-section titled 'District Performance Indicators'. District Performance Indicators (DPIs) are the criteria among which the district current conditions and the different retrofitting scenarios will be evaluated and ranked.

Section 5.1 lists the DPIs per case study so that, when user-objective(s) are defined, users will select one or a set of DPIs. Then, for each DPI, the user could define a target to be used to select and optimise the relevant retrofitting scenarios. This enables the users of the platform not having to define DPIs as they will be OptEEmAL platform's intrinsic characteristics. However, by defining their objectives through these criteria, users will directly interact with the platform DPIs.

Section 5.2 lists the essential requirements concerning the availability, accuracy and reliability of the input data that will be used for calculating the DPIs and computing the baseline models. The input data required to generate and optimise the retrofit scenarios will also be used for generating the baseline models that estimate the current conditions of the district. DPIs are broadly classified in terms of energy, comfort, environment, economic, social, and urban performance indicators of the district. They could have overlapping requirements, especially, for the group consisting of (1) energy, comfort and environment DPIs and (2) urban, social and economic DPIs.

5.1 District Performance Indicators

OptEEmAL DPIs have been determined based on the expert knowledge of various members of the consortium together with the needs from different case studies and information provided by the three demo site responsible partners to ensure their relevance. Table 4:Relationships between Case studies DPIs and OptEEmAL DPIs lists the DPIs per case study.

Table 4:Relationships between Case studies DPIs and OptEEmAL DPIs

Case study	DPI used in the case study	Corresponding OptEEmAL DPI
CS1 - Cuatro de Marzo district – Valladolid (Spain)	Net fossil energy consumption	ENE06
	Energy demand covered by renewable resources	ENE09
	Energy use from PV	ENE15
	Total investment (€)	ECO02
	Return of investment (years)	ECO06
	Global Warming Potential	ENV01
	GWP reduction	ENV03
CS2 - Manise Province District, Soma (Turkey)	Energy demand	ENE01
	Final energy consumption	ENE02
	Energy demand covered by renewable sources	ENE09
	Energy use from district heating	ENE13
	Energy use from PVs	ENE15
	Energy use from solar thermal	ENE16
	Global warming potential	ENV01
	GWP reduction	ENV03
	Investments	ECO02

	Return of investment	ECO06
CS3 - Historic city District, Santiago de Compostela (Spain)	Total Primary Energy Demand	ENV04
	Operational Energy Use	ENE02
	Energy Demand Embodied	ENV05
	Share of Renewable Energy on Site	ENE09
	Global Warming Potential (GWP)	ENV01
	Life cycle costs aggregated	ECO04
	Investment costs aggregated	ECO02
	Return on Investment	ECO06
CS4 - Linero District, Lund (Sweden)	Energy demand	ENE01
	Primary energy consumption	ENV04
	Global warming potential	ENV01
	Total investments	ECO02
CS5 - Mogel District, Eibar (Spain)	Primary energy used from energy need in building	ENE01
	Greenhouse gas emissions from energy need in building	ENV01
	Investment cost	ECO02
	Maintenance	Included in ECO03
	Total cost in present value	ECO05
	Total energy cost in present value	ECO01
	Building on-site generation systems connected to the energy infrastructure (PV, Solar thermal)	Related to ENE15 and ENE16
CS6 - Sneinton District, Nottingham (UK)	Energy demand	ENE01
	Final energy consumption	ENE02
	Energy use from district heating	ENE13
	Local thermal comfort	COM01
	Investments	ECO02
	Return of investment	ECO05
DC1 - San Bartolomeo District, Trento (Italia)	Net energy source	ENE01
	Net Energy source per inhabitant	ENE02 (diagnosis)
	Energy savings for the "i" scenario	ENE02 (evaluation)
	Investment for the "i" scenario	ECO02
	Ratio of the Investment and the Energy savings	ECO06
	Net Energy share of RES production	ENE09
	Total investment	ECO02
	Return of investment	ECO06
DC2 - Txomin Enea District, San Sebastián (Spain)	Investment Cost	ECO02
	Maintenance Cost	Included in ECO03
	Greenhouse gas emissions	ENV01
	Primary energy consumption	ENV04

	Internal rate of return and the time needed to get back the investment.	ECO05 and ECO06
DC3 - Möllevangen District, Lund (Sweden)	Energy demand	ENE01
	Primary energy consumption	ENV04
	Global warming potential	ENV01
	Total investments	ECO02

Based on this analysis, the following list of DPIs is currently envisaged for the OptEEmAL platform. This list is currently being investigated in Task 2.2 and will be finalised in deliverable D2.2. The detailed calculation methodology for each DPI will be provided in D2.2. Detailed input data required for the calculation of these indicators are mentioned in the following sections.

Table 5: OptEEmAL DPI list and associated requirements

Category	District Performance Indicator	Unit
Energy	ENE01 - Energy demand	kWh/m^2
	ENE02 - “Final Energy Consumption” or “Operational Energy Use”	kWh/m^2
	ENE03: Peakload and profile of electricity demand	kW
	ENE04 - Peakload and profile of thermal energy demand	kW
	ENE05 - Degree of energetic self-supply	kWh/kWh
	ENE06 - Net fossil energy consumed	kWh/m^2
	ENE07 - Total energy use per capita	kWh/hab.year
	ENE08 - Total residential electrical energy use per capita	kWh/hab.year
	ENE09 - Energy demand covered by renewable sources (%)	%
	ENE10 - Total residential natural has energy use per capita	kWh/hab.year
	ENE11 - Total residential butane gas energy demand	kWh/hab.year
	ENE12 - Energy consumption of public buildings per year	kWh/m^2
	ENE13 - Energy use from District Heating	kWh/year
	ENE14 - Energy use from Biomass	kWh/year
	ENE15 - Energy use from PV	kWh/year
	ENE16 - Energy use from Solar Thermal	kWh/year
	ENE17 - Energy use from Hydraulic	kWh/year
	ENE18 - Energy use from Mini-Eolica	kWh/year
	ENE19 - Energy use from Geothermal	kWh/year
Comfort	COM01 – Local thermal comfort	Level
	COM02 – Percentage outside range	%
	COM04 – Indoor Air Quality	n.a
Environment	ENV01 – Global Warming Potential	kg CO_2/y·m^2
	ENV02 – GWP investment	kg CO_2
	ENV03 – GWP reduction	kg CO_2/y
	ENV04 – Primary energy consumption	MJ/y·m^2
	ENV05 – Embodied energy of refurbishment scenarios	MJ
	ENV06 – Energy payback time	Year

Economic	ECO01 – Operational energy cost	€, €/m^2
	ECO02 – Investments	€, €/m^2
	ECO03 – Grants	€, €/m^2
	ECO04 –Life cycle cost	
	ECO05 – Internal rate of return	
	ECO06 – Return of investment	Year
	ECO07 – Total energy cost	€/year
Social	SOC01 - Energy poverty measured as % of incomes used to pay energy bills	%
Urban	URB01 - Percentage of buildings compliant with EPBD standard	%
	URB04 – Percentage of buildings compliant with nZEB standard	%
	URB02 – Percentage of buildings compliant with PassivHause standard	%
	URB03 – Percentage of buildings compliant with EnerPhit standard	%
Global	GLO01 – kWh energy saved / euro invested	kwh.y / €

An overview of the link between input data is given in the figure below (Figure 7).

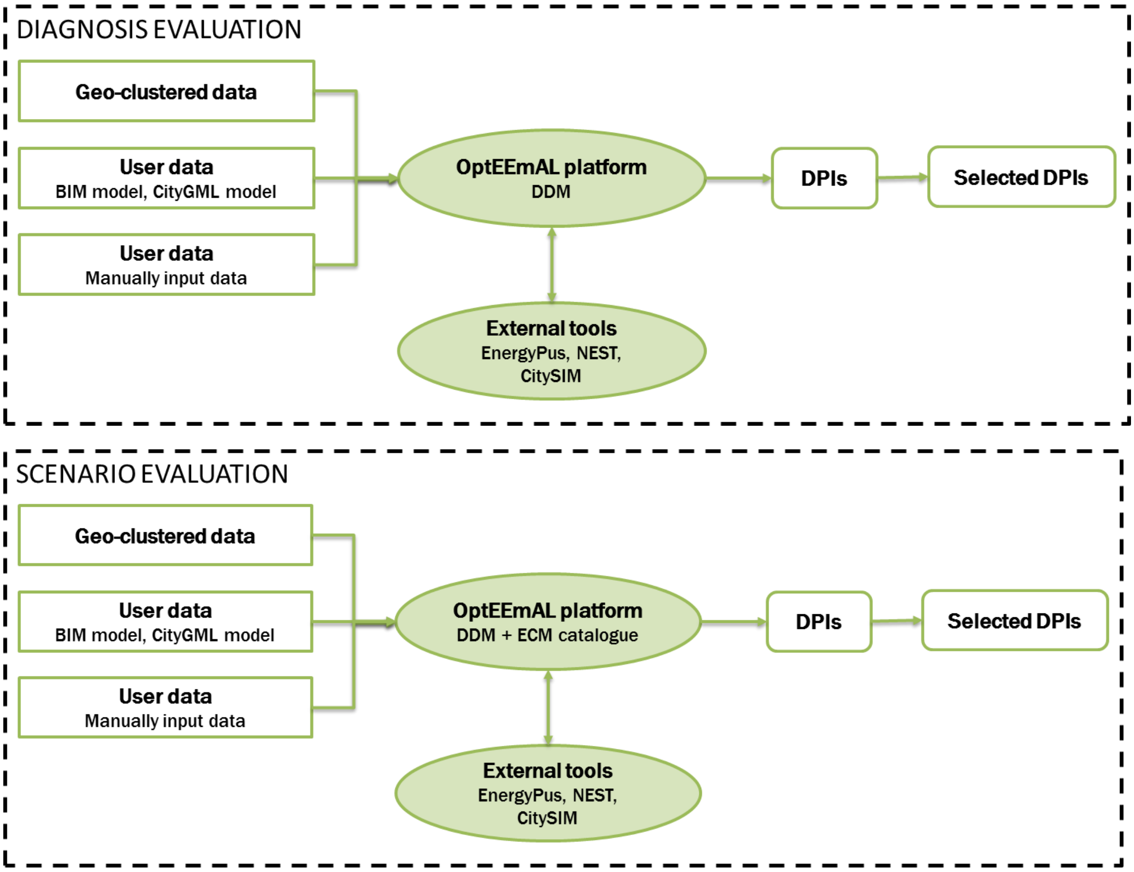


Figure 7: Overview of the relationship between input data and DPIs

5.2 District current conditions

Requirements for energy, comfort and environment DPIs:

- Hourly, weekly, seasonal and annual averages consumption of the energy per building
- Average daily weather (temperature, humidity, precipitation, sunlight, etc.) and climate zone
- Peak/Off-peak demand for each building and district-wide
- Breakdown of energy consumption into HVAC, lighting, appliances, elevators, escalators, operational equipment, machinery, etc. for each floor or building
- List of various energy types/sources, utility providers, payback time, and their source mix
- Prices of fuel, standing charges, etc. across providers
- Local generation, renewables, storage estimates, global warming potential
- Volatility of the prices of diverse energy sources
- Room-temperature, set-points, airflow data
- Indoor and outdoor acoustic levels
- Indoor air-quality
- Generation, transmission and storage efficiencies of the fuels
- Hourly occupancy estimates
- Local holidays, vacations, event calendars
- Energy consumption quartiles
- Hourly noise-level estimates
- List of appliances, machinery, etc., in each zone
- Heat transfer efficiencies of the appliances, equipment, etc.
- Heat generation from each zone
- List and types of lighting in each zone
- Type of activities in each zone
- Properties (conductivity, thickness, density, durability, thermal capacitance, etc.) of building components used for each thermal zone

Requirements for estimating urban, social and economic DPIs:

- Estimates of average household income, average living costs, GDP
- Breakdown of population into age-groups and type of employment
- Estimates of annual average household social benefits, utility discounts, energy poverty, etc.
- Estimate of annual average household expenditure on utility, dwelling maintenance, etc.
- Prices of fuel, standing charges, etc. across providers
- Life-cycle cost and return-on-investment of refurbishments
- Percentage of buildings under refurbishment

6 Input data content requirements

OptEEmAL adopted the Integrated Project Delivery (IPD) philosophy in a refurbishment project as IPD strives to maximize the opportunities to influence positive outcomes with minimal cost of changes by making design decisions as early as possible. The effect of changes that inevitably happen in any refurbishment project can be substantially minimized if the design requirements are stated clearly. From the perspective of the OptEEmAL platform, the design is captured in terms of the input data and, therefore, design requirements are input data requirements. In this section, the requirements of the contents of the input data with respect to their source, scale, types, fields, tools, variability, etc. are presented.

In Sections 6.1 and 6.2 the requirements for BIM-related input data and CityGML-related input data are provided. These categories of input data requirements are important because much of the input data content will be presented as BIM and CityGML files. These requirements enable quick design decisions because (a) BIM and CityGML could capture the input data from diverse sources systematically, organises the intermediate data from diverse simulations and scenarios, and presents the output data for diverse IPD actors, and (b) BIM and CityGML could enable easy, flexible, cost-effective and speedy adaptation of the project to changing IPD requirements of design and demands of the actors.

In Sections 6.2 and 6.3 the requirements for the input data specific to the refurbishment project are provided. Broadly categorising, such data fall into (a) contextual data, which includes district or location-specific information such as location, periodically metered or monitored data, and socio-economic data of the municipality, city or district and (b) configuration data, which includes users and their categories as well as the identified objectives and barriers for district refurbishment.

6.1 BIM-related data

In OptEEmAL, the BIM data supplies the design metadata, rules, thresholds, parameters and strategies configured in (1) building management / automation system (BMS / BAS), (2) building structure and architecture modelling system, and (3) building energy management system (BEMS). E.g., building use and schedules, HVAC equipment specifications, HVAC controls / set-points can be obtained from the BMS / BAS systems whereas, renewables, local generation and storage information can be obtained from the BEMS systems.

Table 6: Required BIM related data

Required BIM related data	
Exchange Information	Building and District Data
Availability of the Information	Generated by external tools and manual inputs
Actors	Owner, Prime Designer (who plays the role of Integrated Project Coordinator) and Prime Constructor.
Information Type	Climate District and building geometries Building and district data semantics, links and hierarchies HVAC controls, specifications, and measurements Schedules for utilities, operations and occupancies

Scale	Building use and schedules: Weekly medians Construction elements: Thermal zones Internal gains: Thermal zones HVAC equipment/controls/set-points: Terminal units at HVAC zones; Central units at building/floor Renewables, local generation and storage: Building/district level
Variability of the information	Building use and schedules: Low Construction elements: Low Internal gains: Medium HVAC equipment/controls/set-points: High Renewables, local gen and storage: Medium
Data Formats	IFC
Tools	BIM Authoring tools (Revit, AllPlan, etc.) IFC chequer (IfcObjectCounter, Solibri, etc.) BIM - BAS/BMS interfaces (BACnet, WebCtrl, KNX) BIM – BEMS interface (PlantCtrl, I3CON BSG)
Required Precision	High

6.1.1 Building use and schedules

Each building, depending on their use, may have a different occupation schedule and activity, affecting building energy profiles including internal gains. Even when the construction characteristics, location or orientation of a building are the same, internal conditions of a residential or service building could be completely different.

It is estimated that there are 25 billion m² of useful floor space in the EU27 [2]. The residential stock is the biggest segment with an EU floor space of 75% of the building stock (see Figure 8).

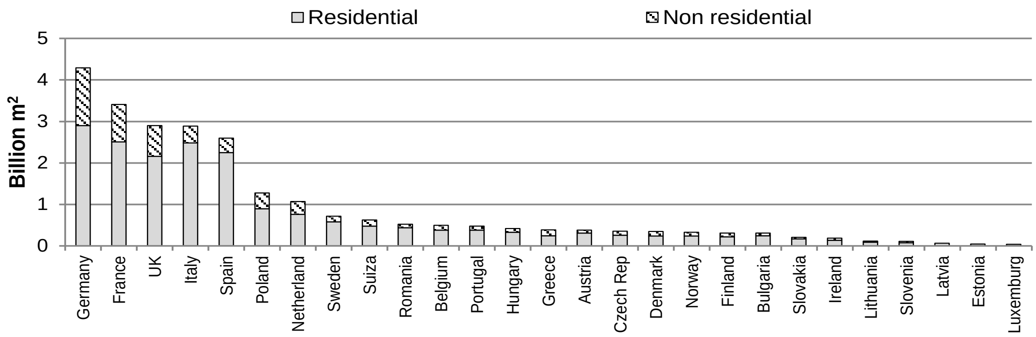


Figure 8: Distribution of floor space between residential and commercial buildings per country.

Non-residential buildings account for 25% of the total stock in Europe and comprise a more complex and heterogeneous sector compared to the residential sector. The retail and wholesale buildings comprise the largest portion (28%) of the non-residential stock while office buildings are the second biggest category with a floor space corresponding to one quarter of the total non-residential floor space (23%). Variations in usage pattern, energy intensity, and construction techniques are some of the factors adding to the complexity of the sector.

OptEEmAL proposes to differentiate the following building use categories:

- **Residential**: Single family building; semi-detached house; and multi-family building
- **Service buildings**: Office building; hotel & apartment; school & university; museum, library, theatre; and hospital.

It is necessary, during the first phase of the project, to define the **use** of each building in the district to be by the platform. To do this, in conjunction with the definition of the use, it will be necessary to determinate the **hours of the operation** (schedules) of each building and the **occupation rate** (person per living square meter) of each building.

Table 7: Use and schedule requirements

Use and schedule requirements	
Use	For buildings with more than one use (for example: ground floor commercial and other floors dwelling), it would be necessary to define each of them.
Operation	For building with different use during weekdays, weekends and holidays, it would be necessary to define different operation schedules.
Occupation rate	For buildings with more than one use, it would be necessary to define the occupation rate for each use. This information can be defined by two different measurement units (according to available information): - Number of people per square meter (person/m²) - Minimum square meter per person (m²/ person)

The accuracy of these parameters will be directly related to the availability of information. Therefore, it will be necessary to work with different stakeholders such as municipality, inhabitants, community responsible and owner.

The following table shows some generic data related to the occupancy rate and schedules of different buildings. In the case of the end user having detailed information, it will be necessary to update this information to improve the accuracy of the inputs and hence the outputs of the platform.

Table 8: Generic occupancy values and schedules of the different buildings

<table>
<tr><th colspan="4">OCCUPANCY</th></tr>
<tr><th colspan="2"></th><th>Unit</th><th>Value</th></tr>
<tr><td rowspan="3">Residential</td><td>Single family building</td><td>People/m²</td><td>0.03</td></tr>
<tr><td>Semi-detached house</td><td rowspan="2">Schedule</td><td rowspan="2">Until 07:00 (100%), Until 15:00 (25%), until 23:00 (50%), until 24:00 (100%)</td></tr>
<tr><td>Multi-family building</td></tr>
<tr><td rowspan="5">Service</td><td rowspan="2">Office building</td><td>People/m²</td><td>0.111</td></tr>
<tr><td>Schedule</td><td>Weekdays: Until 07:00 (0%), Until 08:00 (25%), until 09:00 (50%), until 12:00 (100%), until 14:00 (75%), until 17:00 (100%), until 18:00 (50%), until 19:00 (25%), until 24:00 (0%)</td></tr>
<tr><td rowspan="2">Hotel & apartment</td><td>People/m²</td><td>0.05</td></tr>
<tr><td>Schedule</td><td>Every day: Until 08:00 (100%), until 09:00 (25%), until 21:00 (0%), until 22:00 (25%), until 23:00 (75%), until 24:00 (100%)</td></tr>
<tr><td>School & University</td><td>People/m²</td><td>0.2</td></tr>
</table>

		Schedule	Weekdays: Until 07:00 (0%), until 08:00 (25%), until 09:00 (50%), until 12:00 (100%), until 14:00 (75%), until 17:00 (100%), until 18:00 (50%), until 19:00 (25%), until 24:00 (0%)
	Museum, library, theatre	People/m²	0.1238
		Schedule	Every day: Until 07:00 (0%), until 09:00 (50%), until 17:00 (100%), until 20:00 (50%), until 24:00 (0%)
	Hospital	People/m²	0.11
		Schedule	Every day: Until 24:00, (100%)

6.1.2 Construction elements

Input data requirements for passive construction elements of the district are specified in this section. The objective is to define the different properties of the construction elements that are needed to be included in the BIM (IFC) model to be simulated by the OptEEmAL platform. In order to achieve a better optimisation in the platform the input data elements to be selected are going to be as general as possible.

The construction elements are a group of objects with different physical and technical properties and configurations that constitute the building envelope and interior elements. These construction elements include the envelope, walls, roofs, floors, windows, and doors of the buildings.

6.1.2.1 Requirements

Construction elements have to be built from the basic thermal and other material properties of the physical construction. In that sense, materials are specified by types and names and defined by the composition of materials. Different surfaces of these elements are specified for the building with geometric coordinates as well as referenced constructions. Different types of elements along with different input data requirements are going to be described in the following sections: Building envelope new elements, Windows, Construction existing elements.

6.1.2.2 Building envelope

There are several material “types” which may be used to describe layers within opaque construction elements. This requires knowledge of many of the thermal properties of the material and allows the OptEEmAL simulation tools to take into account the thermal mass of the material and thus allows the evaluation of transient conduction effects.

These materials should have these main thermal properties: thickness, conductivity and density.

To represent a construction element that will suit the different requirements of the BIM software and then the possible simulation tools, an example is illustrated in Table 9 documenting the properties of the construction element.

Table 9: Construction element input data

Construction Element		
Field	**Description**	**Units**
Name	Unique reference that the user assigns to a material	

Estimated Service Life	Estimated Service Life of the material	[years]
Thickness	Thickness of the material layer	[meter]
Conductivity	Thermal conductivity of the material layer	[W/(m-K)]
Density	Density of the material layer	[kg/m3]
Solar / Thermal Capacitance	It represents solar or thermal capacitance that is absorbed and maintained by the material	[J/K]

6.1.2.3 Glass Windows

To describe materials that are transparent in some percentage there are other types of properties that should be specified as inputs for the energy efficiency simulation of the construction element.

Through a BIM archive the OptEEmAL platform should be able to transform this archive into a suitable format for the simulation tools. Same structure as for the building envelope elements will be followed for windows.

The orientation of different glass layers (windows) and oriented description has to be also specified due to its impact in the calculation of solar parameters. The windows are differentiated from other materials because of the solar radiation transmitted through them, which enters the zone and becomes a component of the zone load. The solar radiation absorbed in each solid layer (glass, shade, screen or blind) participates in the window layer heat balance calculation. That is why windows have another characterization that should be integrated in the simulation models within the OptEEmAL platform.

Table 10: Glass window element input data

Glass Window Element		
Field	**Description**	**Units**
Name	Unique reference that the user assigns to the window construction	
Estimated Service Life	Estimated Service Life of the material	[years]
Thermal transmittance	It characterizes the thermal transmittance of the window: glass + air cavity + frame	[W/(m^2-K)]
Solar / Thermal Transmittance	It represents solar or thermal that goes through the windows warming the inside of the room	[%]

6.1.2.4 Existing construction elements

For existing construction elements such as walls, roofs, floors, windows and doors, additional considerations associated with possible problems in the construction are included here. These parameters are to be considered in addition to those specified for the building envelope data above and have to be also included in the description of construction existing elements.

These parameters are important given that existing elements are going to co-exist with the new elements from refurbishment.

Table 11: Existing construction element input data

Existing Construction Element		
Field	**Description**	**Units**

Age of Building	Years from the construction or from the last renovation	[years]
Humidity Inside / Outside	Relative Humidity of Outside Face Surface	[%]

6.1.2.5 Data sources

To obtain the information needed for construction elements the following are methods and formats of data:

Table 12: Passive elements input data collection methods

Method / Tools	Description	Who - Where
BIM	Building surrounding, constructive existing elements and envelope, etc.	Developed Prime Designer – Prime Constructor
City GML	Building shape for envelope and area	Web tool
Surveys to the occupants	Comfort conditions and building use profile	Citizens
Cadastre	Construction year information, areas, age, different renovation, protection level...	Web cadastre
Web data bases	Additional constructive information, but usually disperse and incomplete	Web tools

The input data for construction elements upgrades will be part of the ECM catalogue to be integrated in the OptEEmAL platform for use in the calculation of the different retrofitting scenarios.

To do so, the following Table provides some of the existing databases about constructive elements. The idea is to establish direct connections between these databases and the input data that will facilitate the completion of the different required fields for passive constructive elements in the ECMs catalogue.

Table 13: Possible data bases for passive elements

BPIE Data Hub Energy Performance Buildings http://www.buildingsdata.eu/ EU 2016	The Data Hub introduces a data search engine that allows for cross-country comparisons, generation of customised country profiles.
	U-values for wall, roof, floor, windows for different building types per country.
ENTRANZE database - web tool http://www.entranze.enerdata.eu/ EU 2016	Structure of buildings and related energy systems in EU-27 (+Cro & Serb); some trends.
	Weighted average U-values per country and per building element (floor, wall, ceiling, window).
EPISCOPE project database tool http://episcope.eu/monitoring/episcope-tool/ EU 2015	It is an interactive and user-friendly website that provides a comprehensive overview of all project results for 20 European countries.
	Building insulation improvements level per building elements and per countries (not available for all EU countries) [Details on used technologies available in pdf reports].

6.1.3 Internal gains

Internal heat gains are combination of sensible and latent heat emitted within an internal space from any source resulting in an increase in the temperature and humidity of the space. Benchmark values for internal heat gains are based on either surveys of measured internal heat gains from a number of buildings of particular types and usage, or empirical values found appropriate from experience, survey and considered good practice in the industry.

In buildings heat gains from occupants, lighting, electrical equipment and the like can have a considerable effect on the energy balance of the building. Therefore it is important to have an appropriate model of these heat sources, which are called internal gains. Typically the time dependent behaviour is specified in fixed schedules. Internal heat may also be a function of other parameters, e.g., daylight responsive luminaire dimming.

Internal heat gains are separated into radiant and convective gains. Convective gains are considered as an instantaneous air load, longwave radiant gains are apportioned between the internal surfaces. Because of the construction capacity, radiant gains contribute to the air load with some time lag.

Table 14: Internal gains-related input data

Internal gains (People, Lights, Electric Equipment, Gas Equipment, Steam Equipment, Hot Water Equipment)		
Exchange Information	Design level	kW
	Operation	0-1
	Fraction latent	[0,1]
	Fraction radiant	[0,1]
	Fraction lost	[0,1]
Availability of the Information	Reference data: • ISO 15251:2007 • ISO 12464:2002 • ISO 13790:2009 • ISO 13779:2008 Measured data • In Building sensor measurements IFC, RDF	
Information Type	Simulation data	
Scale	Building	
Variability of the information	Static, Hourly	
Data Formats	STEP, JSON, RDF	
Tools	OptEEmAL GUI, BIM Server, SPARQL endpoint	
Required Precision	Medium	

BIM is able to store the source of heat gains data.

Examples of generic heat gains from equipment and by building use are illustrated in Tables 6-10 and 6-11.

Table 15: Equipment internal gains

Electric and electronic equipment	**Typical Heat emission (W)**
Desktop computer	150
Computer printer	100
Visual display unit	200
Photocopier	800
Hair dryer	800
Oven	2500

Table 16: Buildings annual internal gain values

Annual internal gains (kWh/(m² living area))			
		Occupancy	Equipment
Residential	Single family building	14.9	12.6
	Semi-detached house		
	Multifamily building		
Service	Office building	18.5	43
	Hotel & apartment	13.8	14.1
	School & University	40.9	16.5
	Museum, library, theater	23.2	7.8
	Hospital	71.3	10.1

6.1.4 HVAC equipment

Since the HVAC equipment consume a very significant part of the total energy consumption of a district, in the developed world, it is important to get its layout, hierarchy, zones, specifications, efficiency, sizing, etc., as accurate as possible. Building Automation / Management Systems (BAS / BMS) should be compliant with international standards BACnet (ASHRAE/ANSI/ISO 16484-5 protocol) and have industry-wide acceptance for design, installation, commissioning, monitoring, and refurbishment. Therefore, it is required that the IPD methodology ensures that BAS/BMS design data is translated / transformed / transported to the BIM and DDM during the course of a refurbishment problem. Equipment related requirements are shown in Table 6-15.

Table 17: Requirements of HVAC equipment

HVAC equipment related required data	
Exchange Information	Design metadata, configurations and parameters from BMS/BAS
Availability of the Information	HVAC Designers
Actors	Owner, Prime Designer
Information Type	Configuration and specification parameters; mechanical engineering information; sizing, capacity, tolerance, etc.
Scale	Plant/Building/Floor/Room level
Variability of the information	Static
Data Formats	Connected variables; JSON name-value pairs; semantic tags; configuration XML
Tools	Interfaces / convertors / drivers between BACnet (or another international standard) compliant BAS/BMS .xml to IFC
Required Precision	At least building-level HVAC equipment

6.1.5 HVAC controls/set points

Accurate estimation of the energy used in a district to meet its heating and cooling demands is necessary for (1) generating realistic refurbishment scenarios and (2) selecting and tuning the appropriate ECM optimization parameters. Estimates are typically made based on the heating and cooling demand from the terminal units (e.g., VAV, FCU) in the HVAC zones and from the central equipment (e.g., HP, Chillers, AHU). These are typically based on daily averages over all months in a year based on data obtained from BAS/BMS systems. In residential units or buildings with no central HVAC management system, such information can be error-prone estimates from the energy meters or smart meters or owner's estimates. Nowadays smart-devices can estimate occupancy and operational hours to estimate energy usage. Some residential owners subscribe to transmit their thermostat information to cloud-based computing devices to estimate energy usage, e.g., Google Nest. Table 18 depicts requirements for HVAC controls.

Table 18: HVAC controls requirements

HVAC controls related required data	
Exchange Information	Design estimates or simulation or historic averages from Building Management/Automation System (BMS/BAS), Cloud-based energy estimates
Availability of the Information	HVAC Designers, Building Owners
Actors	Owner, Prime Designer
Information Type	Hourly values from thermal or HVAC zones
Scale	Building/Floor/Room level
Variability of the information	Time-series (sampled across hour of the day, day of the week, month of the year); seasonal variations should be available
Data Formats	Connected variables; name-value pairs; time-series
Tools	BAS, BMS, ICS
Required Precision	At least hourly values for a week at building-level

6.1.6 Renewables, local generation and storage

Renewable energy production does not have an influence on the building or district energy consumption. However, it could significantly influence the building/district need from the grid and thus have a significant influence on the building/district energy mix and associated Greenhouse Gases (GHG) emissions.

The evaluation of renewable energy generation is influenced by production system characteristics (technology, orientation and inclination for solar systems) but also by contextual data (local sun irradiation, shadows, etc.). Local storage is only influenced by storage system characteristics.

If a Building Energy Management System (BEMS) from industry vendors (e.g., Trend, Carrier, Schneider, Siemens, Honeywell) is present in a building equipped with renewables systems, production and storage data can be retrieved from this system on a daily basis over a year. In buildings where no BEMS system is available or where it is planned to install renewable production systems, local generation and storage will be estimated through simulations based on renewable systems characteristics (contained in the BIM or CityGML model depending on the scale).

Table 19: Renewables, local generation and storage related required input data

Renewables, local generation and storage related required data	
Exchange Information	Design estimates or historic averages from Building Energy Management System (BEMS), Cloud-based energy estimates
Availability of the Information	Building Owners, Prime Designer
Actors	Owner, Prime Designer
Information Type	Energy source and storage specifications, transmission voltages, performance, power-rating, etc.
Scale	Building/District
Variability of the information	Static, Monthly and/or Annual
Data Formats	JSON name-value pairs; configuration XML
Tools	OptEEmAL GUI, BIM Server, CityGML server
Required Precision	High

6.2 CityGML-related data

Information at district level will be provided by CityGML models needed to generate the District Data Model. A LOD 2 will be required in the CityGML models in order to meet the requirements for simplified methods in where all the information of buildings in a project is provided through a CityGML model. The information of CityGML models will be introduced in the platform by the owner and the primer designer. In cases where the owner does not have a CityGML model of their district, shapes files from the cadastre (which are usually available) may be used to generate the CityGML.

Table 20: CityGML related required data

CityGML related required data	
Exchange Information	District Data
Availability of the Information	Generated by External tools Open Data
Actors	Owner, prime designer
Information Type	Geometric Basic Semantics
Scale	District Building
Variability of the information	Static
Data Formats	CityGML (File or Data Base)
Tools	GIS Tools (ArcGIS, QGIS, gvsig, etc.) CityGML generation Tools (FME, TECNALIA, etc.) Cadastre
Required Precision	Low (LoD 2 from CityGML)

6.3 Contextual data

Contextual data refer to district data such as location and weather data coming from monitoring stations and historic archives, monitored and metered data useful for computation of energy and utility consumptions, and socio-economic data which are necessary to evaluate and optimise the refurbishment design according to the district performance indicators. Such data can be provided to the platform through geo-clustering/data-harvesting techniques and also provided by IPD users, in particular, by the owners.

6.3.1 Location and weather data

Location and weather data refer to parameters characterizing the building's prevailing conditions, consisting of the air surrounding the building and the ground space it is founded on information. They significantly affect the behaviour of the building and are one of the major disturbances to Building Energy Performance (BEP) simulation.

The IFC and CityGML schemas are able to store the geographical coordinates of the building location and its orientation. The orientation is normally transmitted together with the geometry data of building components. However, they do not contain any actual information on weather conditions, such as temperature, solar radiation, wind direction, etc. This climate data and weather conditions are derived from geographic coordinates read from external data sources.

A plethora of weather data for BEP simulation exist, ranging from locally recorded weather data to preselected “Actual” or “Typical” years (reference data). Concerning the reference data, several organizations have developed typical weather data sets. Examples of these typical data include TMY2. Another BEP simulation related, frequently used, weather data repository is METEONORM. METEONORM is a database of ground stations measurements made by a combination of several databases from different parts of the world. METEONORM extrapolates hourly data from statistical data for a location. Where statistical data are not available, METEONORM interpolates from other nearby sites. The traditional simulated energy performance, using reference data, represents the building performance for a typical year but not necessarily the average or typical long-term performance as buildings with different energy systems and designs respond differently to weather changes. Aiming at higher BEP simulation results accuracy, instead of reference data, measured data could be used.

In BEP simulation engines, weather data are provided as input through a properly formatted weather file. The weather file creation process can be defined as a dedicated service; every time a new weather file is required, the service is invoked, using as arguments the starting date, the end date and the time-stepping for the weather file (hourly timestep is commonly used). Subsequently, the service gathers past weather data and weather predictions (if necessary) from the appropriate databases.

Requirements for location and weather input data are provided in the following tables:

Table 21: Location-related input data

Location data		
Exchange Information	Latitude	deg
	Longitude	deg
	Time zone	hr
	Elevation	m
Availability of the Information	• IFC • CityGML • User manual input	
Information Type	Location data	
Scale	City	
Variability of the information	Static	
Data Formats	TXT, CSV, EPW, TMY2, CLI	
Tools	Platform APIs Client Libraries, Platform GUI	
Required Precision	High	

Table 22: Weather-related input data

Weather data		
Exchange Information	Dry Bulb Temperature	ºC
	Relative Humidity	%
	Barometric Pressure	Pa
	Wind Speed	m/s
	Wind Direction	deg
	Global Horizontal Solar Radiation	W/m^2
	Cloud Cover	tens
Availability of the Information	Reference data (typical meteorological year data): • Typical Meteorological Year data (TMY2) • METEONORM • EnergyPlus website (https://energyplus.net/weather) Measured data: • Weather Stations • Weather Services	
Information Type	Climatic data	
Scale	City	
Variability of the information	Hourly	
Data Formats	TXT, CSV, EPW, TMY2, CLI	
Tools	Platform APIs Client Libraries	
Required Precision	High	

6.3.2 Monitored or metered data

Generation of Building Energy Performance (BEP) simulation models require significant effort for set-up, stemming from the difficulty to collect and appropriately define the input data for accurate BEP simulation modelling. Given the large number of parameters involved, calibrating a detailed energy model is a highly recommended process.

In [9] the state of the art of calibration methodologies in the domain of building energy performance assessment is presented. For each calibration methodology, models are calibrated based on measured monthly or hourly data at different levels of detail. This section does not aim at presenting those methodologies, but listing the most frequently used monitored or metered data in a plethora of those calibration methodologies' implementations.

Table 23: Monitored or metered data

Monitored or metered data		
Exchange Information	Energy Consumption data (End Uses)	
	Heating	kWh
	Cooling	kWh
	Interior Lighting	kWh
	Exterior Lighting	kWh
	Interior Equipment	kWh
	Exterior Equipment	kWh
	Fans	kWh
	Pumps	kWh
	Heat Rejection	kWh
	Humidification	kWh
	Heat Recovery	kWh
	Water Systems	kWh
	Refrigeration	kWh
	Generators	kWh
	Energy Generation data	
	Fuel-Fired Power Generation	kWh
	High Temperature Geothermal Electric Energy Generation	kWh
	Photovoltaic Electric Energy Generation	kWh
	Wind Turbine Electric Energy Generation	kWh
	Thermal Zone level data	
	Zone Air Temperature	ºC
	Zone Radiant Temperature	ºC
	Zone Air Relative Humidity	%
	Illuminance at a reference point	lux
	CO2 Emissions Carbon Equivalent Mass	kg
Availability of the Information	In-Building Sensors Measurements	
Information Type	Measured data	

Scale	Building, Thermal Zone
Variability of the information	Hourly
Data Formats	TXT, CSV
Tools	Platform GUI……..
Required Precision	High

6.3.3 Socio-economic data

Socio-economic data give information about a population and its characteristics. As the link between energy consumption and socio-economic characteristics of a given population appears more and more important [10], this data represents an important feature of the district to be studied and should be integrated in the assessments to be performed in the OptEEmAL platform. Of course, economic criteria are also critical criteria for the selection of optimised retrofitting scenarios considering the financial limits for investment all retrofitting projects are facing.

The main challenges regarding the socio-economic data are data availability and data granularity. Indeed, accurate socio-economic data at the district scale are mostly scarce. It is envisaged that some socio-economic data such as energy costs for instance could be provided by the building owner. However, considering the confidentiality of the information, it is often difficult to collect other socio-economic data such as the average income level per inhabitant for instance. For such data, the use of European/national statistical databases is envisaged.

Table 24: Requirements for socio-economic data

Socio-economic data		
Exchange Information	Income level	€/month/inhabitant
	Energy costs	€/kWh or €/MJ
Availability of the Information	Measured data (from building owner mainly) • Energy bills Reference data (European, national statistical institutes): • EUROSTAT • BPIE Data Hub, http://www.buildingsdata.eu/ • Italy: Istat, www.istat.it • Sweden: The Swedish National Board of Housing, Building and Planning, www.boverket.se • Spain: INE, www.ine.es • UK: Construction Market Intelligence (CMI) publications, https://www.gov.uk/government/collections/building-materials-and-components-monthly-statistics-2012	
Information Type	Socio-economic data	
Scale	City, Region, Country, Europe	
Variability of the	Yearly	

information	
Data Formats	TXT, CSV, XLS
Tools	Platform APIs Client Libraries
Required Precision	Medium

6.4 Configuration data

Configuration data refer to project-specific data such as users and their objectives, barriers, etc., can be provided to the platform through geo-clustering/data-harvesting techniques and also provided by IPD users, in particular, by the owners.

6.4.1 User set data

User data is needed by the platform to follow the workflow and complete the objectives. It is needed to identify the users (full name, login name, email, roles that the user can play, projects in which is involved) and their roles.

Table 25: Requirements for User data

User data	
Exchange Information	Identification data
Availability of the Information	User manual input
Actors	Every user in the platform
Information Type	Personal; name, log name, email…
Scale	Not applicable
Variability of the information	Very low. The changes will be made on user demand
Data Formats	TEXT, references in data base
Tools	Not applicable
Required Precision	Each datum has to be exactly identical to the one introduced by the user for the whole design process

The following data is also needed to create an IPD group:

- Roles of each user
- Type of group set selected
- Contract to follow after the project
- Possible secondary actors included as users of the platform.

Table 26: User data

User set data	
Exchange Information	Identification data
Group Set Selected	Select one from Group: A, B, C, D, E, F, G, H.
Owner	User that is going to act this role
Prime Designer	User that is going to act this role
Prime Constructor	User that is going to act this role
Integrated project coordinator	User that is going to act this role
Secondary actors	Actors that will be involved in the project in the future
Variability of the information	Very low. The changes will be made on user demand
Data Formats	TEXT, references in data base

6.4.2 User objectives

By applying different Energy Conservation Measure strategies, the main objective of an Energy refurbishment is based on improving the energy performance of the buildings and districts. In this manner, energy refurbishment project objectives are directly and indirectly related to different pillars of the concept of sustainability.

According to various aspects such as the type of assessed district, barriers, the results of the diagnosis or the concerns of the involved stakeholders, the objectives of the end user may vary significantly:

- **Energy objectives**: reduction of the energy demand, reduction of the final energy consumption, increase the degree of energetic self-supply, reduce the total energy use per capita, increase the energy demand converted by renewable sources, etc.
- **Comfort objectives**: increase the local thermal comfort, increase the acoustic comfort…
- **Environmental objectives**: reduce the environmental impact (Global Warming potential, primary energy, etc.), select the ECMs with the lowest energy payback, etc.
- **Economic objectives**: reduce the operational energy cost, optimize the life cycle cost, and select the ECM with the lowest value of return of investment.
- **Social objective**: reduce the energy poverty of the assessed district

The fundamental requirement regarding the user-objectives is to adhere to well-established objectives of the European Union, international standards and codes set by the industries and professional associations, sustainability and developmental goals of European and international organizations as listed below:

Table 27: List of user objectives by category

Environmental Objectives	
Reduced air pollution	By reducing the need for energy production from fossil fuels, there is a reduction in the amount of pollutants such as SO2, NOx and particulates that are damaging to health, to buildings and the

	environment
Reduce emissions	Europe's roadmap towards a low carbon economy 2050 [3], sets a target for reducing emissions in the European Union's buildings by between 88 and 91% by 2050
Energy Objectives	
Energy security	The reduction of the energy demand could increase the European energy security [4]
Reduced peak loads	Energy demand reduction measures save a disproportionate amount at times of high demand
Social Objectives	
Reduced fuel poverty	Improving the energy efficiency of homes could be vital to achieving affordable warmth for families on low incomes. Between 50 million and 125 million people in Europe (10-25% of the total EU population) are estimated to be fuel poor [5]
Health	Health benefits from warmer homes with less condensation and improved indoor air quality
Increased comfort and productivity	Improvement in terms of increased comfort. It is well established that a better working environment leads to increased productivity
Architecture-society relationship	The demolition of these urban areas by substituting new ones, influence directly in the social life of a high percentage of occupants. Therefore, refurbishment projects benefit directly in maintaining air quality and occupant architectural-social relationship
Economic Objectives	
Energy cost saving	Renovation potential for net energy costs savings as much as €1300 billion (2012 value), arising to end users [2]
Economic stimulus	The employment generated could be on average as much as 1.1 million net additional jobs throughout the period to 2050 [6]
Impact on Gross Domestic Product.	Energy Efficiency Directive impact assessment identified that achieving the targeted savings would result in an increase in the EU's GDP of €33.8 bn in 2020 [7]
Property values	Buildings with high energy performance could be more valuable than their less efficient counterparts
R&D	By creating the drive towards ever more efficient ways to reduce energy consumption in buildings, a major programme of building renovation will spur research & development
Impact on public finances	According to a Copenhagen Economics report [8] (*Copenhagen Economic, 2012*), investment in building retrofits will have a positive impact on public budgets, equivalent to 0.5-1.0% of GDP.
Energy import bill	With virtually all Member States being reliant on energy imports to satisfy demand the energy savings achieved through building renovation will have a positive impact on a nation's balance of payments.

6.4.3 User identified barriers

Restrictions will be set in the platform for the use of the measures included in the catalogue. These can be categorized as follows:

- **Technical barriers** related to technical issues. These are required to prevent selection of measures from the catalogue that are not compatible.
- **Normative barriers** imposed by the administration of the area in which the project is located. Its nature will be heterogeneous since the norms are expected to be different from one area to another.
- **Social barriers** related to customs that the platform should respect when using certain measures.
- **Economic barriers** are some of the most important barriers for any retrofitting work as it relate the cost. In OptEEmAL platform, the retrofitting works will be motivated by the desire to reduce the energy consumption while having a reasonable payback period.

These four types of barriers must be respected by the platform. Other barriers can be implemented with certain tolerance. Among these are:

- Time and knowledge barriers
- Resistance to change
- Organizational barriers
- Resistance to change and adoption of new technologies
- Lack of expertise in fields such as BIM or IFC
- Lack of expertise in web platforms

7 Input data quality and access control requirements

The information provided by the users of the OptEEmAL platform should be checked to ensure that it is compliant with the platform requirements in particular with those of the ontology-based District Data Model (DDM). This becomes more important since the information of a building and a city can be generated in many ways depending on the authoring CAD tool used. These tools facilitate the conversion from native models (e.g., Revit, ArchiCAD) to a standard data models such as IFC or CityGML. In this conversion, export data options must be defined appropriately to obtain the desired result. In the case of IFC, this includes proper definition of IFC Property Sets for mapping them to already standardized groups of properties. In this manner, these properties can be automatically interpreted by software tools, which are able to import IFC files such as energy simulation engines. If this is not taken into account by the modellers or if the requirements of the platform to process the models are not defined, then the resulting BIM model may not be processed by the platform. To assist users to meet these requirements, manuals and guides that explain the import requirements should be provided on the platform.

There are systems and tools for checking the input models such as the BIM Server [11] developed by TNO which provides methods for developing rules to check the IFC models such as the mvdChecker [12]. These rules can be set to check if the models have at least one IFCBuilding, naming conventions according to a particular normative, presence of specific properties in an IFC element, and relationships between elements such as if all elements contain a relationship with either a space or a building story. Another example is Model Solibri Checker [13], which enables users to load IFC files that can be checked according to rules defined by users themselves. As an alternative to existing solutions, an ad-hoc checking method can be developed within OptEEmAL. The checking rules to be implemented should follow the District Data Model requirements defined in Task 2.1.

City models, such as CityGML, enable to have different representations of the same object. For example, a building can be modelled as a solid or as a set of surfaces. This leads to the implementation of validation procedures that apply rules to check the consistency of the model at the geometric, topological and semantic levels. The first step is to ensure that the model is compliant with the schema definition of CityGML. However, a building model can be syntactically correct and still contain geometric errors. There are different recommendations based on best-practices to model cities in 3D such as those proposed by the Special Interest Group 3D of the Geo Data Infrastructure (SIG-3D—GDI) [14]. The geometrical correctness can be validated with tools such as QS-City 3D [15]. Since CityGML provides a semantic model to add further information to a spatial object, it is necessary to validate its geometry. In this line, Wagner et al. [16] proposed a semantic validation method to check the consistency of the geometry and the semantic model.

The selection of rules to check the input models is based on the use of the models. In the case of the OptEEmAL platform the final use of the model is to calculate the District Performance Indicators that enable users to make decisions. Two kinds of validation will be needed for this purpose:

- Validation of the geometry: Checking for geometrical inconsistencies such as external walls crossed and missing elements (e.g., ground plane surfaces).
- Completeness of information: Checking if the input data meet the requirements of the platform (e.g., Model view definition for IFC models) including its components such as DDM, scenario optimizer, and models' visualization.

Moreover, the platform has to guarantee a proper access control to its processes. The access control will be implemented according to the users' profiles, in particular to the role they will play in the IPD-based processes. Since the platform will be compliant with the IPD approach, the members of the IPD group will need access to all information provided by the users or generated within the platform.

8 Conclusions

We specified the input data required to build and compare retrofit scenarios based on the knowledge and expertise of the project partners, requirements from the OptEEmAL case studies and demo-sites, and through review of relevant literature. The data identification exercise was done assuring that the data complies with the platform requirements. Four types of input data were identified to enable the platform to support the design objectives. These are BIM models, CityGML models, contextual data, and configuration data.

A link was established, following the IPD process, connecting the input data to the platform users responsible for providing it. This was reinforced by the platform general workflow highlighting input data required at each step of the design.

The results of this task are the foundation for the development of the diagnosis module that will be developed in Task 1.5. Specified input data will be used by the platform to build the baseline model of the district. The model output will enable the evaluation of DPIs for the current state of the district. The outcomes of this task, through the baseline model, will also enable the development of the platform module responsible for the formulation of retrofit scenarios. A set of relevant ECMs will be used to formulate the scenarios and this brings up and important issue that the requirements specified in this deliverable need to be in agreement with those of the ECM catalogue (D3.1) and those of the DDM (D2.1).

9 References

[01] Integrated Project Delivery: A Guide, American Institute of Architects, AIA California Council, Report, 2014

[02] Europe's building under the microscope. A country-by- country review of the energy performance of buildings, Buildings Performance Institute Europe

[03] A Roadmap for moving to a competitive low carbon economy in 2050, COM (2011) 112 final, European Commission

[04] Energy 2020: A strategy for competitive, sustainable and secure energy, COM (2010) 639 final, European Commission

[05] European Fuel Poverty and Energy. Tackling Fuel Poverty in Europe

[06] Energy Efficiency in Buildings: Transforming the Market, World Business Council for Sustainable Development

[07] European Parliament and the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

[08] Multiple benefits of investing in energy efficient renovation of buildings, commissioned by Renovate Europe, Copenhagen Economics report, Copenhagen Economic, 2012

[09] E. Fabrizio and V. Monetti, Methodologies and Advancements in the Calibration of Building, Energies, pp. 2548-2574, 2015

[10] S. Schmidt and H. Weigt, A Review on energy consumption from a socio-economic perspective: Reduction through energy efficiency and beyond, 2013. Retrieved from https://fonew.unibas.ch/fileadmin/fonew/redaktion/Paper/FoNEW_2013_02.pdf

[11] BIMserver, 2016. Building information model server, retrieved February, 2016. www.bimserver.org

[12] Chi Zhang, Jakob Beetz, Matthias Weisen (2015). Interoperable validation for IFC building models using open standards. Journal of Information Technology in Construction (ITcon), Special Issue: ECPPM 2014, Vol. 20, pg. 24-39, http://www.itcon.org/2015/2

[13] Solibri, 2016. Solibri model checker, retrieved February, 2016. http://www.solibri.com/products/solibri-model-checker/

[14] SIG 3D, 2016. Special Interest Group 3D, retrieved February 2016. http://www.geoportal.de/EN/GDI-DE/Research-Groups/SIG-3D/sig-3d.html?lang=en

[15] QS-CITY 3D 2016. Quality assurance for CityGML models, retrieved February 2016. https://www.uni-koblenz-landau.de/de/koblenz/fb4/uebergreifend/er/stormodelling/tools/qscity

[16] Wagner, D., Wewetzer, M., Bogdahn, J., Alam, N., Pries, M., Coors, V. 2013. Geometric-semantical consistency validation of CityGML models. In Progress and new trends in 3D geoinformation sciences, pp. 171-192.

10 Appendix

10.1 IPD Group Sets

10.1.1 Secondary actors

Secondary actors are needed to comply with the objectives of the projects but their responsibility is not so important. In an IPD approach the inclusion of these actors in the different phases will improve the later result because of the interaction of common interests and responsibilities between all the members in all phases. In the case of the OptEEmAL tool the secondary actor will not be placed in the design phase proposed in the project, this phase will include only the interactions between the principal actors and the platform.

In the Outputs of the platform there will be an IPD Guide and some stipulated IPD Contracts in order to integrate, later in the next phases, all the possible interactions and responsibilities of the different actors including the secondary actor, because these ones are important to develop the entire project.

10.1.2 Classification

10.1.2.1 Users Set B

OW – PD – IPC (PC)

In this set one of the principal or main actors that will be later a platform user is missing. In this case the Prime Constructor is not present. To replace this actor there can be different options:

- The Owner acts also as IPC and can assume the responsibilities and tasks of the Prime Constructor to comply with all the objectives.
- An extern IPC that coordinates the project can and wants to assume the responsibilities and tasks of the Prime Constructor to comply with all the objectives because they do not want to give this role to other entity.
- An external IPC that coordinates the project can and wants to assume the responsibilities and tasks of the Owner to comply with all the objectives because they do not want to give this role to other entity.

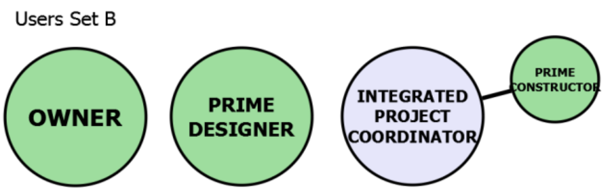


Figure 9: User set B

10.1.2.2 Users Set C

OW – PC – IPC (PD)

In this set one of the principal or main actors that will be later a platform user is missing. In this case the Prime Designer is not present. To replace this actor there can be different options:

- The Owner acts also as IPC and can assume the responsibilities and tasks of the Prime Designer to comply with all the objectives.
- The Prime Constructor acts also as IPC and can assume the responsibilities and tasks of the Prime Designer to comply with all the objectives.

- An external IPC that coordinates the project can and wants to assume the responsibilities and tasks of the Prime Designer to comply with all the objectives because they do not want to give this role to other entity.

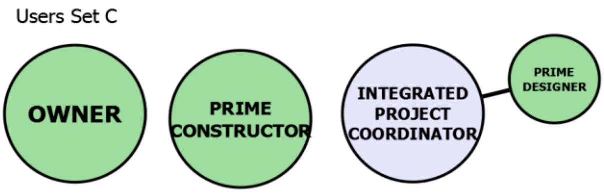


Figure 10: User Set C

10.1.2.3 Users Set D

PD – PC – IPC (OW)

In this set one of the principal or main actors that will be later a platform user is also missing. In this case the Owner is not present. This can happen when there is another agency o external company that promotes the project. To replace this actor there can be different options:

- The Prime Designer acts also as IPC and can assume the responsibilities and tasks of the Prime Designer to comply with all the objectives.
- The Prime Constructor acts also as IPC and can assume the responsibilities and tasks of the Prime Designer to comply with all the objectives.
- An external IPC that coordinates the project can and want to assume the responsibilities and tasks of the Owner to comply with all the objectives because they do not want to give this role to other entity.

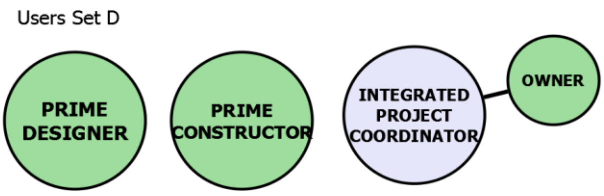


Figure 11: Users Set D

10.1.2.4 Users Set E

OW – IPC (PD-PC)

In this set two of the principal or main actors that will be later platform users are missing. In this case the Prime Designer and the Prime Constructor are not present. This can happen when there is another agency o external company that promotes the project. To replace these actors there are different options:

- The Owner acts also as IPC and can assume the responsibilities and tasks of the Prime Designer and the Prime Constructor to comply with all the objectives. In this case the owner in normally a big construction company that promotes the project and has a design department and can make the works of construction.
- An external company acts as IPC, it can coordinate the project but has to assume the responsibilities and tasks of the Prime Designer and Prime Constructor to comply with all the objectives. Normally this company is a technical one or it has to contract other entities to make these jobs under a high responsibility.

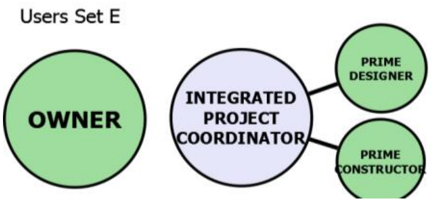


Figure 12: Users Set E

10.1.2.5 Users Set F

PD – IPC (OW-PC)

In this set **two** of the principal or main actors that will be later platform users are missing. In this case the Owner and the Prime Constructor are not present. The situation can happen when there is another external company, in this case it will be normally a construction company that promotes and also constructs the project. To replace these actors there are different options:

- The Prime Designer acts also as IPC and can assume the responsibilities and tasks of the Owner and the Prime Constructor to comply with all the objectives. In this case the designer should have a construction company in charge and must take the responsibilities as owner.
- An external company acts as IPC, it can coordinate the project and has to assume the responsibilities and tasks of the Owner and Prime Constructor to comply with all the objectives. Normally this company is a construction one.

Figure 13: Users Set F

10.1.2.6 Users Set G

PC – IPC (OW-PD)

In this set **two** of the principal or main actors that will be later platform users are missing. In this case the Owner and the Prime Constructor are not present. The situation can happen when there is another external company, in this case it will be normally a construction company, which promotes and also constructs the project. To replace these actors there are different options:

- The Prime Designer acts also as IPC and can assume the responsibilities and tasks of the Owner and the Prime Constructor to comply with all the objectives. In this case the designer should have a construction company in charge and must take the responsibilities as owner.
- An external company acts as IPC, it has to coordinate the project and has to assume the responsibilities and tasks of the Owner and Prime Constructor to comply with all the objectives. Normally this company is a construction one.

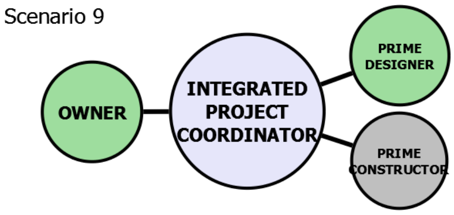


Figure 14: Users Set G

10.1.2.7 Users Set H

PC – IPC (OW-PD)

In this set there is one coordinator that has the role of IPC, it has the responsibilities and must comply with all the tasks. It should be a company with different departments, to assume the different roles. It can also be possible to contract other smaller companies to make some specific parts of the project. These smaller parts will have another type of responsibilities. In this project each department assumes big responsibilities.

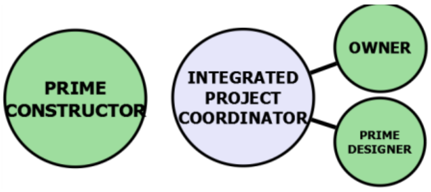


Figure 15: Users Set H