OptEEmAL

OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

Optimised Energy Efficient Design Platform for Refurbishment at District Level

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D6.2: Report on platform prototype demonstration in relevant environment

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Table of Content

List of tables

List of figures

Abbreviations and acronyms

Acronym	Description
AEC	Architecture, Engineering and Construction
BIM	Building Information Model
DDM	District Data Model
DEM	Data Exportation Module
DIM	Data Insertion Module
DMM	District Management Module
DPI	District Performance Indicator
ECM	Energy Conservation Measure
EPC	Energy Performance Certificate
ETL	Extract-Transform-Load
GIS	Geographic Information System
ESB	Enterprise Service Bus
GUI	Graphical User Interfaces
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
NEST	Neighbourhood Evaluation for Sustainable Territories
JSON	JavaScript Object Notation
OM	Optimisation Module
OptEEmAL	Optimised Energy Efficient Design Platform for Refurbishment at District Level.
OWL	Ontology Web Language
RDB	Relational DataBase
RDF	Resource Description Framework
RDFS	Resource Description Framework Scheme
SM	Simulation Module
TDB	Triple DataBase
XML	eXtensible Mark-up Language

Executive summary

The document describes the validation activities of the OptEEmAL platform at TRL6 "Platform prototype demonstration in relevant environment" and the associated results.

The methodology implemented has consisted in applying the platform on already performed district retrofitting projects and comparing the obtained results with the results available in these projects. Also, some general information regarding the time needed to run the OptEEmAL platform are provided (and further detailed in D5.5). Finally, the potential impacts of the platform were evaluated and are presented at the end of the document. The main objectives of this deliverable are:

- To demonstrate the platform at TRL6 showing that it can be used on more complex (real) projects in comparison to the previous validation activities performed at TRL5.
- To validate the results provided by the platform both in terms of calculations and recommendations.

Regarding the first point, the performed activities showed that the OptEEmAL platform can be successfully used on real district retrofitting projects. Three case studies were used to validate the platform representing different "district profiles":

- *Cuatro de Marzo* district, Valladolid, Spain: This district includes 5 residential buildings with 2 of them that can be considered as complex buildings (Turina Tower). No district energy systems are considered in this district.
- *Mogel* district, Eibar, Spain: This district includes 15 residential buildings with quite simple geometries and characteristics. It has been used to test the computation capabilities of the platform for a district with numerous buildings. No district energy systems are considered in this district.
- *Polhem* district, Lund, Sweden: This district includes 6 buildings (1 library and 5 high school buildings). It has been used to test the platform on non-residential buildings with quite complex geometries and to investigate the district scale (a district heating system is already in place in this district).

Regarding the second points, the three abovementioned district were used to investigate different aspects:

- The *Cuatro de Marzo* district has been used to validate the overall DPI calculation procedures and to check that the ECMs recommended by the platform are relevant. The conclusion of these activities is that the DPI calculation procedures are correct and the platform provides relevant information as an output.
- The *Mogel* district has been used to validate the energy demand calculations and also to check the recommended ECMs. A focus was made on energy demand calculations considering their importance in the platform (key indicator, basis for most other DPI calculations). These activities showed that the energy demand and final energy consumption calculations of the platform are correct but are highly sensible to certain parameters which have to be carefully inserted into the platform (mainly through the IFC files used as input data). Overall, the recommended ECMs are also in line with the ones implemented in reality.
- The *Polhem* district has been used to investigate the district scale. Results of these activities show that still some improvements are needed to properly account for this scale in the platform but that it is not critical for the platform. It has to be highlighted that, as this case was initially considered as a demo site (TRL7 validation), the results associated with the validation activities are described in D6.4.

Finally, this deliverable presents the potential impacts of the OptEEmAL platform which are overall in line with what was expected at the beginning of the project.

Summary of actions month 44 (April 2019)

This deliverable D6.2 ("Report on platform prototype demonstration in relevant environment") is a reviewed and improved version of the deliverable D6.2 delivered in month 42 (February 2019). This section of the document summarizes the actions taken and changes introduced in response to the comments and recommendations provided by the Project Officer and reviewer to the EC during the final review meeting.

Action 1: Make the deliverable more clear, understandable and consistent.

[This deliverable needs to be clear, understandable and consistent. At this moment, it is not. It should be clear what is the accuracy of the tool and what aspect still need to be improved. The goal is to get the reliable tool. Be clear which values are before and which after renovation (always put in the table titles).]

A general improvement of D6.2 has been done to make results and comparison among existing data and data provided by OptEEmAL more clear, understandable and consistent (see following actions for more details). Further developments that could improve the behavior of the tool have been also presented in section 5.3.2.8.

On the other hand, table titles have been modified to show clearly the values of the district behavior before and after renovation.

Action 2: Analysis of existing data for *Cuatro de Marzo* district.

[P.19 (chapter 2.14): How you can compare the data before the renovation modelled with DesignBuilder and after renovation measured during monitoring? The heating demand after renovation is higher than before renovation, how this is possible? The comments under table 4 need to be clarified - it is not clear why the data before and after renovation are compared. The same for table 5. Normally it should be opposite that after renovation building reduces energy consumption.]

The whole section for Cuatro de Marzo has been reformulated in order to better show the comparison of real data (from the implemented project) with the results obtained through the OptEEmAL platform. All tables leading to confusing values have been removed.

Action 3: Consistent and unified comparison between energy simulation and measured data.

[The comparison between energy simulations and measured data p.20 and p.23 should be unified. Use the same wording and be consistent.]

The wording has been modified and the title of the different figures have been also adjusted. The same wording is used: "Measured" data are related to values obtained from energy bills or sensors while "Simulated" data are related to values obtained from simulations/calculations.

Action 4: Update of U-values for windows in *Cuatro de Marzo* district.

[For Cuatro de Marzo: Check the values in table 19 for windows, it is very difficult to understand that real inserted windows had the U-value of 2,6 or 2,8 - in my opinion this is not possible, I have never see such high values for new windows, this has to be explained.]

The values inserted within the tables are those that have been provided by the project implemented in the district. It should be noticed that the original windows presented very low U-values and that the project in which the retrofitting was carried out needed to consider that some dwelling owners had already modified their windows before the integrated retrofitting of the neighbourhood. Therefore, the limiting U-values that were fixed for the new windows were those of the most recently changed windows which are clearly not the most efficient.

Action 5: Improvement of data analysis for *Cuatro de Marzo* district.

[For Cuatro de Marzo: Show the table such table 8 but add the values calculated with OptEEmAL platform for the baseline scenario (without renovation). Try give a table with the energy consumption

after renovation and calculated or measured ones (depending on what is available). Check why the windows were not proposed to be changed - this can be related with the very high U-values, not changing the windows causes large thermal bridge. Why the internal insulation option was allowed? - This is good only for buildings under cultural heritage protection, such solution is very inconvenient for the occupants, more difficult to perform and expensive. Consider repeating the simulation with different boundary conditions. At this moment, the solutions that are proposed by the platform are not clear and justified.]

All these comments have been tackled within the reformulated section for Cuatro de Marzo, where a table comparing the real project and the scenarios (both baseline and candidate retrofitting) proposed by OptEEmAL are shown. Also, a comparison of the ECMs proposed and the conclusions of the comparison are depicted.

Action 6: Clarification regarding who provide BES information of the districts and renovation options.

[Explain who was answering the Building Energy System questionnaire and what were the possible renovation options - this should be in agreement with the real possibilities of intervention on the building. Why the answers for Building Energy System questionnaire were not in agreement of the real renovations. P.71. Why the external roof insulation was eliminated in the platform for Eibar case study (in reality such approach was used).]

A sentence has been added at the beginning of each section related to the data introduced in the platform for the different case studies (sections 3.1, 3.2 and 3.3) in order to mention who has provided the information.

Also the answers to the ECM questionnaire have been added for all the case studies (this information was missing in the previous version).

Regarding the no consideration of external roof insulation for the Eibar case study, this is because this ECM was not implemented while performing the analysis. A new project has been set up and is considered for the results analysis provided in section 5.3.3. (Section 5.3.2 related to energy demand and final energy consumption analysis has not been changed as this section is related to baseline results and this error has only an influence on optimisation results).

Action 7: Clarification of Table 23.

[Table 23: Those values are before or after renovation? Be clear what data before the renovation and after are available]

Those values are before retrofitting. For all the tables in section 5.3.2, a “before retrofitting” mention has been added to the titles for clarity purposes.

Action 8: Clarification in Section 5.3.2.1.

[5.3.2.1: This baseline calculation are done before renovation?]

Yes. The following sentence has been added at the beginning of the section “It shall be reminded that in OptEEmAL, the baseline situation refers to the situation before retrofitting.”

Action 9: Clarification of Table 29.

[Table 29 are the results before the renovation? If yes, compare them also to the measured values]

Yes, these results are before retrofitting (the title of the table has been modified according to the previous comment). Also a comparison with measured values has been added (new section 5.3.2.7). However, as explained in this section, and due to available data, only the final electricity consumption is compared.

Action 10: Clarification in Section 5.3.1.

[5.3.1. It is written “see section 0 for more details” - section 0?]

This is an error. The correct reference is section 2.1.4. This has been modified.

<u>Action 11:</u> Improvement of data analysis for *Mogel* district.

[For Mogel, show in the table values measured / calculated with Zenn project/opteemal before the renovation and explain the deviations. If there are the deviations write what parts of the platform still need research.]

A new section (5.3.2.8) has been added to conclude this results analysis section. The final results obtained with OptEEmAL are compared both to simulated and measured data from ZenN. Also, a paragraph has been added to explain the remaining deviations.

<u>Action 12:</u> Clarification of Table 30.

[Table 30 p.88: It should be U glass, frame, window. What is the U of the panel?]

After verification with people involved in the Mogel district retrofitting project, U_{panel} is U_{glass}.

1 Introduction

1.1 Purpose and target group

This document presents the work performed in task 6.2 “TRL6 Platform prototype demonstration in relevant environment”. The purpose of this task is to demonstrate the platform prototype on existing case studies (already performed district energy retrofitting projects). This task constitutes the first testing of the platform on real districts and is thus of particular importance to validate that the platform:

- Fulfils its technical requirements: correct calculations, relevant calculation time, etc.
- Answers end-user needs: Provide relevant and useful information in a time efficient process (even though this part is mainly reported in T6.3).

This document starts with a description of the case studies used to demonstrate the platform prototype providing the context and the objectives of the different retrofitting projects. Then, a section describes how the data related to these case studies have been introduced into the platform, describing the process from raw data to “OptEEmAL input data”. This section is presented separately considering the importance of this work (from raw data to “OptEEmAL input data”) for the future exploitation of the platform. Then, results obtained from the platform are presented and discussed, when possible with other similar studies (e.g. energy simulations, environmental assessment…) already performed on the case studies. After this analysis, a performance assessment of the platform as a whole is presented (further detailed in D5.5), in order to validate that the platform has all the characteristics to ensure a proper use by future end-users. Finally, impacts of the platform (in its current status) are discussed in comparison to the ones mentioned in the proposal.

1.2 Contributions of partners

Table 1 presents the main contributions of partners to the work of this task and content of this document.

Table 1: Contribution of partners

Participant short name	Contributions
CAR	Initial ToC validation. Elaboration of input data and relation sections for the *Cuatro de Marzo* district. Elaboration of section 6.
TEC	Elaboration of input data (in particular CityGML files). Follow up of all validation activities in relation to TRL7 activities (Txomin Enea district). Follow up of the ECM catalogue in relation to the case studies.
NBK	Deliverable leader. Elaboration of (part of the) input data and related sections for the *Mogel* and *Polhem* districts. Elaboration of section 4, 5 and 7.
ACC	Initial ToC validation.
UTRC-I	Contribution to the BES questionnaire fulfilment for all case studies. Validation of the proper validation of energy systems.
FSS	Follow up of all validation activities in relation to TRL7 activities (Txomin Enea district)

DTTN	Follow up of all validation activities in relation to TRL7 activities (San Bartolomeo district)
LUND	Collection and elaboration of all input data (subcontractor for IFC models). Follow up of all validation activities in relation to TRL7 activities (*Polhem* district)

1.3 Relation to other activities in the project

This work aims at validating the whole OptEEmAL platform in its relevant environment. As a consequence, it is somehow related to all the project activities. However, it has to be mentioned that this work has stronger relationships with the work performed in WP1 (IPD methodology implementation, GUIs definition, etc.) and WP5 (platform development).

1.4 Glossary

These are the terms and definitions of some key concepts used in this document:

- **Case study:** In OptEEmAL, a case study is an already retrofitted district used for TRL6 validation (platform prototype demonstration in relevant environment).
- **Demo site:** In OptEEmAL, a demo site is a “to be retrofitted” district used for TRL7 validation (platform ready for demonstration in operational environment).

2 Description of the case studies

As part of the subtask 6.2.1, a deep analysis of the different and available case studies was done with the aim of choosing a representative set of districts covering the different needs for validating the platform at TRL6. Towards this objective, several criteria were taken into consideration:

- Data availability of the case study
- Building typologies
- Covering different climatic zones
- Covering different pre-OptEEmAL baseline energy systems
- Market perspective,
- Etc.

Finally, and also due to the complexities and issues appearing when jumping from a simple and controllable fictive case (Demo4) to the real world, three case studies were used for TRL6 validation (Figure 1). Two of them (*Cuatro de Marzo* and *Mogel* districts) are reported in this deliverable. The other one (*Polhem* district) is reported in D6.4 as it was initially planned as a demo site and as the retrofitting project is not started in this district (and thus no existing data about the retrofitting project is available).

It has to be noted that initially, 6 case studies were planned for the validation of the platform at TRL6. However, due to limited data availability, only 2 of them (plus the *Polhem* district initially considered as a demo site) were really used. The main explanation is that the elaboration of the IFC files is a very time consuming process which was not necessarily planned at the beginning of the project. Important efforts (see D6.3 for more details) have been dedicated by the project partners to elaborate the IFC files for the three finally investigated case studies and it was impossible to dedicate more time for the elaboration of the same files for other initially planned case studies.

Figure 1: Location of the case studies according to climatic zones

2.1 *Cuatro de Marzo* district, Valladolid (Spain)

Some parts of the *Cuatro de Marzo* district will be used to demonstrate the OptEEmAL platform prototype in relevant environment (TRL6). The main information for the *Cuatro de Marzo* district is described below.

2.1.1 General introduction

The *Cuatro de Marzo* district is a residential neighbourhood located in the city of Valladolid, Spain. All the buildings were built between 1955 and 1960. The *Cuatro de Marzo* district is a compact residential area of dwellings of medium-poor constructive quality in a progressive ageing and is demarcated between *Pisuerga* River and *Paseo Zorrilla* Avenue (Figure 2 and Figure 3).

Figure 2: *Cuatro de Marzo* district aerial view

Figure 3: South area of the *Cuatro de Marzo* district

2.1.2 Objectives of the retrofitting project

In this district, the retrofitting project has been set up in order to answer the following needs:

- Lift installation in buildings.
- Improvement of the building envelope (façades, roofs, etc.).
- Replace individual gas boiler for efficient condensation low-temperature boilers.
- Change of windows (doubling or substitution) and glazed enclosure of the balconies.

- Installation of hot water production system by means of solar thermal collectors with central storage system (almost 60% of the building DHW demand should be covered).
- Improvement of lighting efficiency in common areas. More efficient lighting (low consumption even LEDs bulbs) will replace old lighting systems and controlled by occupancy sensors.

2.1.3 Buildings under study

Of the total of 27 portals, 5 are objects of the present retrofitting project, affecting a total of 150 homes and 302 neighbours (Figure 4).

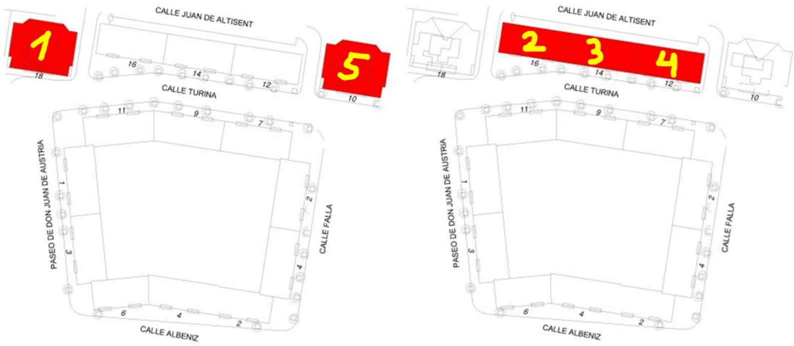


Figure 4: The 5 portals selected for the retrofitting project in the *Cuatro de Marzo* district

Table 2: Building's uses in the *Cuatro de Marzo* district, Valladolid

Building n°	Use
1	Residential
2	Residential
3	Residential
4	Residential
5	Residential

2.1.4 Existing information

For the *Cuatro de Marzo* district, existing information were taken from the R2CITIES project[1]. The R2CITIES project was funded from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 314473 (http://r2cities.eu/). Several partners involved in the OptEEmAL project were also involved in this project. The values obtained from this project for some of the DPIs used for the validation activities are shown in Table 3. These values have been obtained from both simulation and measurement in the district according to the procedures that were implemented within the R2CITIES project in order to calculate the indicators.

[1] R2Cities Consortium (2018), *D5.2: Report of the energy performance analysis*, Valladolid, Spain.

Table 3: Values from real project for Cuatro de Marzo

Indicator		Units	REFERENCE	
			Baseline	Retrofitting scenario (implemented)
ENV01	Global Warming Potential	kg CO_2 eq/m²year	36,73	14,40
ENV04	Primary energy consumption	MJ/m²year	640,80	255,60
ENV06	Energy payback time	years	n/a	-
ECO02	Investments	€/m²	n/a	164,82
ECO03	Life cycle cost	€	-	-
ECO05	Payback Period	years	n/a	12
ENE01	Energy demand (heating)	kWh/m².year	120,75	61,70
ENE02	Final energy consumption	kWh/m².year	167,25	66,91
ENE06	Net fossil energy consumed	kWh/m².year	167,25	54,71
ENE09	Energy demand covered by RES	%	0,00	18,23
ENE13	Energy use from District Heating	kWh/m².year	0,00	0,00
COM01	Local thermal comfort	Level	0	0
ENE14	Energy use from Biomass	kWh/m².year	0,00	0,00
ENE15	Energy use from PV	kWh/m².year	0,00	0,00
ENE16	Energy use from Solar Thermal	kWh/m².year	0,00	12,20
ENE17	Energy use from Hydraulic	kWh/m².year	0,00	0,00
ENE18	Energy use from Mini-Eolic	kWh/m².year	0,00	0,00
ENE19	Energy use from Geothermal	kWh/m².year	0,00	0,00

2.2 *Mogel* district, Eibar (Spain)

Below are given the main information from the *Mogel* district that will be useful to demonstrate the OptEEmAL platform prototype in relevant environment (TRL6).

2.2.1 General description

The district of *Mogel* is a residential neighbourhood located in the municipality of Eibar, and consists of 21 collective buildings which were inaugurated in 1949 (Figure 5). The entire neighbourhood dates back to the year 1949 and enjoys a homogeneous appearance that has remained up to the present day.

The terrain is inclined with a slope difference of 15 meters maximum, being its geotechnical characteristics suitable for superficial foundation, with the phreatic level below the level of foundation.

Figure 5: Eibar and *Mogel* district aerial view

The residential buildings are integrated into similar portals in various blocks in line. Each portal is a rectangular plot elongated with the façades orientated on both streets. The portals have access from two streets (Figure 6).

The blocks consist on ground floor, four floors and pitch roof. On the ground floor there are homes, while on the pitch roof there are storerooms. There are two apartments per floor, and 10 homes per portal with an estimated population of about 450 persons. Of the total of 21 portals, 15 are object of the present rehabilitation project, affecting a total of 150 homes and 302 neighbours.

Figure 6: North area of the *Mogel* district

2.2.2 Objectives of the retrofitting project

In this district, the retrofitting project was set up in order to answer the following needs:

- Lift installation in buildings
- Improvement of the building envelope (facades, roofs, etc.)
- Duplicate the effect of the implementation of the Spain Technical Building Code (CTE) for the new building, regarding the losses of the building envelope
- Change of windows (some of them were already upgraded)
- Installation of hot water production system by means of solar panels with central storage system
- Improvement of lighting efficiency in common areas

2.2.3 Buildings under study

Buildings studied in the OptEEmAL platform are the ones which were investigated in the frame of the ZenN project (Figure 7).

Figure 7: Buildings to be retrofitted in *Mogel* (in blue portals included in the retrofitting project)

2.2.4 Existing information

For the *Mogel* district, existing information was taken from the ZenN project. The ZenN project has received funding from the Seventh Framework Programme (FP7/2007-2013) under grant agreement n°314363 (http://zenn-fp7.eu/). TECNALIA was involved in this project and has provided the related information.

All the information provided in this section are related to the situation before retrofitting (corresponding to the "Baseline" in OptEEmAL).

2.2.4.1 Simulation data

As for the majority of retrofitting project, the *Mogel* district was studied from an energy perspective prior to the implementation of the retrofitting measures. As part of this study, energy simulations were performed. Those energy simulations were done using the DesignBuilder energy simulation software (and thus EnergyPlus calculations). This is an interesting point as OptEEmAL also uses EnergyPlus calculations for the elaboration of ENERGY DPIs. So it will provide interesting data to be compared with the ones obtained from OptEEmAL.

The simulated energy demand results are provided in the table below (Table 4).

Table 4: Energy demand before retrofitting in the *Mogel* district, Eibar

Mogel district, Eibar	Total district energy demand – Simulation (MWh/yr)	Building energy demand[2] – Simulation (kWh/m².yr)
Space heating	536,5	56,8
Domestic hot water	278,5	29,5
Internal lightings	111,5	11,8
Technical equipment	137,9	14,6

[2] The « Building energy demand » is obtained by dividing the « Total district energy demand » by the total floor area of the district.

Cooling, ventilations	0,0	0
TOTAL	1064,4	112,7

2.2.4.2 Measured data

Historical energy bills measures collected from selected meters in some flats of blocks 1, 2, 6 and 7 of *Mogel* during the 2010 – 2011 period were collected. Natural gas bills include heating and DHW consumptions, while electricity bills include internal lighting, appliances and kitchen consumption.

Table 5: Energy bills of selected meters in *Mogel* before retrofitting

Gas (kWh)							
Block	**Flat**	**8-9 2010**	**10-11 2010**	**12/10 1/2011**	**2-3 2011**	**4-5 2011**	**6-7 2011**
1	2ºD	247	678	2454	1618	534	429
2	1ºD	556	217	1661	1013	266	319
6	Ground D	222	508	2145	1494	400	368
6	4ºD	247	968	4067	2816	533	380
7	4ºD	160	666	3112	2507	121	110

Electricity (kWh)								
Block	**Flat**	**8-9 2010**	**10-11 2010**	**12/10 1/2011**	**2 2011**	**3 2011**	**4-5 2011**	**6-7 2011**
1	2ºD	217	338	374	216	94	293	270
2	3ºD	208	502	948	608		357	281
6	Ground D	278	405	671	246	230	445	436
6	4ºD	158	0	582	140	130	235	210
7	4ºD	161	0	468	102	79	190	148

2.2.4.3 Comparison between simulated data and measured data

Table 6: Final energy consumption before retrofitting

Mogel district, Eibar	SIMULATED			MEASURED		
	Delivered energy (MWh/yr)	Specific delivered energy (kWh/m^2.yr)	% of total delivered energy	Delivered energy (MWh/yr)	Specific delivered energy (kWh/m^2.yr)	% of total delivered energy
Natural gas	906	86	77	832	88	76
Electricity	249	26	23	270	28	24

2.3 *Polhem* district, Lund (SE)

The main information from the *Polhem* district used for TRL6 validation of the platform are described below. As already mentioned, this information was used to validate the platform at TRL6 considering the interesting profile (climate conditions, district heating, etc.) of this case study. However, as this district was initially considered as a demo site (TRL7) and that the testing activities for this district are not fully finalised, the associated results are provided in D6.4

2.3.1 General description

The *Polhem* district is located in the municipality of Lund. It is composed of different high school buildings (5) and one library built at different periods ranging from 1914 to 1991 (Figure 8). Both the high school and the library are public buildings managed by the municipality of Lund. The total net area of the district's buildings is 26,987 m^2.

The district energy supply is done through a regional heating network fuelled by natural gas, biogas. This heating network is also supplied with energy from large scale heating pumps and waste heat from industries.

Figure 8: Location of the *Polhem* district in the city of Lund (left) and aerial view of the district (right)

2.3.2 Objectives of the retrofitting project

For the time being, there are no specific goal for the district since a retrofitting plan does not exist yet. The goals mentioned below are the ones set by the municipality as a whole:

- The energy consumption in the municipal buildings shall decrease by 10% until 2016 compared with 2014.
- The municipality shall be a fossil fuel free organisation by 2020.
- The primary energy use in the municipal building shall decrease by 2020 compared to 2013.

In more details, the municipality is facing some energy and retrofitting related problems that OptEEmAL could possibly help to solve. Problems that have been identified by the municipal staff are:

- No gains related to energy savings are set before a retrofitting project. This is partly due to that there is in most cases no detailed energy data for the buildings which makes a before and after comparison difficult. Energy savings can also be hard to identify since buildings might have a changed user pattern after retrofitting (although this is not the case in the *Polhem* district retrofitting project).
- Retrofitting projects are in most cases not chosen because of energy saving possibilities, but rather out of an urgent retrofitting need such as leaking roofs or problems with mould/damp.

2.3.3 Buildings under study

In total, 6 buildings are part of the retrofitting projects (Figure 9). Building's uses are described in the Table 7 below.

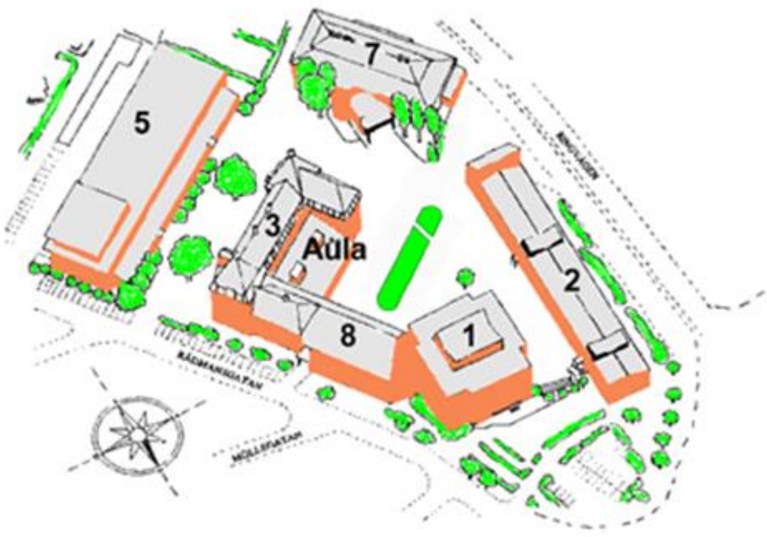


Figure 9: Buildings under study in the *Polhem* district, Lund

Table 7: Building's uses in the *Polhem* district, Lund

Building n°	Use
1	Library
2	School
3	School
5	School
7	School
8	School

2.3.4 Existing information

One particular challenge for the *Polhem* district is that very little information is existing about the buildings under study. Paper plans are existing but are not necessarily up to date and no numeric information is available at all. Similarly, no detailed information about the materials or energy systems used in the different buildings is available. This has been a particular challenge for the elaboration of the BIM/IFC files and this is why a subcontractor has been hired.

In terms of energy consumptions, the total energy consumption of the district before retrofitting is available (from the Lund municipality). The values, obtained from the district heating company (measured data), are displayed in the table below.

Table 8: Final energy consumption (in kWh) before retrofitting of the *Polhem* district in the last 4 years – Measured data

Month	2014	2015	2016	2017
January	419239	408623	346411	408512
February	349646	354407	373885	375509

March	284809	236205	290311	319507
April	190437	177175	170719	217508
May	94656	145955	100936	79078
June	22759	42368	19686	38244
July	15364	15412	17519	17198
August	20976	14467	17937	19752
Septemb er	115545	45438	37444	55735
October	112256	141985	171299	165507
Novemb er	275410	273556	293599	301549
Decemb er	376855	436456	447947	383867
TOTAL	**2277952**	**2292047**	**2287693**	**2381966**

Also, the Energy Performance Certificates of some buildings are available. The key information from those documents are mentioned in the table below. It shall be mentioned that these values are obtained from simulations.

Table 9: Energy consumption data (from EPC) before retrofitting in the *Polhem* district – Simulated data

Building (Figure 9)	Surface (m^2)	Energy source	Energy consumption (kWh)	Electricity consumption (kWh)
1	9 744	District heating	899 830	636 272
3	7 005	District heating	646 892	457 418
4	3 885	District heating	358 769	253 686
6	3269	District heating	301 883	213 462

3 Introduction of the case studies into the OptEEmAL platform

In order to use the platform, different input data are needed in specific formats with a specific content. The elaboration of these data, for the different case studies and from the general description, are described in this section.

As a reminder, from a general perspective, the OptEEmAL platform requires (from its users) the input data listed below. This section of the report is organised according to this list.

- BIM models
- CityGML model
- Baseline Energy Systems related information (questionnaire)
- Targets, boundaries and barriers
- Prioritisation criteria
- Biomass prices

3.1 *Cuatro de Marzo* district, Valladolid (Spain)

As a general comment, it should be mentioned that all the information related to the *Cuatro de Marzo* district were provided by CARTIF and were mainly coming from the R2Cities project.

3.1.1 BIM models

For the *Cuatro de Marzo* district, 4 BIM models have been elaborated (Figure 10 and Figure 11) for OptEEmAL project by CARTIF, using previous models available from R2Cities project that had to be modified for OptEEmAL following the platform recommendations. Those models correspond to the different buildings highlighted in red in Figure 4.

Figure 10: BIM models for portals 16 (left), 14 (middle) and 12 (right) of the *Cuatro de Marzo* district

Figure 11: BIM models for portals 10 and 18 (same building)

3.1.2 CityGML model

The CityGML model of the district was elaborated for OptEEmAL project by CARTIF using CityEditor plugin. The model was generated with the cadastre data and the information available in the BIM models of the buildings. The CityGML model of the district is shown in the figure below (Figure 12).

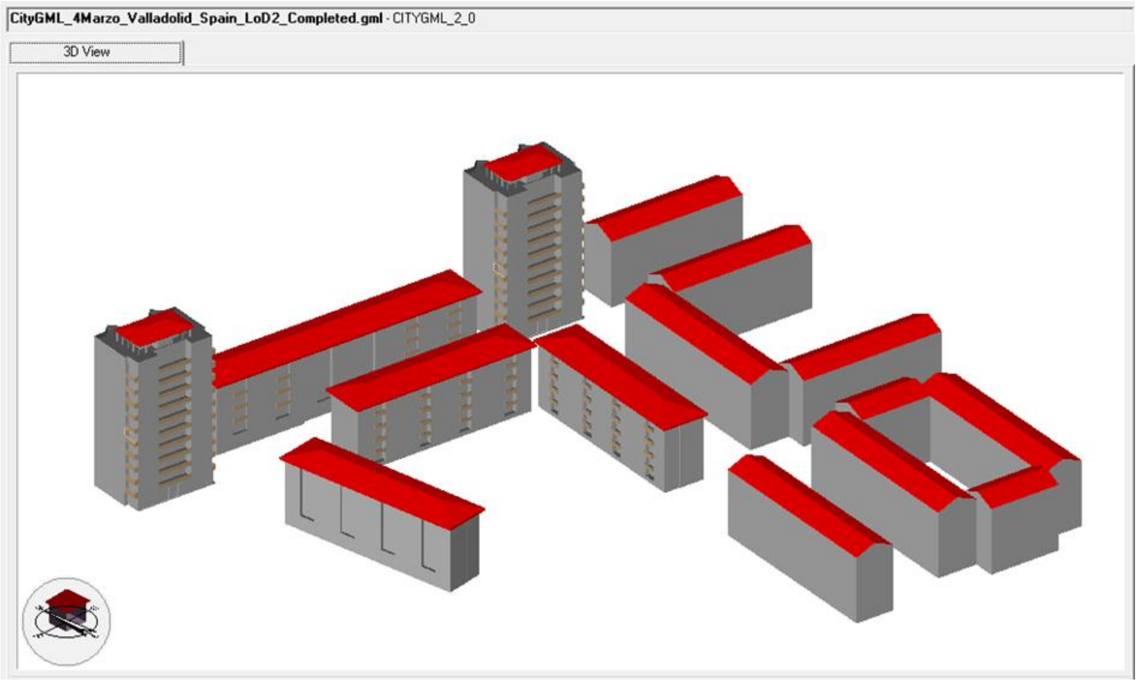


Figure 12: CityGML model of the *Cuatro de Marzo* district

3.1.3 Baseline Energy Systems

Using information available of the *Cuatro de Marzo* district, the Baseline Energy Systems questionnaire from the platform was answered as illustrated below. Only applicable questions from the BES questionnaire are reported below for ease of understanding. It has to be noted that except for question 2.3.1.1.1.1.1. (Total boiler capacity), answers are the same for all the buildings of the district.

BES questionnaire – *Cuatro de Marzo* district, Valladolid (Spain)

1_District

1.1_Do you have a district energy supply system? NO

2_Buildings

For each building of the district: **(in this case studies, all buildings have the same characteristics)**

2.1_Does this building have access to natural gas? YES

2.2_Does this building have a Building Energy Management System or platform with measurements system for controls implementation? NO

2.3_Please select the system type for this building? **a. Heating only**

2.3.1.1_Is this heating system connected to the district supply? NO

2.3.1.1.1.1_Please choose the system type? **a. Boilers**

2.3.1.1.1.1.1.i_What is the total boiler capacity? **18 kW per boiler (22 boilers in portals 10 and 18 / 10 boilers in portals 12, 14 and 16)**

2.3.1.1.1.1.1.ii_What is the boiler type? **Non-condensing**

2.3.1.1.1.1.1.iii_What is the fuel type? **Natural gas**

2.3.1.1.1.1.1.iv_What is the boiler efficiency? **0.722**

2.3.1.1.1.1.1.v_What is the system start and stop time? **Unknown**

2.3.1.1.1.1.1.vi_What is the hot water set-point? **Unknown**

2.3.1.1.1.1.4_For each HVAC zone in this building, what is the demand system? (for all the HVAC zones)

2.3.1.1.1.1.5 **a. Baseboard heating**

3.1.4 Targets, boundaries and barriers

3.1.4.1 Barriers / ECM questionnaire

ECM questionnaire – *Cuatro de Marzo* district, Valladolid (Spain)

District level questions

1_Will you connect buildings to a District Heating & Cooling system? **NO**

Building level questions

1_Can you modify building façades? **YES**

1.1_Can they be refurbished externally? **YES**

1.2_Can they be refurbished internally? **YES**

1.3_Do you know the thickness of the air chamber of your façades? **NO**

2_Can you modify building windows? **YES**

3_Can you modify buildings roofs? **YES**

3.1_Can you apply external roof insulation? **NO**

3.2_Can they be internally refurbished? **YES**

3.3_Can you consider the implementation of renewable generation systems on the roofs? **YES**

3.3.1_Can you use the roof for thermal energy production? **YES**

3.3.2_Can you use the roof for electricity production? **YES**

4_Can you modify building floors? **NO**

5_Can you change the energy generation system? **YES**

5.1_Do the buildings have functional space to implement biomass boilers? **NO**

6_Can you replace or implement the energy control system? **YES**

3.1.4.2 Targets and boundaries

TB questionnaire – *Cuatro de Marzo* district, Valladolid (Spain)

1.a_Investment (ECO02.2): **790.000 € (considering the 5 portals).**

1.b_Payback period (ECO05): **15 years.**

1.c_Energy Payback Time (ENV06): **30 years.**

2_Are there values that you would not like to surpass? **NO**

3_Are there targets that you would like to achieve? **NO**

3.1.5 Prioritisation criteria

Prioritisation criteria – *Cuatro de Marzo* district, Valladolid (Spain)

Prioritisation criteria have been defined using pre-defined weighting scheme. The following inputs have been introduced in the platform.

What is your main objective to be achieved within the OptEEmAL platform? To achieve a low carbon district

Do you want to prioritise economic aspects as well? NO

3.1.6 Biomass prices

In this case study there is not biomass in the buildings. In the default scenario will be used the same price that the *Mogel* district (explained below in the *Mogel* case study) because the districts are located in the same country and the distance between the city of Valladolid and Eibar is only 300km. Value introduced into the platform are 22.5 €/t and 3% yearly increase rate.

3.2 *Mogel* district, Eibar (Spain)

As a general comment, it should be mentioned that all the information related to the *Mogel* district were provided by TECNALIA and were mainly coming from the ZenN project.

3.2.1 BIM models

In the *Mogel* district, 15 buildings are part of the retrofitting project. Considering the similarities between these buildings and the OptEEmAL platform characteristics (e.g. shadows are assessed based on information provided in the CityGML file), 5 BIM models were elaborated to assess this case study in the platform. Those models are presented below as well as their relationships with the real buildings of the district. It has to be noted that most of the IFC files used for this case study are quite similar. Indeed, “Mogel_1”, “Mogel_2”, “Mogel_3” and “Mogel_14” files are very similar. The only difference is their ground footprint and this is the only reason why different files have been used. All the IFC models used in this case study have been elaborated during the project.

Table 10: Relationships between existing buildings and IFC files in the *Mogel* district

Building n° (Figure 7)	IFC file
1	Mogel_1
2	Mogel_2
3	Mogel_3
4	Mogel_3
5	Mogel_5
6	Mogel_1
7	Mogel_3
8	Mogel_1
9	Mogel_1
13	Mogel_1

14	Mogel_14
15	Mogel_14
17	Mogel_1
18	Mogel_1
20	Mogel_1

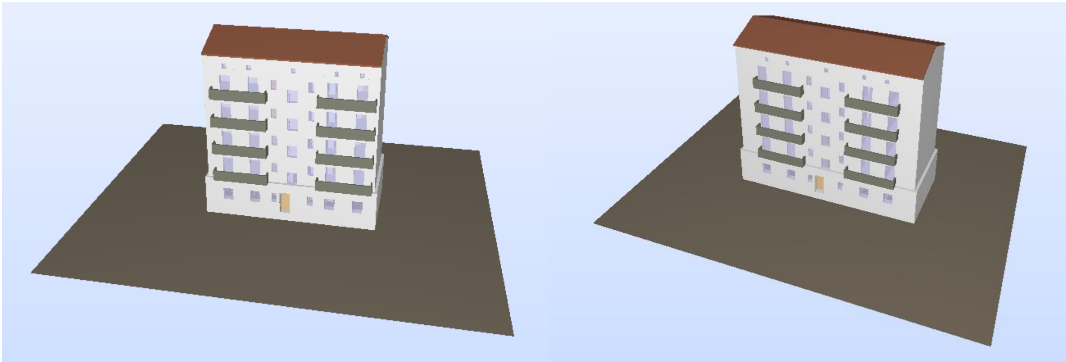


Figure 13: “*Mogel*_1” (left) and “*Mogel*_2” (right) IFC files

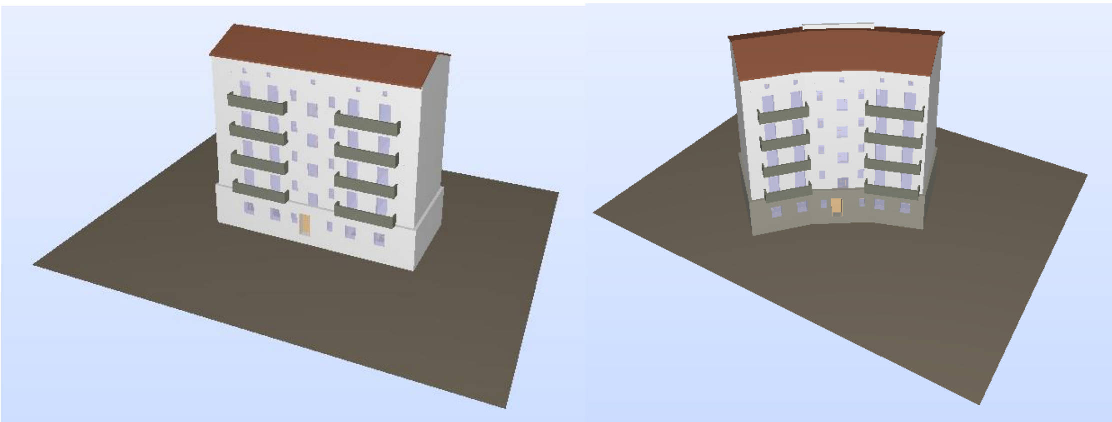


Figure 14: “*Mogel*_3” (left) and “*Mogel*_5” (right) IFC files

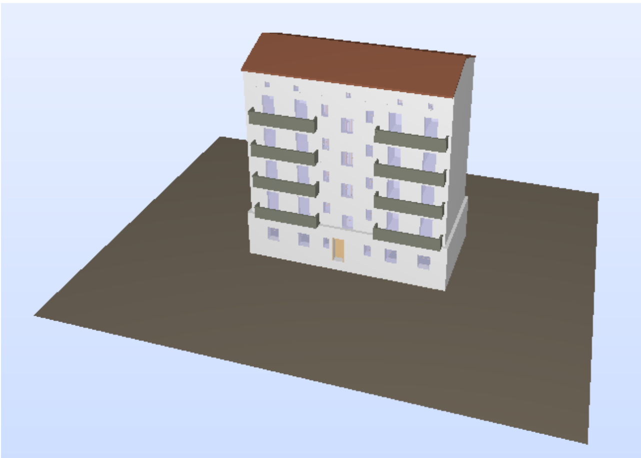


Figure 15: “*Mogel*_14” IFC file

3.2.2 CityGML model

The CityGML model of the district was elaborated using the tool developed by TECNALIA which allows to generate a CityGML file from a shape file containing the building footprints and LIDAR data (containing the DTM[3] and DSM[4] of the same area). An illustration of the model is provided in the figure below (Figure 16). Considering the significant topography in the area, it was necessary to model a large area around the buildings under study in order to consider potential shadows from neighbouring buildings. This is reflected in the figure below. This model has been elaborated as part of the OptEEmAL project.

Figure 16: *Mogel* district CityGML model

3.2.3 Baseline Energy Systems

Using information collected in the *Mogel* district, the Baseline Energy Systems questionnaire from the platform was answered as illustrated below. Only applicable questions from the BES questionnaire are reported below for ease of understanding. It has to be noted that answers provided are the same for all the buildings in the *Mogel* district.

BES questionnaire – *Mogel* district, Eibar (Spain)

1_District

1.1_Do you have a district energy supply system? **NO**

2_Buildings

For each building of the district (**in this case studies, all buildings have the same characteristics**)

2.1_Does this building have access to natural gas? **YES**

2.2_Does this building have a Building Energy Management System or platform with measurements system for controls implementation? **NO**

2.3_Please select the system type for this building? **a. Heating only**

2.3.1.1_Is this heating system connected to the district supply? **NO**

2.3.1.1.1.1_Please choose the system type? **a. Boilers**

2.3.1.1.1.1.i_What is the total boiler capacity? **200 kW**

[3] Digital Terrain Model

[4] Digital Surface Model

2.3.1.1.1.1.ii_What is the boiler type? **Non-condensing**

2.3.1.1.1.1.iii_What is the fuel type? **Natural gas**

2.3.1.1.1.1.iv_What is the boiler efficiency? **0.8**

2.3.1.1.1.1.v_What is the system start and stop time? **Unknown**

2.3.1.1.1.1.vi_What is the hot water set-point? **Unknown**

2.3.1.1.1.1.4_For each HVAC zone in this building, what is the demand system? **a. Baseboard heating (for all the HVAC zones)**

3.2.4 Targets, boundaries and barriers

3.2.4.1 Barriers/ECM questionnaire

ECM questionnaire – *Mogel* district, Eibar (Spain)

District level questions

1_Will you connect buildings to a District Heating & Cooling system? **NO**

Building level questions

1_Can you modify building façades? **YES**

1.1_Can they be refurbished externally? **YES**

1.2_Can they be refurbished internally? **YES**

1.3_Do you know the thickness of the air chamber of your façades? **NO**

2_Can you modify building windows? **YES**

3_Can you modify buildings roofs? **YES**

3.1_Can you apply external roof insulation? **YES**

3.2_Can they be internally refurbished? **YES**

3.3_Can you consider the implementation of renewable generation systems on the roofs? **YES**

3.3.1_Can you use the roof for thermal energy production? **YES**

3.3.2_Can you use the roof for electricity production? **YES**

4_Can you modify building floors? **YES**

5_Can you change the energy generation system? **YES**

5.1_Do the buildings have functional space to implement biomass boilers? **YES**

6_Can you replace or implement the energy control system? **YES**

3.2.4.2 Targets and boundaries

The values selected for the mandatory boundaries are:

- Investment (ECO02.2): 8,000,000 € (considering the total maximum investment displayed in the different scenarios investigated in the ZenN project).
- Payback period (ECO05): 15 years (considering the maximum payback period considered in the different scenarios investigated in the ZenN project).
- Energy Payback Time (ENV06): 50 years (this value cannot be calculated with the available information, a maximum value was retained).

No additional targets were considered.

3.2.5 Prioritisation criteria

Considering the objectives of the retrofitting project in Eibar, the choice was made to select the pre-defined prioritisation criteria "To prioritise the reduction of operational energy costs".

3.2.6 Biomass prices

Biomass prices were collected as part of the ZenN project: 4.5 c€/kWh. In OptEEmAL, biomass prices have to be entered in €/t or €/kg. The conversion has been made using a 5 kWh/kg Lower Heating Value (LHV). The value introduced into the platform is 22.5 €/t.

3.3 *Polhem* district, Lund (SE)

As a general comment, it should be mentioned that all the information related to the *Polhem* district were provided by the municipality of Lund.

3.3.1 BIM models

For the *Polhem* district, 6 BIM models were elaborated to represent the 6 buildings present in the district (see Figure 17, Figure 18, Figure 19 and Figure 20). It was needed to have one specific model for each building considering the diversity of the buildings present in the district. The relationship between the BIM models and the different buildings are presented in the Table 11 below. Those models were elaborated as part of the OptEEmAL project. They were first elaborated by a subcontractor (from LUND) and were then modified by the project partners in order to follow the latest evolutions of the OptEEmAL platform.

Table 11: Relationship between the buildings and the IFC files for the *Polhem* district

Building n° (Figure 7)	IFC file
1	Polhem_1
2	Polhem_2
3	Polhem_3
5	Polhem_5
7	Polhem_7
8	Polhem_8

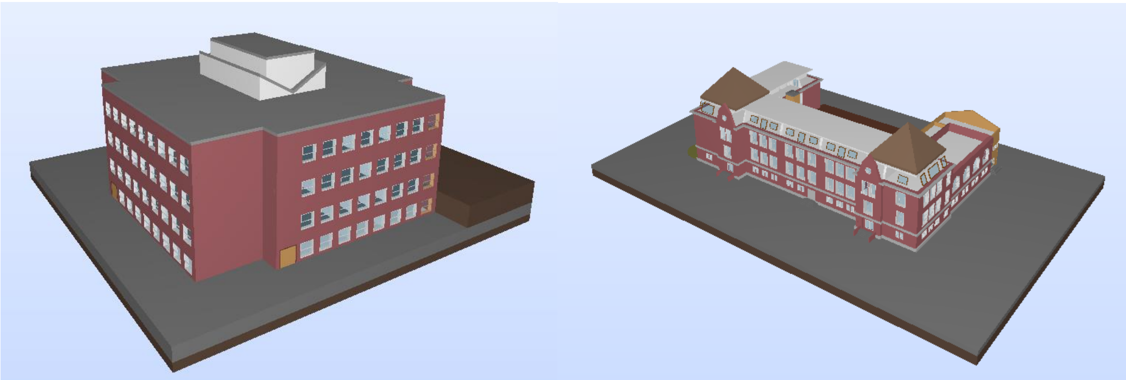


Figure 17: "Polhem_1" (left) and "Polhem_3" (right) IFC files

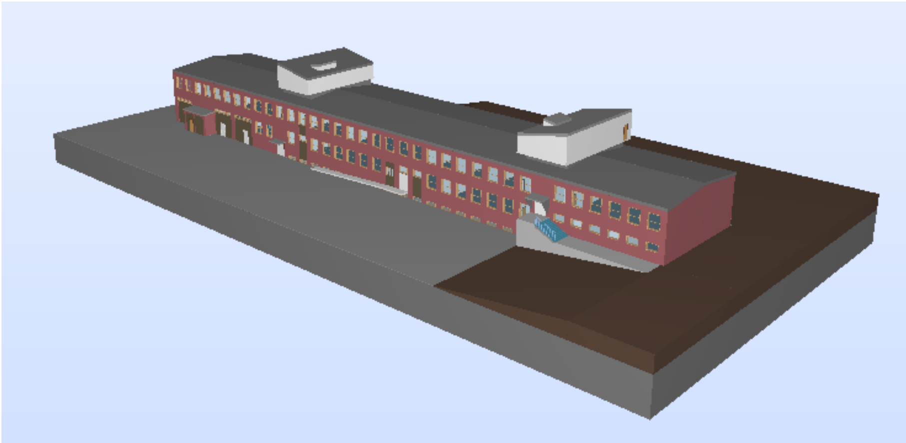


Figure 18: “Polhem_2” IFC file

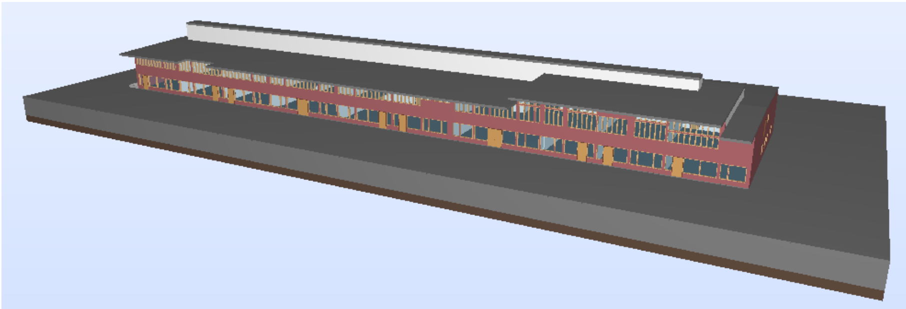


Figure 19: “Polhem_5” IFC file

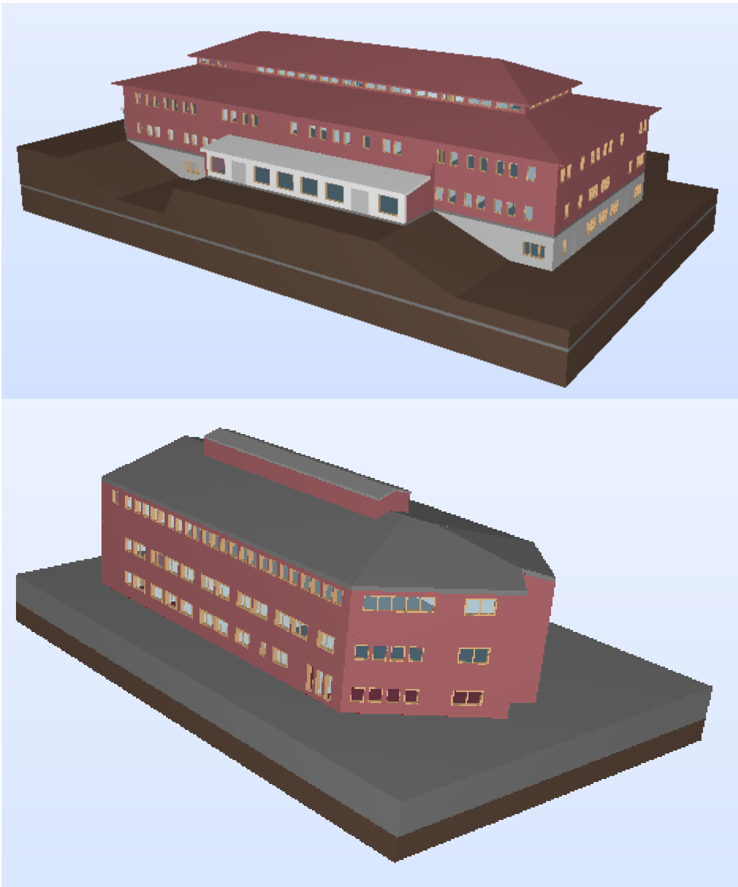


Figure 20: “Polhem_7” and “Polhem_8” IFC files

3.3.2 CityGML model

The CityGML file for the *Polhem* district was elaborated using the existing SketchUp (.skp) files of the municipality of Lund and the CityEditor plugin for SketchUp which allows to generate CityGML files from .skp files. The CityGML file is illustrated in the Figure 21 below. This model was elaborated as part of the OptEEmAL project.

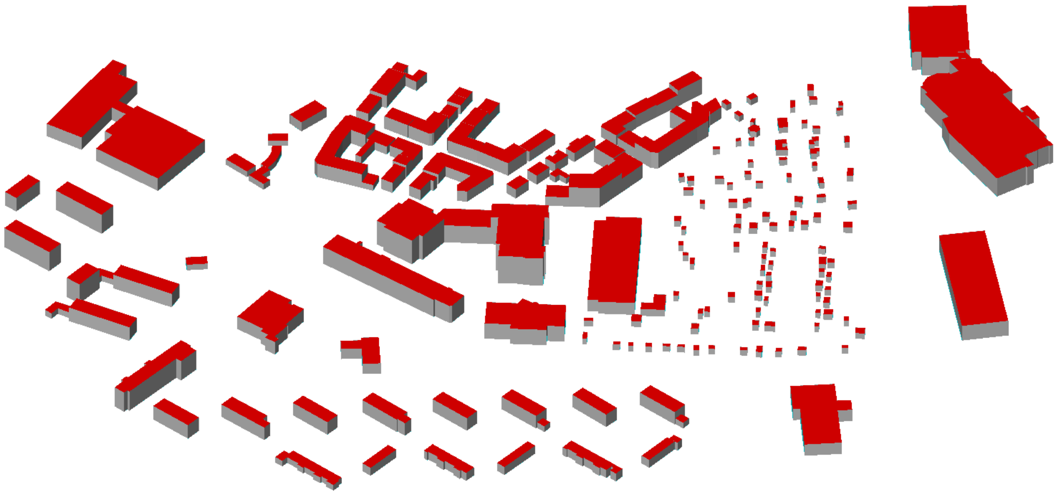


Figure 21: CityGML file for the *Polhem* district, Lund

3.3.3 Baseline Energy Systems

The answers related to the Energy systems are listed below. For the *Polhem* district, it has to be noted that a district heating is present (regional heating network supplying all the building of the district). Also, as energy systems are different for some buildings of the district, the answers mentioned below are thus separated per group of buildings with the same characteristics.

BES questionnaire – *Polhem* district, Lund (Sweden)

1_District

1.1_Do you have a district energy supply system? **YES**

1.1.1_If YES, please select system type? **A. Heating only**

1.1.1.1_If A, what is the district heating supply system? **B. Boiler and CHP plant**

1.1.1.1.1.i. How many boilers do you have? **14 (at regional level)**

1.1.1.1.1.ii. What is the total boiler capacity? **300 MW (at regional level)**

1.1.1.1.1.iii. What is the boiler type? **Non-condensing**

1.1.1.1.1.iv. What is the fuel type? **Natural gas**

1.1.1.1.1.v. What is the boiler efficiency? **0.9**

1.1.1.1.2.i. How many CHPs do you have? **2 (at regional level)**

1.1.1.1.2.ii. What is the CHP electrical capacity? **42 MW (at regional level)**

1.1.1.1.2.iii. What is the CHP thermal capacity? **102 MW (at regional level)**

1.1.1.1.2.iv. What is the CHP fuel type? **Natural gas**

1.1.1.1.2.v. What are the CHPs efficiencies? **Electrical: 0.32 / Thermal: 0.75**

1.1.1.1.4. What is the district heating start and stop times? **It runs 24/7**

1.1.1.1.5. What is the hot water set point? **70°C**

2_Buildings (for Buildings n°1,2,3 and 7)

2.1_Does this building have access to natural gas? NO

2.2_Does this building have a Building Energy Management System or platform with measurements system for controls implementation? NO

2.3_Please select the system type for this building? **a. Heating only**

2.3.1.1_Is this heating system connected to the district supply? YES

2.3.1.1.1_If yes, do you have additional local building level supply system? NO

2.3.1.1.1.1.4_For each HVAC zone in this building, what is the demand system? **a. Baseboard heating (for all the HVAC zones)**

2_Buildings (for Building n°5)

2.1_Does this building have access to natural gas? NO

2.2_Does this building have a Building Energy Management System or platform with measurements system for controls implementation? NO

2.3_Please select the system type for this building? **b. Heating and cooling**

2.3.1.1_Is this heating system connected to the district supply? YES

2.3.1.1.1_If yes, do you have additional local building level supply system? NO

2.3.1.1.1.1.4_For each HVAC zone in this building, what is the demand system? **a. Baseboard heating (for all the HVAC zones)**

2.3.2.2_Is this cooling system connected to the district supply? NO

2.3.2.2.1.1.1_What is the total chiller capacity? **3.8**

2.3.2.2.1.1.2_What is the chiller COP? **2.52**

2.3.2.2.1.1.3_What is the system start and stop times? **7-17**

2.3.2.2.1.1.4_What is the chilled water set-point? **11°C**

2.3.2.2.1.1.5_For each HVAC zone in this building, what is the demand system? **Fan coils (only for rooms 183 & 283)**

2_Buildings (for Building n°8)

2.1_Does this building have access to natural gas? NO

2.2_Does this building have a Building Energy Management System or platform with measurements system for controls implementation? YES

2.3_Please select the system type for this building? **a. Heating only**

2.3.1.1_Is this heating system connected to the district supply? YES

2.3.1.1.1_If yes, do you have additional local building level supply system? NO

2.3.1.1.1.1.4_For each HVAC zone in this building, what is the demand system? **a. Baseboard heating (for all the HVAC zones)**

3.3.4 Targets, boundaries and barriers

3.3.4.1 Barriers/ECM questionnaire

ECM questionnaire – *Polhem* district, Lund (Sweden)

District level questions

1_Will you connect buildings to a District Heating & Cooling system? NO

Building level questions

1_Can you modify building façades? **YES**
1.1_Can they be refurbished externally? **YES**
1.2_Can they be refurbished internally? **YES**
1.3_Do you know the thickness of the air chamber of your façades? **NO**
2_Can you modify building windows? **YES**
3_Can you modify buildings roofs? **YES**
3.1_Can you apply external roof insulation? **YES**
3.2_Can they be internally refurbished? **YES**
3.3_Can you consider the implementation of renewable generation systems on the roofs? **YES**
3.3.1_Can you use the roof for thermal energy production? **YES**
3.3.2_Can you use the roof for electricity production? **YES**
4_Can you modify building floors? **NO**
5_Can you change the energy generation system? **NO**
5.1_Do the buildings have functional space to implement biomass boilers? **NO**
6_Can you replace or implement the energy control system? **YES**

3.3.4.2 Targets and boundaries

The values selected for the mandatory boundaries are:

- Investment (ECO02.2): 1,000,000 €
- Payback period (ECO05): 15 years
- Energy Payback Time (ENV06): 20 years

The optional targets (values not to be surpassed) are:

- Final energy consumption (ENE02.0): 140 kWh/m2.yr
- Energy demand covered by renewable sources (ENE09): 100%

3.3.5 Check strategies

The only constraints to be taken into account for the check strategies screen is the historical protection of building n°3. It means that all ECMs affecting the external envelope of this building cannot be implemented.

3.3.6 Prioritisation criteria

The prioritisation criteria selected by the municipality of Lund is "To achieve a carbon-neutral district". Economic aspects have also to be prioritised.

3.3.7 Biomass prices

The biomass cost indicated by the municipality of Lund is 54 €/ton with an annual increase of 2.54%.

4 Integration / End-to-end tests

4.1 Description of end-to-end tests

The software integration testing, or end-to-end test, covers the phase in software testing where individual software modules (and components) are combined and tested as a group. This kind of tests are executed after the unitary tests (where the individual functionality of a module or component has been validated) and before the validation testing. The purpose of this level of testing is to expose faults in the interaction between integrated units. Although the activities carried out in this task were validation activities, it was decided to perform end-to-end tests in order to validate the proper functioning of the platform as a whole with more complex cases than the ones investigated in T6.1.

Indeed, in D6.1, end-to-end tests was performed in order to validate the proper integration of the different individual modules (and components) of the platform using a fictive example. In this section, the objective is to test the proper integration of the different modules using real data from the case studies and thus investigate how the platform performs in conditions which are closer to the reality. As a consequence, the sequence of test identified in D6.1 has been reused in this work, eliminating those tests which are not relevant anymore (because functionalities have already been tested and are not related to the insertion of real data) and adding new tests especially related to the insertion and checking of real district and building files.

In the first part, the list of test is defined and described. In the second part, the results of the tests are given for the different case studies.

In terms of partner's responsibility, NBK has been in charge of performing all the tests (as WP6 leader in charge of the demonstration) and has been supported by the different partners mentioned in the table below.

Table 12: Battery of end-to-end tests

Test Id	Name	What is tested	Comment	Pass Condition	Partners involved
Data-1	Data upload CityGML	A CityGML file is selected by the user, checked by the system and stored into the CityGML repository	Use the GUI to select the CityGML file and upload it into the BIM-City Repository. The Data Insertion Module will process and validate the correctness of the uploaded file	The CityGML has been stored in the repository.	NBK (TEC)
Data-2	CityGML with errors	Errors are found when checking the CityGML and they are shown to the user through the GUI. Errors can be found in: • XML validation • GML validation • Location validation	The correctness of the uploaded CityGML file includes the XML and XSD validation, geometric and semantic validation. The correctness is checked in the Data Insertion Module. The consistency of the CityGML file validates the location of the CityGML. This validation is performed visually by the user through the GUI.	The user has received an alert	NBK (TEC)
Data-3	Data upload IFC	An IFC file is selected by the user, checked by the system and stored into the BIM repository	Use the GUI to select the BIM file and upload it into the BIM-City Repository. The Data Insertion Module will process and validate the correctness of the uploaded file. If the BIM file needs to be completed with additional information (through validation, CBIP tool or other processes), the completed file will be uploaded again and their status updated.	The original IFC has been stored in the repository.	NBK (TEC)
Data-4	IFC with errors	Errors are found when checking the IFC and they are shown to the user through the GUI. Errors can be found in:	The correctness of the uploaded IFC files is done for three categories of rules:	The user has received an alert	NBK (TUC)

		• Location • Orientation • Space (at least one) • Site (at least one) • Correctness check	• space boundary rules • space rules • material rules		
Matching-1	BIM-CityGML matching	Links between the IFC files and the CityGML model is obtained and stored into the Link Database and in the Project Repository for parameters like the altitude.	Use the GUI to select in a 2D map the footprint of the buildings represented by each IFC file previously uploaded into the repository. A new instance of the IFC file is generated and the file is uploaded into the BIM-City Repository. Once performed the matching in the GUI, the links are stored into the Link Database. This process is performed by the Data Insertion Module.	Links has been stored into the Link database and Project Repository .The database table rel_project_matched_citygml_bim is containing the reference to the matched document	NBK (ARG, TEC, ES)
Matching-2	Matching with errors	Errors are found when matching and they are reported to the user through the GUI. Errors can be found in: • Location • orientation	Matching is done manually and links can be edited or deleted through the GUI. No errors are automatically identified during the matching.	The user has received an alert	NBK (ARG, TEC, ES)
ES-2	System Vector generation	Using the responses of the questionnaire, the system vector is generated by the Data Insertion Module	The API /bes/get_system_vector builds the system vector taking the values from the table rel_bes_to_project of the project repository.	The system vector is properly generated	NBK (ES, FUN, UTRC)
HVAC	HVAC zone identification	Uploading the IFC files, the HVAC zones are automatically extracted from the file.	During the upload of the IFC models, the HVAC ZONES are extracted if present and stored into the project repository table rel_project_hvac_zones. This HVAC zones will be exposed by the getprojectdetail API inside the model object toghether with all the other data regarding the IFC. The GUI will	List of HVAC zones displayed in GUI for BES definition	NBK (ES)

			display this zones in the dedicated BES questionnaire section definition.		
Unstr	Unstructured data	Information related to the project and to specific key words are shown to the user through the GUI	The unstructured service is gathering information's about a set of predefined keywords from the google news engine. A semantic engine will extract categories, places, orgs, people from the extracted news and the GUI will display all the items into a dedicated section of the platform.	The user is able to visualise unstructured data through a dedicated GUI	NBK (ES, ARG)
RegUval-1	U-values displayed	Default regulation U-values are retrieved from the Context repository and displayed to the user.	The GUI displays the default regulation U-values for the location (country) of the project.	The user is able to visualise U-values for envelope element through a dedicated GUI.	NBK (ARG)
RegUval-2	U-values edited and stored	The user edits (if needed) U-values for the envelope elements. Then he is able to save the edited values (which are stored into the Project repository)	The GUI will give the possibility to edit the U-values and save the results of the editing process.	The user is able to edit U-values for envelope element through a dedicated GUI and to save them into the Project repository	NBK (ARG)
Baseline-1	Basic SIMMODEL generated	The ETL1 and ETL2 transformations are correctly executed generating a basic SIMMODEL that is stored into the Project Repository	The GUI will give the functionality to download each of the generated models in the scenario selection section. The exportation module is in charge to link each generated model to the GUI.	The baseline SIMMODEL is stored correctly into the Project Repository.	NBK (FUN, ES)
Baseline-2	Enriched SIMMODEL generated	Energy systems, shadows, second level space boundaries and other enriched information is correctly included into the SIMMODEL, that is newly stored into the Project Repository	The GUI will give the functionality to download each of the generated models in the scenario selection section. The exportation module is in charge to link each generated model to the GUI.	The baseline enriched SIMMODEL is stored correctly into the Project Repository.	NBK (FUN, TUC, ES)
BaselineDPI	Baseline DPI	The baseline enriched SIMMODEL is transformed into IDF for the calculation of Energy DPIs.	The GUI will give the functionality to download each	DPI values are stored into the Project Repository for the	NBK (FUN,

	calculation	Economic, environmental, urban and other DPIs are also calculated for the baseline. All these DPIs are stored into the Project Repository and are also showed to the user through the GUI	of the generated models in the scenario selection section. The exportation module is in charge to link each generated model to the GUI.	baseline and shown to the user through a dedicated GUI.	TUC, ES, ARG)
BasUval	Baseline U-values calculation and storage	The baseline U-values for the envelope elements are calculated using E+ (baseline enriched SIMMODEL transformed into IDF)	Using the simulation module, the baseline U-values are calculated (E+). Those values are then stored into the Project repository.	Calculated baseline U-values are stored into the Project repository.	NBK (TUC)
ECM-2	Check strategies	According to the results of the questionnaire, applicable ECMs are presented to the user through the GUI. The user can edit the sale and installation costs of each ECM, and also deselect ECMs from the proposed list. The new information is updated into the Project Repository.	The GUI have a dedicated section to manage the remaining ECM's giving the functionality to edit costs, prices or disable a single ECM. All the disabled ECM's will not be managed by the optimization module.	The edited and deselected information is updated into the Project Repository.	NBK (ES, TEC, ARG)
P-Info	Project information retrieval	A summary of all the information collected for a project is presented to the user through the GUI. Information has to be retrieved from several Repositories.	The scenario selection and the exportation module are the GUI sections dedicated to display in detail all the information's retrieved from the various repositories and related to the project repository information's	The GUI shows the correct information	NBK (ARG)
AM	Applicable matrix generation	As result of ECM filtering and checking the strategies, an applicable matrix is generated for the project and stored into the Project Repository.	The applicable matrix is calculated from the ECM filtering process. A dedicated API of the Data Insertion Module can reproduce the matrix on request taking the values from the project repository.	The correct matrix is calculated from the strategies checker results stored into the Project Repository	NBK (ES, TEC)
Uval-proc	U-values processed	The scenario generator retrieve the (1) regulation U-values as inserted by the user, (2) the baseline U-values as calculated by the simulation module and (3) the ECMs U-values for the passive ECMs as stored within the ECMs catalogue. With this information, the scenarios generator will	This checking is done for every ECM of the catalogue belonging to the construction type, starting with the highest insulating and going backwards until finding the ECM that doesn't fulfil the	Non-compliant ECMs are eliminated from the applicable matrix.	NBK (TUC, CAR)

		implement the checking function: U-value after < U-value regulation.	checking function. All ECMs with less insulating properties than that ECM will be considered as non-compliant.		
SV	Scenario vector generation	Based on the applicable matrix and internal combination rules, the Optimisation Module will generate 50 scenarios per iteration and send to the queues of the ESB	The scenario vector is generated using the applicable matrix	send to the queues of the ESB	NBK (TEC, ES)
IC	Instances creation	Using the information of every scenario vector and the enriched baseline SIMMODEL, a new SIMMODEL is generated inserting the snippets necessary for the concrete scenario.		The new SIMMODEL is stored into the Project Repository.	NBK (FUN, TUC)
Evaluation DPI	Scenario DPI calculation	The SIMMODEL is transformed into IDF for the calculation of Energy DPIs. Economic, environmental, urban and other DPIs are also calculated for each considered scenario. All these DPIs are stored into the Project Repository to be then used by the OPT module.	Once generated by the simulation module, the DPI's are stored into the project repository. The GUI will display this stored DPI for the scenario selection.	DPIs for a given scenario are properly stored into the Project Repository.	NBK (ES, TUC, UTRC)
EE	Evaluator execution	DPIs, TB and the weights of the prioritization criteria are retrieved from the Project Repository. The evaluator is executed and the result (cost-benefit functions and information related to the Targets and Boundaries of the project) is obtained.	The Evaluator needs as inputs: the Prioritisation Criteria, the Targets and Boundaries and the DPIs	The results of the evaluator are delivered to the OPT module.	NBK (CAR, TEC)
OPT-1	OPT execution	Using the cost-benefit results of the evaluator, the OPT algorithm is launched and new scenario vectors are proposed and send to the queues of the ESB		New scenario vectors are send to the queues of the ESB	NBK (TEC)
OPT-3	Generation of the Pareto Front	Once the Optimisation Process finish obtain the Pareto Front with the best scenarios of the last two iterations and store it into the Project Repository	The Pareto front generation is the final result of the OPT algorithm. The Pareto front is stored into the project repository and displayed by the GUI in a dedicated section together with some graphs	The Pareto Front is stored into the Project Repository	NBK (TEC, ES)

EXP-1	Generation of data to be exported	The different outputs to be exported are generated by retrieving information of the optimal scenario from different repositories: BIM and CityGML Repository, Project Repository. The new outputs (reports and summaries) are stored into the Project Repository.	The GUI will give the functionality to download each of the generated models in the scenario selection section together with the generation of all the defined reports. The exportation module, once the user selects a scenario and exports the data, generates a series of defined reports containing all the detailed information for the selected scenario.	Export files are stored into the Project Repository.	NBK (ES)
EXP-2	Data exportation	The outputs generated are retrieved from the Project Repository, BIM and CityGML repositories (if needed) are provided to the user through the GUI.	The GUI will give the functionality to download each of the generated models in the scenario selection section together with the generation of all the defined reports. The exportation module, once the user selects a scenario and exports the data, generates a series of defined reports containing all the detailed information for the selected scenario.	The user is able to download the export files.	NBK (ARG, ES)

4.2 Results of the test

Results of the different tests are described in the Table 13 below for the *Cuatro de Marzo* and *Mogel* case studies. As already explained, they are similarly reported for the *Polhem* district in D6.4.

Results of the individual tests are described in details for the *Cuatro de Marzo* district in Valladolid in the following sub-section. Results for the *Mogel* district are provided in annex of this document (see §9, p. 108).

Table 13: Results of end-to-end tests

Test Id	Name	*Cuatro de Marzo* district, Valladolid	*Mogel* district, Eibar
Data-1	Data upload CityGML	PASSED	PASSED
Data-2	CityGML with errors	PASSED	PASSED
Data-3	Data upload IFC	PASSED	PASSED
Data-4	IFC with errors	PASSED	PASSED
Matching-1	BIM-CityGML matching	PASSED	PASSED
Matching-2	Matching with errors	PASSED	PASSED
ES-2	System Vector generation	PASSED	PASSED
HVAC	HVAC zone identification	PASSED	PASSED
Unstr	Unstructured data	PARTIALLY PASSED	PARTIALLY PASSED
RegUval-1	U-values displayed	PASSED	PASSED
RegUval-2	U-values edited and stored	PASSED	PASSED
Baseline-1	Basic SIMMODEL generated	PASSED	PASSED
Baseline-2	Enriched SIMMODEL generated	PASSED	PASSED
BaselineDPI	Baseline DPI calculation	PASSED	PASSED
BasUval	Baseline U-values calculation and storage	PASSED	PASSED
ECM-2	Check strategies	PASSED	PASSED
P-Info	Project information retrieval	PASSED	PASSED
AM	Applicable matrix generation	PASSED	PASSED
Uval-proc	U-values processed	NOT IMPLEMENTED	NOT IMPLEMENTED
SV	Scenario vector generation	PASSED	PASSED

IC	Instances creation	PASSED	PASSED
Evaluation DPI	Scenario DPI calculation	PASSED	PASSED
EE	Evaluator execution	PASSED	PASSED
OPT-1	OPT execution	PASSED	PASSED
OPT-3	Generation of the Pareto Front	PASSED	PASSED
EXP-1	Generation of data to be exported	PASSED	PASSED
EXP-2	Data exportation	PASSED	PASSED

4.3 Detailed results of end-to-end tests

This section describes the results obtained for each end-to-end tests. The results provided below are related to the *Cuatro de Marzo* district in Valladolid.

Data-1: Data upload CityGML

In this test, the CityGML file of the district under study is uploaded to the platform, checked to analyse its correctness and stored into the CityGML repository. Using the GUI, the user starts by uploading the CityGML file and then checks it (Figure 22). If the uploaded file is correct, the GUI indicates to the user a “Valid” text indicating that the file is checked and properly stored (Figure 23). The user can then proceed to the next step.

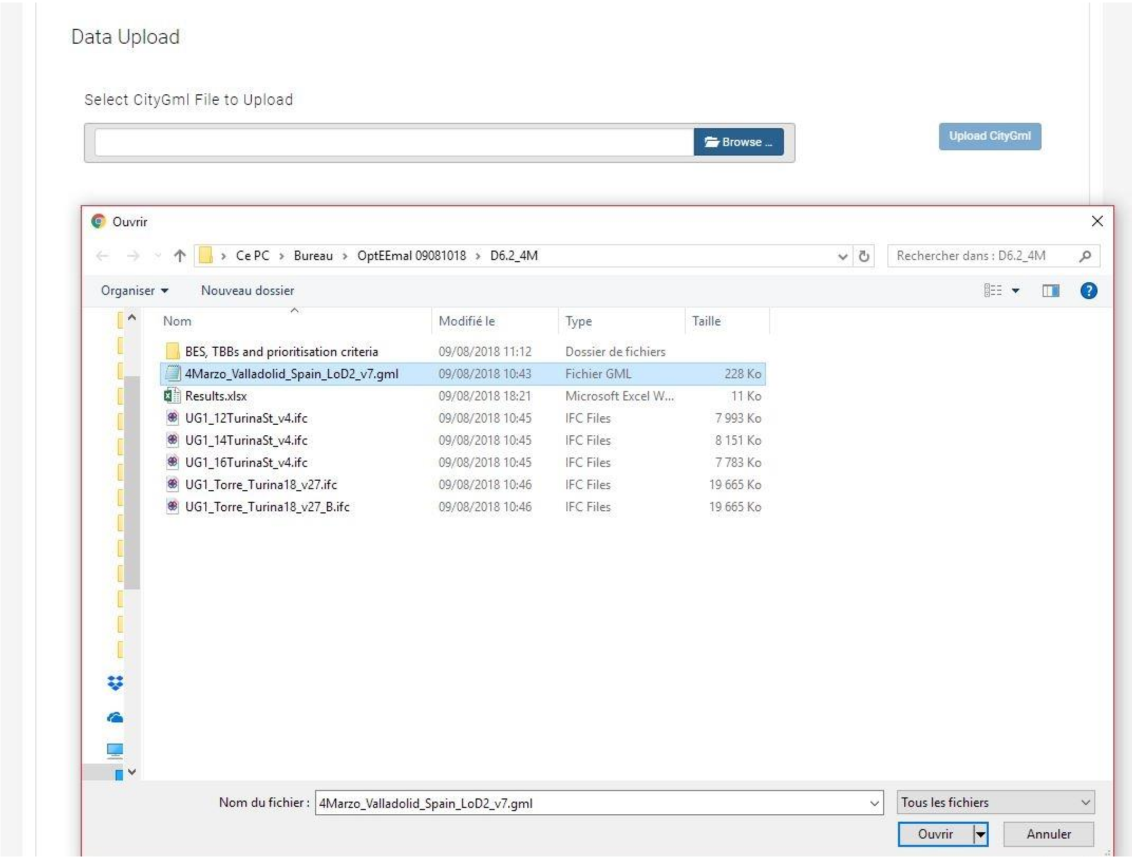


Figure 22: GUI – Selecting the CityGML file to be uploaded

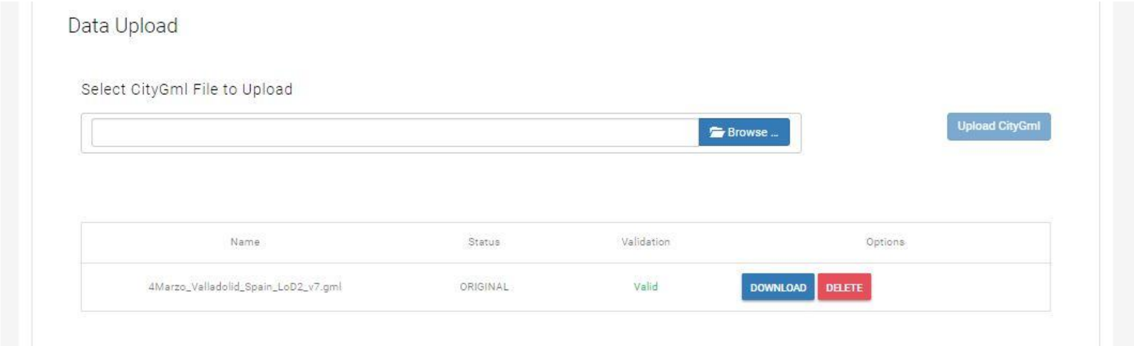


Figure 23: GUI – Correct upload of the CityGML file

The result of this test is PASSED.

Data-2: CityGML with errors

In this test, an incorrect CityGML is uploaded in order to check both the checking process and the message provided to the user. The results of this test is illustrated in the Figure 24 below.

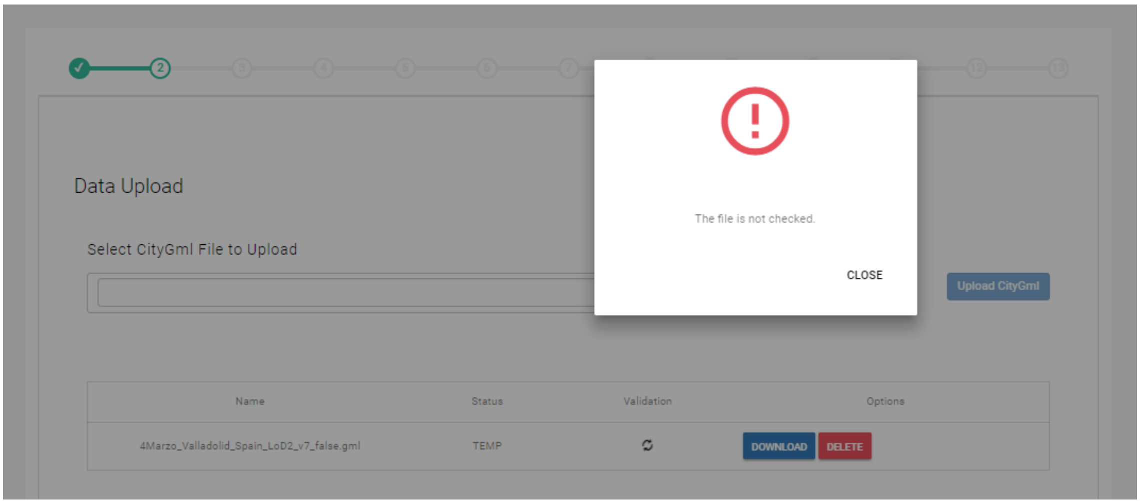


Figure 24: GUI – Message for a non checked CityGML file

The result of this test is PASSED.

Data-3: Data upload IFC

In this test, the IFC files of the different buildings under study are uploaded to the platform, checked to analyse their correctness and stored into the BIM repository. Using the GUI, the user starts by uploading the BIM files and then checks them one by one (Figure 25). If the uploaded file is correct, the GUI indicates to the user a "Valid" text indicating that the file is checked and properly stored (Figure 26). The user can then proceed to the next step.

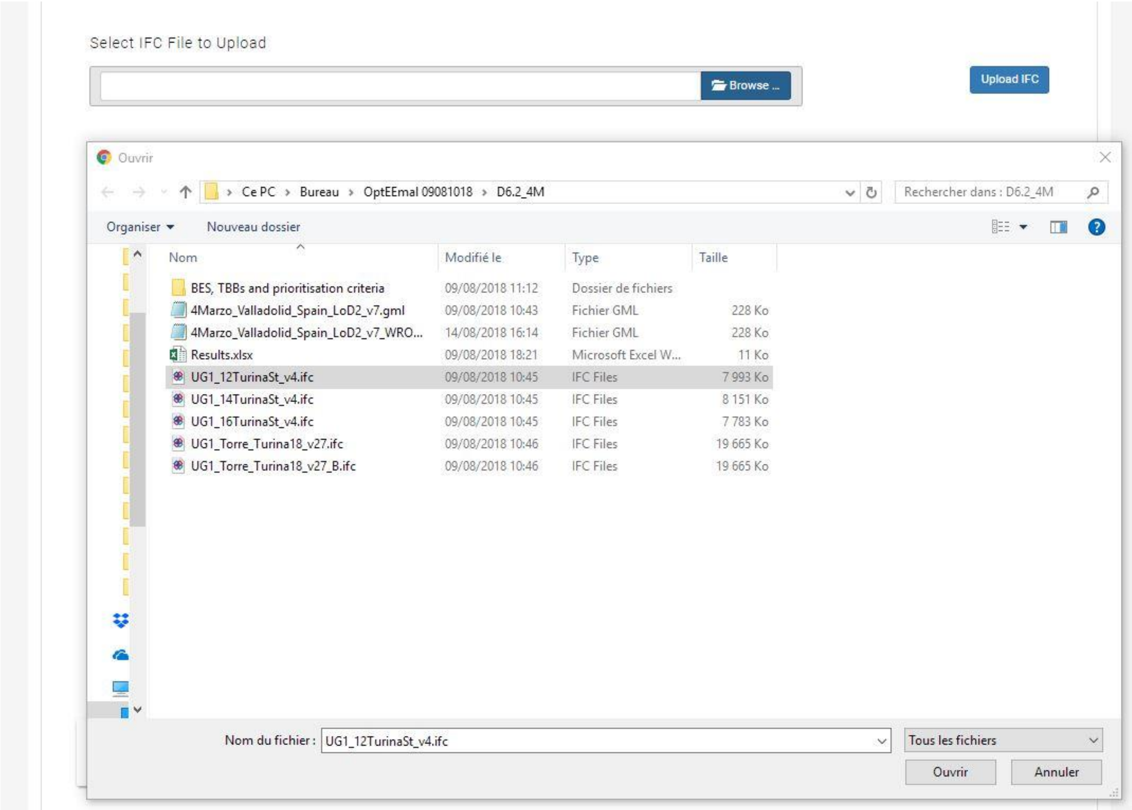


Figure 25: GUI - Selecting the IFC file to be uploaded

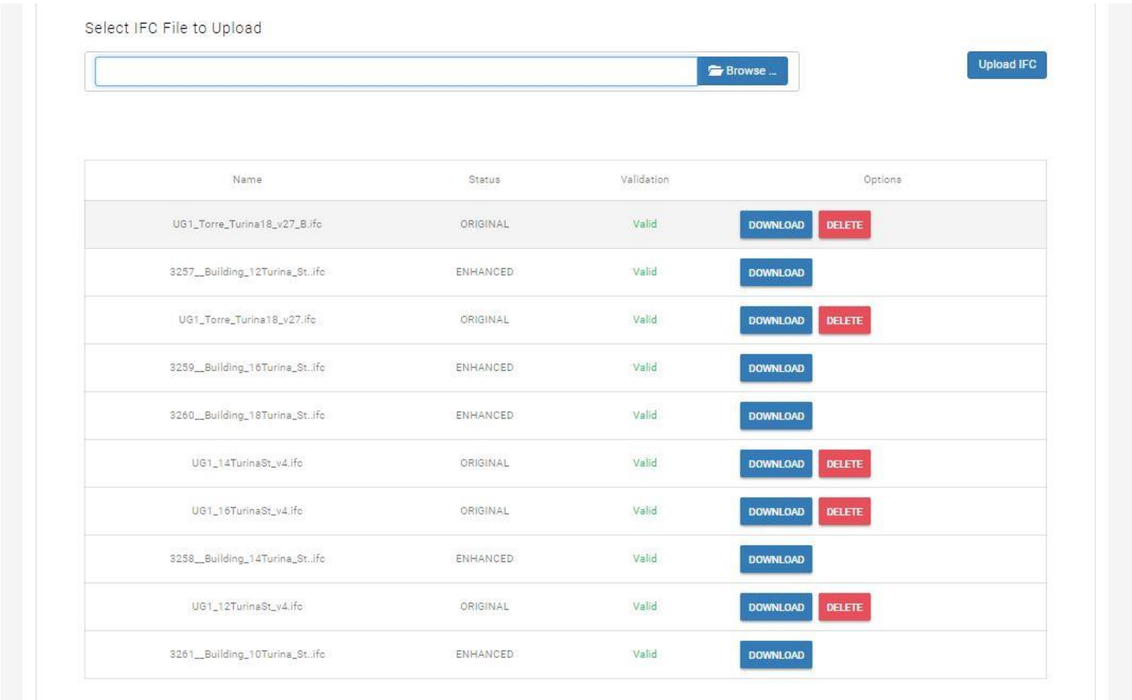


Figure 26: GUI – Correct upload of the different IFC files

The result of this test is PASSED.

Data-4: IFC with errors

In this test, a wrong IFC file is updated in order to verify that the checking process is working as required. The result of the test is mentioned in the Figure 28 and Figure 28 below.

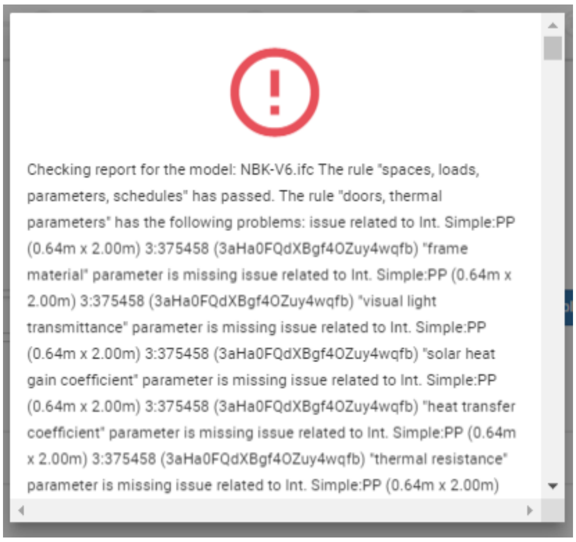


Figure 27: GUI – Feedback provided to the user for an incorrect IFC file

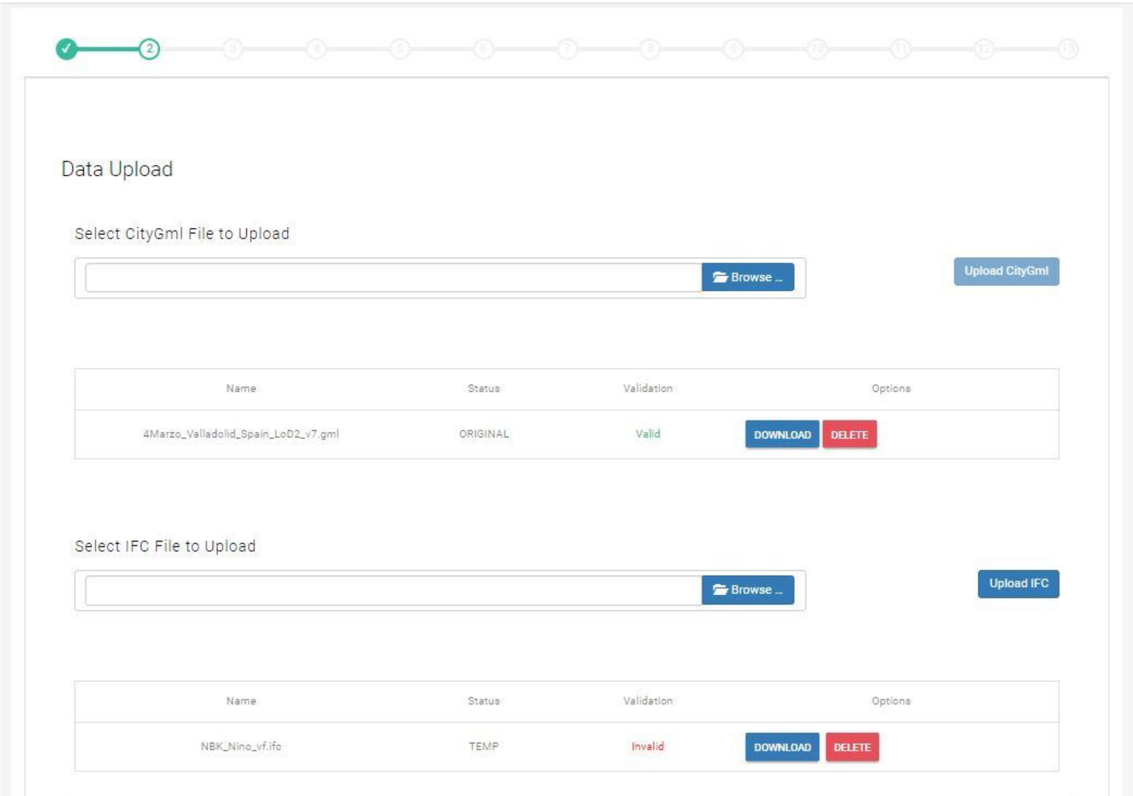


Figure 28: GUI –Invalid IFC file listed in the GUI

The result of this test is PASSED.

Matching-1: BIM-CityGML matching

In this test, the link between the uploaded IFC files and the CityGML file has to be performed. The result of this link has to be stored into the Link Database and in the Project Repository for parameters like the altitude for instance.

To perform this matching, the GUI of the platform has been used (Figure 29). In this GUI, the user has to select a building footprint on the map of the district and then select the corresponding IFC model in the top left corner. After clicking “Create Matching” button, the footprint of the IFC model is visible on the map and the user is able to make it fitting perfectly with the one of the CityGML model file through rotation or translation (Figure 30).

Once done for each building of the district, the user is able to save this matching (Figure 31). Once saved, the building footprints are then highlighted in green and the links defined by the user are then stored into the Link Database and in the Project Repository.

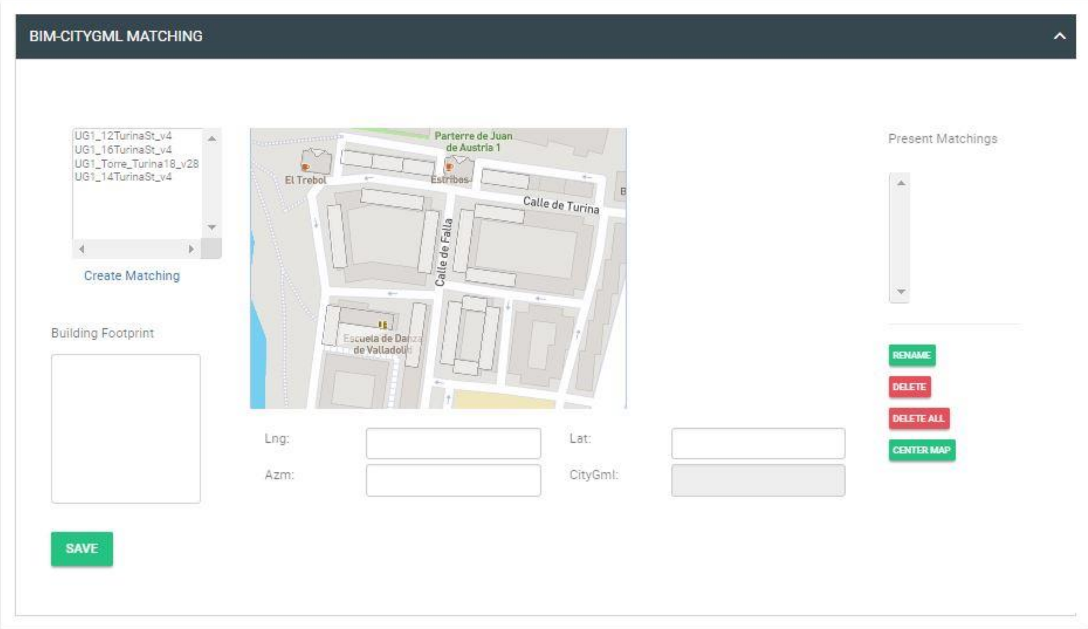


Figure 29: GUI – Matching interface before proceeding to the matching

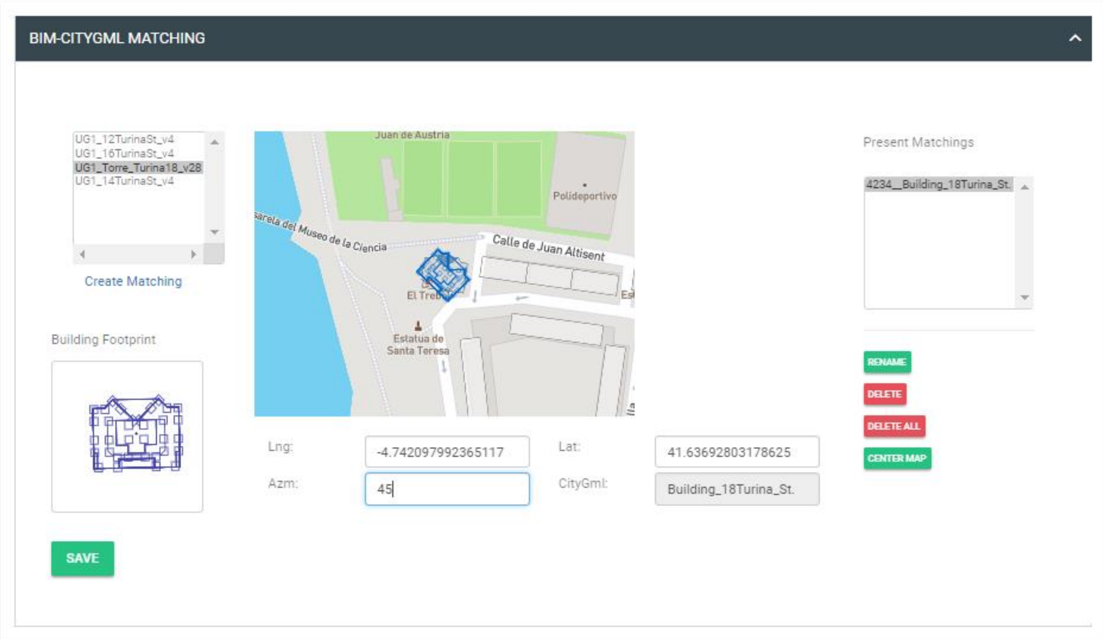


Figure 30: GUI – Moving the IFC footprint to match it with the CityGML footprint

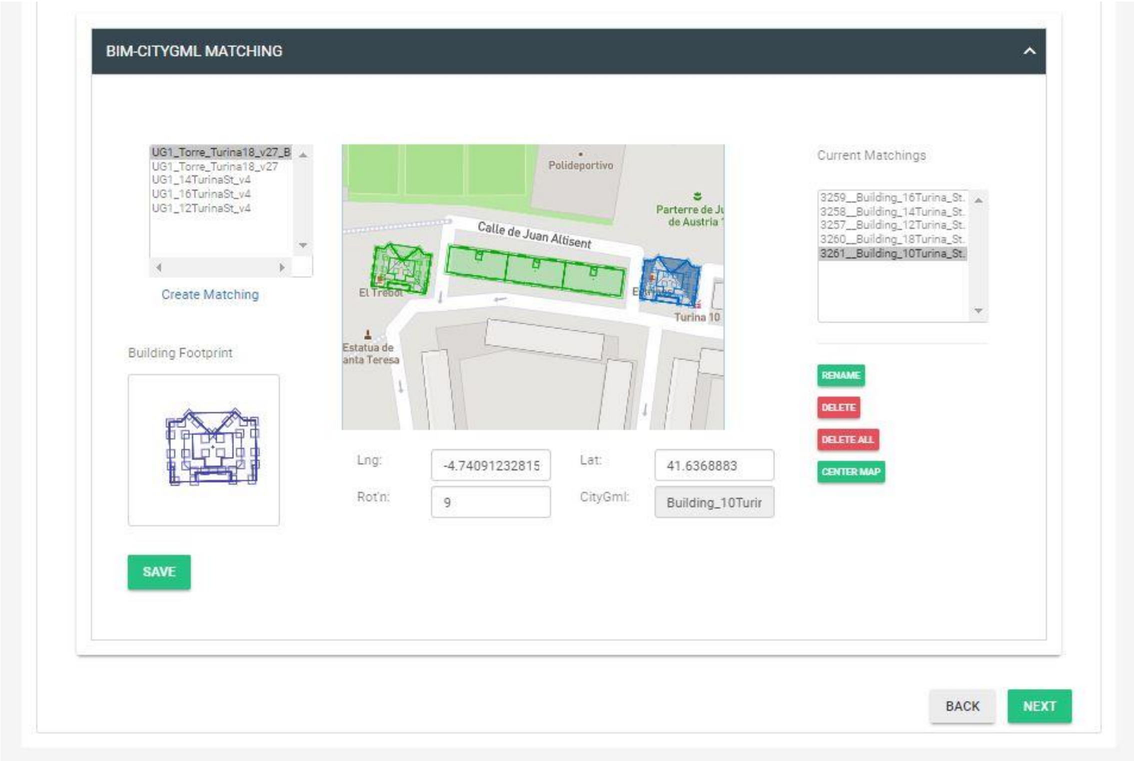


Figure 31: GUI – Saved matching of CItyGML and BIM files

The result of this test is PASSED.

Matching-2: Matching with errors

From a theoretical point of view, it is not possible to perform a wrong matching. Indeed, the user is able to match any IFC footprint with any CityGML footprint and no checking are made by the tool. This is done because it is impossible to match perfectly (with a precision of a mm) the two footprints. Hence, having an automatic matching process would results in an error almost all the times. This is not important from the calculation perspective because matchings are used mainly for shadows calculations and these calculations do not required a precision of a mm.

Considering this, this test is considered as PASSED even though no message is provided to the user. It is up to the user to verify that the performed matchings are OK. This has been explained in details in the "How to use" manual of the platform.

The result of this test is PASSED.

ES-2: System vector generation

After the matching, the user has to fulfil the Energy System questionnaire in order to provide to the platform the necessary information related to the district and building energy systems. The objective is to generate the system vector which will then be stored into the Project Repository. Using the GUI, the user has first to select the buildings for which he wants to answer the questionnaire. Once at least one building is selected, the questionnaire is visible and can be fulfilled by the user (Figure 32). The user has then to go through the whole questionnaire and provide an answer for all the questions (Figure 33).

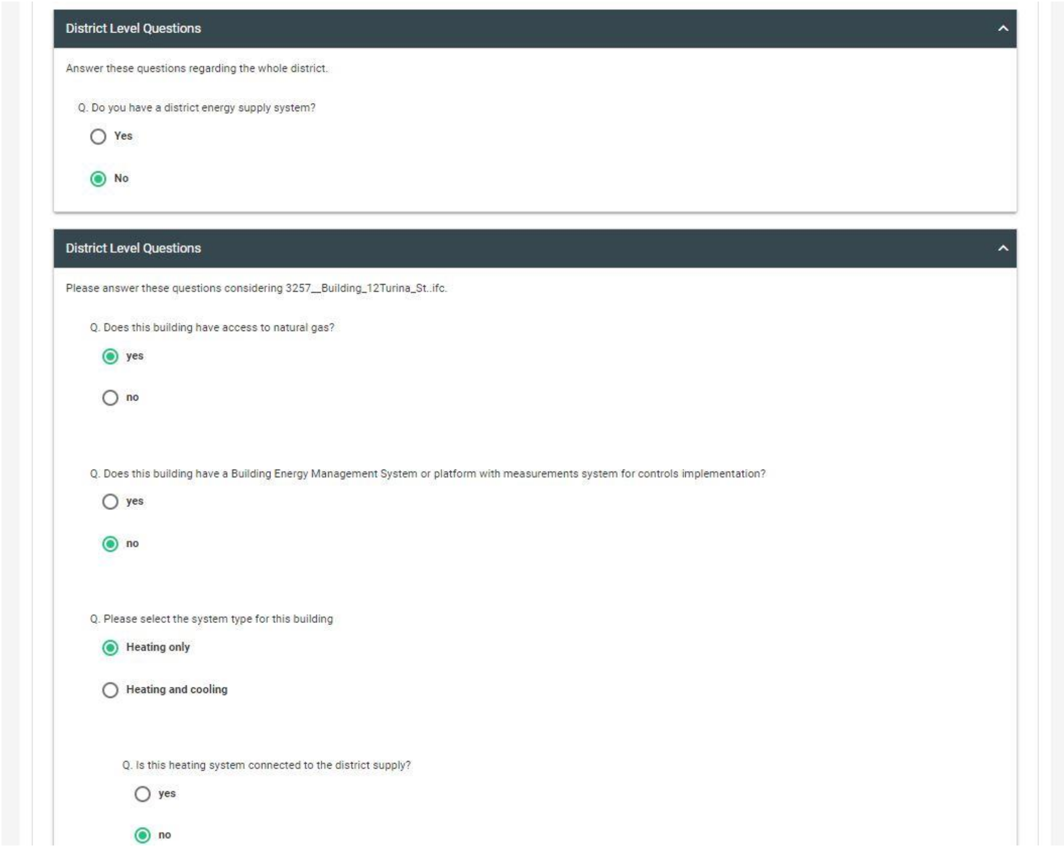


Figure 32: GUI – BES questionnaire completion

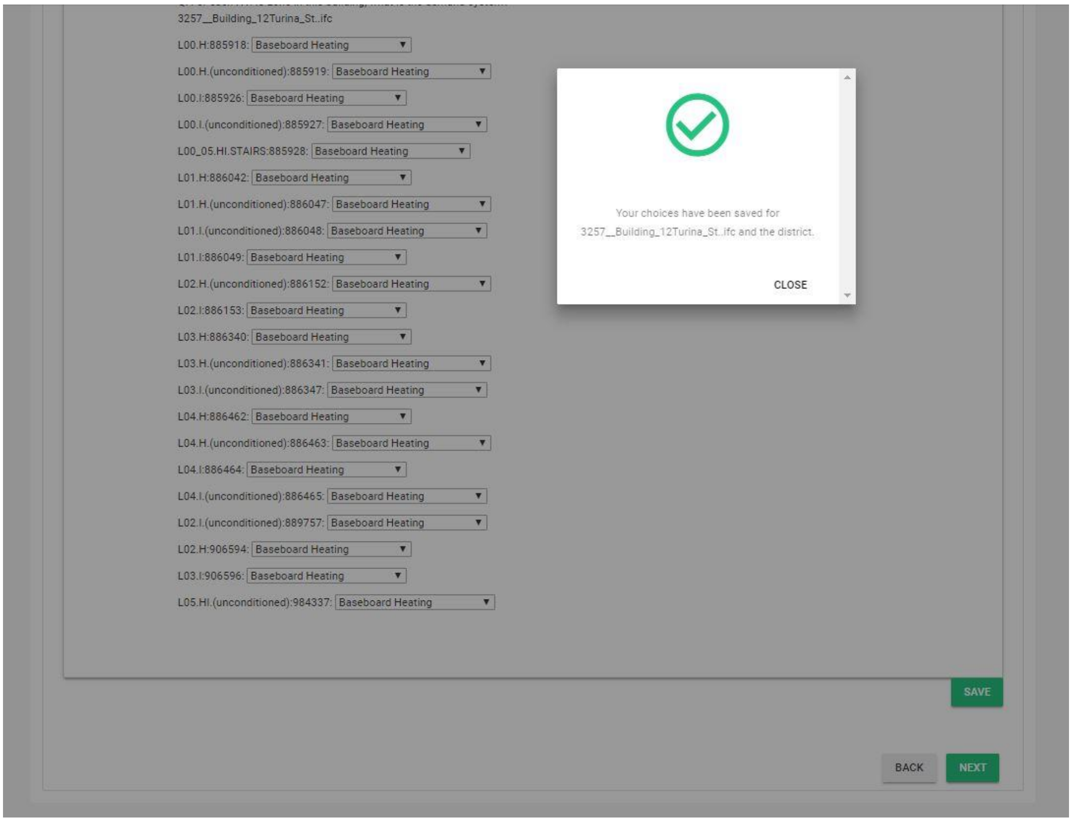


Figure 33: GUI – Successful completion of the BES questionnaire

Once the questionnaire is fulfilled for all the buildings of the district, then the user can save its answers and the system vector is generated (Figure 34).


```
project_id:                                              280
SupplySystems:                                           {}
▼Buildings:
  ▼4284:
      building_id:                                       "4284"
      AccessToNaturalGas:                                true
      ExistBEMS:                                         false
    ▼SupplySystems:
      ▼B_4284_AC.BL.SP.PL.01:
          id:                                            "AC.BL.SP.PL.01"
          category:                                      "Boiler Plant"
          total_capacity:                                "180"
          boiler_type:                                   "Non-condensing"
          fuel_type:                                     "Natural Gas"
          efficiency:                                    "0.722"
        ▼controller_properties:
            SystemStartTime:                             "unknown"
            SystemStopTime:                              "unknown"
            HotWaterSetPoint:                            "unknown"
    ▼DemandSystems:
      ▼B_4284_AC.DE.HZ.DM.01_L00.D.(unconditioned):906529:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L00.D.(unconditioned):906529"
      ▼B_4284_AC.DE.HZ.DM.01_L00.D:906528:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L00.D:906528"
      ▼B_4284_AC.DE.HZ.DM.01_L00.E.(unconditioned):906531:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L00.E.(unconditioned):906531"
      ▼B_4284_AC.DE.HZ.DM.01_L00.E:906530:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L00.E:906530"
      ▼B_4284_AC.DE.HZ.DM.01_L00_05.DE.STAIRS:855479:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L00_05.DE.STAIRS:855479"
      ▼B_4284_AC.DE.HZ.DM.01_L01.D.(unconditioned):906525:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L01.D.(unconditioned):906525"
      ▼B_4284_AC.DE.HZ.DM.01_L01.D:906524:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L01.D:906524"
      ▼B_4284_AC.DE.HZ.DM.01_L01.E.(unconditioned):906527:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L01.E.(unconditioned):906527"
      ▼B_4284_AC.DE.HZ.DM.01_L01.E:906526:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
          HVACZone_id:                                   "L01.E:906526"
      ▼B_4284_AC.DE.HZ.DM.01_L02.D.(unconditioned):906521:
          demandSystem_id:                               "AC.DE.HZ.DM.01"
```


Figure 34: Extract of the generated system vector JSON file (first lines)

The result of this test is PASSED.

HVAC: HVAC zone identification

To perform this test, it has been checked that HVAC zones defined by the user in the BIM models are correctly retrieved from the models and presented to the user so that he can select the relevant demand system in the BES questionnaire. As presented in the Figure 33 above, the different HVAC zones of the building under study are well presented to the user and he is able to select the correct demand system. Moreover, as presented in the previous test, results of its answers are correctly included in the system vector (Figure 34).

The result of this test is PASSED.

Unstr: Unstructured data

The collection of unstructured data has been tested using the GUI. Information are properly retrieved but not correctly displayed to the user (Figure 35). Considering that this test is not critical in the execution of the platform from end-to-end, this test has been delayed for the time being.

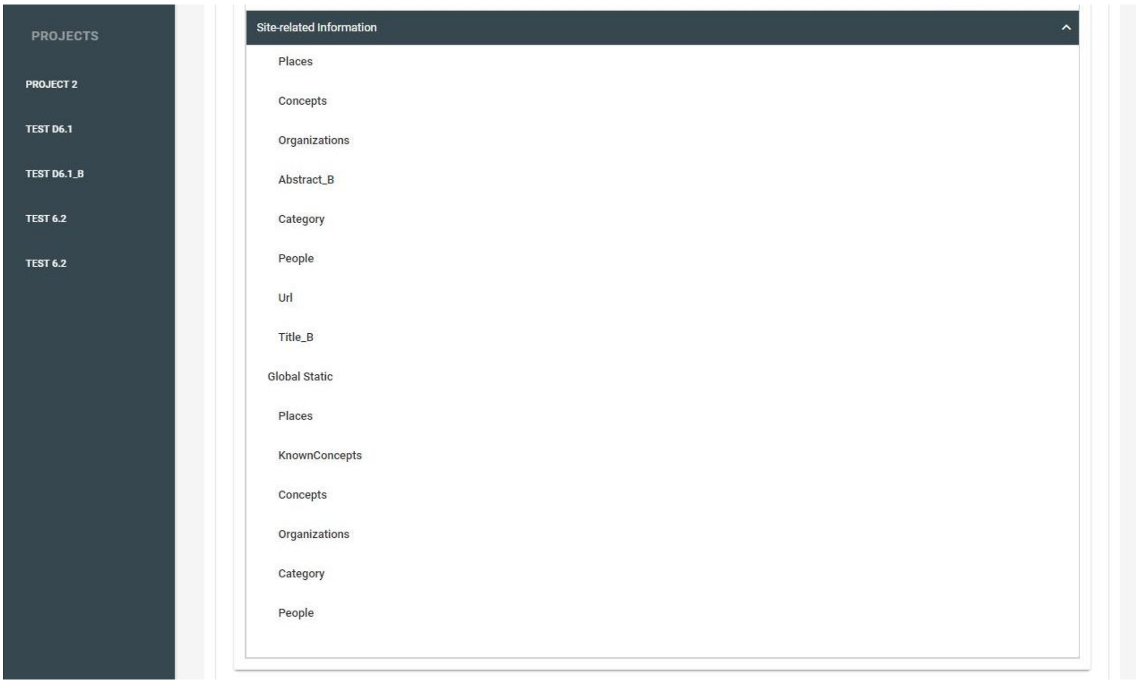
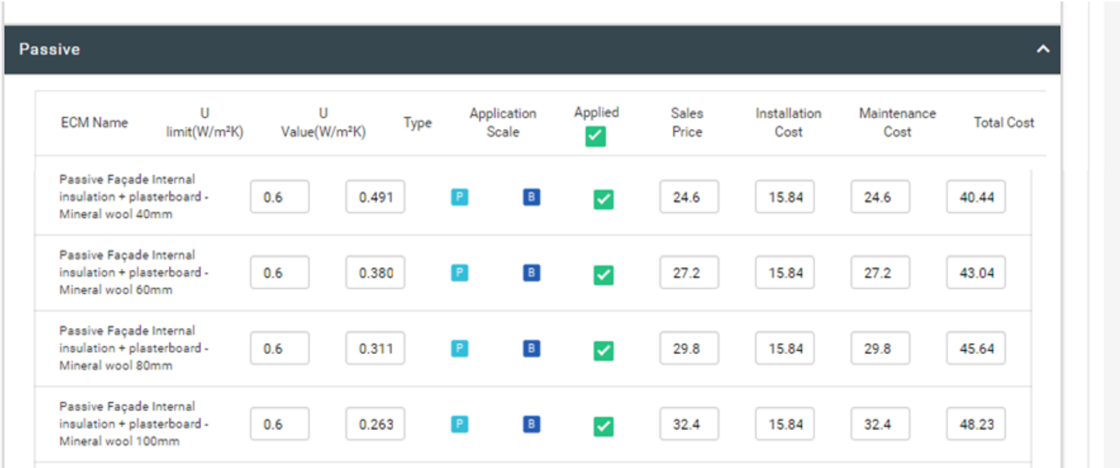


Figure 35: GUI – Current status of the unstructured data related GUI (*Cuatro de Marzo* district)

The result of this test is PARTIALLY PASSED.

RegUval-1: U-values displayed

This new functionality (not implemented at TRL5) allows the user to visualise, in the GUI, the U-value of the regulation for the different passive elements of the building. Similarly, the user is able to visualise the U-value associated with the different passive ECMs (when relevant). This functionality allows the user to select/discard an ECM considering the regulation in terms of U-value requirements (Figure 36).



Passive

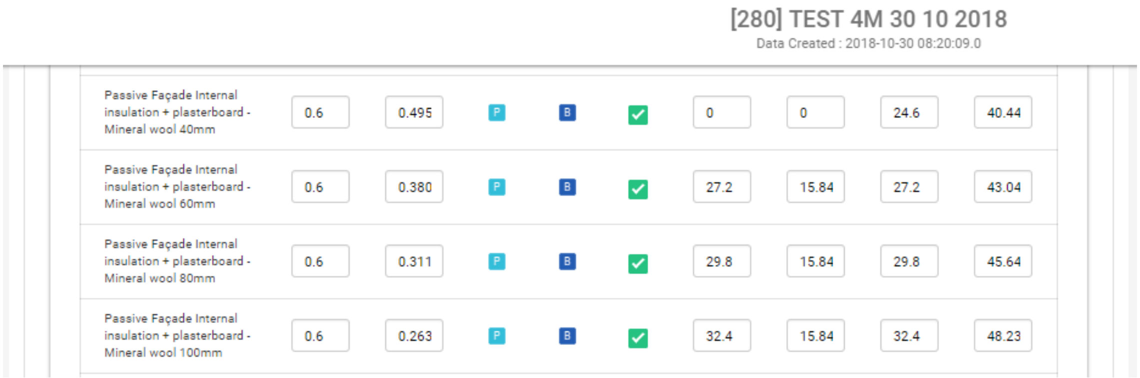
ECM Name	U limit(W/m²K)	U Value(W/m²K)	Type	Application Scale	Applied	Sales Price	Installation Cost	Maintenance Cost	Total Cost
Passive Façade Internal insulation + plasterboard - Mineral wool 40mm	0.6	0.491	P	B	✓	24.6	15.84	24.6	40.44
Passive Façade Internal insulation + plasterboard - Mineral wool 60mm	0.6	0.380	P	B	✓	27.2	15.84	27.2	43.04
Passive Façade Internal insulation + plasterboard - Mineral wool 80mm	0.6	0.311	P	B	✓	29.8	15.84	29.8	45.64
Passive Façade Internal insulation + plasterboard - Mineral wool 100mm	0.6	0.263	P	B	✓	32.4	15.84	32.4	48.23

Figure 36: GUI - Regulation and ECM U-values displayed in the GUI

The result of this test is PASSED.

RegUval-2: U-values edited and stored

This new functionality is associated to the previous one. It allows the user to modify the U-values considered in the calculation and the associated parameters (cost and price values). In this test, the U-values associated with one ECM (the first one displayed in the figure below) is modified and saved for considerations in the next steps of the platform (Figure 37 and Figure 38).



[280] TEST 4M 30 10 2018

Data Created : 2018-10-30 08:20:09.0

Passive Façade Internal insulation + plasterboard - Mineral wool 40mm	0.6	0.495	P	B	✓	0	0	24.6	40.44
Passive Façade Internal insulation + plasterboard - Mineral wool 60mm	0.6	0.380	P	B	✓	27.2	15.84	27.2	43.04
Passive Façade Internal insulation + plasterboard - Mineral wool 80mm	0.6	0.311	P	B	✓	29.8	15.84	29.8	45.64
Passive Façade Internal insulation + plasterboard - Mineral wool 100mm	0.6	0.263	P	B	✓	32.4	15.84	32.4	48.23

Figure 37: GUI – Modified U-value for one passive ECM

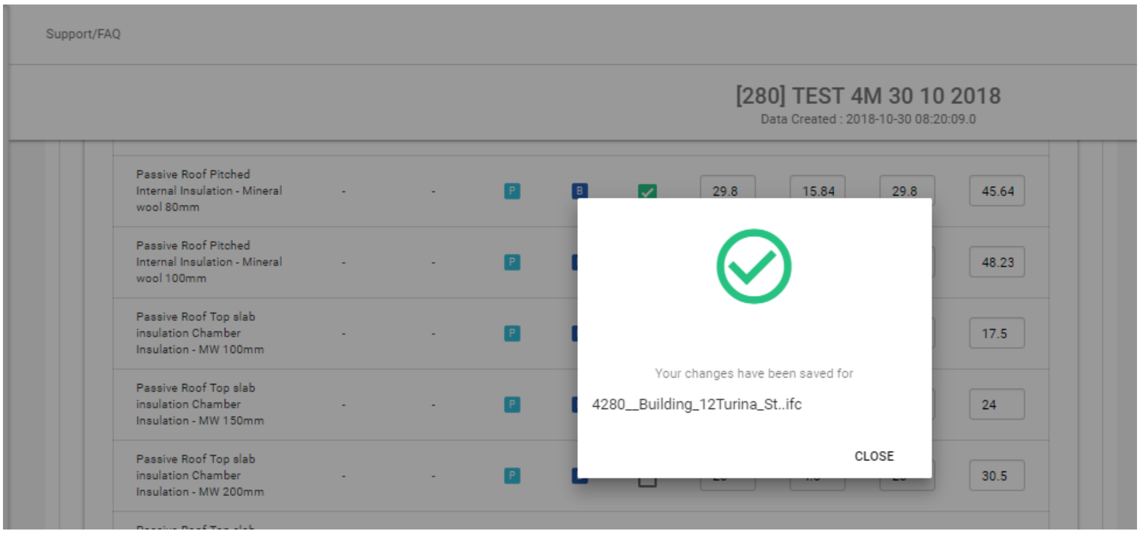


Figure 38: GUI – Message indicating the correct saving of the new U-value for the modified passive ECM

The result of this test is PASSED.

Baseline-1: Basic SIMMODEL generated

In this test, the different simulation data models – building simulation models represented according to SimModel ontology – are generated as a result of a data integration process. Data sources include inserted information about the project, IFC models including second level space boundaries (CBIP tool), shadows among buildings (DNS tool), automatic zoning and other elements (SimModel Enrichment tool), and the data collected from the geo-clustering service that is stored into the Context Repository. Figure 39 shows an excerpt of the data model.

```
@prefix schema: <http://schema.org/> .
@prefix simbldg: <http://www.opteemal.eu/schema/2017/01/BuildingModel#> .
@prefix inst:  <http://opteemal-project.eu/resource/simmodel/174/0/0/3546#> .
@prefix simgeom: <http://www.opteemal.eu/schema/2017/01/ResourcesGeometry#> .
@prefix simmodel: <http://www.opteemal.eu/schema/2017/01/Model#> .
@prefix simcore: <http://www.opteemal.eu/schema/2017/01/SimModelCore#> .

inst:IfcBuildingStorey_133
        a                                   simbldg:SimBuildingStory_BuildingStory_Default ;
        simbldg:bldgStoryInSpatialContainer inst:IfcBuilding_120 ;
        simbldg:name                        "Level 1" ;
        simcore:compositionType             "ELEMENT" ;
        simcore:ifcGlobalID                 "16Y9ahzJ5DjhmNdLGQnkZc" ;
        simcore:isTemplateObject             false ;
        simcore:longName                    "Level 1" ;
        simcore:placement                   inst:IfcLocalPlacement_131 ;
        simcore:refId                       "ID133"^^xsd:ID ;
        simcore:simModelSubtype             "Default" ;
        simcore:simModelType                "BuildingStory" ;
        simcore:simUniqueID                 "not defined" ;
        simcore:sourceModelObjectType       "IfcBuildingStorey" ;
        simcore:sourceModelSchema           "IFC4" .
...

inst:IfcWall_2263  a                        simbldg:SimWall_Wall_Default ;
        simbldg:materialLayerSet            inst:IfcMaterialLayerSet_2370 ;
        simbldg:wallGrossSideArea           "13.5980160000955"^^xsd:double ;
        simcore:containingSpatialStructure  inst:IfcBuildingStorey_133 ;
        simcore:ifcGlobalID                 "1ePVfoWu9969NqC_VZUMUC" ;
        simcore:isTemplateObject            false ;
        simcore:name                        "Basic Wall:Case1-extwall:182667" ;
        simcore:objectType                  "Wall" ;
        simcore:refId                       "ID2263"^^xsd:ID ;
        simcore:simModelSubtype             "Default" ;
        simcore:simModelType                "Wall" ;
        simcore:simUniqueID                 "not defined" ;
        simcore:sourceModelObjectType       "IfcWall" ;
        simcore:sourceModelSchema           "IFC4" ;
        simcore:tag                         "not defined" .
...
```

Figure 39: Excerpt from a building energy simulation model (SimModel) showing an instance that defines the basic data of the building and other that defined the data of a wall element.

The result of this test is PASSED.

Baseline-2: Enriched SIMMODEL generated

Once a SimModel has been generated as a result of the data integration process, this SimModel has to be enriched with additional information. For example, Figure 39 includes the description of a generic wall element that is enriched through this process by replacing it by a more specific wall type: Exterior above grade, as shown in Figure 40. This conversion is the result of inferring some surrounding conditions.

```
...
inst:SimWall_Wall_ExteriorAboveGrade_ID1000920
        a                                          simbldg:SimWall_Wall_ExteriorAboveGrade ;
        simbldg:materialLayerSet                   inst:SimMaterialLayerSet_OpaqueLayerSet_Default_ID1002509 ;
        simbldg:simWall_ConstructionName           inst:SimMaterialLayerSet_OpaqueLayerSet_Default_ID1002509 ;
        simbldg:simWall_NumbVerts                  "4.0"^^xsd:double ;
        simbldg:simWall_OutsdBndCond               "Outdoors" ;
        simbldg:simWall_SpaceName                  inst:SimSpace_Occupied_Default_ID1002383 ;
        simbldg:simWall_SunExposure                "SunExposed" ;
        simbldg:simWall_SurfType                   "Wall" ;
        simbldg:simWall_Vertex_1_120_X_Coord       inst:DoubleList_HBXLHWYAKCMM_1000 ;
        simbldg:simWall_Vertex_1_120_Y_Coord       inst:DoubleList_TKKE6QVPBX4Q_1000 ;
        simbldg:simWall_Vertex_1_120_Z_Coord       inst:DoubleList_C2SQL9WB1G50_1000 ;
        simbldg:simWall_ViewFactToGnd              "0.5"^^xsd:double ;
        simbldg:simWall_WindExposure               "WindExposed" ;
        simbldg:simWall_ZoneName                   inst:SimSpatialZone_ThermalZone_Default_ID1000844 ;
        simbldg:wallGrossSideArea                  "17.185725123129032"^^xsd:double ;
        simbldg:wallNetSideArea                    "17.185725123129032"^^xsd:double ;
        simcore:containingSpatialStructure         inst:SimBuildingStory_BuildingStory_Default_ID1001571 ;
        simcore:ifcGlobalID                        "1ePVfoWu9969NqC_VZUMJ5" ;
        simcore:isTemplateObject                   false ;
        simcore:name                               "SURFACE-10016" ;
        simcore:objectType                         "Wall" ;
        simcore:refId                              "ID1000920"^^xsd:ID ;
        simcore:simModelSubtype                    "ExteriorAboveGrade" ;
        simcore:simModelType                       "Wall" ;
        simcore:simUniqueID                        "7a3cf6aa-081e-4dae-888c-47692a554cae" ;
        simcore:sourceModelObjectType              "SimWallWallDefault" ;
        simcore:sourceModelSchema                  "TucMapper" ;
        simcore:tag                                "not defined" .
...
```

Figure 40: Excerpt from a building energy simulation model (SimModel) after having been enriched.

The result of this test is PASSED.

Baseline DPI: Baseline DPI calculation

At this step, the user has introduced all the information (and the platform has generated the complementary one) needed to run the baseline calculation. Before starting the calculation process, a warning message is provided to the user (Figure 41).

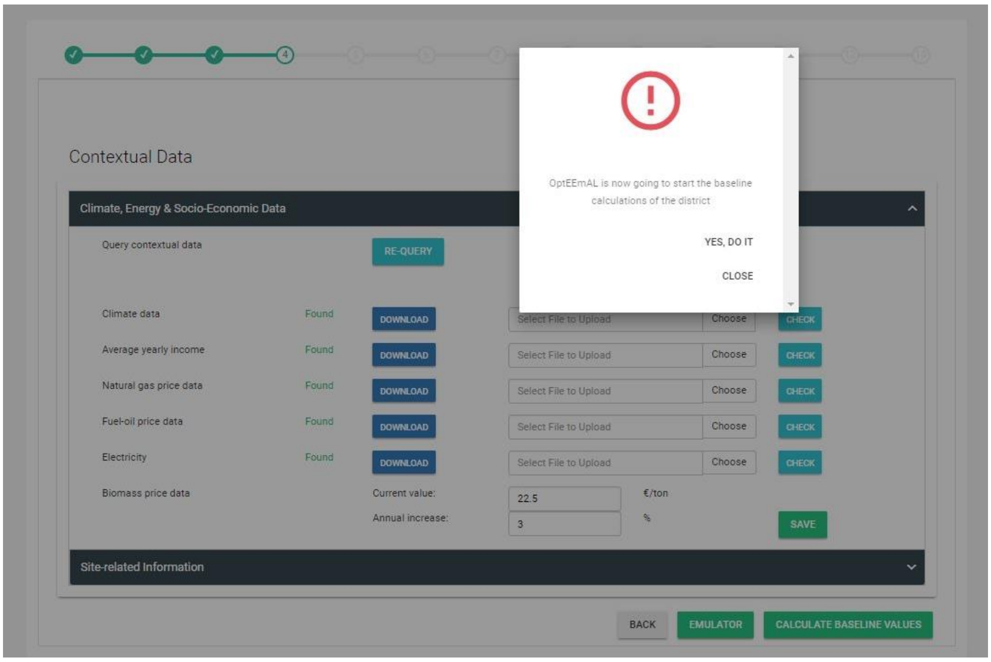


Figure 41: GUI – Warning message before launching the baseline calculation process

After validation of the warning message, the baseline calculation process is launched (Figure 42) and the baseline enriched SIMMODEL is used for the calculation of Energy, Economic, Environmental, and others DPIs (Figure 40). All the calculated DPIs have to be stored into the Project Repository.

Using the Simulation module that includes the EnergyPlus service, ECO service, NEST service and HVAC service, the baseline DPIs are calculated and showed using the GUI (Figure 43). The “BaselineDPI” json (Figure 44) is also generated at this step and stored into the Project Repository.

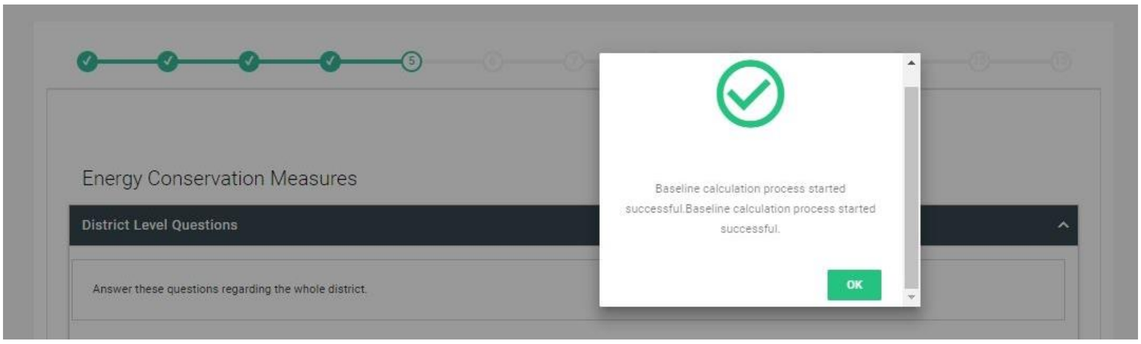
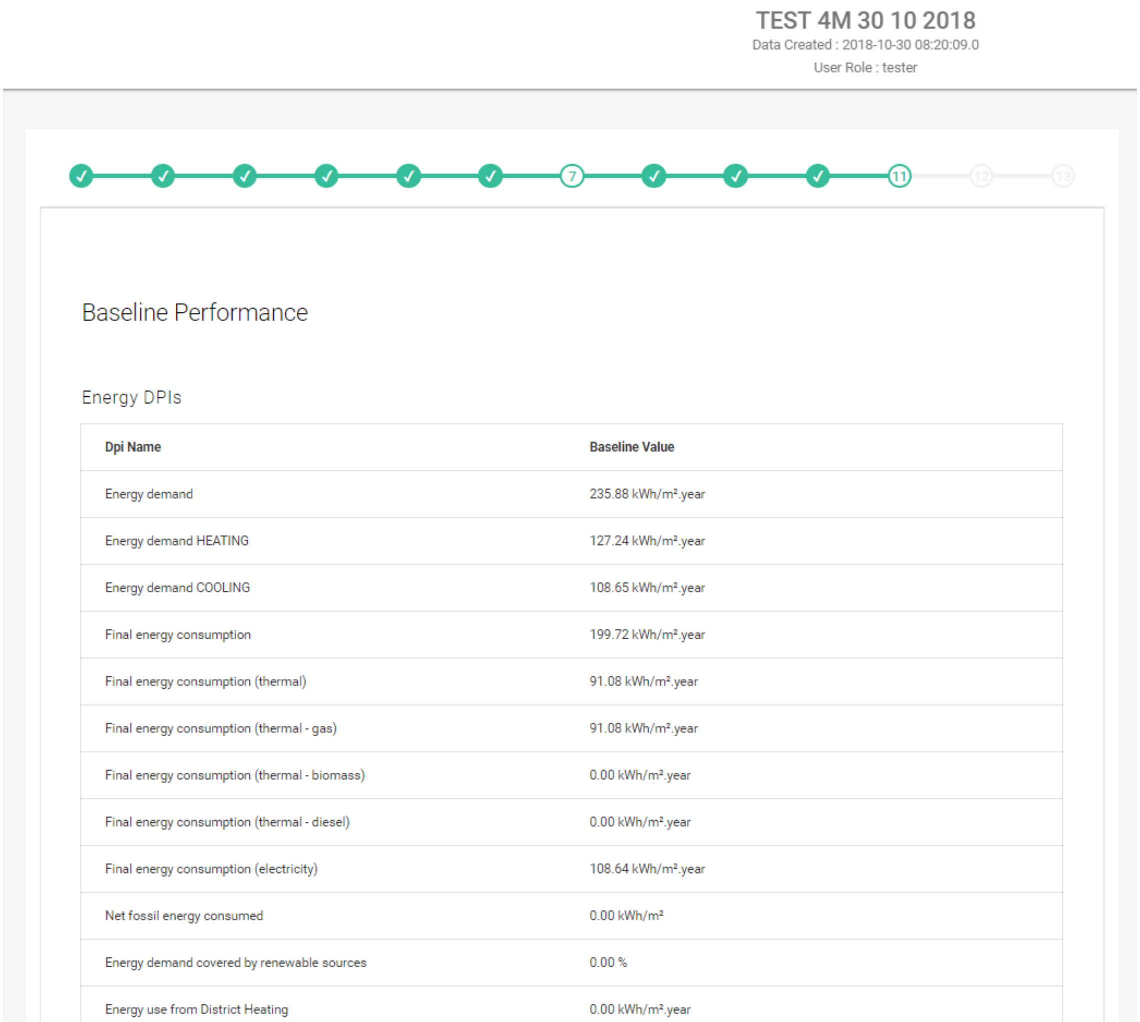


Figure 42: GUI – Launching the Baseline DPI calculation process



Dpi Name	Baseline Value
Energy demand	235.88 kWh/m².year
Energy demand HEATING	127.24 kWh/m².year
Energy demand COOLING	108.65 kWh/m².year
Final energy consumption	199.72 kWh/m².year
Final energy consumption (thermal)	91.08 kWh/m².year
Final energy consumption (thermal - gas)	91.08 kWh/m².year
Final energy consumption (thermal - biomass)	0.00 kWh/m².year
Final energy consumption (thermal - diesel)	0.00 kWh/m².year
Final energy consumption (electricity)	108.64 kWh/m².year
Net fossil energy consumed	0.00 kWh/m²
Energy demand covered by renewable sources	0.00 %
Energy use from District Heating	0.00 kWh/m².year

Figure 43: GUI: Baseline DPIs

```
Projectid:     280
▼opts:
  ▼0:
    ▼scenariosdpis:
      ▼0:
          id:      0
        ▼dpis:
          ▼0:
              dpi:    "COM01"
              value:  0
          ▼1:
              dpi:    "ECO01.0"
              value:  31.946360799143918
          ▼2:
              dpi:    "ECO01.1"
              value:  6.05656031604587
          ▼3:
              dpi:    "ECO01.2"
              value:  0
          ▼4:
              dpi:    "ECO01.3"
              value:  0
          ▼5:
              dpi:    "ECO01.4"
              value:  25.889800483098046
          ▼6:
              dpi:    "ECO03"
              value:  8907180.699998729
          ▼7:
              dpi:    "ENE01.0"
              value:  235.88472041828257
          ▼8:
              dpi:    "ENE01.A"
              value:  127.23836667224305
          ▼9:
              dpi:    "ENE01.B"
              value:  108.64635374603951
          ▼10:
              dpi:    "ENE02.0"
              value:  199.7197783670926
          ▼11:
              dpi:    "ENE02.A"
              value:  91.07609497813337
          ▼12:
              dpi:    "ENE02.A.1"
              value:  91.07609497813337
          ▼13:
              dpi:    "ENE02.A.2"
              value:  0
```


Figure 44: Extract of the baseline DPIs JSON file (first lines)

The result of this test is PASSED.

BasUval: Baseline U-values calculation and storage

As already mentioned, the U-value functionality has only been implemented as a proof of concept for the *Cuatro de Marzo* and *Mogel* case studies. In this test, baseline U-values are calculated and then stored into the project repository. For this proof of concept, the calculations were done outside the platform and the associated results were included manually in the platform.

This functionality needs further development (full integration in the platform) but its principles were showed and the test is considered to be PASSED.

ECM-2: Check strategies

In this test, the user is able to select/deselect the ECM proposed by the platform (based on the answers provided in the ECM questionnaire, Figure 45).

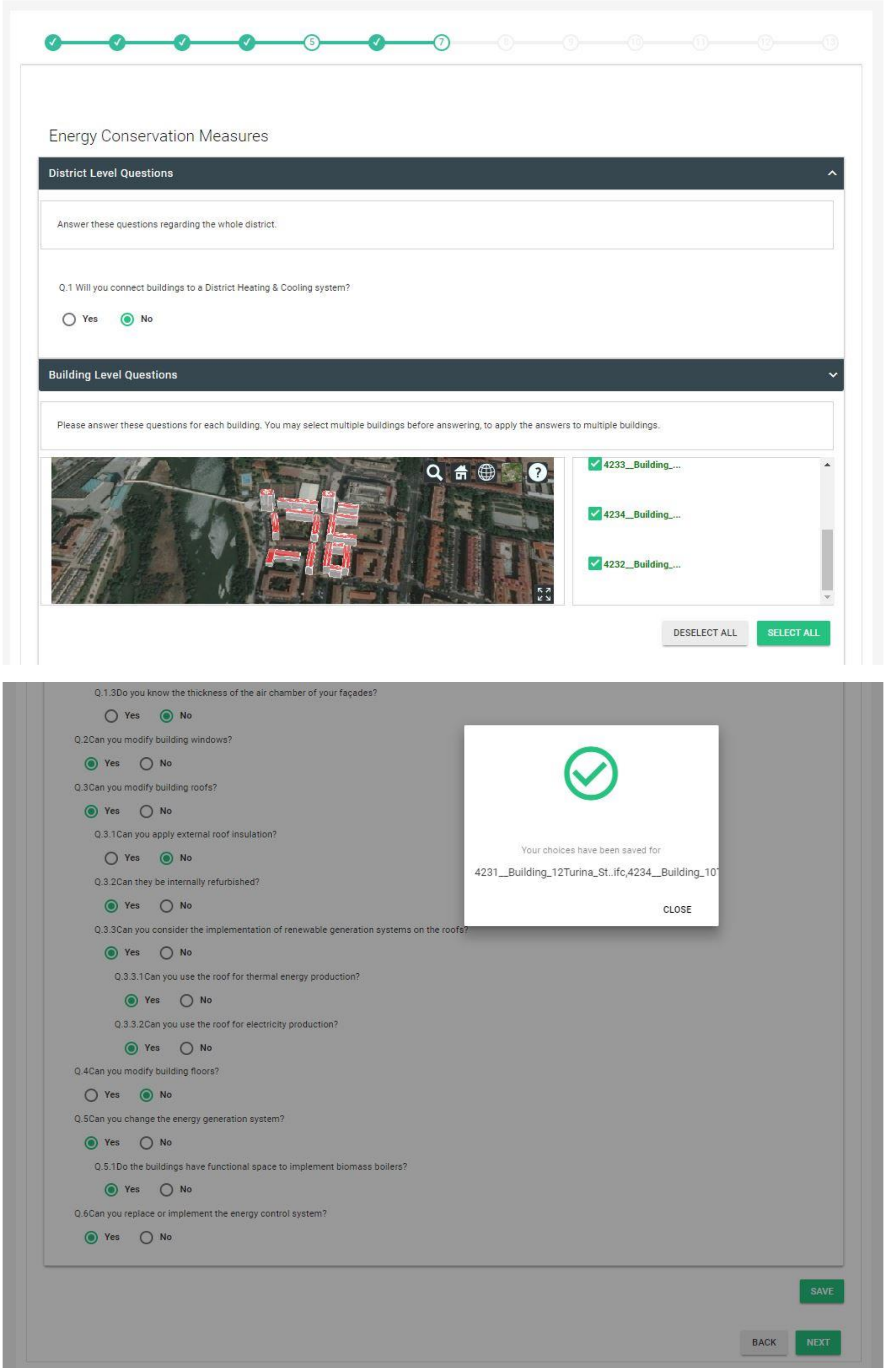


Figure 45: GUI – Completion of the ECM questionnaire (top) and saving of the answers (down)

Using the GUI, the user is able to select/deselect the building to be studied (Figure 46), then to select/deselect all the ECM in order to consider it or not in the retrofitting project. Then, once the user has filled all the questionnaire, he can save its answers (Figure 47) which are then stored into the Project Repository.

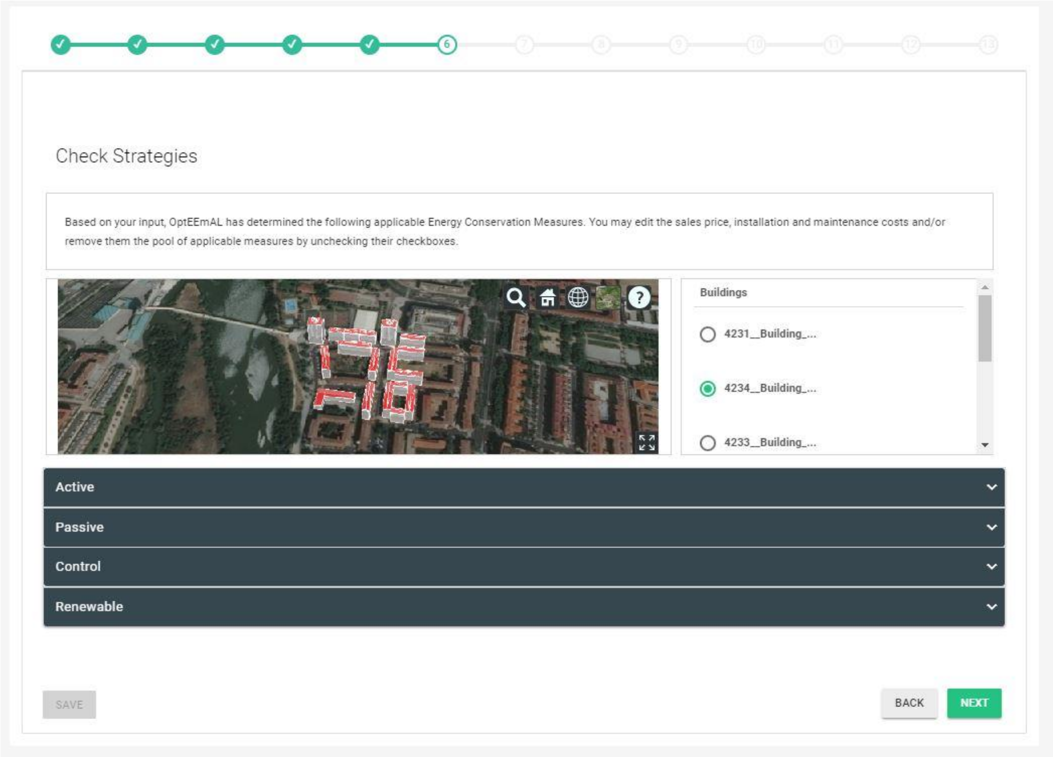


Figure 46: GUI – Selecting the building in order to check the ECMs proposed by the platform

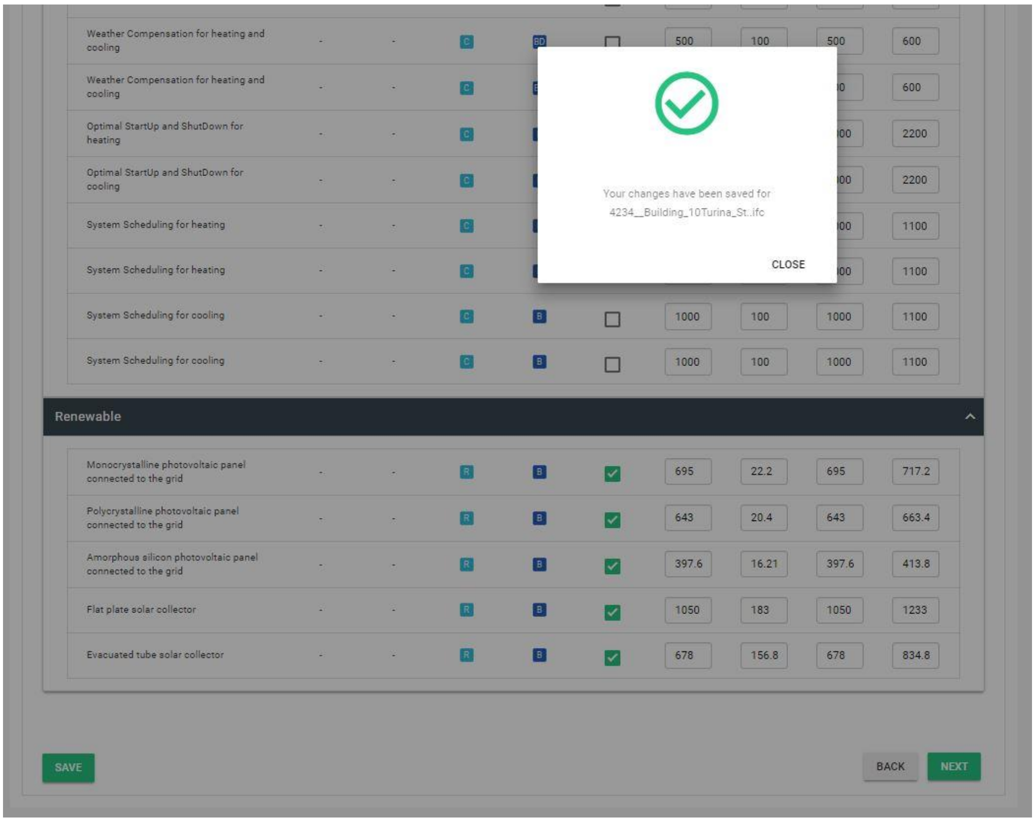
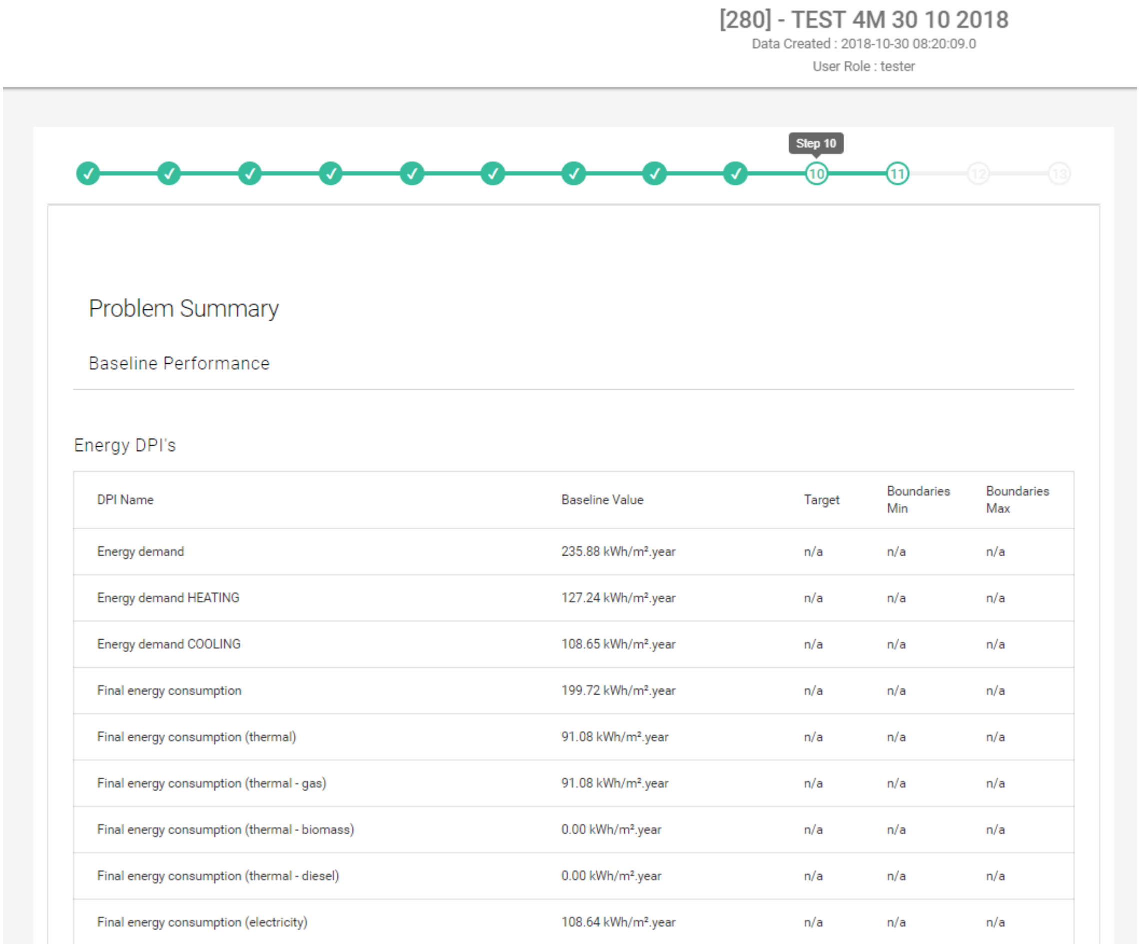


Figure 47: GUI – Saving the ECM applied through the Check strategies screen

The result of this test is PASSED.

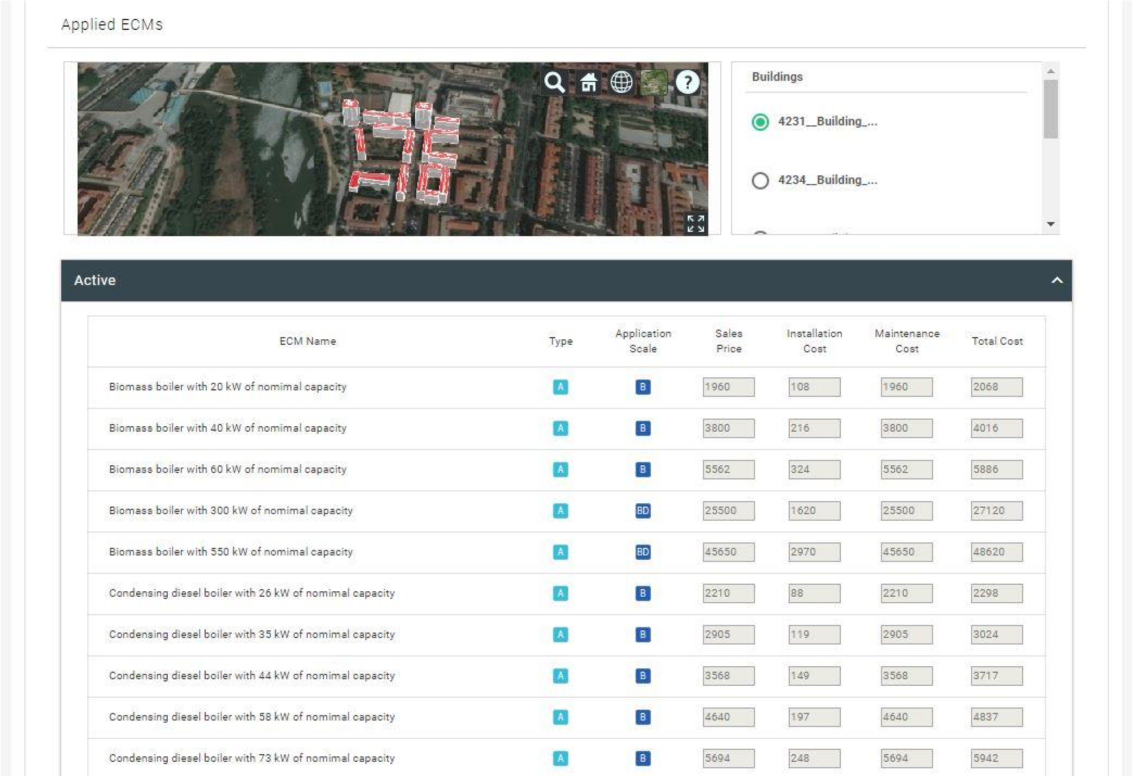
P-info: Project information retrieval

In this test a summary of all the information collected for the project is shown through the GUI. The information is retrieved mainly from the Project repository. The information contained in this page is divided into two parts 1) baseline DPIs (Figure 48) and 2) applied ECMs (Figure 49).



DPI Name	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	235.88 kWh/m².year	n/a	n/a	n/a
Energy demand HEATING	127.24 kWh/m².year	n/a	n/a	n/a
Energy demand COOLING	108.65 kWh/m².year	n/a	n/a	n/a
Final energy consumption	199.72 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal)	91.08 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - gas)	91.08 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - biomass)	0.00 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - diesel)	0.00 kWh/m².year	n/a	n/a	n/a
Final energy consumption (electricity)	108.64 kWh/m².year	n/a	n/a	n/a

Figure 48: GUI – Problem summary – Baseline DPIs



ECM Name	Type	Application Scale	Sales Price	Installation Cost	Maintenance Cost	Total Cost
Biomass boiler with 20 kW of nomimal capacity	A	B	1960	108	1960	2068
Biomass boiler with 40 kW of nomimal capacity	A	B	3800	216	3800	4016
Biomass boiler with 60 kW of nomimal capacity	A	B	5562	324	5562	5886
Biomass boiler with 300 kW of nomimal capacity	A	BD	25500	1620	25500	27120
Biomass boiler with 550 kW of nomimal capacity	A	BD	45650	2970	45650	48620
Condensing diesel boiler with 26 kW of nomimal capacity	A	B	2210	88	2210	2298
Condensing diesel boiler with 35 kW of nomimal capacity	A	B	2905	119	2905	3024
Condensing diesel boiler with 44 kW of nomimal capacity	A	B	3568	149	3568	3717
Condensing diesel boiler with 58 kW of nomimal capacity	A	B	4640	197	4640	4837
Condensing diesel boiler with 73 kW of nomimal capacity	A	B	5694	248	5694	5942

Figure 49: GUI – Problem summary – Applied ECMs

The result of this test is PASSED.

AM: Applicable matrix generation

In this test, as a result of filtering the ECMs (check strategies), an applicable matrix of applicable ECMs for a specific project has to be generated and stored into the Project repository. This step is invisible from the GUI point of view but the applicable matrix has been successfully generated for this test (Figure 50).

IdProject: 280
IdBuilding: 4288
ecm_types:
0: "PA.FA.EX.VE."
1: "PA.FA.EX.CS."
2: "PA.FA.IN.CA."
3: "PA.FA.ID.CW."
4: "PA.RO.PI.IN."
5: "PA.RO.PI.EX."
6: "PA.RO.FL.EX."
7: "PA.RO.FL.EI."
8: "PA.RO.TS.FC."
9: "PA.RO.TS.CI."
10: "PA.FL.NC.DE."
11: "PA.FL.CS.DE."
12: "PA.OP.DG.DE."
13: "PA.OP.TG.DE."
14: "RE.RO.SC.PV."
15: "RE.RO.SC.TC."
16: "RE.DE.GT.HP."
17: "RE.DE.WT.HZ."
18: "AC.DE.BO.CD."
19: "AC.DE.BO.NG."
20: "AC.DE.BO.CG."
21: "AC.DE.BO.BM."
22: "AC.DE.CP.HE."
23: "AC.DE.CH.ER."
24: "AC.DE.HP.WA."
25: "CO.DE.TH.SS."
26: "CO.DE.TH.OS."
27: "CO.DE.PL.WC."
28: "CO.DE.PL.SE."
29: "CO.DE.PL.LF."
ecm_types_count:
0: 4
1: 5
2: 4
3: 1
4: 4
5: 4
6: 4
7: 4
8: 3
9: 4
10: 4
11: 3
12: 3
13: 3
14: 3
15: 2
16: 3
17: 3
18: 5
19: 6
20: 6
21: 5
22: 5
23: 6
24: 5
25: 4
26: 2
27: 4
28: 3
29: 1
ecm_types_values:
0: 0
1: 0
2: 0
3: 0
4: 1
5: 1
6: 1
7: 1
8: 1
9: 1
10: 1
11: 1
12: 1
13: 0
14: 1
15: 1
16: 1
17: 1
18: 1
19: 1
20: 1
21: 1
22: 0

Figure 50: Extracts of the generated applicable matrix for one building (first lines)

The result of this test is PASSED.

Uval-proc: U-values processed

Although initially planned in the overall “U-value functionality”, the automatic discarding of ECMs based the comparison of their U-value with the legal U-value has not been implemented. This choice was done both due to the time needed for such a development and also because it was considered interesting for user to study certain ECMs, even though they are not respecting the national legal U-value.

The result of this test is NOT IMPLEMENTED.

SV: Scenario vector generation

In this test, and using the information of the applicable matrix and internal combination rules, the Optimization module generates 10 scenarios per iteration and send this information (using the queues of the ESB) to the DMM, and more concretely to the Instance Creator to generate the appropriate SIMMODELS.

As result of this test, the Optimization model has created correctly the first scenario vector (scenarioVector_idProject_280_iter_1.json, Figure 51) and the other 9 once evaluation DPIs have been calculated by the Simulation model.


```
IterationId:            1
Projectid:              280
▼scenarios:
  ▼0:
    ▼district:
      ▼0:
        ▼buildings:
          ▼0:
              building_id:  4284
            ▼ecms:
                0:          "PA.FA.IN.CA.04"
                1:          "PA.RO.PI.IN.02"
                2:          "RE.RO.SC.PV.03.25"
                3:          "RE.RO.SC.TC.01.40"
                4:          "AC.DE.BO.NG"
                5:          "AC.DE.BO.CG"
          ▼1:
              building_id:  4286
            ▼ecms:
                0:          "PA.FA.IN.CA.04"
                1:          "PA.RO.PI.IN.03"
                2:          "RE.RO.SC.PV.01.70"
                3:          "RE.RO.SC.TC.02.15"
                4:          "AC.DE.BO.BM"
          ▼2:
              building_id:  4288
            ▼ecms:
                0:          "PA.FA.IN.CA.03"
                1:          "PA.RO.PI.IN.02"
                2:          "RE.RO.SC.PV.01.40"
                3:          "RE.RO.SC.TC.01.55"
                4:          "AC.DE.BO.CD"
          ▼3:
              building_id:  4290
            ▼ecms:
                0:          "PA.FA.IN.CA.03"
                1:          "PA.RO.PI.EX.01"
                2:          "RE.RO.SC.PV.02.5"
                3:          "RE.RO.SC.TC.01.80"
                4:          "AC.DE.BO.CD"
```


Figure 51: Extract of the scenario vector generated (first lines)

The result of this test is PASSED.

IC: Instances creation

For every scenario vector generated by the Optimization module, the Instance Creator has to create new instances of the enriched baseline SimModel including the appropriate information of the ECM (snippets) to be applied. These new models have to be stored into the Project repository.

In the test, the Instance Creator generated several models for all scenarios and iterations. The following Figure displays an excerpt of a SimModel where the PA.FA.EX.CS ECM (External Thermal Insulation Composite System) has been applied:

```
inst:SimMaterial_OpaqueMaterial_Default_MOD_PA_FA_EX_CS_1
        a                                        simres:SimMaterial_OpaqueMaterial_Default ;
        simres:category                          "Cement" ;
        simres:name                              "Cement/Mortar plater" ;
        simres:simMaterial_Cond                  "0.35"^^xsd:double ;
        simres:simMaterial_Density               "950."^^xsd:double ;
        simres:simMaterial_Rough                 "MediumSmooth" ;
        simres:simMaterial_SolarAbsorptance      "0.6"^^xsd:double ;
        simres:simMaterial_SpecificHeat          "840."^^xsd:double ;
        simres:simMaterial_ThermalAbsorptance    "0.9"^^xsd:double ;
        simres:simMaterial_VisAbsorptance        "0.6"^^xsd:double ;
        simcore:refId                            "ID1033569"^^xsd:ID ;
        simcore:simModelSubtype                  "Default" ;
        simcore:simModelType                     "OpaqueMaterial" ;
        simcore:sourceModelObjectType            "SimMaterial" ;
        simcore:sourceModelSchema                "InstanceCreator" .

inst:DoubleList_GX2AKYICYTF6_1001
        a                 simcore:DoubleList ;
        list:hasContents  "0.08845960813761522"^^xsd:double ;
        list:hasNext      inst:DoubleList_GX2AKYICYTF6_1002 .
```

Figure 52: Excerpt of a SimModel with one ECM applied

The result of this test is PASSED.

Evaluation DPI: Scenario DPI calculation

Once the new SIMMODELs containing the ECM snippets are created they are used for the Simulation module to obtain the different evaluation DPIs.

In the test, the Simulation module works properly obtaining DPIs for all the scenarios and iterations, using the EnergyPlus, ECO and NEST services (i.e. EvaluationDPIIntheprojectRepositoryIt1.json, EvaluationDPIIntheprojectRepositoryIt2.json, etc.). Calculated DPIs are stored into the Project repository and used by the Optimization module to obtain the Pareto Front (Figure 53).


```
Projectid:                280
▼ opts:
  ▼ 0:
    ▼ scenariosdpis:
      ▼ 0:
          id:             1
        ▼ dpis:
          ▼ 0:
              dpi:        "COM01"
              value:      0
          ▼ 1:
              dpi:        "ECO01.0"
              value:      28.633538498536183
          ▼ 2:
              dpi:        "ECO01.1"
              value:      1.4561941329743855
          ▼ 3:
              dpi:        "ECO01.2"
              value:      0
```


Figure 53: Extract of the scenario DPIs JSON file (first lines)

The result of this test is PASSED.

EE: Evaluator execution

In this test the correct functionality of the evaluator (a component included within the Optimization module) is validated. For that, the evaluator takes the evaluation DPIs generated by the Simulation module, the Target and Boundaries and the prioritization criteria defined by the user to generate a cost-benefit function. Using this function the evaluator provides cost-benefit results to the Optimization algorithm to execute a new iteration. Figure 54 below, which is an xls extract used to verify the proper functioning of the evaluator, shows the results obtained for the different DPIs and the associated cost and benefit values (lines 34 and 35).

	A	B	C
1		Baseline	Scenario 1
2	COM01	0	0
3	ECO01.0	31,9463608	28,6335385
4	ECO01.1	6,05656032	1,456194133
5	ECO01.2	0	0
6	ECO01.3	0	4,685534486
7	ECO01.4	25,8898005	22,49180988
8	ECO02.1	-	58,94061877
9	ECO02.2	-	523525,429
10	ECO03	8907180,7	8004190,718
11	ECO04	-	-1297,863877
12	ECO05	-	100
13	ENE01.0	238,884713	227,0937136
14	ENE01.A	127,238367	118,4474233
15	ENE01.B	108,646354	108,6463902
16	ENE02.0	199,719778	6,893845864
17	ENE02.A	91,076095	0,080754087
18	ENE02.A.1	91,076095	0,044290402
19	ENE02.A.2	0	0,010945432
20	ENE02.A.3	0	0,025518252
21	ENE02.B	49,153931	6,813091587
22	ENE06	0	0
23	ENE09	0	0,029435399
24	ENE13	0	0
25	ENE14	0	0
26	ENE15	0	7,060241691
27	ENE16	0	32,96944672
28	ENV01	45,436	4,29
29	ENV02	-	57,794
30	ENV03	-	365466,568
31	ENV04	874,015	89,489
32	ENV05	-	945,477
33	ENV06	-	1,205
34	Benefit :		0,440838996
35	Cost :		0,361500252
36			1
37			**BuildingId: 4284**
38			PA.FA.EX.CS.02
39			PA.RO.PI.IN.04
40			RE.RO.SC.PV.01.65
41			RE.RO.SC.TC.02.25
42			AC.DE.BO.BM
43			**BuildingId: 4286**
44			PA.FA.EX.CS.04
45			PA.RO.PI.EX.01
46			RE.RO.SC.PV.03.5
47			[illegible]

DPIs | NormalisedDPIs | Weigthe

Figure 54: Excerpt of the Excel file used to verify the proper functioning of the evaluator

The result of this test is PASSED.

OPT-1: Optimisation execution

Once the evaluator provides the cost-benefit results, the Optimization algorithm uses this information to create new scenarios vectors (as the one presented in Figure 52).

In the test, new scenario vectors are generated in every iteration and send to the DMM using the queues of the ESB.

The result of this test is PASSED.

OPT-3: Generation of the Pareto Front

Once the optimization process achieves the stopping criteria, according to the TB and prioritization criteria defined by the user, the process finishes and generates what is called the Pareto Front, a set of best scenarios obtained from the last two iterations. These results are stored into the Project repository and are represented using the GUI.

In the test exercise the Pareto Front is obtained successfully for the project id. 280 (Figure 55), stored into the Project repository and showed though the GUI (Figure 56).


```
project_id:                280
▼ pareto_dpi:
  ▼ 0:
      benefit:             0.21149022391501174
      cost:                0.47842622546968344
      target_reached:      0
      is_inside_boundaries: 1
  ▼ 1:
      benefit:             0.22417113839192113
      cost:                0.5835745158010325
      target_reached:      0
      is_inside_boundaries: 0
  ▼ 2:
      benefit:             0.22922678641897629
      cost:                1.3063136039940368
      target_reached:      0
      is_inside_boundaries: 1
success:                   true
```


Figure 55: Json file including the information of the Pareto front

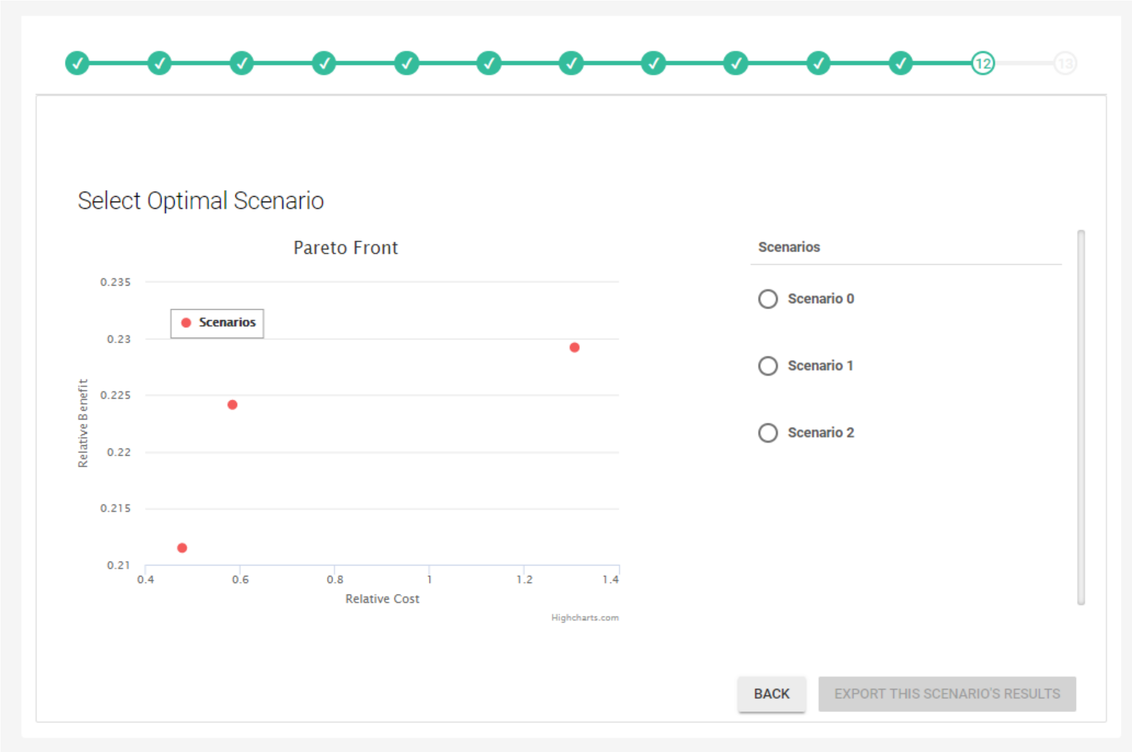


Figure 56: GUI – Visualization of the Pareto Front

The result of this test is PASSED.

EXP-1: Generation of data to be exported

Once the optimal scenario has been chosen, the user can start the exportation process by clicking the green button in the previous screen of the GUI (Figure 57).

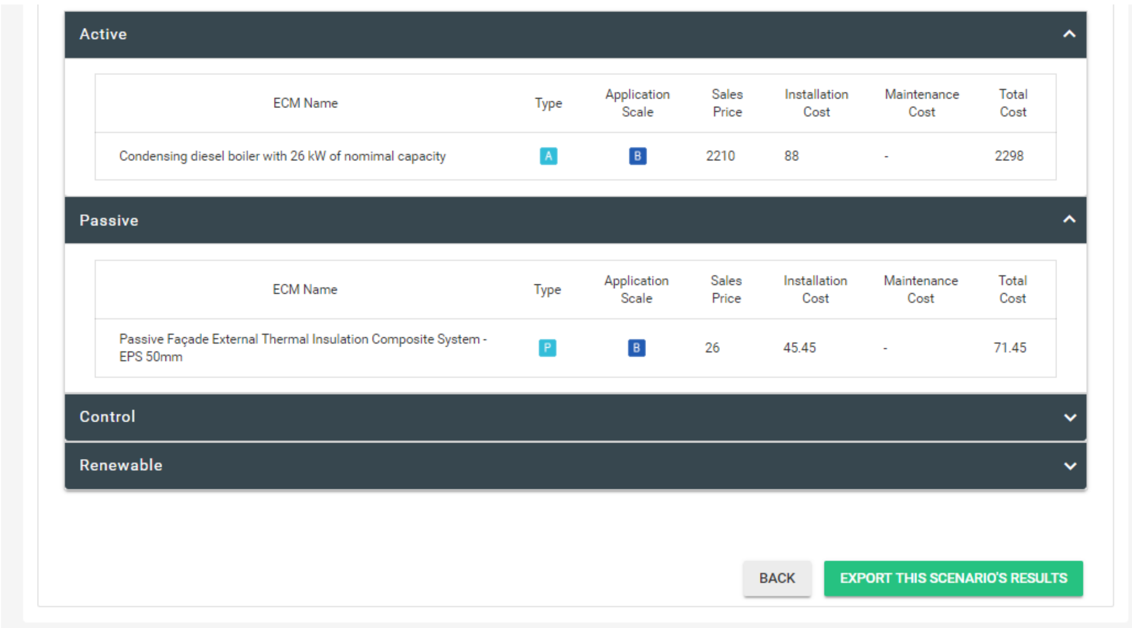


Figure 57: GUI – Page while generating the final reports

The results of this test is PASSED (see next tests for more details).

EXP-2: Data exportation

Once generated, the reports are available for download. The user can then select between excel reports and/or models generated by the platform during the process (Figure 58 and Figure 59).

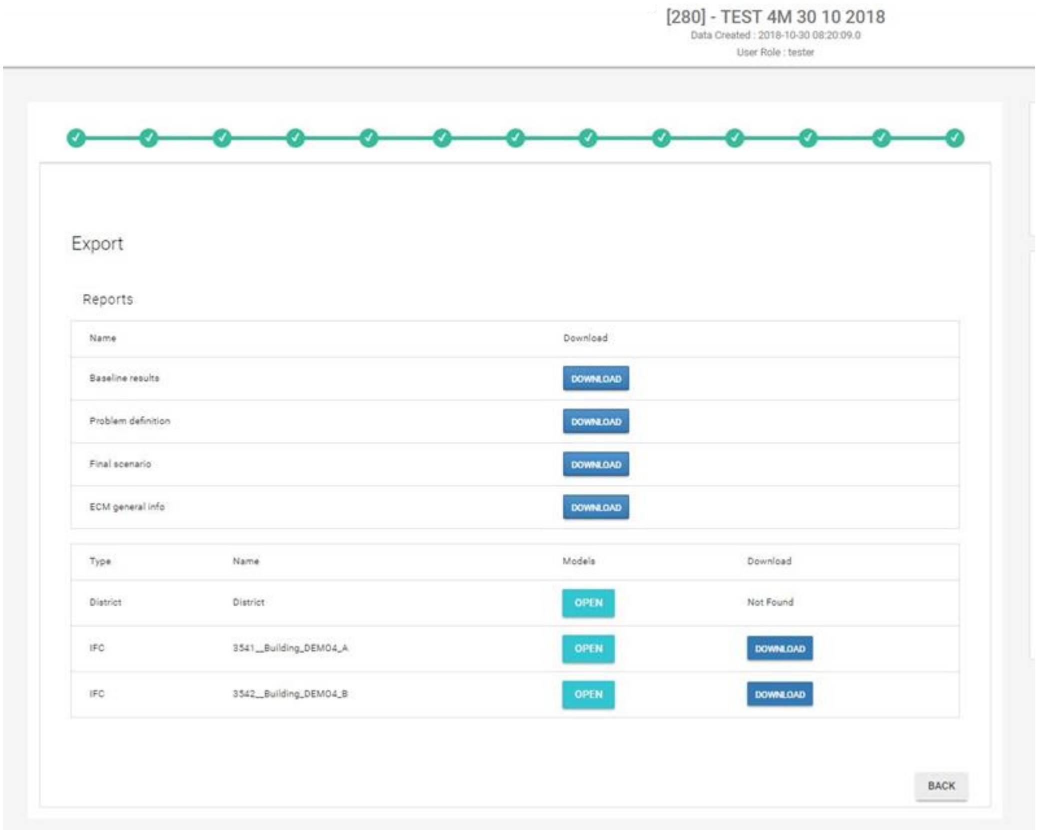


Figure 58: GUI – Final reports available for download

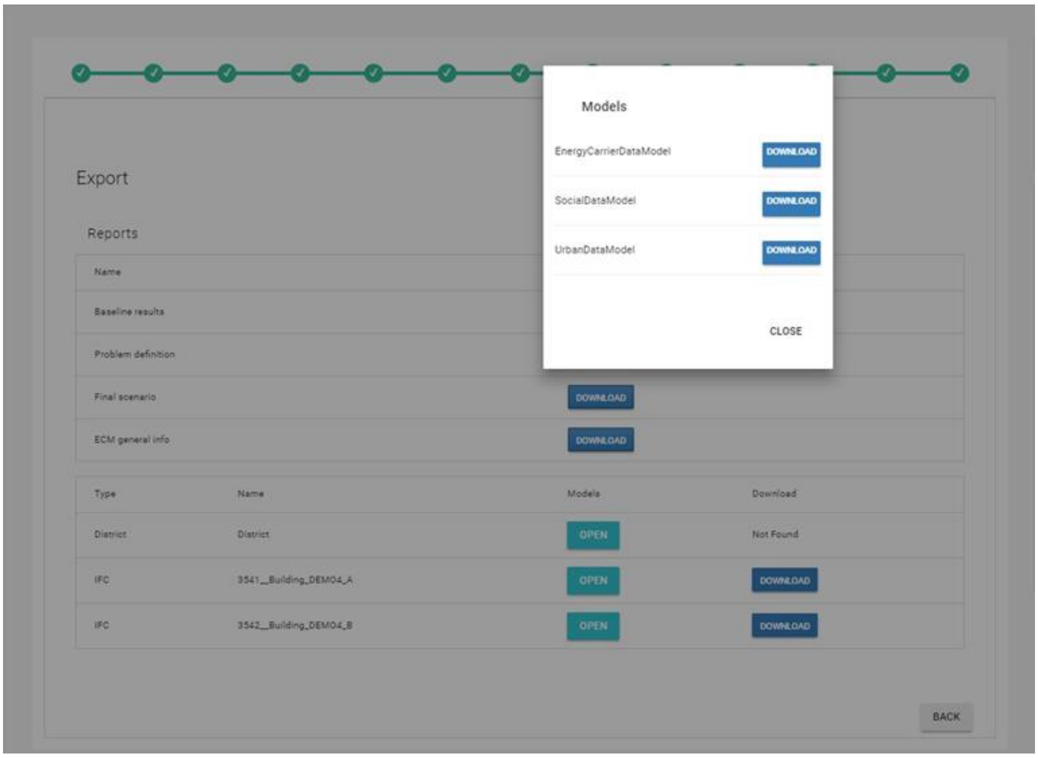


Figure 59: GUI – Final reports available for download – Available models generated by the platform

Finally, the user is able to download the files and have the needed details on the selected scenario (e.g. in Figure 60 with the excel file presenting the detailed results for the final scenario).

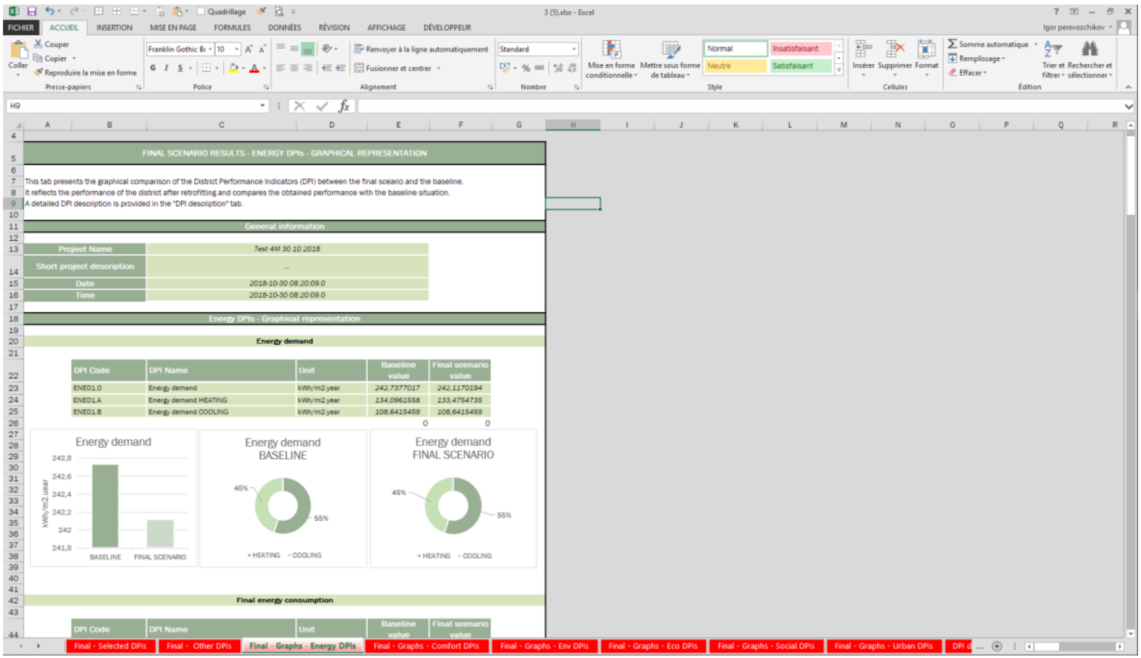


Figure 60: Final excel files exported from the platform

The result of this test is PASSED.

5 Results obtained from the platform and comparison with existing information

5.1 Purpose

The purpose of this section is the analysis of the results obtained by the platform.

On one hand the DPIs results are analysed taking into account their nature and typical values they take in similar contexts.

On the other hand the results (DPI values) provided by the platform are compared with existing data on the different districts under study. This is critical to ensure the relevance of the results provided by the platform. This comparison is done both on the calculations performed by the platform as well as the outcomes of the platform in terms of ECM recommendations. In each sub-sections, the first part is dedicated to the results analysis. “Results” refers here to the values obtained for the different DPIs.

The second part is dedicated to the comparison of ECMs recommended by the platform and the ones implemented in reality (when relevant).

The different case studies were used for different validation purposes (because of district configuration and available data from the real project) as described below:

- The *Cuatro de Marzo* district was used to validate the overall DPI calculation procedures and to check that the ECMs recommended by the platform are relevant.
- The *Mogel* district was used to validate the energy demand calculations and also to check the recommended ECMs. A focus was made on energy demand calculations considering their importance in the platform (key indicator, basis for most other DPI calculations).
- The *Polhem* district has been used to investigate the district scale but is not reported here for the reasons already mentioned.

5.2 *Cuatro de Marzo*, Valladolid

The *Cuatro de Marzo* district has been used to demonstrate the OptEEmAL platform prototype in relevant environment (TRL6). This district was the first complex case tested within the platform, and therefore it has served in order to fix errors within the calculation of DPIs and to improve the overall processes of data mapping and calculation, as shown in the following sections, as well as to validate the results obtained through the platform.

The following subsection 5.2.1 provides the explanations on the modifications carried out during the validation process for DPIs calculation, while section 5.2.2 provides the results of the execution carried out in order to compare them with the real data from the district (both for the baseline and retrofitting scenarios).

5.2.1 Validation activities to fix errors

The errors encountered by the global analysis were varied and originated in different parts of the platform. Here are some of the problems encountered and how they were solved.

5.2.1.1 Results for some DPIs nulls

In the first test certain DPIs in some of the scenarios had null values contrary to expectations. Particularly the value of Energy use from Solar Thermal (ENE16) was 0 in some scenarios with thermal solar system selected as ECMs in some buildings (for example RE.RO.SC.TC.01.75, RE.RO.SC.TC.01.55). The results of the calculation are shown in the Figure 61.

A	B	C	D	E
	Baseline	Scenario 1	Scenario 2	Scenario 3
ENE15	0	7,060241691	3,52316653	49,80981179
ENE16	0	32,96944672	0	0
ENV01	45,436	4,29	5,782	-15,091
		1	2	3
		BuildingId: 4284	**BuildingId: 4284**	**BuildingId: 4284**
		PA.FA.EX.CS.02	PA.FA.IN.CA.02	PA.FA.IN.CA.03
		PA.RO.PI.IN.04	PA.RO.PI.IN.01	PA.RO.PI.EX.02
		RE.RO.SC.PV.01.65	RE.RO.SC.PV.03.5	RE.RO.SC.PV.01.10
		RE.RO.SC.TC.02.25	**RE.RO.SC.TC.01.75**	**RE.RO.SC.TC.02.90**
		AC.DE.BO.BM	AC.DE.BO.CD	AC.DE.BO.NG
		BuildingId: 4286	**BuildingId: 4286**	**BuildingId: 4286**
		PA.FA.EX.CS.04	PA.FA.EX.CS.03	PA.FA.EX.CS.02
		PA.RO.PI.EX.01	PA.RO.PI.IN.02	PA.RO.PI.IN.04
		RE.RO.SC.PV.03.5	RE.RO.SC.PV.02.45	RE.RO.SC.PV.03.5
		RE.RO.SC.TC.01.40	**RE.RO.SC.TC.01.55**	**RE.RO.SC.TC.02.95**
		AC.DE.BO.NG	AC.DE.BO.NG	AC.DE.BO.CD
		BuildingId: 4288	**BuildingId: 4288**	**BuildingId: 4288**
		PA.FA.IN.CA.04	PA.FA.IN.CA.04	PA.FA.EX.CS.03
		PA.RO.PI.EX.03	PA.RO.PI.IN.01	PA.RO.PI.IN.03
		RE.RO.SC.PV.02.25	RE.RO.SC.PV.03.45	RE.RO.SC.PV.02.70
		RE.RO.SC.TC.01.25	**RE.RO.SC.TC.02.15**	**RE.RO.SC.TC.02.25**
		AC.DE.BO.NG	AC.DE.BO.BM	AC.DE.BO.BM
		BuildingId: 4290	**BuildingId: 4290**	**BuildingId: 4290**
		PA.FA.IN.CA.01	PA.FA.IN.CA.02	PA.FA.IN.CA.01
		PA.RO.PI.IN.04	PA.RO.PI.EX.03	PA.RO.PI.IN.01

Figure 61: Excerpt of the Excel file created by the evaluator, in red the unexpected results

Once the problem was identified, the calculation method was corrected in the tool that calculated this DPI (specifically the HVAC tool). In the following figure the results of the DPIs once the problem has been corrected can be seen.

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
ENE15	0	0,916525702	18,6239643	9,423134103	7,184217296	10,24594205	8,9517177
ENE16	0	51,05866697	24,19459923	87,06428717	5,24483366	90,52721409	24,194599
		1	2	3	4	5	
		BuildingId: 4284	BuildingId: 4284	BuildingId: 4284	BuildingId: 4284	BuildingId: 4284	BuildingId: 4284
		PA.FA.IN.CA.01	PA.FA.IN.CA.04	PA.FA.EX.CS.02	PA.FA.EX.CS.05	PA.FA.IN.CA.02	PA.FA.EX.CS.02
		PA.RO.PI.IN.04	PA.RO.PI.IN.03	PA.RO.PI.EX.04	PA.RO.PI.IN.04	PA.RO.PI.IN.04	PA.RO.PI.IN.02
		RE.RO.SC.PV.01.40	RE.RO.SC.PV.03.70	RE.RO.SC.PV.02.45	RE.RO.SC.PV.03.20	RE.RO.SC.PV.02.10	RE.RO.SC.PV.03.
		RE.RO.SC.TC.01.30	RE.RO.SC.TC.01.30	RE.RO.SC.TC.01.55	RE.RO.SC.TC.02.75	RE.RO.SC.TC.02.50	RE.RO.SC.TC.01.2
		AC.DE.BO.CG	AC.DE.BO.CG	AC.DE.BO.BM	AC.DE.BO.BM	AC.DE.BO.CD	AC.DE.BO.NG
		BuildingId: 4286	BuildingId: 4286	BuildingId: 4286	BuildingId: 4286	BuildingId: 4286	BuildingId: 4286
		PA.FA.IN.CA.03	PA.FA.EX.CS.02	PA.FA.EX.CS.03	PA.FA.EX.CS.03	PA.FA.IN.CA.02	PA.FA.EX.CS.02
		PA.RO.PI.IN.04	PA.RO.PI.EX.02	PA.RO.PI.IN.01	PA.RO.PI.IN.03	PA.RO.PI.EX.03	PA.RO.PI.IN.04
		RE.RO.SC.PV.03.95	RE.RO.SC.PV.02.30	RE.RO.SC.PV.01.95	RE.RO.SC.PV.03.75	RE.RO.SC.PV.01.45	RE.RO.SC.PV.01.
		RE.RO.SC.TC.02.5	RE.RO.SC.TC.02.50	RE.RO.SC.TC.02.5	RE.RO.SC.TC.02.10	RE.RO.SC.TC.02.55	RE.RO.SC.TC.02.
		AC.DE.BO.BM	AC.DE.BO.CD	AC.DE.BO.CD	AC.DE.BO.CG	AC.DE.BO.CD	AC.DE.BO.NG
		BuildingId: 4288	BuildingId: 4288	BuildingId: 4288	BuildingId: 4288	BuildingId: 4288	BuildingId: 4288
		PA.FA.EX.CS.04	PA.FA.EX.CS.04	PA.FA.IN.CA.03	PA.FA.IN.CA.04	PA.FA.EX.CS.05	PA.FA.EX.CS.02
		PA.RO.PI.EX.01	PA.RO.PI.IN.01	PA.RO.PI.IN.01	PA.RO.PI.EX.02	PA.RO.PI.EX.04	PA.RO.PI.EX.02
		RE.RO.SC.PV.01.70	RE.RO.SC.PV.02.95	RE.RO.SC.PV.03.25	RE.RO.SC.PV.01.35	RE.RO.SC.PV.01.75	RE.RO.SC.PV.01.
		RE.RO.SC.TC.02.30	RE.RO.SC.TC.02.5	RE.RO.SC.TC.02.60	RE.RO.SC.TC.02.30	RE.RO.SC.TC.01.15	RE.RO.SC.TC.02.
		AC.DE.BO.BM	AC.DE.BO.NG	AC.DE.BO.CG	AC.DE.BO.CG	AC.DE.BO.BM	AC.DE.BO.CG
		BuildingId: 4290	BuildingId: 4290	BuildingId: 4290	BuildingId: 4290	BuildingId: 4290	BuildingId: 4290
		PA.FA.EX.CS.03	PA.FA.IN.CA.04	PA.FA.EX.CS.04	PA.FA.IN.CA.02	PA.FA.EX.CS.02	PA.FA.IN.CA.01
		PA.RO.PI.IN.01	PA.RO.PI.IN.02	PA.RO.PI.IN.01	PA.RO.PI.IN.04	PA.RO.PI.IN.04	PA.RO.PI.IN.01
		RE.RO.SC.PV.03.25	RE.RO.SC.PV.02.25	RE.RO.SC.PV.01.35	RE.RO.SC.PV.02.70	RE.RO.SC.PV.03.25	RE.RO.SC.PV.03.
		RE.RO.SC.TC.02.15	RE.RO.SC.TC.02.30	RE.RO.SC.TC.02.35	RE.RO.SC.TC.02.25	RE.RO.SC.TC.02.65	RE.RO.SC.TC.02.
		AC.DE.BO.CD	AC.DE.BO.BM	AC.DE.BO.CD	AC.DE.BO.CG	AC.DE.BO.CG	AC.DE.BO.CG

Figure 62: Excerpt of the Excel file created by the evaluator, once the error has been corrected

5.2.1.2 Problems with PV production calculation

Another issue detected in the first testing phase was related to the ENE15 DPI calculation. In some scenarios with strong introduction of PVs system as renewable ECMs the Energy production from PV (ENE15) was detected as very low.

In Figure 63 one scenario in which PV systems have been introduced in each building of the *Cuatro de Marzo* district can be seen. Despite having so much presence of PV systems the calculated production is only of 0.91 kWh/m^2.year.

	Baseline	Scenario 1
ENE15	0	0,916525702
		1
		BuildingId: 4284
		PA.FA.IN.CA.01
		PA.RO.PI.IN.04
		RE.RO.SC.PV.01.40
		RE.RO.SC.TC.01.30
		AC.DE.BO.CG
		BuildingId: 4286
		PA.FA.IN.CA.03
		PA.RO.PI.IN.04
		RE.RO.SC.PV.03.95
		RE.RO.SC.TC.02.5
		AC.DE.BO.BM
		BuildingId: 4288
		PA.FA.EX.CS.04
		PA.RO.PI.EX.01
		RE.RO.SC.PV.01.70
		RE.RO.SC.TC.02.30
		AC.DE.BO.BM
		BuildingId: 4290
		PA.FA.EX.CS.03
		PA.RO.PI.IN.01
		RE.RO.SC.PV.03.25
		RE.RO.SC.TC.02.15
		AC.DE.BO.CD
		BuildingId: 4292
		PA.FA.IN.CA.01
		PA.RO.PI.EX.03
		RE.RO.SC.PV.02.10
		RE.RO.SC.TC.02.35
		AC.DE.BO.BM

Figure 63: Excerpt of the Excel file created by the evaluator, in red the renewable ECMs applied to the scenario

This error was detected and corrected. In the Figure 64 it is shown the results for the energy use from PV system after the calculation process was corrected. It can be seen that the values of the energy use are as expected.

	Sc 1	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	Sc 9	Sc 10
ENE15	13,92	18,00	11,69	16,93	13,34	10,91	11,39	15,71	10,13	12,38
	1	2	3	4	5	6	7	8	9	10
	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375	BuildingId: 5375
	PA.FA.EX.CS.04	PA.FA.IN.CA.01	PA.FA.IN.CA.04	PA.FA.IN.CA.01	PA.FA.EX.CS.05	PA.FA.EX.CS.01	PA.FA.EX.CS.05	PA.FA.EX.CS.02	PA.FA.EX.CS.04	PA.FA.EX.CS.03
	PA.RO.PI.IN.01	PA.RO.PI.IN.02	PA.RO.PI.IN.02	PA.RO.PI.IN.01	PA.RO.PI.IN.04	PA.RO.PI.IN.03	PA.RO.PI.IN.03	PA.RO.PI.IN.04	PA.RO.PI.IN.03	PA.RO.PI.IN.01
	RE.RO.SC.PV.03.85	RE.RO.SC.PV.01.20	RE.RO.SC.PV.03.30	RE.RO.SC.PV.01.65	RE.RO.SC.PV.01.50	RE.RO.SC.PV.03.65	RE.RO.SC.PV.01.50	RE.RO.SC.PV.02.75	RE.RO.SC.PV.03.25	RE.RO.SC.PV.02.25
	AC.DE.BO.NG	AC.DE.BO.CD	AC.DE.BO.NG	AC.DE.BO.NG	AC.DE.BO.NG	AC.DE.BO.CD	AC.DE.BO.NG	AC.DE.BO.NG	AC.DE.BO.CD	AC.DE.BO.CD
	AC.DE.BO.CG	BuildingId: 5377	AC.DE.BO.CG	AC.DE.BO.CG	AC.DE.BO.CG	BuildingId: 5377	AC.DE.BO.CG	AC.DE.BO.CG	BuildingId: 5377	BuildingId: 5377
	BuildingId: 5377	PA.FA.EX.CS.02	BuildingId: 5377	BuildingId: 5377	BuildingId: 5377	PA.FA.EX.CS.04	BuildingId: 5377	BuildingId: 5377	PA.FA.EX.CS.05	PA.FA.IN.CA.04
	PA.FA.EX.CS.04	PA.RO.PI.IN.04	PA.FA.IN.CA.01	PA.FA.EX.CS.03	PA.FA.IN.CA.01	PA.RO.PI.IN.03	PA.FA.IN.CA.04	PA.FA.IN.CA.03	PA.RO.PI.IN.02	PA.RO.PI.IN.02
	PA.RO.PI.IN.02	RE.RO.SC.PV.03.95	PA.RO.PI.IN.04	PA.RO.PI.IN.03	PA.RO.PI.IN.01	RE.RO.SC.PV.03.50	PA.RO.PI.IN.04	PA.RO.PI.IN.02	RE.RO.SC.PV.02.85	RE.RO.SC.PV.02.10
	RE.RO.SC.PV.03.55	AC.DE.BO.NG	RE.RO.SC.PV.01.65	RE.RO.SC.PV.03.55	RE.RO.SC.PV.02.10	AC.DE.BO.CD	RE.RO.SC.PV.03.70	RE.RO.SC.PV.01.5	AC.DE.BO.CD	AC.DE.BO.NG
	AC.DE.BO.NG	AC.DE.BO.CG	AC.DE.BO.NG	AC.DE.BO.CD	AC.DE.BO.CD	BuildingId: 5379	AC.DE.BO.NG	AC.DE.BO.CD	BuildingId: 5379	AC.DE.BO.CG
	AC.DE.BO.CG	BuildingId: 5379	AC.DE.BO.CG	BuildingId: 5379	BuildingId: 5379	PA.FA.EX.CS.02	AC.DE.BO.CG	BuildingId: 5379	PA.FA.EX.CS.01	BuildingId: 5379
	BuildingId: 5379	PA.FA.IN.CA.01	BuildingId: 5379	PA.FA.EX.CS.05	PA.FA.IN.CA.03	PA.RO.PI.IN.04	BuildingId: 5379	PA.FA.IN.CA.01	PA.RO.PI.IN.01	PA.FA.IN.CA.02
	PA.FA.IN.CA.02	PA.RO.PI.IN.02	PA.FA.IN.CA.02	PA.RO.PI.IN.01	PA.RO.PI.IN.02	RE.RO.SC.PV.01.50	PA.FA.EX.CS.05	PA.RO.PI.IN.04	RE.RO.SC.PV.02.10	PA.RO.PI.IN.01
	PA.RO.PI.IN.02	RE.RO.SC.PV.02.40	PA.RO.PI.IN.03	RE.RO.SC.PV.03.60	RE.RO.SC.PV.03.75	AC.DE.BO.CD	PA.RO.PI.IN.01	RE.RO.SC.PV.02.45	AC.DE.BO.NG	RE.RO.SC.PV.03.90
	RE.RO.SC.PV.02.10	AC.DE.BO.NG	RE.RO.SC.PV.02.50	AC.DE.BO.NG	AC.DE.BO.CD	BuildingId: 5381	RE.RO.SC.PV.01.50	AC.DE.BO.NG	AC.DE.BO.CG	AC.DE.BO.CD
	AC.DE.BO.NG	AC.DE.BO.CG	AC.DE.BO.NG	AC.DE.BO.CG	BuildingId: 5381	PA.FA.EX.CS.03	AC.DE.BO.NG	AC.DE.BO.CG	BuildingId: 5381	BuildingId: 5381
	AC.DE.BO.CG	BuildingId: 5381	AC.DE.BO.CG	BuildingId: 5381	PA.FA.IN.CA.03	PA.RO.PI.IN.04	AC.DE.BO.CG	BuildingId: 5381	PA.FA.EX.CS.04	PA.FA.IN.CA.02
	BuildingId: 5381	PA.FA.IN.CA.04	BuildingId: 5381	PA.FA.EX.CS.02	PA.RO.PI.IN.02	RE.RO.SC.PV.03.55	BuildingId: 5381	PA.FA.EX.CS.03	PA.RO.PI.IN.01	PA.RO.PI.IN.01
	PA.FA.EX.CS.05	PA.RO.PI.IN.03	PA.FA.IN.CA.04	PA.RO.PI.IN.02	RE.RO.SC.PV.02.55	AC.DE.BO.NG	PA.FA.IN.CA.03	PA.RO.PI.IN.02	RE.RO.SC.PV.03.50	RE.RO.SC.PV.02.65
	PA.RO.PI.IN.02	RE.RO.SC.PV.01.65	PA.RO.PI.IN.02	RE.RO.SC.PV.03.75	AC.DE.BO.NG	AC.DE.BO.CG	PA.RO.PI.IN.03	RE.RO.SC.PV.03.40	AC.DE.BO.CD	AC.DE.BO.NG
	RE.RO.SC.PV.01.80	AC.DE.BO.CD	RE.RO.SC.PV.03.20	AC.DE.BO.CD	AC.DE.BO.CG	BuildingId: 5383	RE.RO.SC.PV.02.15	AC.DE.BO.NG	BuildingId: 5383	AC.DE.BO.CG
	AC.DE.BO.CD	BuildingId: 5383	AC.DE.BO.NG	BuildingId: 5383	BuildingId: 5383	PA.FA.EX.CS.03	AC.DE.BO.NG	AC.DE.BO.CG	PA.FA.EX.CS.05	BuildingId: 5383
	BuildingId: 5383	PA.FA.EX.CS.04	AC.DE.BO.CG	PA.FA.IN.CA.04	PA.FA.EX.CS.03	PA.RO.PI.IN.04	AC.DE.BO.CG	BuildingId: 5383	PA.RO.PI.IN.01	PA.FA.IN.CA.04
	PA.FA.IN.CA.02	PA.RO.PI.IN.03	BuildingId: 5383	PA.RO.PI.IN.01	PA.RO.PI.IN.02	RE.RO.SC.PV.01.10	BuildingId: 5383	PA.FA.IN.CA.04	RE.RO.SC.PV.03.40	PA.RO.PI.IN.03
	PA.RO.PI.IN.01	RE.RO.SC.PV.03.95	PA.FA.EX.CS.02	RE.RO.SC.PV.02.60	RE.RO.SC.PV.03.50	AC.DE.BO.CD	PA.FA.IN.CA.02	PA.RO.PI.IN.04	AC.DE.BO.NG	RE.RO.SC.PV.01.30
	RE.RO.SC.PV.02.5	AC.DE.BO.NG	PA.RO.PI.IN.02	AC.DE.BO.NG	AC.DE.BO.NG		PA.RO.PI.IN.02	RE.RO.SC.PV.01.65	AC.DE.BO.CG	AC.DE.BO.NG
	AC.DE.BO.CD	AC.DE.BO.CG	RE.RO.SC.PV.02.30	AC.DE.BO.CG	AC.DE.BO.CG		RE.RO.SC.PV.02.10	AC.DE.BO.CD		AC.DE.BO.CG
			AC.DE.BO.NG				AC.DE.BO.NG			
			AC.DE.BO.CG				AC.DE.BO.CG			

Figure 64: Excerpt of the Excel file after correcting the calculation process

5.2.1.3 Problems with the DPI Energy demand covered by renewable sources (ENE09)

In all the scenarios were renewables systems were present the DPI Energy demand covered by renewable sources was very low. This error is shown in the next table

Table 14: Value expected and calculated for Energy demand covered by renewable energy DPI (ENE09)

DPI	Results from Platform	Results expected
Energy use from PV	7.06 kWh/m2.year	-
Energy use from Solar Thermal	32.96 kWh/m2.year	-
Final energy consumption	6.9 kWh/m2.year	7.06 + 32.96 + 6.9=46.92 kWh/m2.year
Energy demand covered by renewable sources	**0.029%**	**85.3%**

The error was originated by two different reasons:

- The final energy consumption did not take into account the values of the energy generated from PV and Solar Thermal systems for its calculation (in the HVAC tool)
- The result were normalized by an erroneous value (in the post processing in the simulation module)

Once the problems were identified, the error was eliminated.

5.2.1.4 Problems with the units

Analysing the Final energy consumption it was detected that the value decreased in the scenarios by a very large amount. It is shown in the Table 15.

Table 15: Results of the final energy consumption for the 10 scenarios of the first iteration

Scenario	Base	1	2	3	4	5	6	7	8	9	10
Final energy consumption (kWh/m^2year)	91.07	0.083	0.099	0.094	0.106	0.102	0.086	0.074	0.095	0.087	0.103

The problem here was that the values coming from the scenarios were loaded at the repository in the wrong units (in MWh/m^2year). So the values were divided by 10^3. This error was immediately corrected.

5.2.1.5 Problems with investment boundary

In the evaluation was detected that the normalized value of the investment DPI was significantly smaller than other DPIs in all the scenarios. The normalization of this value, as explained in D4.2, is done using the value of the investment boundary. In the first place, the value introduced as investment boundary was 5,000,000€. This value is much bigger than the value of the investment in the different scenarios, as can be seen in the Table 16, so the normalization process was decreasing the importance of the economic cost.

Table 16: Results of the investment cost for the 10 scenarios of the first iteration

Scenario	1	2	3	4	5	6	7	8	9	10
Investment (€)	858,202	690,982	547,492	725,589	799,617	747,877	519,716	784,865	717,646	698,631

A new boundary was introduced, more adequate to the district (and also for the normalization process) for solving this problem. The new value was 790,000 €.

5.2.1.6 Problems with the pre-configured schemes

Analysing the calculated weighted values in the evaluator was observed that they are not as expected taking into account the predefined scheme selected in the GUI. The problem was that the weights had not the correct value. It was detected that the GUI was not binding the right values of the weights for most of the pre-defined schemes. The error was immediately corrected.

5.2.2 Results

After the processes of error fixing, new executions were launched for the case study, providing the results shown in the following sub-sections.

5.2.2.1 Analysis of best scenarios

Under the selected prioritisation scheme (priority to achieve a low carbon district), a total of 100 scenarios were evaluated (in 10 iterations) leading to presenting 2 scenarios in the Pareto Front. The scenarios shown as “best scenarios” belong to different iterations, not being all them within the latest iterations as it should be expected in order to close the optimisation process and effectively show those that are the best options for the defined criteria. However, the evaluation of 100 scenarios is considered sufficient in order to demonstrate the viability of the platform in order to optimise the candidate retrofitting scenarios, providing results that are considered sufficient for validation purposes.

The following table shows the DPIs used for the optimisation for these 2 scenarios, as well as for the baseline calculated for this execution, comparing also these values with those used as reference from the real case.

Table 17: Comparison of reference real values vs OptEEmAL obtained values – Before and after retrofitting

Indicator		Units	REFERENCE		OptEEmAL		
			Baseline	Retrofitting scenario (implemented)	Baseline	Candidate Scenario 1	Candidate Scenario 2
ENV01	Global Warming Potential	kg CO_2 eq/m²year	36,73	14,40	57,69	40,22	39,94
ENV04	Primary energy consumption	MJ/m²year	640,80	255,60	1237,33	874,72	868,70
ENV06	Energy payback time	years	n/a	-	n/a	3,69	4,48
ECO02	Investments	€/m²	n/a	164,82	n/a	128,95	138,19
ECO03	Life cycle cost	€	-	-	7.665.852	11.645.133	12.208.537
ECO05	Payback Period	years	n/a	12	n/a	9,13	8,21
ENE01	Energy demand (heating)	kWh/m².year	120,75	61,70	90,31	60,37	58,78
ENE02	Final energy consumption	kWh/m².year	167,25	66,91	151,80	86,24	83,98
ENE06	Net fossil energy consumed	kWh/m².year	167,25	54,71	151,80	37,60	33,64
ENE09	Energy demand covered by RES	%	0,00	18,23	0,00	56,40	59,94
ENE13	Energy use from District Heating	kWh/m².year	0,00	0,00	0,00	0,00	0,00
COM01	Local thermal comfort	Level	0	0	0	0	0
ENE14	Energy use from Biomass	kWh/m².year	0,00	0,00	0,00	0,00	0,00

ENE15	Energy use from PV	kWh/m2.year	0,00	0,00	0,00	23,10	23,19
ENE16	Energy use from Solar Thermal	kWh/m2.year	0,00	12,20	0,00	25,54	27,14
ENE17	Energy use from Hydraulic	kWh/m2.year	0,00	0,00	0,00	0,00	0,00
ENE18	Energy use from Mini-Eolic	kWh/m2.year	0,00	0,00	0,00	0,00	0,00
ENE19	Energy use from Geothermal	kWh/m2.year	0,00	0,00	0,00	0,00	0,00

5.2.2.2 Analysis of recommended ECMs

The real ECMs implemented in the case study *Cuatro de Marzo* for the R2Cities project[5] are presented in the Table 18 below with a representative block of building in line.

Table 18: Real ECMs implemented in the block of buildings of Turina Street

Type	Energy Conservation Measure	Description	U-value (W/m²·K)	ECM in the OptEEmAL catalogue
Passive	Façade External Thermal Insulation Composite system (ETICs)	EPS 120mm	0.24	PA.FA.EX.CS.06 (120 mm)
Passive	Additional external windows (Doubling) / Glazed enclosure of the balconies	Glazing: 4/12/6 low emissive. Frame: PVC for balconies and aluminium for windows. Solar factor (g): 0.76 Solar factor balconies (g): 0.73	2.60 (North) 2.70 (East, West and South) 2.80 (Balconies)	PA.OP.DG.DE.01 (similar U-value) Not for the glazed enclosure of the balconies
Passive	Roof insulation below top slab	Rockwool 100mm	0.38	PA.RO.TS.CI.01
Control	Efficient lighting systems in common areas	LED efficient lighting (emergency lighting and standard lighting). Occupancy detection sensors and timers. LED downlights (24W): 11 (3 ground floor and 2 per floor).	-	No similar ECM
Renewable	Solar thermosiphon collectors for DHW	Standard flat plate collectors. Number of collectors: 7 Tank: 1000 l	-	RE.RO.SC.TC.01 RE.RO.SC.TC.02
Active	Efficient condensation low-temperature boiler for heating and support of DHW	Boiler 24 KW per each dwelling	-	AC.DE.BO.CNG.01

The distribution of scenarios and the Pareto front (blue line) obtained in the OptEEmAL platform for the *Cuatro de Marzo* project is shown in the Figure 65. From the two scenarios proposed as “best” candidate retrofitting scenarios, the one with higher benefit for a slightly higher relative cost.

[5] R2Cities Consortium (2018), *D5.2: Report of the energy performance analysis*, Valladolid, Spain.

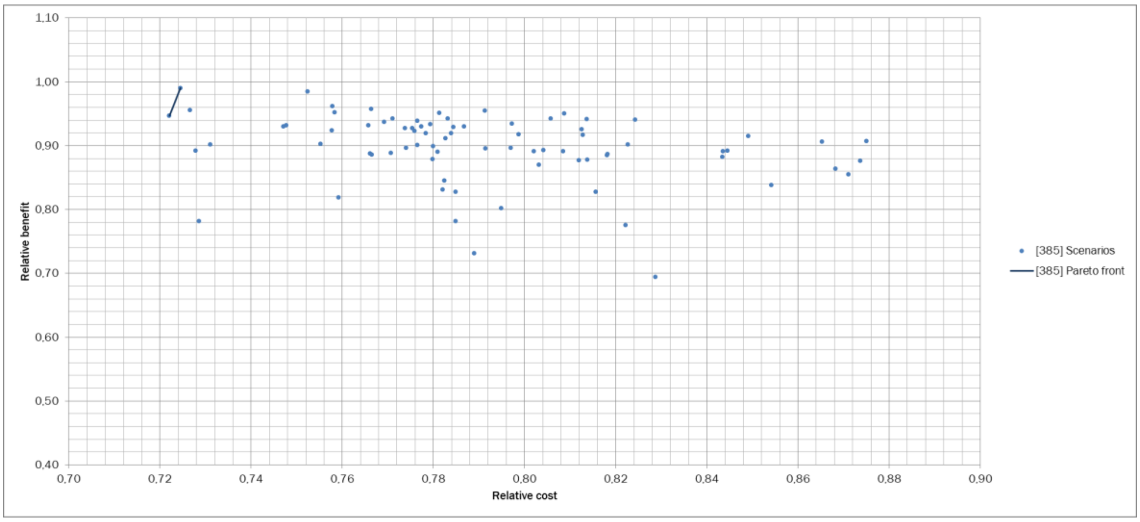


Figure 65: Relative cost and benefit for the scenarios evaluated for Cuatro de Marzo district

The ECMs proposed by OptEEmAL for this scenario are shown in the following table.

Table 19: ECMs selected in the selected optimal scenario

ECM Category	Building 1 (tower)	Building 2 (block)	Building 3 (block)	Building 4 (block)	Building 5 (tower)
Passive (PA)	FA.EX.CS.06 RO.PI.IN.03 OP.DG.DE.02	FA.EX.CS.09 RO.PI.IN.01 OP.DG.DE.02	FA.EX.CS.11 RO.PI.IN.02 OP.DG.DE.02	FA.EX.CS.10 RO.PI.IN.02 OP.DG.DE.02	FA.EX.CS.02 RO.PI.IN.02 OP.DG.DE.02
Active (AC)	-	DE.BO.NG	DE.BO.CG	DE.BO.CD	
Renewable (RE)	RO.SC.PV.01.65 RO.SC.TC.02.35	RO.SC.PV.02.80 RO.SC.TC.01.20	RO.SC.PV.01.60 RO.SC.TC.01.25	RO.SC.PV.03.85 RO.SC.TC.02.15	RO.SC.PV.01.75 RO.SC.TC.01.25
Control (CO)	DE.TH.SS DE.PL.LF	DE.TH.OS	DE.PL.LF	DE.PL.TV	DE.PL.LF DE.PL.TV

5.2.2.3 Conclusions

From the comparison of ECMs proposed, it can be noticed that those that OptEEmAL has considered for the selected scenario are in line with those implemented in reality.

In the passive category, external insulation, roof insulation and change of windows are proposed. While for the windows the same ECM is proposed for the 5 buildings, in terms of roof and wall insulation different thicknesses are proposed. This is explained through the fact that the energy balance is done at district level (where the district is optimised as a whole, instead of individual building optimisation) and by the previously mentioned fact of the population of 100 scenarios evaluated, while the evaluation of more iterations would probably lead to similar thicknesses for all buildings under the same typology. In terms of openings, windows with better U-values than those implemented in the reality are proposed (1,68 W/m^2K against 2,7 W/m^2K in the real project).

Regarding the active ECMs, for the scenario selected only the modification of boilers in the building blocks are proposed, and not in the towers. Again, this issue is explained through the fact of optimising the performance of the district while keeping certain values for the investment or payback period. Thus, the tool has considered that for this scenario there is no need for changing all active systems and combining them (both new and existing) with RES and control strategies.

For RES, the OptEEmAL tool proposes installing both PVs and solar thermal in different percentages depending on the building and the available surface. The reality, however, has been the installation of only solar thermal in the buildings retrofitted. This is explained through the fact that in the real project only the blocks where retrofitted, and not the towers, and for these buildings the owners blocked the implementation of PVs. However, in the OptEEmAL tool, these ECMs have been allowed in order to evaluate the impacts of implementing different technologies for RES production.

All in all, it can be concluded that the OptEEmAL platform has proposed ECMs that are in line with the real project, optimising in some cases the measures proposed and, in orders, discarding some of them as the change of boilers in all the dwellings.

Regarding the comparison of indicators, as it can be noticed within Table 17, the values obtained through the platform are quite similar for the baseline with some discrepancies in the Global Warming Potential, the Primary Energy Consumption and the Heating Demand. For the two firsts, currently the project is exploring the calculation of these indicators to verify and solve the issues that show these differences, as the problem is most probably in the calculation procedures implemented.

For the evaluation of the candidate scenarios proposed, it can be noticed that values are in ranges similar to the one implemented in reality with some discrepancies in the same indicators mentioned above for the baseline. Perhaps the most noticeable differences are on the investments, which are slightly minor for the candidate scenarios proposed by OptEEmAL than in the one implemented. This is explained through the fact that OptEEmAL proposes not changing all the boilers, as mentioned above, resulting thus in a minor investment for similar savings, which leads to shorter payback periods. Regarding the contribution by RES, OptEEmAL also proposes the integration of combined thermal and PV production and therefore values for both thermal and electricity production by RES are obtained, which leads to a reduction in the fossil energy consumed.

5.3 *Mogel* district, Eibar

5.3.1 Reference values and verification methodology

As presented above, for the *Mogel* district in Eibar, two different information is available: calculated values (from DesignBuilder simulations, where EnergyPlus is the simulation engine) and measured values (from energy bills) (see section 2.1.4 for more details). As Table 20 highlights, the calculated values are considerably close to the measures data. This point has also been confirmed in the frame of the ZenN project.

Table 20: Comparison of simulated and measured data for the Mogel district in Eibar (from ZenN project) – Before retrofitting

OptEEmAL DPI	Simulated	Measured	Unit
Energy demand - TOTAL	86,3	-	kWh/m^2.year
Energy demand - HEATING	56,8	-	kWh/m^2.year
Energy demand - COOLING	0,0	-	kWh/m^2.year
Energy demand - DHW	29,5	-	kWh/m^2.year
Internal lighting	11,8	-	kWh/m^2.year
Technical equipment	14,6	-	kWh/m^2.year
Final energy consumption	122,0	114,0	kWh/m^2.year
Final energy consumption (thermal)	96,0	88,0	kWh/m^2.year
Final energy consumption (thermal - gas)	96,0	88,0	kWh/m^2.year
Final energy consumption (thermal - biomass)	0,0	0,0	kWh/m^2.year
Final energy consumption (thermal - diesel)	0,0	0,0	kWh/m^2.year
Final energy consumption (electricity)	26,0	26,0	kWh/m^2.year

As a first attempt to validate the results provided by the platform, it has been decided to compare the DPI values provided by the platform with the calculated values retrieved from the ZenN project. The comparison has been focused on energy demands and consumption DPIs, considering the followings:

- relevant (and validated) simulation values (in contrast to *Cuatro de Marzo* district) are available from the ZenN project;
- energy demands and energy consumption are the most challenging DPIs to be computed and consist the guiding principle for other DPIs calculation;
- the overall DPIs analysis has been carried out for the *Cuatro de Marzo* district.

At this point, it is worth mentioning that DHW energy demands are not considered in this DPIs validation process; DHW energy demands are not calculated in the OptEEmAL platform since we lack relevant information requested for the DHW simulation (neither the IFC files nor the system vector provide such information).

Preliminary results of the aforementioned comparison are reflected in Table 21. Due to high deviations, the necessity for an overall verification methodology to identify the difference sources and "correct/understand" their origin has been underlined. Hence for the *Mogel* district, a methodological approach has been defined, an iterative process consisting of the following steps:

- Elaboration of OptEEmAL baseline calculation to retrieve the energy demands and consumption DPIs.
- Identification of the final electric energy consumption difference and estimation of possible reasons based on building energy performance simulation experience. Since the electric energy consumption stems from the internal gains (artificial lighting and technical equipment) operation only, errors that affect its calculation could be easily detected and corrected.
- Identification of differences at simulation parameter level for the internal gains data, performed by comparing the IDF file from the ZenN project with the IDF files generated by the OptEEmAL platform, and correction of identified different simulation parameters by modifying the IFC files inserted to the platform.
- New elaboration of OptEEmAL baseline calculation. Since inaccurate internal gains data could lead to overestimate (or underestimate) of the thermal energy demands, the baseline calculation with the internal gains corrected is required to investigate the internal gains correction impact on the final thermal energy consumption calculation.
- Identification of the final thermal energy consumption (and demands) difference and estimation of possible reasons based on building energy performance simulation experience.
- Identification of differences at simulation parameter level for the conditioned spaces data, performed by comparing the IDF file from the ZenN project with the IDF files generated by the OptEEmAL platform, and correction of identified different simulation parameters by modifying the IFC files inserted to the platform or updating relevant services of the platform.
- New elaboration of OptEEmAL baseline calculation.
- Identification of the DPIs difference and estimation of possible reasons based on building energy performance simulation experience that could lead to such deviation but cannot be handled within OptEEmAL platform.
- Modification of the IDF file from the ZenN project according to the data of the IDF files generated by the latest OptEEmAL baseline calculation to ensure that reasons of the previous step constitute the source of the final deviation.

The application of this process to the *Mogel* district case study is presented thoroughly in the following sections.

5.3.2 Results

5.3.2.1 Baseline calculation

The first elaboration of the baseline calculation has led to the results presented in Table 21. It shall be reminded that in OptEEmAL, the baseline situation refers to the situation before retrofitting.

Table 21: Comparison of simulated data from ZenN project and OptEEmAL results (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL	ZenN	Unit
Energy demand	213.6	56.8	kWh/m^2.year
Energy demand - Heating	127.2	56.8	kWh/m^2.year
Energy demand - Cooling	86.4	0.0	kWh/m^2.year
Energy demand - Internal lighting	-	11.8	kWh/m^2.year
Energy demand - Technical equipment	-	14.6	kWh/m^2.year
Final energy consumption	315.3	122.0	kWh/m^2.year
Final energy consumption (thermal)	228.9	96.0	kWh/m^2.year
Final energy consumption (thermal - gas)	228.9	96.0	kWh/m^2.year
Final energy consumption (thermal - biomass)	0.0	0.0	kWh/m^2.year
Final energy consumption (thermal - diesel)	0.0	0.0	kWh/m^2.year
Final energy consumption (electricity)	86.4	26.0	kWh/m^2.year

5.3.2.2 Final electric energy consumption difference

According to Table 21, the overestimation of the final electric energy consumption is obvious. Possible reasons for such a deviation could be the following:

1. Internal gains densities (artificial lighting and technical equipment nominal power) that have been defined by the BIM designer (and provided through the exported IFC files) are significantly high;
2. Internal gains operation schedules that have been provided by the IFC files differ from the relevant schedules that have been used within the ZenN project.

Comparing the ZenN project's IDF file with the IDF files generated by the OptEEmAL platform, the following mismatches have been noticed:

1. Indeed, as Table 22 presents, the internal gains densities that have been defined by the BIM designer are enormous in contrast with the densities that have been used in the ZenN project. Hence, the BIM model has been modified properly to adjust to ZenN project densities' values.
2. Regarding the schedules, it has been noticed that their time-variant values differ. While these values have been carefully defined within ZenN project to reflect the true internal gains operation, within OptEEmAL, they have been defined using predefined (according to standards) schedules provided by the BIM authoring tool (e.g. Revit). Although Revit allows for user-defined schedules, such user-defined information is not accessible through the Revit API, hence these schedules cannot be exported in the IFC file.
3. Another difference that has been detected is the daylight control presence. Daylight control has been set in the ZenN project while it has not been set in the OptEEmAL simulations. The inclusion of this parameter is impossible in OptEEmAL, since there is none data source for daylight control implementation.

The effects of the schedules' discrepancy and the daylight control absence are investigated in section 5.3.2.6.

Table 22: Internal gains' densities in OptEEmAL and ZenN (*Mogel* district)

Parameter	OptEEmAL	ZenN
Area per person (m^2)	105.8	25.0
Lighting load density (W/m^2)	10.8	2.0
Power load density (W/m^2)	10.8	2.0

5.3.2.3 Baseline calculation – correct internal gains densities

Results obtained with the internal gains densities correction are presented in Table 23. The final electric energy consumption has been significantly decreased, while it would be expected to be further decreased if it the schedules' values modification and the daylight control implementation could be performed.

Table 23: Comparison of the ZenN project and OptEEmAL results after the internal gains correction (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL Initial	OptEEmAL correct internal gains	ZenN Initial	Unit
Energy demand	213.6	176.5	56.8	kWh/m^2.year
Energy demand - Heating	127.2	159.1	56.8	kWh/m^2.year
Energy demand - Cooling	86.4	17.4	0	kWh/m^2.year
Energy demand - Internal lighting	-	-	11.8	kWh/m^2.year
Energy demand - Technical equipment	-	-	14.6	kWh/m^2.year
Final energy consumption	315.3	225.0	122	kWh/m^2.year
Final energy consumption (thermal)	228.9	188.7	96	kWh/m^2.year
Final energy consumption (thermal - gas)	228.9	188.7	96	kWh/m^2.year
Final energy consumption (thermal - biomass)	0.0	0.0	0	kWh/m^2.year
Final energy consumption (thermal - diesel)	0.0	0.0	0	kWh/m^2.year
Final energy consumption (electricity)	86.4	36.3	26	kWh/m^2.year

5.3.2.4 Final thermal energy consumption difference

According to Table 23, the overestimation of the final thermal energy consumption and relevant indicators is highlighted. After the internal gains densities' correction, the heating indicators are increased, while the cooling indicators are decreased, as expected due to lower internal gains. Moreover, the thermal energy consumption is surprisingly higher than what would be expected, given the calculated thermal energy demands.

Possible reasons for such a thermal energy indicators' deviation could be the following:

1. Thermostat heating and cooling setpoints that have been used within OptEEmAL platform are not representative;
2. Concerning the building's airtightness, the building infiltration rate has been neglected.
3. Unoccupied and unconditioned space have been translated to conditioned spaces with heating and cooling demands that contribute to the total thermal demands' estimation.
4. Boiler's efficiency has not been properly defined or it has not been properly stipulated in the HVAC tool.

Comparing the ZenN project's IDF file and the IDF files generated by the OptEEmAL platform, the following have been noticed:

1. Thermostat's heating setpoints are different between the simulations made in the ZenN project and the platform. In OptEEmAL, data source for such information is missing, hence constant setpoints at 21°C have been considered. In the ZenN project, seasonal and variant setpoints have been considered (20°C, 17°C). Moreover, in ZenN project cooling demands are neglected, while OpEEmAL platform considers a constant thermostat's cooling setpoint at 25°C. The impact of these factors on the heating and cooling demands has been studied in section 5.3.2.6.
2. Buildings infiltration rate has been neglected in the baseline calculations, since their infiltration class has not been defined in the BIM models. To address this issue, the infiltration class of the BIM models has been set to "Medium" to account for heat losses (gains) from cracks (which define the airtightness of the building).
3. In the ZenN project, unconditioned spaces are considered to have a zero-heating energy demand. In this first iteration of the OptEEmAL calculations, these spaces were not defined as unconditioned thus leading to higher energy demands. Investigating the impact of this imperfection, initially some of these wrongly defined spaces as conditioned were changed to unconditioned by modifying specific parameters in the BIM models. Further experiments that have been performed by modifying the ZenN project IDF are documented in section 5.3.2.6.

5.3.2.5 Baseline calculation – correct data for the conditioned spaces

Results obtained by changing a subset of conditioned spaces to unconditioned are presented in Table 24. The final thermal energy consumption and the energy demands have been decreased, as expected. Further experiments could be performed to detect which spaces are still conditioned but should be changed to unconditioned; however, due to heavy workload that should be performed by the OptEEmAL platform towards reporting results for other demo cases currently, these experiments have been performed by modifying properly the ZenN project IDF file.

Table 24: Comparison of the ZenN project and OptEEmAL results after the data for conditioned spaces correction (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL correct internal gains	OptEEmAL correct conditioned spaces	ZenN initial	Unit
Energy demand	176.5	152.1	56.8	kWh/m^2.year
Energy demand - Heating	159.1	139.4	56.8	kWh/m^2.year
Energy demand - Cooling	17.4	12.61	0	kWh/m^2.year
Energy demand - Internal lighting	-	-	11.8	kWh/m^2.year
Energy demand - Technical equipment	-	-	14.6	kWh/m^2.year
Final energy consumption	225.0	203.4	122	kWh/m^2.year
Final energy consumption (thermal)	188.7	173.4	96	kWh/m^2.year
Final energy consumption (thermal - gas)	188.7	173.4	96	kWh/m^2.year
Final energy consumption (thermal - biomass)	0.0	0.0	0	kWh/m^2.year
Final energy consumption (thermal - diesel)	0.0	0.0	0	kWh/m^2.year
Final energy consumption (electricity)	36.3	29.9	26	kWh/m^2.year

5.3.2.6 Remaining differences and their impact to the energy DPIs calculation

This section investigates the impact of drawbacks that have been detected but could not be addressed by modifying the information accessed through the different data sources of the

OptEEmAL platform. To this direction, the ZenN project IDF file has been edited to set few of its simulation parameters according to what has been used within OptEEmAL.

Internal gains schedules and daylight control

Although the final electric energy consumption obtained by the OptEEmAL platform is quite close to the one calculated in the ZenN project, internal gains schedules discrepancy and daylight control absence could explain the remaining difference. To investigate their impact, the internal gains schedules of the ZenN project IDF have been modified in such a way to be identical to the schedules used in OptEEmAL, while the daylight control has been deactivated. Results obtained by performing these modifications are presented in Table 25, where it is obvious that the final electric energy consumption difference is further decreased (the absolute percentage deviation equals to 2.3%). An explanation for the remaining difference could be the presence of an exterior light bulb that is neglected in OptEEmAL.

Table 25: Comparison of OptEEmAL and the ZenN project results after the internal gains schedules modification and the daylight control deactivation (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL final	ZenN initial	ZenN modified internal gains	Unit
Energy demand - TOTAL	152.1	56.8	59.7	kWh/m^2.year
Energy demand - Heating	139.4	56.8	59.7	kWh/m^2.year
Energy demand - Cooling	12.61	0.0	0	kWh/m^2.year
Final energy consumption (electricity)	29.9	26	29.2	kWh/m^2.year

Thermostats' heating/cooling setpoints and spaces condition type

With an acceptable agreement of the final electric energy consumption results, more experiments have been performed towards explaining the enormous deviation of the thermal energy demands results. These experiments have been focused on modifying the ZenN project IDF thermostats' setpoints and changing spaces that are unconditioned to conditioned according to the input data of the OptEEmAL platform (as mentioned above, due to lack of time these modifications could not be performed by further experiments in the OptEEmAL platform).

Results of these modifications are presented in Table 26. Initially, wrongly considering constant values of heating and cooling setpoints within OptEEmAL seems to have great impact on the calculated values; comparing the "ZenN modified internal gains" results of Table 25 with the "ZenN modified setpoints" results of Table 26, the absolute percentage error equals 28.5%. Hence, the necessity for adding a question to the Building Energy Systems questionnaire about the thermostats' heating and cooling setpoints is underlined. Furthermore, the "ZenN modified conditioned spaces" results highlight the importance of the correct conditioned and unconditioned spaces definition; using identical data for the spaces condition type, the energy demands results seems to be at the same scale.

Table 26: Comparison of OptEEmAL and the ZenN project results after the thermostats' setpoints and the spaces condition type modifications (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL final	ZenN modified setpoints	ZenN modified conditioned spaces	Unit
Energy demand - TOTAL	152.1	96.7	137.3	kWh/m^2.year
Energy demand - Heating	139.4	93.9	131.1	kWh/m^2.year
Energy demand - Cooling	12.61	2.8	6.2	kWh/m^2.year

5.3.2.7 Comparison with measured values

In order to provide more insights on the results provided by the OptEEmAL platform, a comparison with the measured data obtained in the ZenN project is provided (Table 27).

Table 27: Comparison of simulated data from OptEEmAL and measured data from ZenN (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL Final	ZenN measured	Unit
Energy demand	152.1	-	kWh/m^2.year
Energy demand - Heating	139.4	-	kWh/m^2.year
Energy demand - Cooling	12.61	-	kWh/m^2.year
Energy demand - Internal lighting	-	-	kWh/m^2.year
Energy demand - Technical equipment	-	-	kWh/m^2.year
Final energy consumption	203.4	114,0	kWh/m^2.year
Final energy consumption (thermal)	173.4	88,0	kWh/m^2.year
Final energy consumption (thermal - gas)	173.4	88,0	kWh/m^2.year
Final energy consumption (thermal - biomass)	0.0	0,0	kWh/m^2.year
Final energy consumption (thermal - diesel)	0.0	0,0	kWh/m^2.year
Final energy consumption (electricity)	29.9	26,0	kWh/m^2.year

At first sight, this comparison shows that the thermal final energy consumption simulated by the platform is much more important (relative difference of 97%) than the measured data from the ZenN project. To the contrary, the electricity final energy consumption is closer (15%).

Regarding the thermal final energy consumption, the comparison is limited has the previous section has showed that the OptEEmAL simulations need to be modified to account properly for the thermostats' heating/cooling setpoints and spaces condition type to be closer to the reality. Indeed, the comment made before regarding the consideration of constant setpoints in OptEEmAL vs variable setpoints in ZenN is even more highlighted when comparing with measured data (building users are not always having the same and constant setpoints). Also, the comment regarding the correct consideration of conditioned spaces is highlighted here. OptEEmAL consider that some building spaces are heated while in reality they are not. It explains the higher thermal energy consumption simulated by the platform in comparison to measured data.

With respect to the final electricity consumption, as mentioned in the previous section, the difference is probably issuing from the different internal gains. In reality, the internal gains are different from the "standard" values considered in the simulations (both in OptEEmAL and ZenN).

Finally, as a general comment, even though it is not the purpose of this section and this project, the differences between simulated and measured data (especially related to user's behaviour) have to be kept in mind for this comparison.

5.3.2.8 Conclusions

The final results obtained from this results analysis activity can be summarised by the Table 28 below.

Table 28: Comparison of initial and final data from OptEEmAL and ZenN project (*Mogel* district) – Before retrofitting

OptEEmAL DPI	OptEEmAL Simulated Initial	OptEEmAL Simulated Final	ZenN Simulated Initial	ZenN Simulated Final	ZenN measured	Unit

Energy demand	213.6	152.1	56.8	137.3	-	kWh/m2.year
Energy demand - Heating	127.2	139.4	56.8	131.1	-	kWh/m2.year
Energy demand - Cooling	86.4	12.61	0	6.2	-	kWh/m2.year
Final energy consumption	315.3	203.4	122	-	114,0	kWh/m2.year
Final energy consumption (thermal)	228.9	173.4	96	-	88,0	kWh/m2.year
Final energy consumption (thermal - gas)	228.9	173.4	96	-	88,0	kWh/m2.year
Final energy consumption (thermal - biomass)	0.0	0.0	0	-	0,0	kWh/m2.year
Final energy consumption (thermal - diesel)	0.0	0.0	0	-	0,0	kWh/m2.year
Final energy consumption (electricity)	86.4	29.9	26	29.2	26,0	kWh/m2.year

From this analysis, the following conclusions can be made (and the associated improvement points can be identified):

- Regarding the electricity final energy consumption :
    - Simulations performed by the OptEEmAL platform are correct (only 2.3% relative difference with ZenN corrected simulations).
    - However, the following additional comments can be made:
        - The BIM modeller has to ensure that the correct **internal gain densities** are entered into the IFC file used as OptEEmAL input. This has been highlighted in the IFC guidelines.
        - **Schedules** have an important role in the electricity consumption simulation. However, the use of Revit as BIM authoring tool prevents the inclusion of detailed schedules in the IFC file used as OptEEmAL input. This can be improved but is more related to Revit than OptEEmAL.
        - **Daylight control presence** is also an important parameter for electricity consumption simulation. In OptEEmAL, it is not possible to consider this parameter since there is no data source for its implementation. This is one improvement point for the platform that will also require additional data collection.
- Regarding the thermal energy demand/consumption:
    - Simulations performed by the OptEEmAL platform are correct (6% relative difference for the heating energy demand with ZenN corrected simulations).
    - However, the following additional comments can be made:
        - Similarly to electricity consumption, **internal gain densities** are important parameters that the BIM modeller should entered precisely in the IFC model and it has been reported in the IFC guidelines.
        - **Building airtightness** is an important parameter that the BIM modeller has to enter carefully while creating the IFC file. This has been highlighted in the IFC guidelines.
        - **Unconditioned spaces** have to be considered as such in the simulations. This was not the case in the initial OptEEmAL simulations and has been corrected.

- **Thermostat's heating and cooling setpoints** are also important parameters that are probably not considered with enough details in the current OptEEmAL simulations. This is an improvement point for the platform.

As a final conclusion to this section, we can say that the platform performs the simulations as expected but that two parameters can be considered with more details in the future: 1) daylight control presence and 2) Thermostat's heating and cooling setpoints. For these two parameters, modifications were not implemented during the project due to limited time.

5.3.3 Recommended ECMs

The real ECMs implemented in the case study *Mogel* for the ZenN project are presented in the Table 29 below.

Table 29: Real ECMs implemented in the *Mogel* district

Type	Energy Conservation Measure	Description	Uvalue (W/m2.K)	ECM in the OptEEmAL catalogue
Passive	Façade External Thermal Insulation Composite system (ETICs)	EPS 120mm	0.029	PA.FA.EX.CS.06
Passive	Pitch Roof External Insulation	Mineral wool 200 mm	0.031	PA.RO.PI.EX.03
Passive	Doubled glazed windows	Double glazed windows with aluminium frame (thermal break)	U_{glass} = 2.7 U_{frame} = 2.2 U_{window} = 2.6	PA.OP.DG.DE.01
Renewable	Solar thermal collector	4 solar panels (9m2) with a central storage of 750 liters - Flat plates	-	RE.RO.SC.TC.01
Active	Condensing natural gas boiler	Individual instant boilers with solar assisted central storage (COP = 0.9), Energy source = Gas, Condensing boiler of 25 kW capacity	-	AC.DE.BO.CG.07

First of all, it is important to mention that the project used for this section is different from the one used for the remaining sections of this deliverable. This is because when elaborating the first version of this deliverable, some ECMs (such as double glazed windows for instance) were not implemented in the platform. In order to consider the finally implemented set of ECMs, a new elaboration has been done. For information, the project used for this section has the 392 internal ID (while the one used for other section has the 318 internal ID).

For this specific project, the platform has provided four scenarios as outputs of the optimisation process (see Figure 66 below). As the prioritisation criteria for this project is "To prioritise the reduction of operational energy costs", the scenario selected for this section is the one with the lowest operational costs (corresponding to scenario 3 in Figure 66).

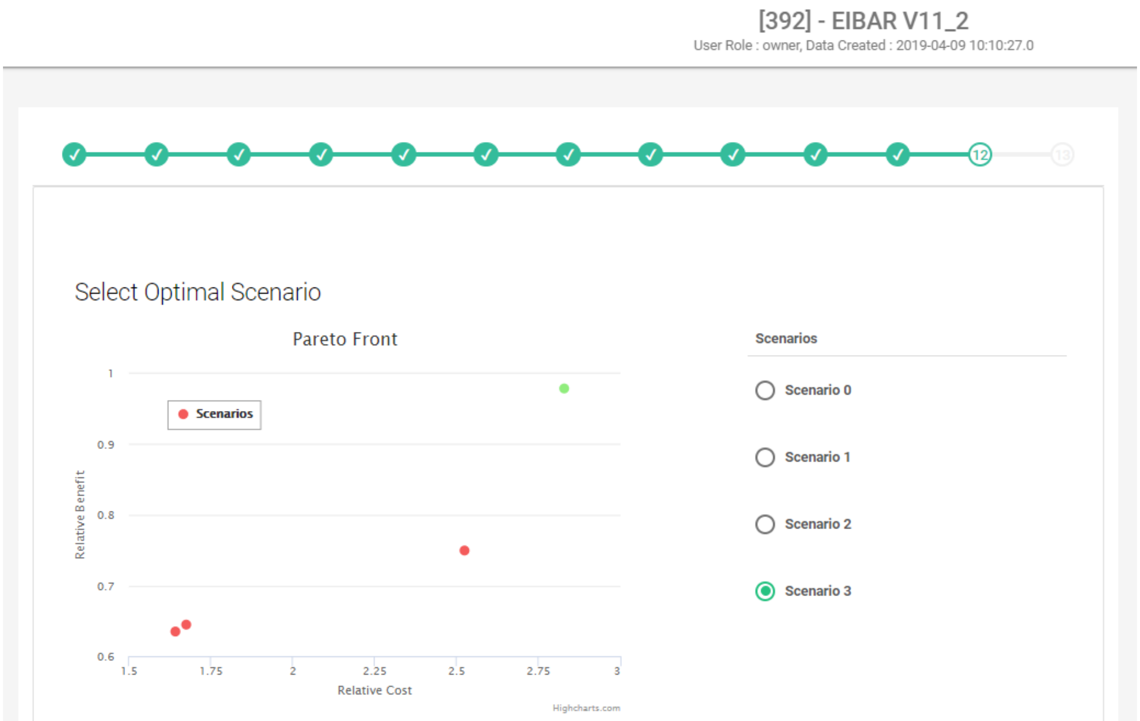


Figure 66: Pareto Front for project 392 (*Mogel* district, Eibar)

The ECMs associated with this scenario are presented in the Table 30 below.

Table 30: ECMs recommended by the platform for the *Mogel* district

Type	Energy Conservation Measure	Description	ECM in the OptEEmAL catalogue
Passive	Façade External Thermal Insulation Composite system (ETICs)	EPS 150mm	PA.FA.EX.CS.03
Passive	Pitch Roof External Insulation	Mineral wool 150 mm	PA.RO.PI.EX.02
Passive	Top Slab insulation/Chamber insulation	Mineral wool 100 mm	PA.RO.TS.CI.01
Passive	Floor insulation (NO crawlspace) over the slab	XPS 150 mm	PA.FL.NC.DE.02
Passive	Double glazed Windows	Aluminium frame	PA.OP.DG.DE.01
Renewable	Solar thermal collector	Flat plate collector, 15 m^2	RE.RO.SC.TC.01
Renewable	Photovoltaic	Polycrystalline photovoltaic panel , 85 m^2	RE.RO.SC.PV.02
Active	Condensing natural gas boiler	Energy source = Gas, Condensing boiler of 18 kW capacity	AC.DE.BO.CG.01
Control	Optimal StartUp and ShutDown	For heating	CO.DE.TH.OS.01

The comparison between the real ECMs implemented in the Mogel district and the ones recommended by the platform is provided in the Table 31 below.

Table 31: Comparison of ECMs implemented in reality and recommended by the platform

Type	Real ECMs implemented		ECMs recommended by the platform	
	Description	Code (in OptEEmAL)	Description	Code
Passive	Façade External Thermal Insulation Composite system (ETICs) – EPS 120 mm	PA.FA.EX.CS.06	Façade External Thermal Insulation Composite system (ETICs) – EPS 150 mm	PA.FA.EX.CS.03
Passive	Pitch Roof External Insulation – Mineral wool 200 mm	PA.RO.PI.EX.03	Pitch Roof External Insulation – Mineral wool 150 mm	PA.RO.PI.EX.02
Passive	Doubled glazed windows – Aluminium frame with thermal break	PA.OP.DG.DE.01	Top slab insulation with Mineral wool 100 mm	PA.RO.TS.CI.01
Passive	-	-	Floor insulation over the slab with XPS 150 mm	PA.FL.NC.DE.02
Passive	Doubled glazed windows – Aluminium frame with thermal break	PA.OP.DG.DE.01	Doubled glazed windows – Aluminium frame with thermal break	PA.OP.DG.DE.01
Renewable	Solar thermal collector – Flat plate (9m^2)	RE.RO.SC.TC.01	Solar thermal collector – Flat plate (15 m^2)	RE.RO.SC.TC.01
Renewable	-	-	Polycrystalline photovoltaic panel (85 m^2)	RE.RO.SC.PV.02
Active	Condensing natural gas boiler – 25 kW	AC.DE.BO.CG.07	Condensing natural gas boiler – 18 kW	AC.DE.BO.CG.01
Control	-	-	Optimal StartUp and ShutDown for heating	CO.DE.TH.OS.01

As presented in Table 31, the **facades** in both cases (real and in the platform) should be refurbished. In both cases, the proposed ECM is an ETIC system with EPS material. The only difference being the thickness of the insulation material, the one proposed by the platform being thicker.

Regarding **roofs**, ECMs have also been recommended by the platform. The proposed ECM is the same as the one implemented in reality. Again, the difference is the thickness of the ECM (in this case the ECM proposed by the platform is thiner).

Regarding the **windows**, they were replaced in the real project by double glazed windows and the platform has proposed exactly the same ones.

Regarding **slabs**, they are not retrofitted in the real district but the platform proposes to insulate both the top and ground slabs.

In terms of **active** systems, the platform has recommended the same ECM as the one implemented in reality (i.e. condensing natural gas boiler), the only difference being the capacity.

Finally, regarding **renewables**, the platform has recommended both solar thermal and photovoltaic panels while in reality only solar thermal panels have been included.

Overall, it appears that the platform recommendations are closed to the real ECMs implemented in the *Mogel* district. The main difference is the size of the different elements (thickness for passive ECMs or area for renewables). Also, another difference lies in the fact that the platform is proposing more ECMs than the ones implemented in reality. Based on the analysis performed, these differences can originate from:

- The different ECM prices between the platform and the reality. Unfortunately, it was impossible to collect the real prices of the ECMs implemented in the *Mogel* district and thus impossible to check this parameter. It is possible that the platform prices are lower than the reality leading to the possibility to implement more ECMs.
- The user configuration of the problem. In OptEEmAL, the user has to configure the problem according to the possibilities provided by the platform. Of course, this is a “simplification” of reality which can include additional factors which cannot be considered in the platform (such as the habit to implement a given ECM for instance). This difference in the problem configuration as for sure a final influence on the ECMs recommended by the platform.

6 Performance assessment

The assessment of the performances of the OptEEmAL platform was performed and reported in D5.5. Then, this section presents a summary of this assessment for the "time needed to use the platform as this aspect is critical from a demonstration perspective.

Tests carried out and reported in D5.5 show that overall, the time needed to run the platform can be approximately estimated to be between 20 and 30 hours with a significant influence of the number of buildings on this time. The two most time consuming steps being "Baseline calculation" and "Optimisation" due to the calculation times required at these steps (Figure 67 and Figure 68).

The total time to use the platform is significant but is still lower than the time needed to make the same work without the OptEEmAL platform (this is further details in the next section). In addition, it has to be noted that a significant amount of time (app. 2 days per model) is needed to elaborate the IFC files needed to run the platform. However, this time is expected to be significantly reduced in the future with the expansion of BIM models for existing buildings.

As a conclusion, and for illustration purpose, it can be mentioned that the total time to use the platform (considering input data elaboration and use of the platform) for a district consisting of 4 buildings is approximately 5 days (i.e. one working week). Again, this time is significant but is much lower than the time required to perform the design of the same project without the OptEEmAL platform.

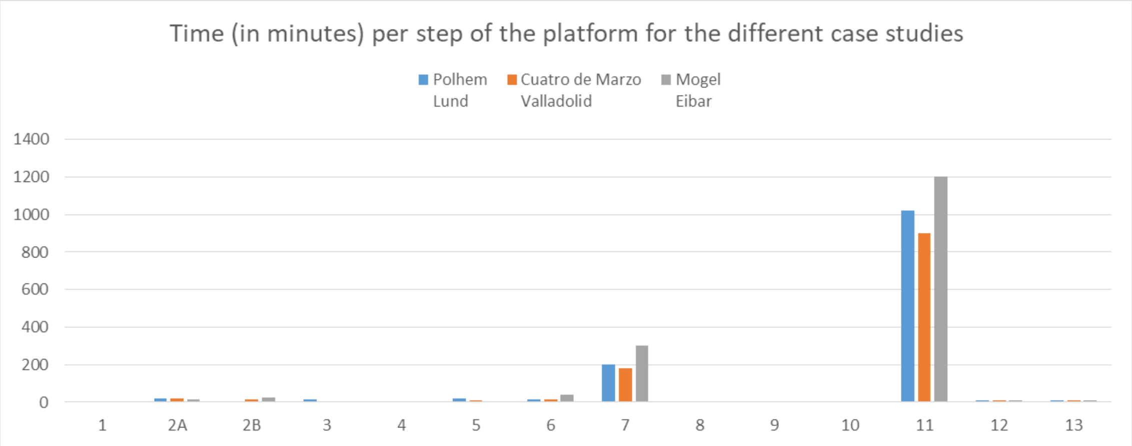


Figure 67: Time needed (in minutes) per step of the platform for the different case studies

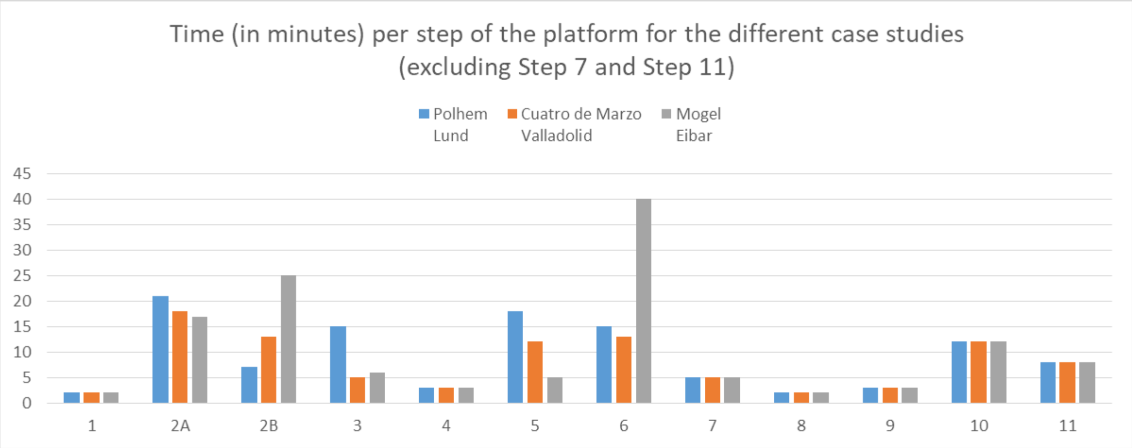


Figure 68: Time needed (in minutes) per step of the platform for the different case studies (excluding step 7 and step 11)

7 Impact assessment

7.1 Introduction

This section aims at comparing the current performance of the OptEEmAL platform (in its current state of development) with the expected impacts mentioned in the Grant Agreement of this project. The objective is to validate that the platform is on the right path to deliver its expected impacts.

7.2 Expected impacts

The expected impacts of the project are listed in the table below (Table 32).

Table 32: Expected impacts of the OptEEmAL project

N°	Description
	Expected impacts of the work programme
1	OptEEmAL delivers a more effective refurbishment at building and district level achieving time reduction during design and construction phases improving quality, comfort and maintenance activities.
2	OptEEmAL delivers an optimised and integrated design of energy-efficient buildings and districts, considering different dimensions with compliance with regulation and user-oriented comfort expectations and constraints.
3	OptEEmAL enables actors to make validated and quantified selections for the optimised design of refurbishment plans at building and district levels.
	Economic impacts
4	OptEEmAL will reduce 259,4 M€ the associated costs during the design phase when compared to current business as usual practices and will design 7800 retrofitting projects in the following 10 years EU-wide.
5	OptEEmAL will reach economic savings associated to energy efficient solutions of 140 M€ per year and will promote reductions in the Return of Investment (RoI) over 50% through provided optimised design solutions at district level.
6	OptEEmAL will contribute to mobilise public and private investments through better decision making procedures, more effective design and operation phases. OptEEmAL potential savings of public funds is 995.64 M€ for the following 10 years.
7	OptEEmAL economic savings during the following 10 years are equivalent to the development of 474 retrofitting projects and 6.83 M m2 EU-wide during the following 10 years.
	Market competitiveness
8	OptEEmAL will enhance the utilisation of innovative and existing solutions in a holistic integration, enhancing the access to applied research and technology transfer such as new technologies, materials, smart and eco-efficient solutions.
9	OptEEmAL will contribute to follow the contractual processes established by the IPD methodology through the BIM adoption, contributing to the EUPPD principles and improving the competitiveness of the European Construction sector in the field of “green” construction technologies.

Growth of the European Construction Sector	
10	OptEEmAL will contribute to the creation of 24,885 direct jobs and 34,839 indirect jobs in the European construction sector in 14 years.
11	OptEEmAL will increase the capacity of SMEs and will contribute to the creation of new typologies of SMEs in the European construction sector.
12	OptEEmAL will contribute to Europe's Economic Recovery.
13	OptEEmAL will increase the knowledge on high performance solutions for energy efficient refurbishment of the professionals of the construction sector.
Environmental impacts	
14	OptEEmAL will contribute to the reduction of the energy consumption in European Buildings in 9.4 millions of KWh in 10 years.
15	OptEEmAL will minimise the life-cycle environmental impacts of the European Building sector reducing the 70% of the GHG emissions in a renovated building through a combination of energy savings and the fostering to use Renewable Energy Sources (RES) in buildings.
Social impacts	
16	OptEEmAL will contribute to the involvement of 6.7 million oh inhabitants in the decision making process on 10 years.
17	OptEEmAL will achieve interventions in compliance with inhabitants' expectations, analysing social impacts of applied measures and considering owners and tenants to be represented in the decision making process.
Other impacts	
18	OptEEmAL will fosters the dissemination of the new knowledge at professional level.
19	OptEEmAL will overcome non-technical barriers preventing the implementation of energy efficiency retrofitting projects

7.3 Platform's current performance

This section compares the platform's current performance with the different expected impacts. It is important to note that the comparison made in this section will evolve in the future in association with the future evolutions of the platform. In addition, it should be highlighted that the quantification of positive and negative impacts of a solution like OptEEmAL is difficult to perform. This is related to the development status of the platform itself but also to the specificities of each construction projects, of each country regulation and of the business model underlying each project. As a consequence, figures mentioned below should be considered as orders of magnitude rather than precise values.

In this section, each expected impact and the associated platform performance is presented. A colour code is used to define if the expected impact is met or not[6].

[6] Green = Already in line with the expected impact / Orange = On track. Considered to the in line by the end of the project / Red = Not in line. A Grey colour indicates that the impact cannot be assessed at this stage of the platform's development.

7.3.1 Expected impacts of the work programme

Table 33: Impact assessment for expected impact no.1

Impact description	OptEEmAL delivers a more effective refurbishment at building and district level achieving time reduction during design and construction phases improving quality, comfort and maintenance activities.
Assessment	In line with the expected impact
Comment	Although the platform development is not fully finalised, we can consider that this expected impact is already met by the platform. Below is given a more detailed explanation: • Time reduction: The usual time of the design phase of a district energy retrofitting project is considered to be from several weeks to several months. The tests mentioned in this deliverable shows that the overall time needed to run the platform is between 20 and 30 hours. Considering that different configurations of the project can be needed to get the best results, we consider that the use of the platform can last several days. The time needed to elaborate the BIM models is not considered here considering the future expansion of BIM model elaboration for existing buildings and also because BIM model elaboration cannot be fully attributed to OptEEmAL (BIM models are used for other purposes). • Improved quality, comfort and maintenance: OptEEmAL delivers an optimised refurbishment projects based on a holistic assessment. This will results in an overall better quality of the project (comfort being included as one of the DPI category in OptEEmAL). Regarding maintenance, the inclusion of a life cycle perspective both in the economic and environmental DPIs leads to the delivery of an optimised project regarding this aspect too (reduce cost and environmental impacts of maintenance activities).

Table 34: Impact assessment for expected impact no.2

Impact description	OptEEmAL delivers an optimised and integrated design of energy-efficient buildings and districts, considering different dimensions with compliance with regulation and user-oriented comfort expectations and constraints.
Assessment	In line with the expected impact
Comment	OptEEmAL already delivers an optimised (mathematically speaking) and integrated (i.e. holistic approach mentioned above) design considering different dimensions (energy, environmental, economy, comfort, etc.). The compliance with regulations and inclusion of user-oriented expectations and constraints are taken into account through prioritisation criteria and targets/boundaries defined by the user. In addition, new functionalities at the proof of concept stage such as the U-value functionality implemented also increase the "link" between OptEEmAL and the regulations.

Table 35: Impact assessment for expected impact no.3

Impact description	OptEEmAL enables actors to make validated and quantified selections for the optimised design of refurbishment plans at building and district levels.
Assessment	In line with the expected impact
Comment	OptEEmAL involves the different actors of the project through the IPD approach. "Validated" selections are made by ensuring communication and validation of the different actors at various stage of the project. Regarding this point, it should be

	noted that the IPD related functionalities are not yet implemented in the GUIs of the platform but are fully described and ready to be implemented. "Quantified" selections are made by using DPIs which provide a quantified assessment of both the baseline and the different refurbishment scenarios.

7.3.2 Economic impacts

Table 36: Impact assessment for expected impact no.4

Impact description	OptEEmAL will reduce 259,4 M€ the associated costs during the design phase when compared to current business as usual practices and will design 7800 retrofitting projects in the following 10 years EU-wide.
Assessment	In line with the expected impacts
Comment	In order to get an order of magnitude of the costs saved by the platform, the following exercise has been done: • The average cost of a holistic district intervention is 3.5 M€[7] (for a 25,000 m² project) • The share of the design phase in the overall cost is 5%[8]. This value is considered to be highly conservative in comparison to NBK's experience in the design of retrofitting project (based on NBK's experience, approximately 10% of the total project cost is dedicated to the design. • This leads to a cost of the design phase of 175,000 €. • Considering a district of 5 buildings, the time needed to run the platform (including the time for the elaboration of the BIM models) is: 5*2 days + 3 days = 13 days. • With an average daily cost of 750 €/day, it represents approximately 10,000 € for the design phase using OptEEmAL. Of course, OptEEmAL does not cover the full design stage. We consider arbitrarily that the total cost of the design phase using OptEEmAL is 50,000 € • With those information, OptEEmAL is expected to save 125,000 € per retrofitting project. • Considering a total number of 7800 projects in the following 10 years (assumptions from the DoA considering a 5% market penetration rate that cannot be define more precisely at this step), this makes a total of **975 M€ saved in the coming 10 years**. • Despite this conclusion, it is important to remind the high uncertainties associated to this exercise. Those uncertainties could be reduced in the future with the commercial exploitation of the platform. • Regarding the total number of projects designed with the OptEEmAL platform, it will not be possible to assess it within the project lifetime.

[7] From the DoA : ECORYS, The Energy Efficiency Investment Potential for the Building Environment, Two approaches, Client: EU DG ENER, 7 November 2012, Table 3.3 p.15 (Moderate scenario). The moderate scenario has been considered in order to use a conservative approach for the evaluation of the project's potential economic impacts.

[8] From the DoA: Association QUALITEL, Le coût global en construction (Life cycle costing in construction), October 2013.

Table 37: Impact assessment for expected impact no.5

Impact description	OptEEmAL will reach economic savings associated to energy efficient solutions of 140 M€ per year and will promote reductions in the Return of Investment (RoI) over 50% through provided optimised design solutions at district level.
Assessment	In line with expected impacts for Operational energy costs
	Will be difficult to achieve for RoI

Comment	**Operational energy costs:**
	For two projects implemented in the platform (ID=329 for *Cuatro de Marzo* and ID=318 for *Mogel*), the operational energy costs (ECO1.0) are:
	• *Cuatro de Marzo*:
	  o Baseline: 32.9 €/m²
	  o "Optimal" scenario: 22.3 €/m²
	  o Operational energy cost reduction: 10.6 €/m²
	• *Mogel*:
	  o Baseline: 35.8 €/m²
	  o "Optimal" scenario: 12.8 €/m²
	  o Operational energy cost reduction: 23.0 €/m²
	This gives as an average a reduction of 16.8 €/m² of operational energy costs. Considering that the EU building stock is 25,000 Mm², the renovation ratio is 1.5% and a 5% market penetration rate for the OptEEmAL platform, this leads to **314 M€ per year** of reduced operational energy costs.
	RoI:
	Regarding the RoI, in the DoA, the RoI for a "classical" retrofitting project is estimated to be 30 years.
	For the two projects above, the RoI associated with the "optimal" scenarios were respectively **22.1 and 18.5 years** for *Cuatro de Marzo* and *Eibar*. This makes a RoI reduction of respectively **26%** and **38%**. This impact is not met.
	Again, the high uncertainties associated with this exercise have to be highlighted (the real impacts of the platform can be much higher or lower than the ones presented here).

Table 38: Impact assessment for expected impact no.6

Impact description	OptEEmAL will contribute to mobilise public and private investments through better decision making procedures, more effective design and operation phases. OptEEmAL potential savings of public funds is 995.64 M€ for the following 10 years.
Assessment	In line with the expected impacts
Comment	As previously mentioned (Table 36 and Table 37), OptEEmAL is expected to save, in the coming **10 years**: • **975 M€** associated with the **design** stage • **3,140 M€** associated with the **operational** stage • A total of **4,115 M€**. Considering, as in the DoA, that 60% of this money is coming from public contribution, this makes a saving of public funds of **2,469 M€**.

Table 39: Impact assessment for expected impact no.7

Impact description	OptEEmAL economic savings during the following 10 years are equivalent to the development of 474 retrofitting projects and 6.83 M m^2 EU-wide during the following 10 years.
Assessment	In line with expected impacts
Comment	Using the impact values mentioned above (4,115 M€ saved over the next 10 years) and an average cost per retrofitting project of 3.5M€, this makes around **1170 projects.** Considering as an average 24,000 m^2/retrofitting project, this leads to **28.1 Mm^2**.

7.3.3 Market competitiveness

Table 40: Impact assessment for expected impact no.8

Impact description	OptEEmAL will enhance the utilisation of innovative and existing solutions in a holistic integration, enhancing the access to applied research and technology transfer such as new technologies, materials, smart and eco-efficient solutions.
Assessment	In line with the expected impact
Comment	Through its ECM catalogue and its holistic approach, OptEEmAL promotes the implementation of efficient (from a holistic perspective) technologies and thus favours the development of new technologies (research and technology transfer).

Table 41: Impact assessment for expected impact no.9

Impact description	OptEEmAL will contribute to follow the contractual processes established by the IPD methodology through the BIM adoption, contributing to the EUPPD principles and improving the competitiveness of the European Construction sector in the field of “green” construction technologies.
Assessment	In line with the expected impact
Comment	OptEEmAL relies on the IPD methodology and promotes the adoption of BIM. This is directly in line with several Commission’s priorities for public procurement such as “improving transparency, integrity and data”, “boosting the digital transformation of procurement” and “cooperating to procure together.

7.3.4 Growth of the European Construction Sector

Table 42: Impact assessment for expected impact no.10

Impact description	OptEEmAL will contribute to the creation of 24,885 direct jobs and 34,839 indirect jobs in the European construction sector in 14 years.
Assessment	In line with the expected impact
Comment	Using the data from the DoA (15 direct jobs created for each million € invested in the building renovation sector, 1.4 indirect jobs per direct job in the building sector) and the total 4,115 M€ expected savings, this leads to:

	• 61,725 direct jobs • 86,415 indirect jobs

Table 43: Impact assessment for expected impact no.11

Impact description	OptEEmAL will increase the capacity of SMEs and will contribute to the creation of new typologies of SMEs in the European construction sector.
Assessment	In line with the expected impact
Comment	This impact is difficult to assess. All the arguments provided in the DoA of the project are still valid and even reinforced considering the higher need for building retrofitting (per year) in comparison to the beginning of the project. However, this impact could not be assessed more precisely.

Table 44: Impact assessment for expected impact no.12

Impact description	OptEEmAL will contribute to Europe's Economic Recovery.
Assessment	In line with the expected impact
Comment	This impact is difficult to assess. All the arguments provided in the DoA of the project are still valid.

Table 45: Impact assessment for expected impact no.13

Impact description	OptEEmAL will increase the knowledge on high performance solutions for energy efficient refurbishment of the professionals of the construction sector.
Assessment	In line with the expected impact
Comment	OptEEmAL will contribute to increase the knowledge of professionals of the construction sector through its optimisation approach that provides the most efficient solutions for energy refurbishment (taking into account end-users priorities). OptEEmAL will also contribute to this impact by providing, through its ECM catalogue, high performance solutions for energy efficient refurbishment.

7.3.5 Environmental impacts

Table 46: Impact assessment for expected impact no.14

Impact description	OptEEmAL will contribute to the reduction of the energy consumption in European Buildings in 9.4 millions of KWh in 10 years.
Assessment	In line with the expected impact

Comment	For the project mentioned above (Table 37), the associated reductions in final energy consumption are:
	• *Cuatro de Marzo*:
	  o Baseline: 213.6 kWh/m^2
	  o "Optimal" scenario: 106.7 kWh/m^2

	○ Final energy consumption reduction: 106.9 kWh/m^2 • *Mogel*: ○ Baseline: 315.3 kWh/m^2 ○ "Optimal" scenario: 53.2 kWh/m^2 ○ Operational energy cost reduction: 262.1 kWh/m^2 This gives an average reduction of 184.5 kWh/m^2. Considering that the EU building stock is 25,000 Mm^2, the renovation ratio is 1.5% and a 5% market penetration rate for the OptEEmAL platform, this leads to **3.45 million of MWh per year** or **34.5 million of MWh in 10 years** of reduced final energy consumption.

Table 47: Impact assessment for expected impact no.15

Impact description	OptEEmAL will minimise the life-cycle environmental impacts of the European Building sector reducing the 70% of the GHG emissions in a renovated building through a combination of energy savings and the fostering to use Renewable Energy Sources (RES) in buildings.
Assessment	Will be difficult to achieve
Comment	For the project mentioned above (Table 37), the associated reductions in GHG emissions are: • *Cuatro de Marzo*: ○ Baseline: 77.3 kg CO_2 eq/m^2 ○ "Optimal" scenario: 46.5 kg CO_2 eq/m^2 ○ GHG emissions reduction: 40% • *Mogel*: ○ Baseline: 99.7 kg CO_2 eq/m^2 ○ "Optimal" scenario: 25.8 kg CO_2 eq/m^2 ○ GHG emissions reduction: 74% From the abovementioned figures, it is difficult to ensure that this impact will be met.

7.3.6 Social impacts

Table 48: Impact assessment for expected impact no.16

Impact description	OptEEmAL will contribute to the involvement of 6.7 million of inhabitants in the decision making process on 10 years.
Assessment	Cannot be assessed at this step
Comment	This impact cannot be assessed at this stage because in case studies, no inhabitants were directly involved in the OptEEmAL process. This impact will be evaluated at TRL7.

Table 49: Impact assessment for expected impact no.17

Impact description	OptEEmAL will achieve interventions in compliance with inhabitants' expectations, analysing social impacts of applied measures and considering owners and tenants to be represented in the decision making process.
Assessment	In line with the expected impact

Comment	The inclusion of inhabitants' expectations is indirect in OptEEmAL. Indeed, these expectations have to be considered by one of the IPD actor defined in OptEEmAL (Owner, Prime Designer, Prime Constructor). This inclusion will be detailed and promoted in the upcoming E-guide on stakeholders involvement and IPD implementation for the design and execution (D1.1).

7.3.7 Other impacts

Table 50: Impact assessment for expected impact no.18

Impact description	OptEEmAL will fosters the dissemination of the new knowledge at professional level.
Assessment	In line with the expected impact
Comment	OptEEmAL is already fostering the dissemination of new knowledge at professional level especially through its holistic approach. As such, energy experts can gain knowledge on the social or environmental performances of a given energy conservation measures. Also, the enhanced communication between the different project actors (through the IPD methodology) is a way to transfer more knowledge at professional level.

Table 51: Impact assessment for expected impact no.19

Impact description	OptEEmAL will overcome non-technical barriers preventing the implementation of energy efficiency retrofitting projects
Assessment	In line with the expected impact
Comment	Through the inclusion of specific IPD actors such as owners for instance, OptEEmAL is already overcoming one major difficulty to implement energy efficient retrofitting projects related to owner persuasion. Also, the detailed economic analysis performed by OptEEmAL is a way to convince the owner that the retrofitting projects is relevant from the economic point of view (which will also facilitate the overcoming of non-technical barriers).

7.4 Discussion

From the elements provided in the previous section, it appears that most of the potential impacts of the OptEEmAL platform are in line with what was expected at the beginning. However, several limitations have to be highlighted here:

- All these assessments suffer from high uncertainties related to the input data used for their calculations. In particular, one critical parameter that is used in these calculations is the market penetration rate (5%) of the platform. This parameter is discussed below but is difficult to evaluate precisely at this stage.
- These results are highly dependent on the type of retrofitting projects considered. Indeed, the higher the energy consumption is before retrofitting, the higher the potential impacts can be.

As mentioned above, the market penetration rate is a critical parameter in all the analyses conducted above. At this step of the project, it is very hard to define it more precisely. However, in order to provide more insights on the influence of this parameter, a sensitivity analysis (Figure 69) has been performed to investigate its influence on the economic impacts of the platform (Table 37 and Table 38) as they are the most critical ones (they influence most of other impacts).

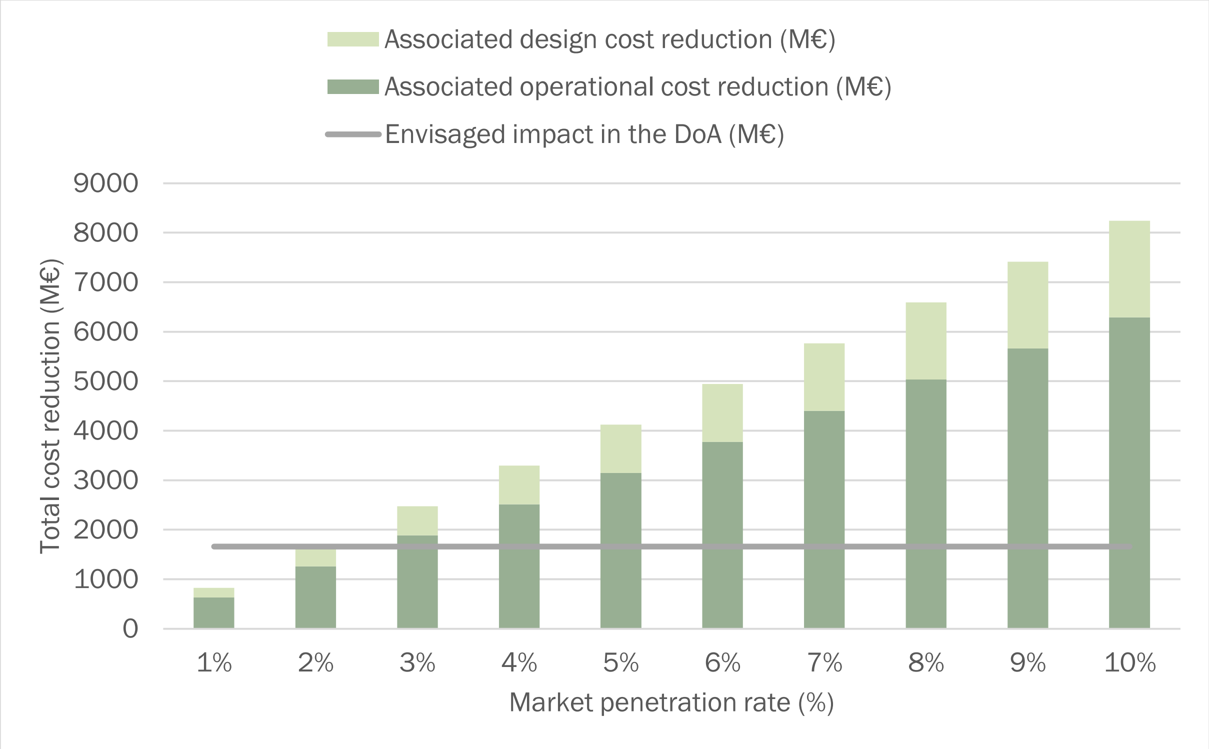


Figure 69: Influence of the market penetration rate on OptEEmAL economic impacts

The conclusion of this sensitivity analysis is that to achieve its objective, the OptEEmAL platform shall reach a 2% market penetration rate. As already mentioned, this parameter cannot be assessed at this step of the project but can be used as a target for the market exploitation of the platform.

8 Conclusion

The work presented in this document is related to validation activities of the OptEEmAL platform at TRL6 “Platform prototype demonstration in relevant environment” and the associated results.

First, a significant time was dedicated to both the collection and the elaboration of the data needed to run the OptEEmAL platform. From a general perspective, it appeared that the numerical models (IFC and CityGML models) are the most critical files to be elaborated to use the platform as they require a significant time for their elaboration and are still rare for existing buildings. All other input data needed to run the platform (baseline energy systems, targets and boundaries, etc.) were quite easily available overall.

Then, all this information was used to test the platform on three real districts (2 case studies: *Cuatro de Marzo* and *Mogel* districts / 1 demo site: *Polhem* district). These tests, reported in this document for the two case studies, show that, from a general perspective, the platform is running properly for these two examples. Adjustments have been identified during the testing. Some have been directly integrated into the platform (e.g. selection of buildings in the BES questionnaire) while some of them have been listed as “future potential” developments and are integrated in other deliverables (D6.3 and D6.4), such as the way to indicate the demand systems in the BES questionnaire for instance.

In addition to testing the platform functionalities, one major challenge for this task was to validate the results provided by the OptEEmAL platform. In this sense, results obtained from the abovementioned projects have been analysed and has revealed the following information:

- Overall DPI calculation: Some mistakes were identified and corrected in the calculation of different DPIs (ENE15, ENE09, etc.). Normally, all errors have been eliminated from the platform.
- Special focus on energy demand and final energy consumption: An important effort has been made to check the calculation of these indicators in the platform as they are the basis for most of other DPIs. Comparing the results of the platform with existing simulations has revealed quite important differences. Some of them were related to the platform development and have been modified (e.g. unoccupied space transformation) but most of them were related to the configuration of the IFC files used as input for the platform (e.g. internal gains). This is both positive and negative for the platform. The positive point is that the platform performs correct calculations for these indicators. The negative point is that the modelling of the IFC files has to be done in a very detailed way to provide relevant results. Those feedbacks were included in the BIM guidelines but can still be considered as a limitation for the platform.
- Recommended ECMs are overall in line with the ones really implemented in the retrofitting projects. However, differences were identified for the two investigated case studies. The identification of difference sources was difficult because the selection process was transparent in the OptEEmAL platform (ECM questionnaire, Check strategies, Targets and Boundaries, etc.) but not necessarily for the real retrofitting projects. In this sense, the parametrisation of the projects were likely to be different and to explain the identified differences.

Then, the performance of the platform has been assessed (in strong relationship with D5.5) especially regarding the time needed to run the OptEEmAL platform. Of course, the time needed to run the platform is highly influence by the district complexity (number of buildings, heterogeneity between buildings, etc.) but was estimated to be around 5 days for a district composed of 4 buildings.

Finally, the potential impacts of the platform were calculated. Overall, they are in line with the ones expected at the beginning of the project. However, this work has highlighted the critical importance of the market penetration rate to achieve those impacts and has revealed that the OptEEmAL platform shall reach a 2% market penetration rate to achieve its objectives.

As a general conclusion, it can be mentioned that the platform has been successfully validated at TRL6. One important limitation to this conclusion is that the platform was tested on 3 case studies instead of the 6 originally planned. This is due to more intense technical works than expected (IT developments in particular) and also to unexpected time to develop the input data (especially BIM models).

9 Annex

9.1 Annex 1: Screenshots of end-to-end tests

9.1.1 *Mogel* district, Eibar

Data-1: Data upload CityGML

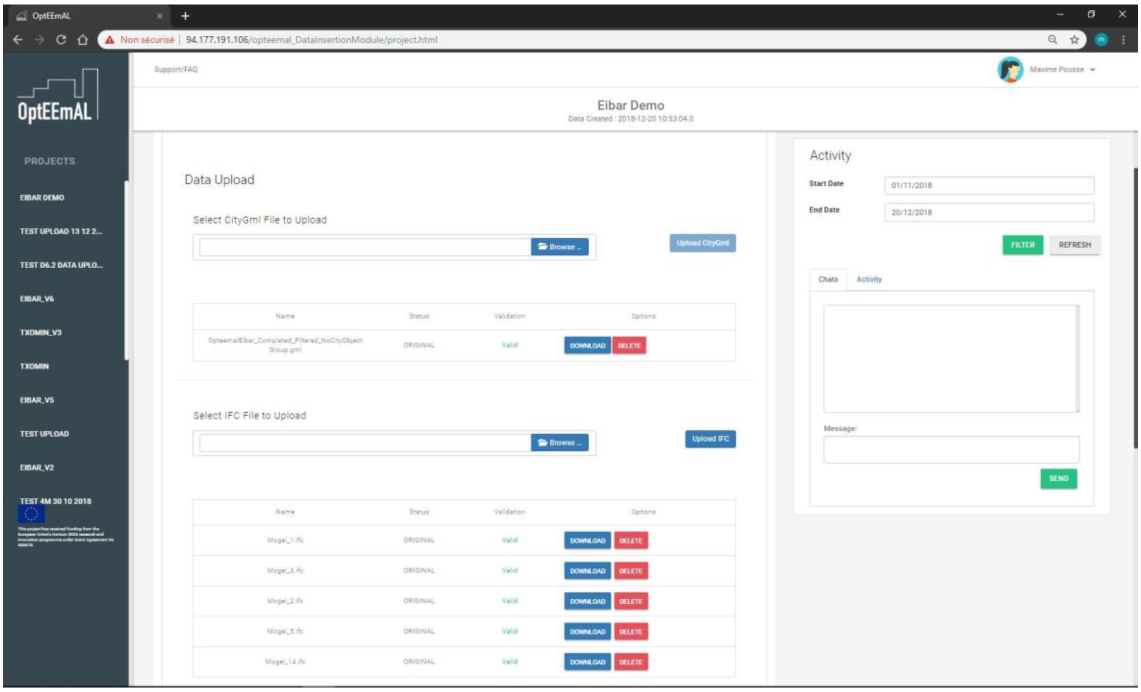


Figure 70: GUI – Uploaded and checked CityGLM file (*Mogel* district)

Data-2: CityGML with errors

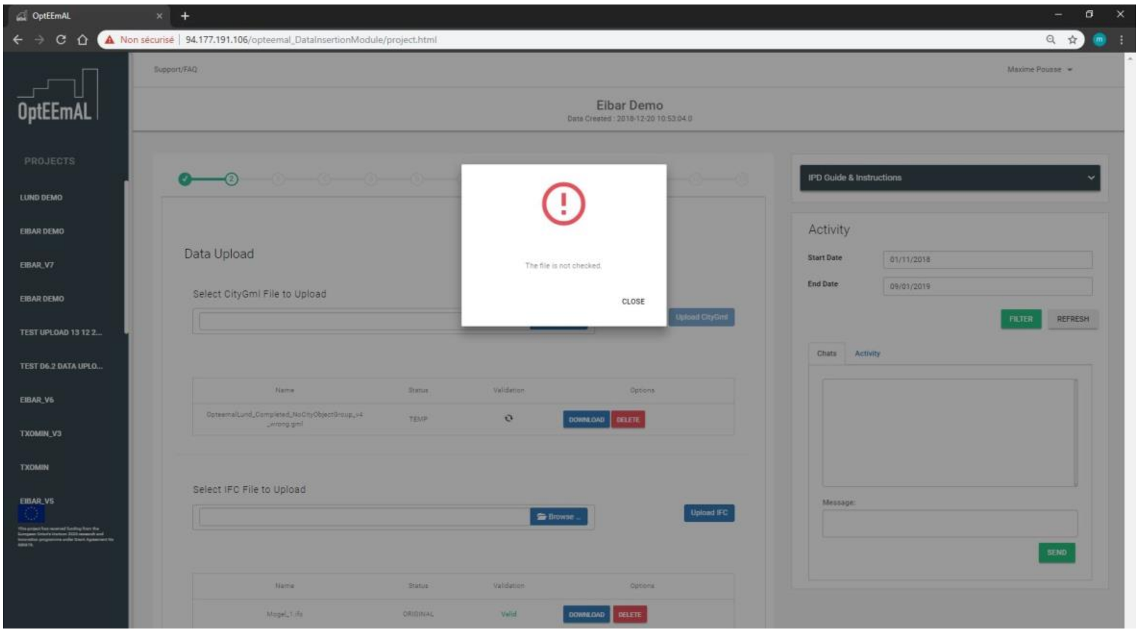


Figure 71: GUI – Wrong CityGML file update

Data-3: Data upload IFC

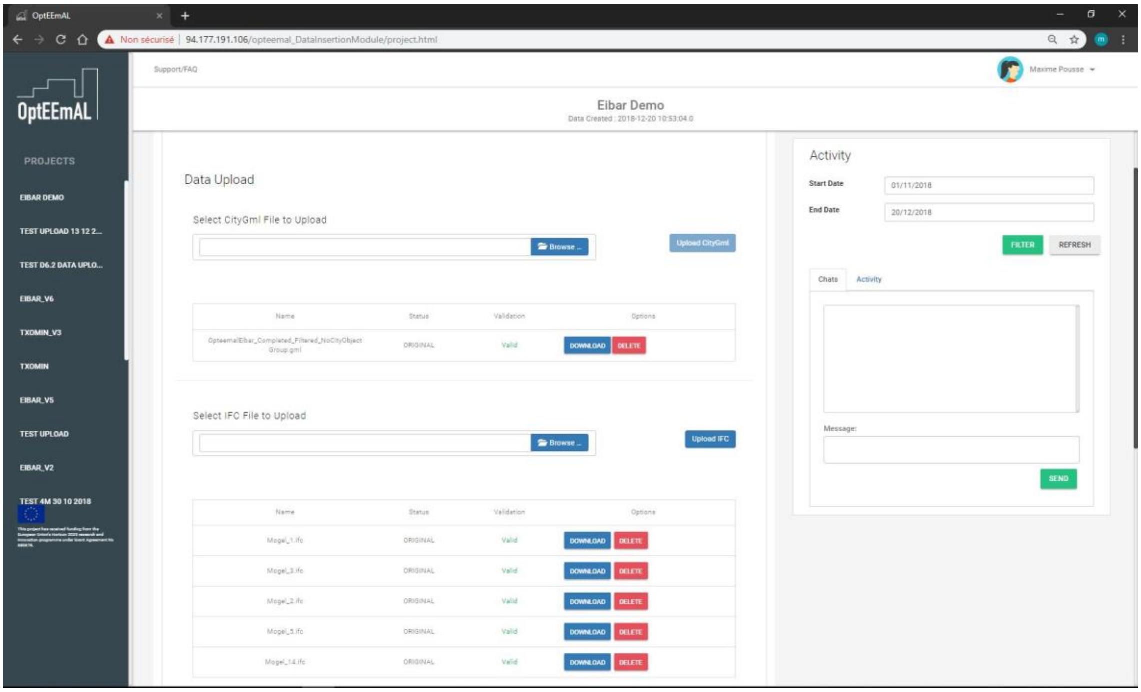


Figure 72: GUI – Uploaded and checked IFC files (*Mogel* district)

Data-4: IFC with errors

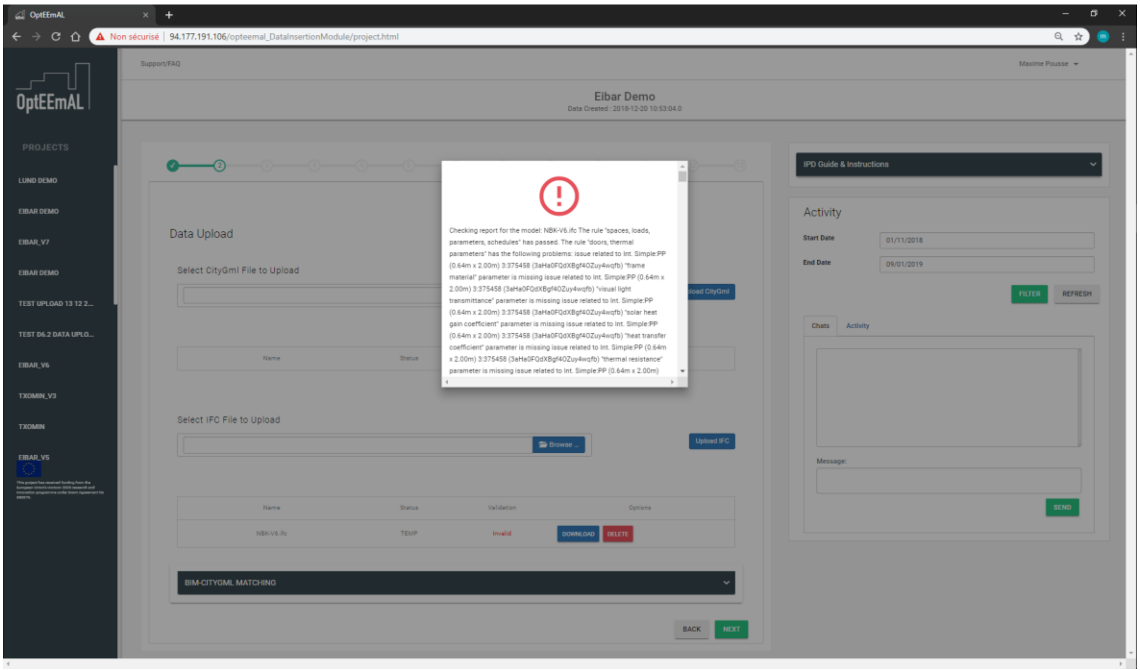


Figure 73: GUI – Error from the IFC checking process reported to the user

Matching-1: BIM-CityGML matching

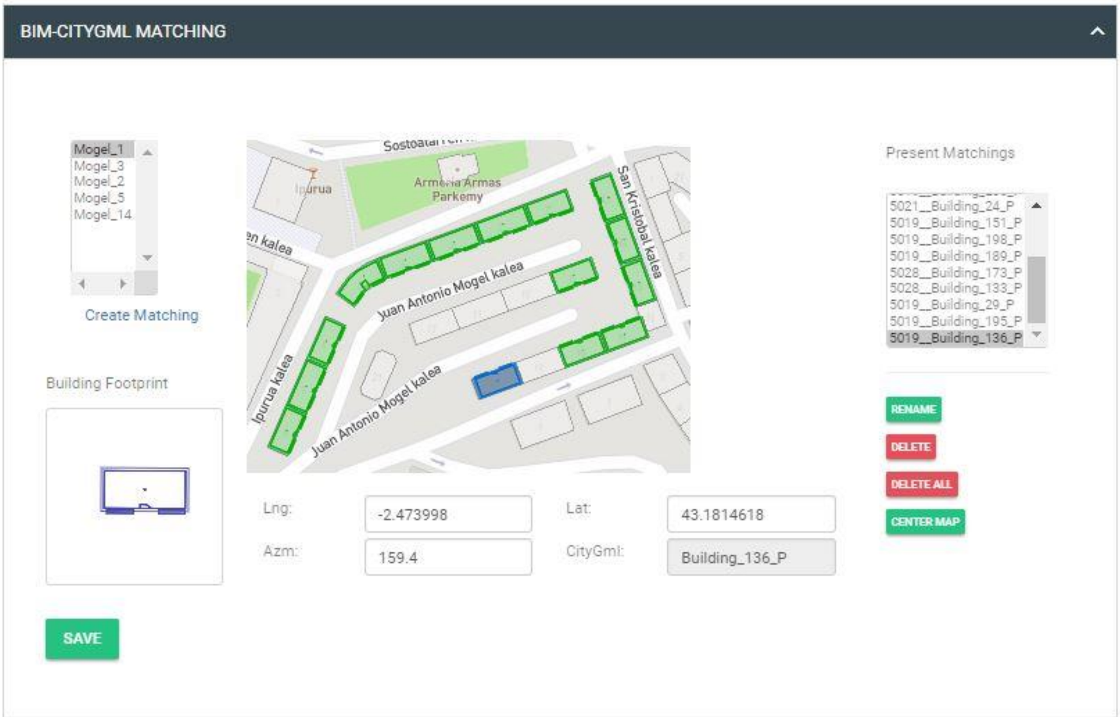


Figure 74: GUI – BIM-CityGML matching

Matching-2: Matching with errors

See §4.3 for more details

ES-2: System vector generation

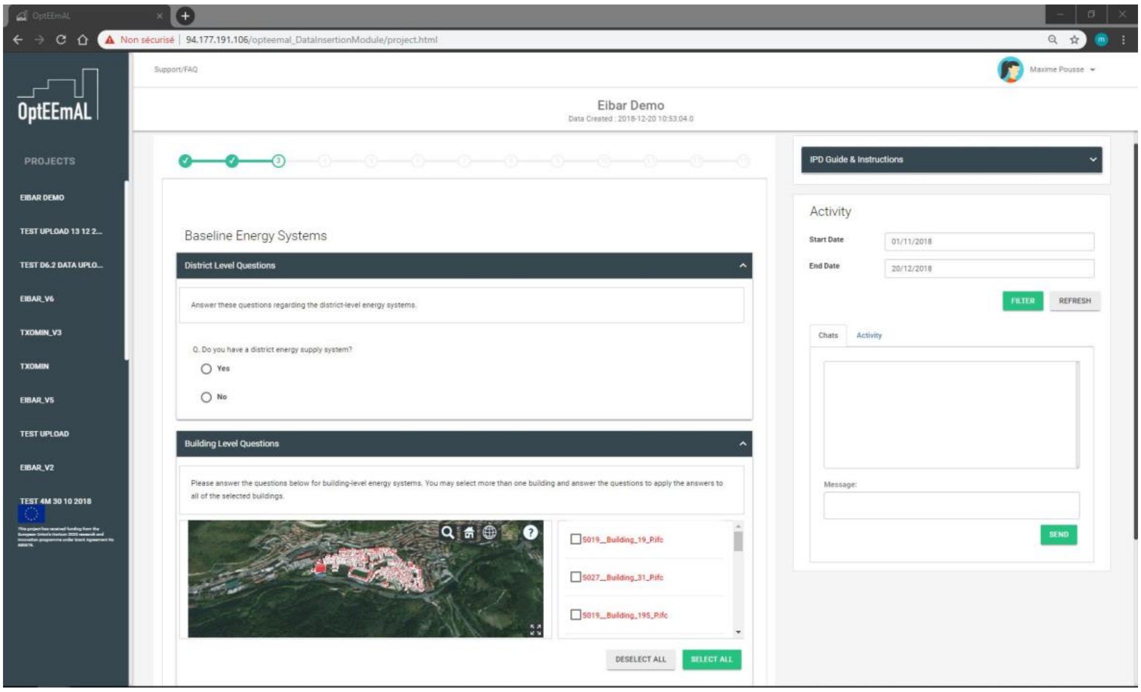


Figure 75: GUI – BES questionnaire before completion

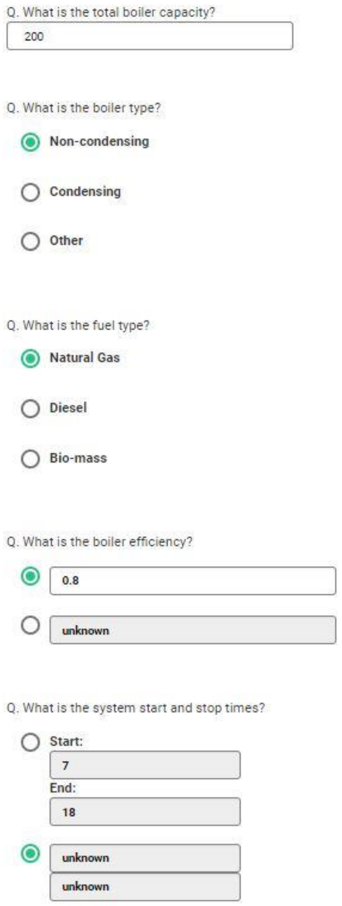


Figure 76: GUI – BES questionnairee during completion

```
project_id: 318
SupplySystems: {}
Buildings:
  5250:
    building_id: "5250"
    AccessToNaturalGas: true
    ExistBEMS: false
    SupplySystems:
      B_5250_AC.BL.SP.PL.01:
        id: "AC.BL.SP.PL.01"
        category: "Boiler Plant"
        total_capacity: "200"
        boiler_type: "Non-condensing"
        fuel_type: "Natural Gas"
        efficiency: "0.8"
        controller_properties:
          SystemStartTime: "unknown"
          SystemStopTime: "unknown"
          HotWaterSetPoint: "unknown"
    DemandSystems:
      B_5250_AC.DE.HZ.DM.01_1st Floor - Apt.1:404900:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt.1:404900"
      B_5250_AC.DE.HZ.DM.01_1st Floor - Apt.2:404901:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt.2:404901"
      B_5250_AC.DE.HZ.DM.01_1st Floor - Apt_1:404900:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt_1:404900"
      B_5250_AC.DE.HZ.DM.01_1st Floor - Apt_2:404901:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt_2:404901"
      B_5250_AC.DE.HZ.DM.01_1st Floor - Hall:405238:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Hall:405238"
      B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt.1:404903:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt.1:404903"
      B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt.2:404904:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt.2:404904"
      B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt_1:404903:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt_1:404903"
      B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt_2:404904:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt_2:404904"
      B_5250_AC.DE.HZ.DM.01_2nd Floor - Hall:405239:
        demandSystem_id: "AC.DE.HZ.DM.01"
```


Figure 77: Generated system vector JSON file

HVAC: HVAC zone identification

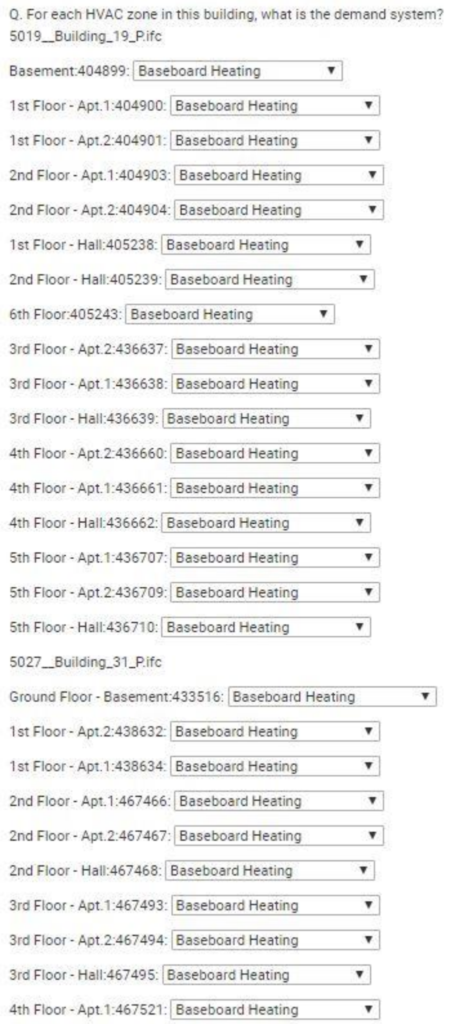


Figure 78: GUI – HVAC zones visible in the GUI and completed

Unstr: Unstructured data

As mentioned in the core of the document, this test is partially passed considering that the information is properly retrieved but not well presented in the GUI.

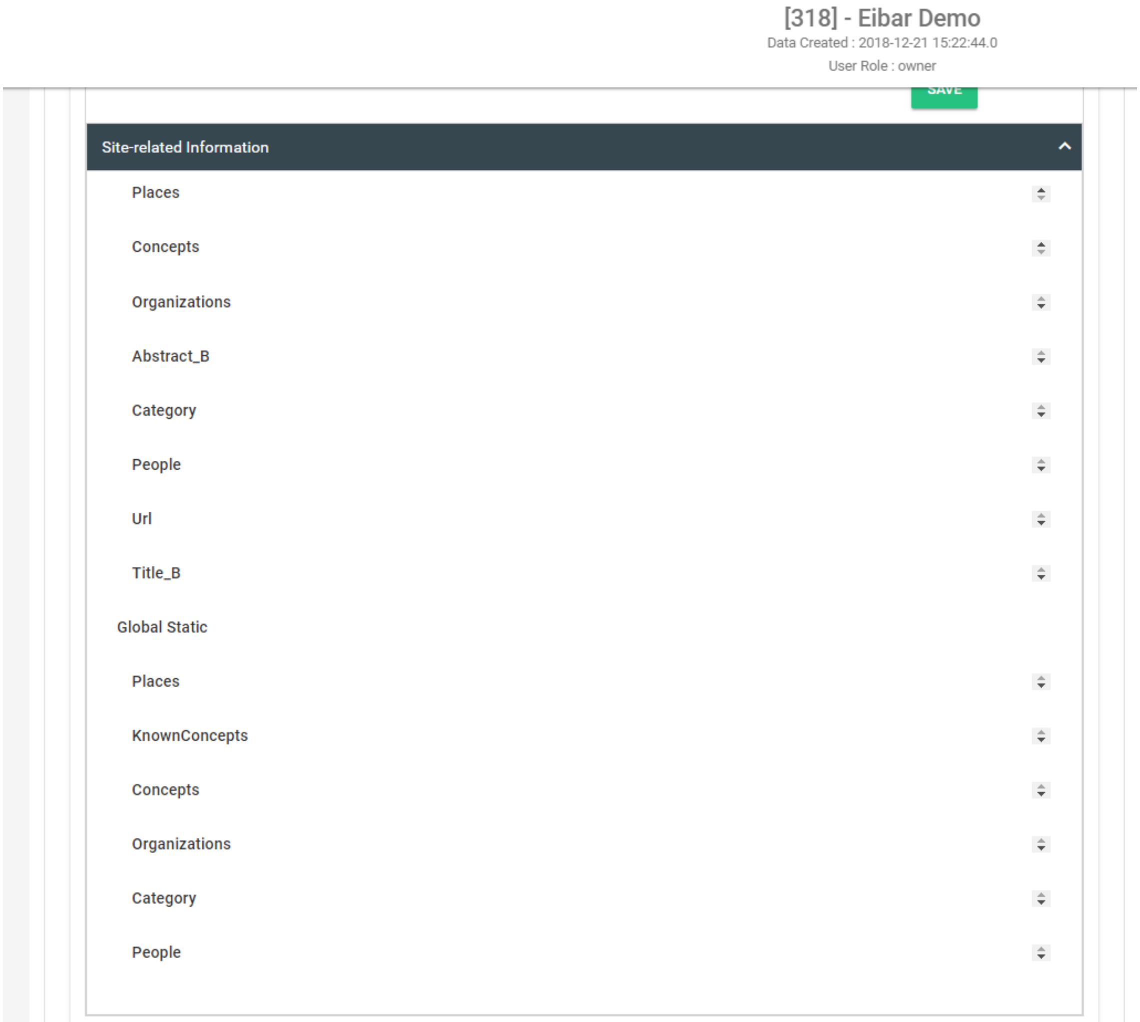


Figure 79: GUI – Current status of the unstructured data related GUI (*Mogel* district)

RegUval-1: U-values displayed

This functionality has been only implemented for demonstration purposes on the *Cuatro de Marzo* district (and Txomin Enea district (will be reported in T6.3 deliverables).

RegUval-2: U-values edited and stored

This functionality has been only implemented for demonstration purposes on the *Cuatro de Marzo* district (and Txomin Enea district (will be reported in T6.3 deliverables).

Baseline-1: Basic SIMMODEL generated

The screenshot for the demonstration of this test is the one as the one presented in the core of the document.

Baseline-2: Enriched SIMMODEL generated

The screenshot for the demonstration of this test is the one as the one presented in the core of the document.

BaselineDPI: Baseline DPI calculation

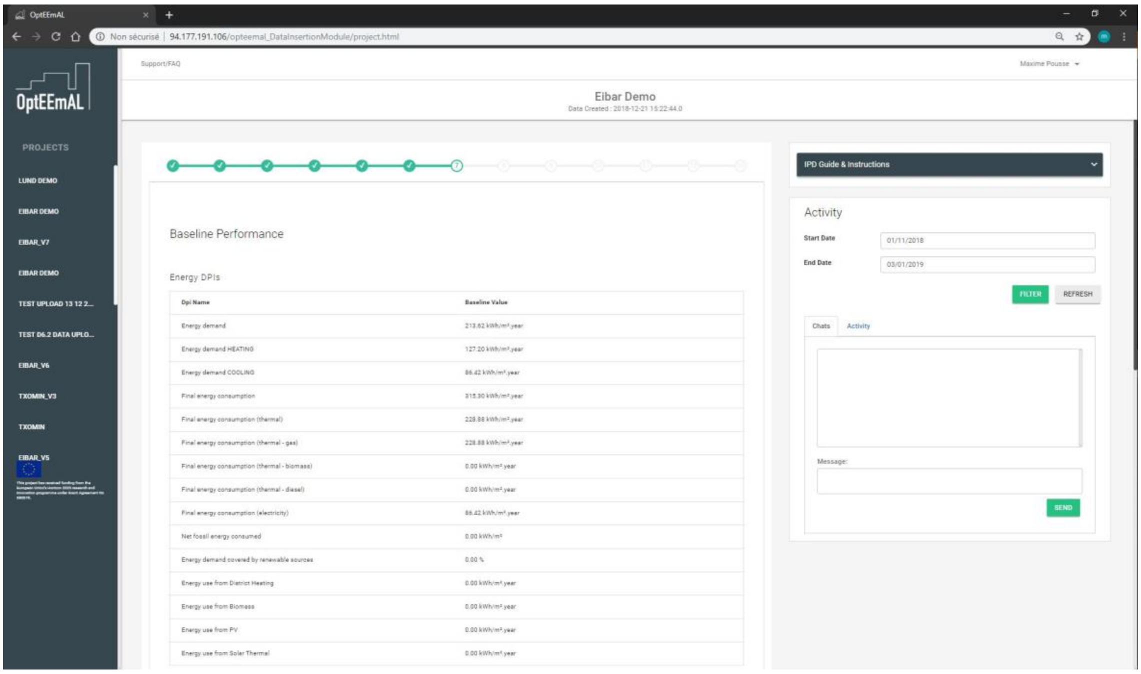


Figure 80: GUI – Baseline DPIs (*Mogel* district)

```
Projectid:          318
▼opts:
  ▼0:
    ▼scenariosdpis:
      ▼0:
        id:         0
        ▼dpis:
          ▼0:
            dpi:    "COM01"
            value:  0
          ▼1:
            dpi:    "ECO01.0"
            value:  35.814868832182654
          ▼2:
            dpi:    "ECO01.1"
            value:  15.220217623040293
          ▼3:
            dpi:    "ECO01.2"
            value:  0
          ▼4:
            dpi:    "ECO01.3"
            value:  0
          ▼5:
            dpi:    "ECO01.4"
            value:  20.59465120914236
          ▼6:
            dpi:    "ECO03"
            value:  9408519.84717053
          ▼7:
            dpi:    "ENE01.0"
            value:  213.6169449658039
          ▼8:
            dpi:    "ENE01.A"
            value:  127.20192627788674
          ▼9:
            dpi:    "ENE01.B"
            value:  86.41501868791718
          ▼10:
            dpi:    "ENE02.0"
            value:  315.29877163740537
          ▼11:
            dpi:    "ENE02.A"
            value:  228.8754529780495
          ▼12:
            dpi:    "ENE02.A.1"
            value:  228.8754529780495
          ▼13:
            dpi:    "ENE02.A.2"
            value:  0
```


Figure 81: Extract of the baseline DPIs JSON file (first lines)

BasUval: Baseline U-values calculation and storage

This functionality has been only implemented for demonstration purposes on the *Cuatro de Marzo* district (and Txomin Enea district (will be reported in T6.3 deliverables).

ECM-2: Check strategies

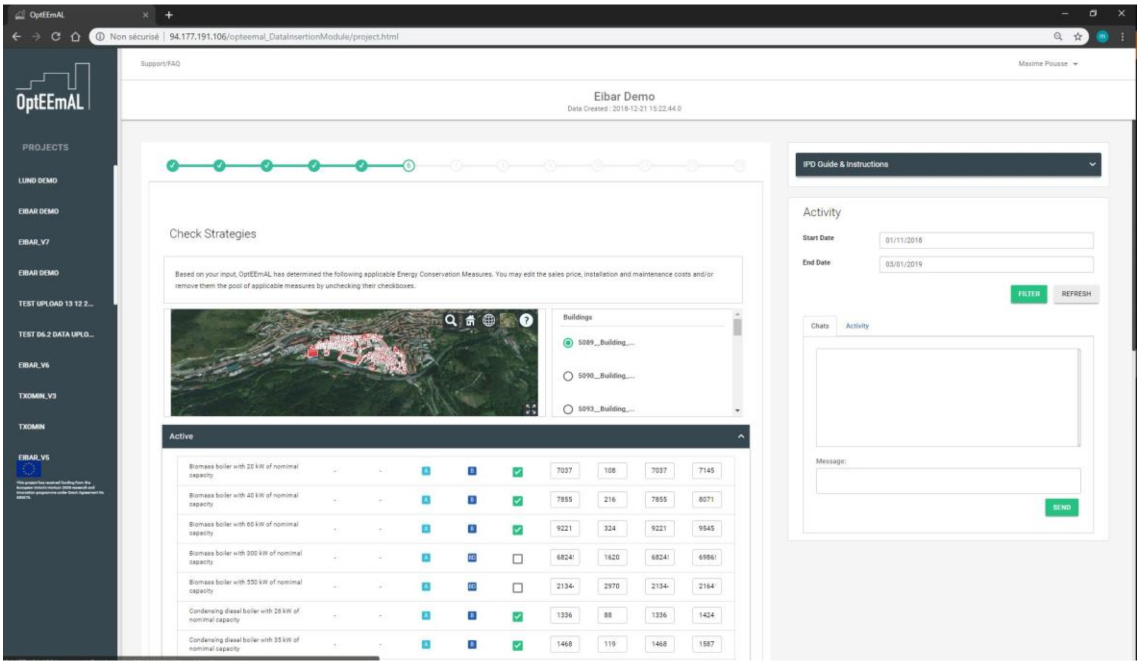


Figure 82: GUI – Visualisation of proposed ECMs (*Mogel* district)

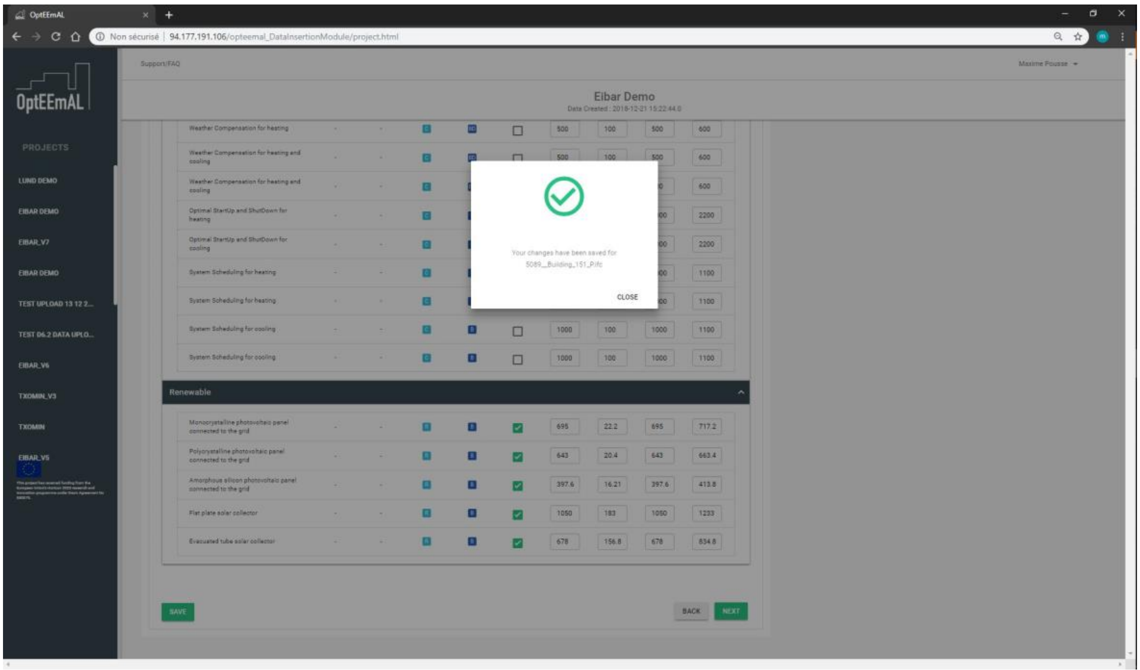


Figure 83: GUI – Validated ECMs (*Mogel* district)

P-info: Project information retrieval

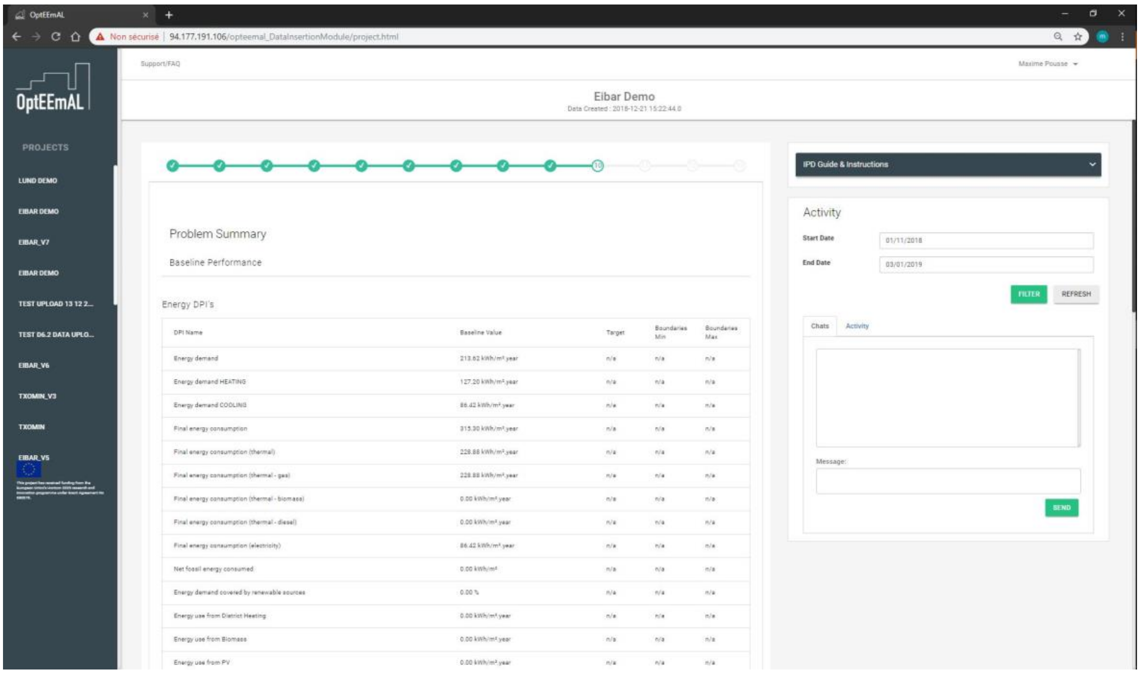


Figure 84: GUI – Problem summary – Baseline DPIs (*Mogel* district)

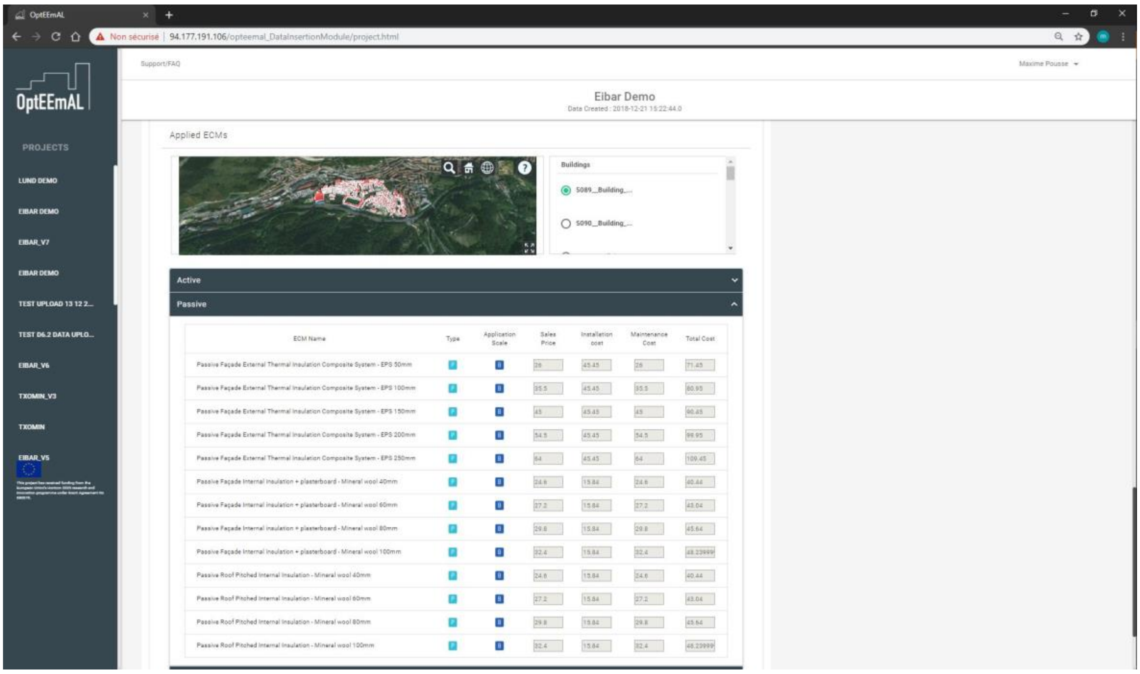


Figure 85: GUI – Problem summary – Applied ECMs (*Mogel* district)

AM: Applicable matrix generation

IdProject: 318
IdBuilding: 5254
ecm_types:
0: "PA.FA.EX.VE."
1: "PA.FA.EX.CS."
2: "PA.FA.IN.CA."
3: "PA.FA.ID.CW."
4: "PA.RO.PI.IN."
5: "PA.RO.PI.EX."
6: "PA.RO.FL.EX."
7: "PA.RO.FL.EI."
8: "PA.RO.TS.FC."
9: "PA.RO.TS.CI."
10: "PA.FL.NC.DE."
11: "PA.FL.CS.DE."
12: "PA.OP.DG.DE."
13: "PA.OP.TG.DE."
14: "RE.RO.SC.PV."
15: "RE.RO.SC.TC."
16: "RE.DE.GT.HP."
17: "RE.DE.WT.HZ."
18: "AC.DE.BO.CD."
19: "AC.DE.BO.NG."
20: "AC.DE.BO.CG."
21: "AC.DE.BO.BM."
22: "AC.DE.CP.HE."
23: "AC.DE.CH.ER."
24: "AC.DE.HP.WA."
25: "CO.DE.TH.SS."
26: "CO.DE.TH.OS."
27: "CO.DE.PL.WC."
28: "CO.DE.PL.SE."
29: "CO.DE.PL.LF."
ecm_types_count:
0: 4
1: 5
2: 4
3: 1
4: 4
5: 4
6: 4
7: 4
8: 3
9: 4
10: 4

Figure 86: Extract of the generated applicable matrix for one building (first lines)

Uval-proc: U-values processed

This functionality has been only implemented for demonstration purposes on the *Cuatro de Marzo* district (and Txomin Enea district (will be reported in T6.3 deliverables).

SV: System vector generation


```
project_id: 318
SupplySystems: {}
▼Buildings:
  ▼5250:
    building_id: "5250"
    AccessToNaturalGas: true
    ExistBEMS: false
    ▼SupplySystems:
      ▼B_5250_AC.BL.SP.PL.01:
        id: "AC.BL.SP.PL.01"
        category: "Boiler Plant"
        total_capacity: "200"
        boiler_type: "Non-condensing"
        fuel_type: "Natural Gas"
        efficiency: "0.8"
        ▼controller_properties:
          SystemStartTime: "unknown"
          SystemStopTime: "unknown"
          HotWaterSetPoint: "unknown"
    ▼DemandSystems:
      ▼B_5250_AC.DE.HZ.DM.01_1st Floor - Apt.1:404900:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt.1:404900"
      ▼B_5250_AC.DE.HZ.DM.01_1st Floor - Apt.2:404901:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt.2:404901"
      ▼B_5250_AC.DE.HZ.DM.01_1st Floor - Apt_1:404900:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt_1:404900"
      ▼B_5250_AC.DE.HZ.DM.01_1st Floor - Apt_2:404901:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Apt_2:404901"
      ▼B_5250_AC.DE.HZ.DM.01_1st Floor - Hall:405238:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "1st Floor - Hall:405238"
      ▼B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt.1:404903:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt.1:404903"
      ▼B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt.2:404904:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt.2:404904"
      ▼B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt_1:404903:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt_1:404903"
      ▼B_5250_AC.DE.HZ.DM.01_2nd Floor - Apt_2:404904:
        demandSystem_id: "AC.DE.HZ.DM.01"
        HVACZone_id: "2nd Floor - Apt_2:404904"
      ▼B_5250_AC.DE.HZ.DM.01_2nd Floor - Hall:405239:
        demandSystem_id: "AC.DE.HZ.DM.01"
```


Figure 87: Generated system vector JSON file

IC: Instances creation

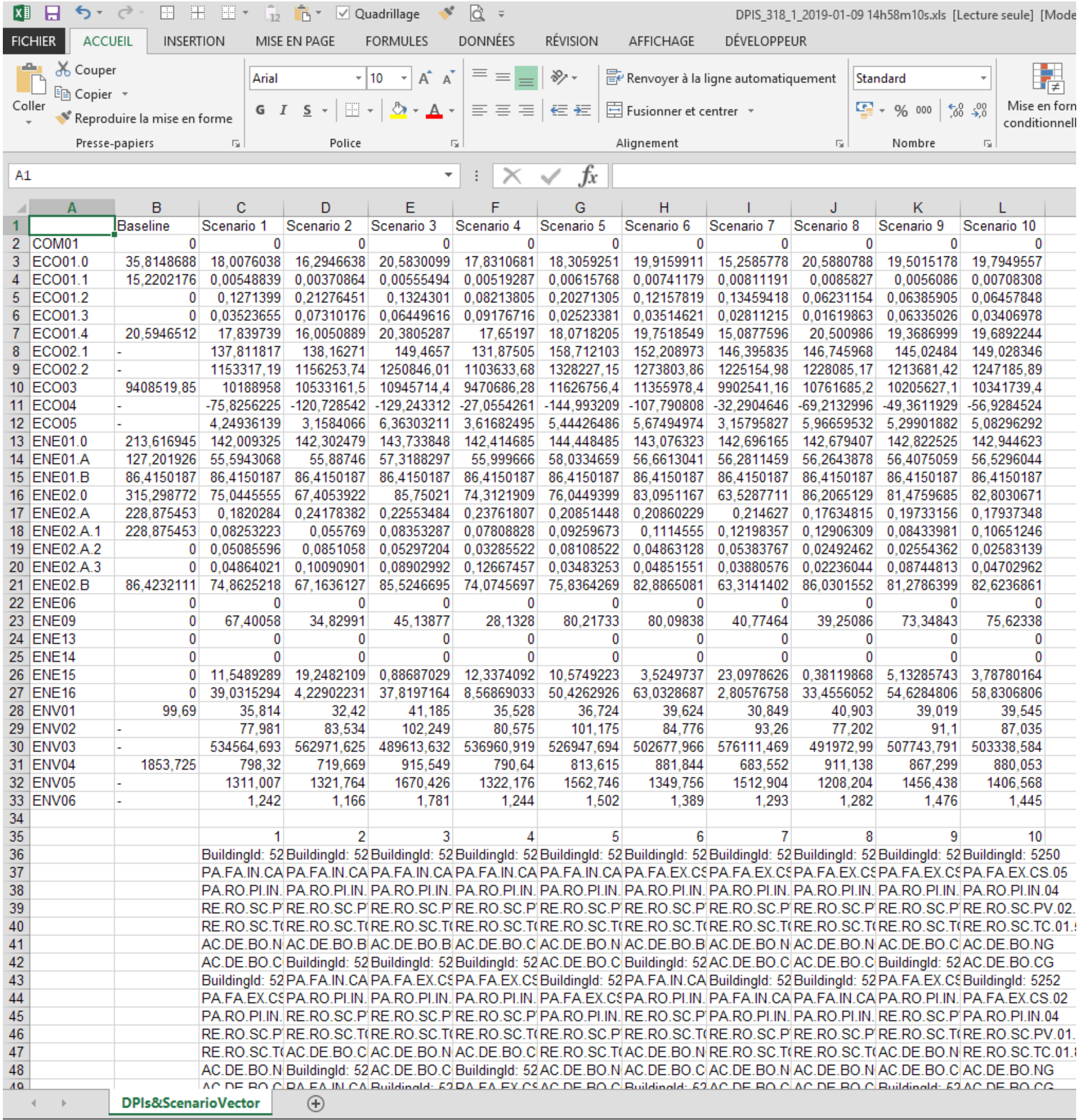
The screenshot for the demonstration of this test is the one as the one presented in the core of the document.

Evaluation DPI: Scenario DPI calculation


```
Projectid: 318
▼ opts:
  ▼ 0:
    ▼ scenariosdpis:
      ▼ 0:
        id: 1
        ▼ dpis:
          ▼ 0:
            dpi: "COM01"
            value: 0
          ▼ 1:
            dpi: "ECO01.0"
            value: 18.007603793650112
          ▼ 2:
            dpi: "ECO01.1"
            value: 0.00548839310924898
          ▼ 3:
            dpi: "ECO01.2"
            value: 0.12713990194273173
          ▼ 4:
            dpi: "ECO01.3"
            value: 0.035236547307363565
          ▼ 5:
            dpi: "ECO01.4"
            value: 17.83973895129077
          ▼ 6:
            dpi: "ECO02.1"
            value: 137.81181676545555
          ▼ 7:
            dpi: "ECO02.2"
            value: 1153317.1893458592
          ▼ 8:
            dpi: "ECO03"
            value: 10188958.03303947
          ▼ 9:
            dpi: "ECO04"
            value: -75.82562249051591
          ▼ 10:
            dpi: "ECO05"
            value: 4.249361387515792
          ▼ 11:
            dpi: "ENE01.0"
            value: 142.00932544162734
          ▼ 12:
            dpi: "ENE01.A"
            value: 55.59430675371017
          ▼ 13:
            dpi: "ENE01.B"
            value: 86.41501868791717
```


Figure 88: Extract of the scenario DPIs JSON file (first lines) (*Mogel* district)

EE: Evaluation execution



	A	B	C	D	E	F	G	H	I	J	K	L
1		Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
2	COM01	0	0	0	0	0	0	0	0	0	0	0
3	ECO01.0	35,8148688	18,0076038	16,2946638	20,5830099	17,8310681	18,3059251	19,9159911	15,2585778	20,5880788	19,5015178	19,7949557
4	ECO01.1	15,2202176	0,00548839	0,00370864	0,00555494	0,00519287	0,00615768	0,00741179	0,00811191	0,0085827	0,0056086	0,00708308
5	ECO01.2	0	0,1271399	0,21276451	0,1324301	0,08213805	0,20271305	0,12157819	0,13459418	0,06231154	0,06385905	0,06457848
6	ECO01.3	0	0,03523655	0,07310176	0,06449616	0,09176716	0,02523381	0,03514621	0,02811215	0,01619863	0,06335026	0,03406978
7	ECO01.4	20,5946512	17,839739	16,0050889	20,3805287	17,65197	18,0718205	19,7518549	15,0877596	20,500986	19,3686999	19,6892244
8	ECO02.1	-	137,811817	138,16271	149,4657	131,87505	158,712103	152,208973	146,395835	146,745968	145,02484	149,028346
9	ECO02.2	-	1153317,19	1156253,74	1250846,01	1103633,68	1328227,15	1273803,86	1225154,98	1228085,17	1213681,42	1247185,89
10	ECO03	9408519,85	10188958	10533161,5	10945714,4	9470686,28	11626756,4	11355978,4	9902541,16	10761685,2	10205627,1	10341739,4
11	ECO04	-	-75,8256225	-120,728542	-129,243312	-27,0554261	-144,993209	-107,790808	-32,2904646	-69,2132996	-49,3611929	-56,9284524
12	ECO05	-	4,24936139	3,1584066	6,36303211	3,61682495	5,44426486	5,67494974	3,15795827	5,96659532	5,29901882	5,08296292
13	ENE01.0	213,616945	142,009325	142,302479	143,733848	142,414685	144,448485	143,076323	142,696165	142,679407	142,822525	142,944623
14	ENE01.A	127,201926	55,5943068	55,88746	57,3188297	55,999666	58,0334659	56,6613041	56,2811459	56,2643878	56,4075059	56,5296044
15	ENE01.B	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187	86,4150187
16	ENE02.0	315,298772	75,0445555	67,4053922	85,75021	74,3121909	76,0449399	83,0951167	63,5287711	86,2065129	81,4759685	82,8030671
17	ENE02.A	228,875453	0,1820284	0,24178382	0,22553484	0,23761807	0,20851448	0,20860229	0,214627	0,17634815	0,19733156	0,17937348
18	ENE02.A.1	228,875453	0,08253223	0,055769	0,08353287	0,07808828	0,09259673	0,1114555	0,12198357	0,12906309	0,08433981	0,10651246
19	ENE02.A.2	0	0,05085596	0,0851058	0,05297204	0,03285522	0,08108522	0,04863128	0,05383767	0,02492462	0,02554362	0,02583139
20	ENE02.A.3	0	0,04864021	0,10090901	0,08902992	0,12667457	0,03483253	0,04851551	0,03880576	0,02236044	0,08744813	0,04702962
21	ENE02.B	86,4232111	74,8625218	67,1636127	85,5246695	74,0745697	75,8364269	82,8865081	63,3141402	86,0301552	81,2786399	82,6236861
22	ENE06	0	0	0	0	0	0	0	0	0	0	0
23	ENE09	0	67,40058	34,82991	45,13877	28,1328	80,21733	80,09838	40,77464	39,25086	73,34843	75,62338
24	ENE13	0	0	0	0	0	0	0	0	0	0	0
25	ENE14	0	0	0	0	0	0	0	0	0	0	0
26	ENE15	0	11,5489289	19,2482109	0,88687029	12,3374092	10,5749223	3,5249737	23,0978626	0,38119868	5,13285743	3,78780164
27	ENE16	0	39,0315294	4,22902231	37,8197164	8,56869033	50,4262926	63,0328687	2,80576758	33,4556052	54,6284806	58,8306806
28	ENV01	99,69	35,814	32,42	41,185	35,528	36,724	39,624	30,849	40,903	39,019	39,545
29	ENV02	-	77,981	83,534	102,249	80,575	101,175	84,776	93,26	77,202	91,1	87,035
30	ENV03	-	534564,693	562971,625	489613,632	536960,919	526947,694	502677,966	576111,469	491972,99	507743,791	503338,584
31	ENV04	1853,725	798,32	719,669	915,549	790,64	813,615	881,844	683,552	911,138	867,299	880,053
32	ENV05	-	1311,007	1321,764	1670,426	1322,176	1562,746	1349,756	1512,904	1208,204	1456,438	1406,568
33	ENV06	-	1,242	1,166	1,781	1,244	1,502	1,389	1,293	1,282	1,476	1,445
34												
35			1	2	3	4	5	6	7	8	9	10
36			BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 52	BuildingId: 5250
37			PA.FA.IN.CA	PA.FA.IN.CA	PA.FA.IN.CA	PA.FA.IN.CA	PA.FA.IN.CA	PA.FA.EX.CS	PA.FA.EX.CS	PA.FA.EX.CS	PA.FA.EX.CS	PA.FA.EX.CS.05
38			PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.04
39			RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.PV.02.
40			RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.TC.01.
41			AC.DE.BO.N	AC.DE.BO.B	AC.DE.BO.B	AC.DE.BO.C	AC.DE.BO.N	AC.DE.BO.B	AC.DE.BO.N	AC.DE.BO.N	AC.DE.BO.C	AC.DE.BO.NG
42			AC.DE.BO.C	BuildingId: 52	BuildingId: 52	BuildingId: 52	AC.DE.BO.C	BuildingId: 52	AC.DE.BO.C	AC.DE.BO.C	BuildingId: 52	AC.DE.BO.CG
43			BuildingId: 52	PA.FA.IN.CA	PA.FA.EX.CS	PA.FA.EX.CS	BuildingId: 52	PA.FA.IN.CA	BuildingId: 52	BuildingId: 52	PA.FA.EX.CS	BuildingId: 5252
44			PA.FA.EX.CS	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.RO.PI.IN.	PA.FA.EX.CS	PA.RO.PI.IN.	PA.FA.IN.CA	PA.FA.IN.CA	PA.RO.PI.IN.	PA.FA.EX.CS.02
45			PA.RO.PI.IN.	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.P	PA.RO.PI.IN.	RE.RO.SC.P	PA.RO.PI.IN.	PA.RO.PI.IN.	RE.RO.SC.P	PA.RO.PI.IN.04
46			RE.RO.SC.P	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.T	RE.RO.SC.P	RE.RO.SC.T	RE.RO.SC.P	RE.RO.SC.P	RE.RO.SC.T	RE.RO.SC.PV.01.
47			RE.RO.SC.T	AC.DE.BO.C	AC.DE.BO.N	AC.DE.BO.C	RE.RO.SC.T	AC.DE.BO.N	RE.RO.SC.T	RE.RO.SC.T	AC.DE.BO.N	RE.RO.SC.TC.01.
48			AC.DE.BO.N	BuildingId: 52	AC.DE.BO.C	BuildingId: 52	AC.DE.BO.N	AC.DE.BO.C	AC.DE.BO.N	AC.DE.BO.N	AC.DE.BO.C	AC.DE.BO.NG

Figure 89: Excerpt of the Excel file used to verify the proper functioning of the evaluator (*Mogel* district)

OPT-1: Optimisation execution

Same justification as in the core of the report. This test is passed.

OPT-3: Generation of the Pareto Front

Due to the configuration of the test, only one scenario was contained in the Pareto Front (see Figure 90 below) but the Pareto front has been successfully generated (Figure 91).

project_id: 318
pareto_dpi:
  0:
    benefit: 1.0274602061358975
    cost: 0.2972543008511557
    target_reached: 0
    is_inside_boundaries: 1
success: true

Figure 90: Json file including the information of the Pareto front (*Mogel* district)

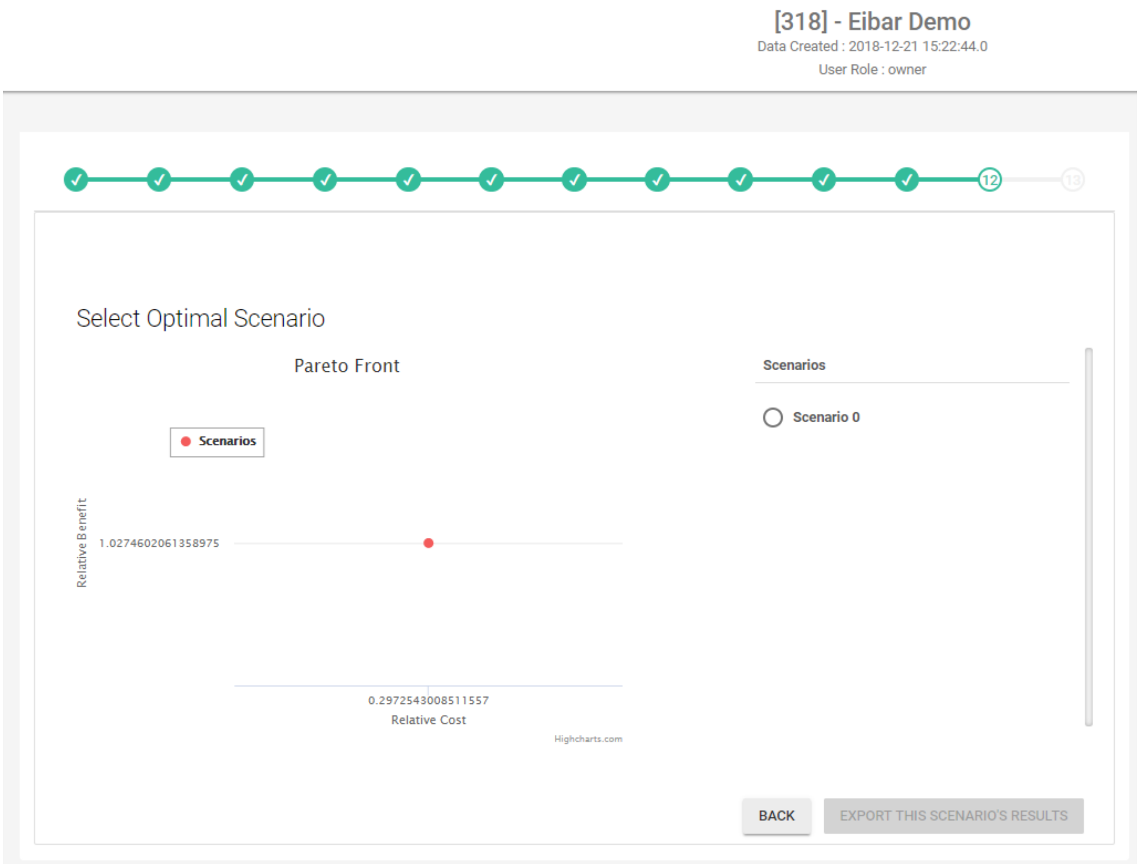


Figure 91: GUI – Visualization of the Pareto Front (*Mogel* district)

EXP-1: Generation of data to be exported

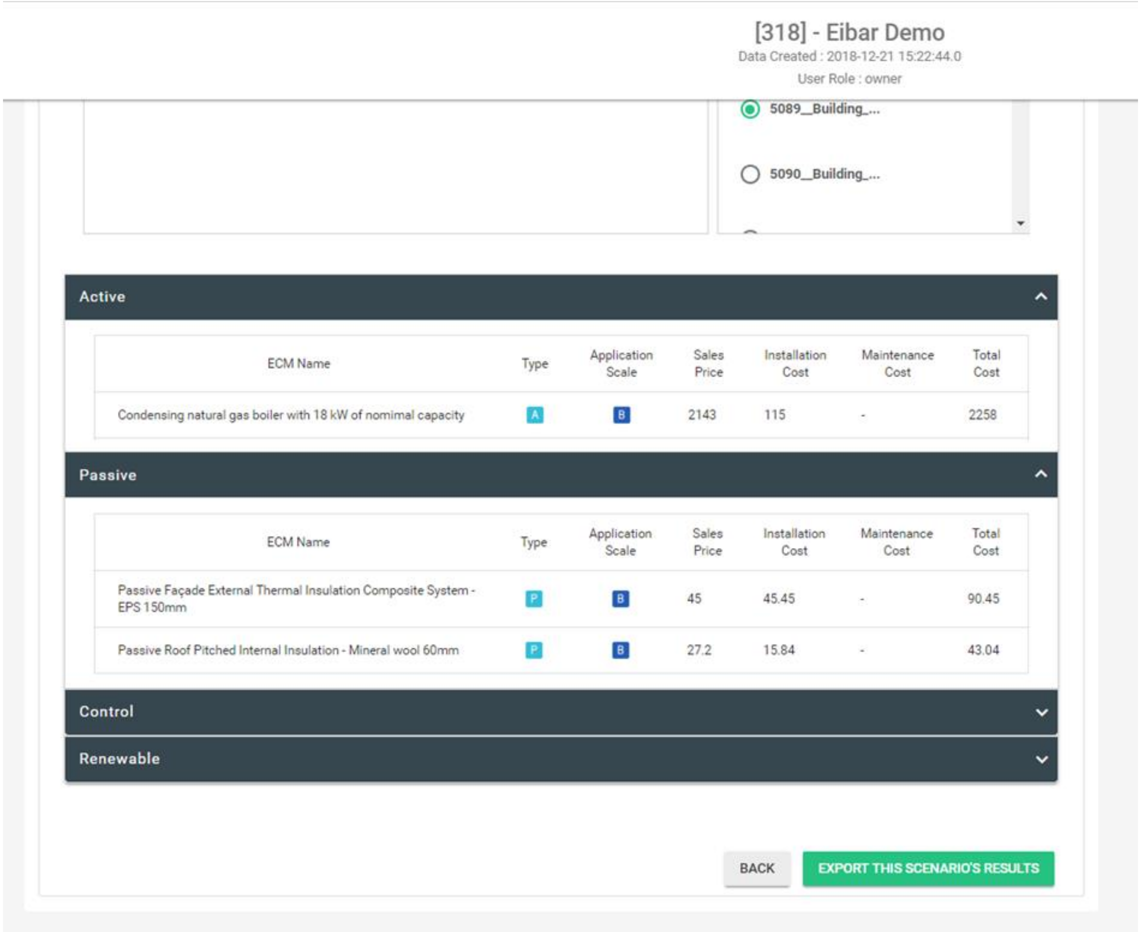


Figure 92: GUI – Page while generating the final reports (*Mogel* district)

EXP-2: Data exportation

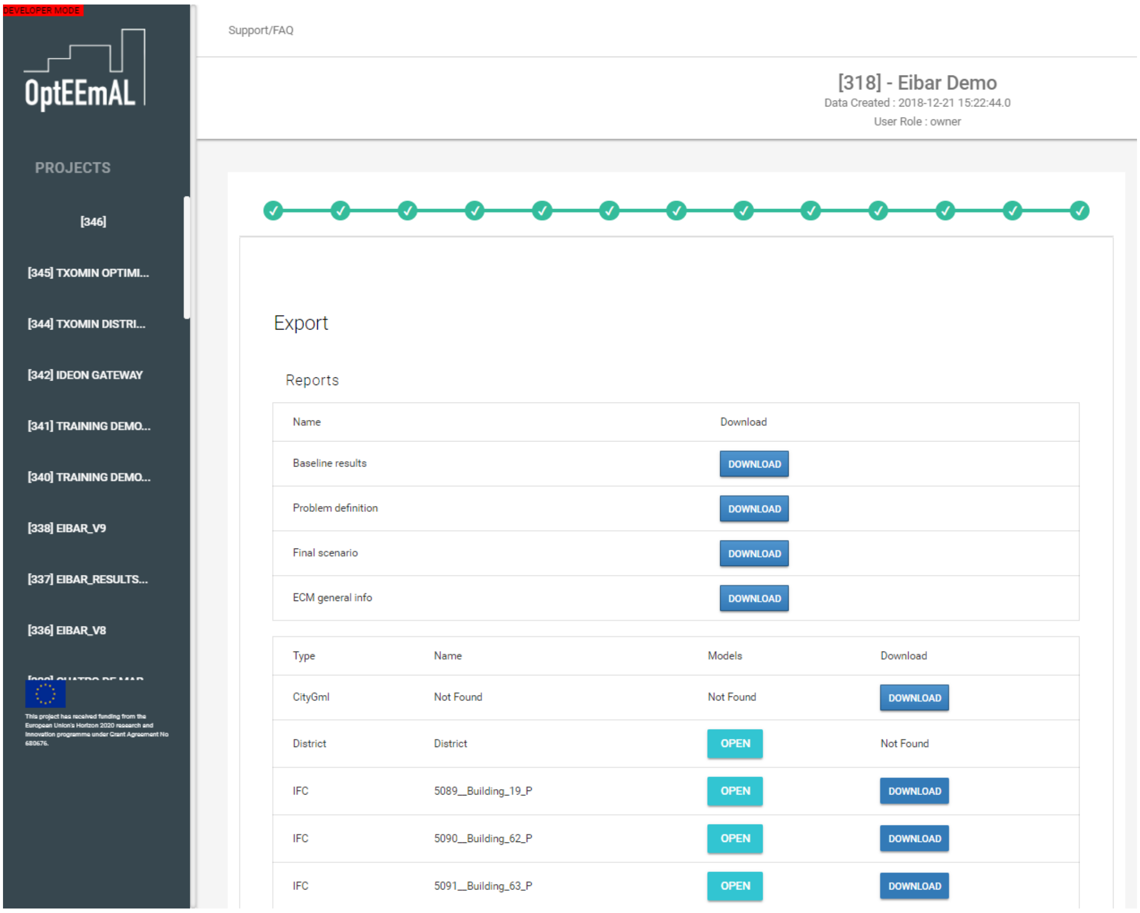


Figure 93: GUI – Final reports available for download (*Mogel* district)

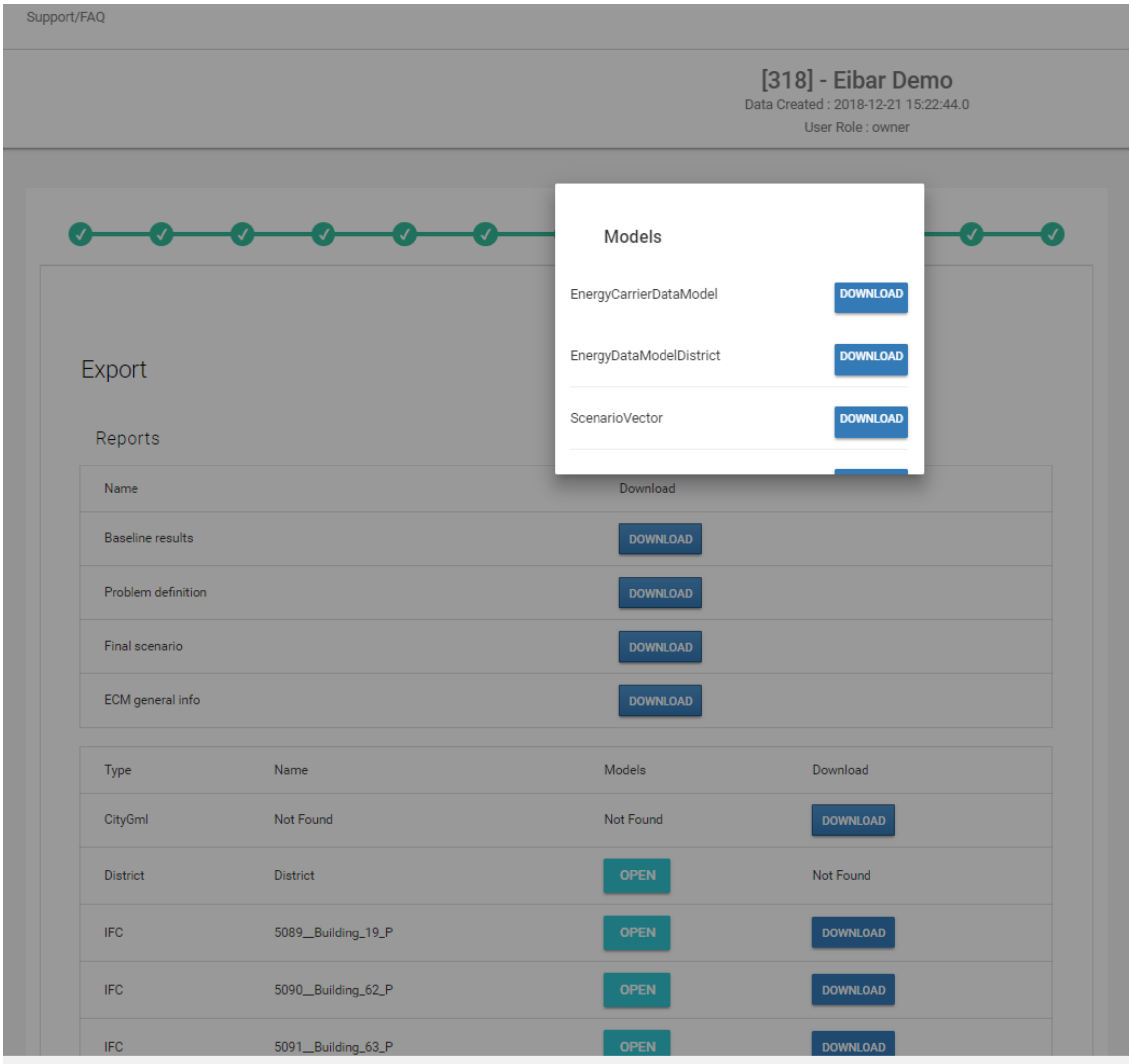


Figure 94: GUI – Final reports available for download – Available models generated by the platform (*Mogel* district)

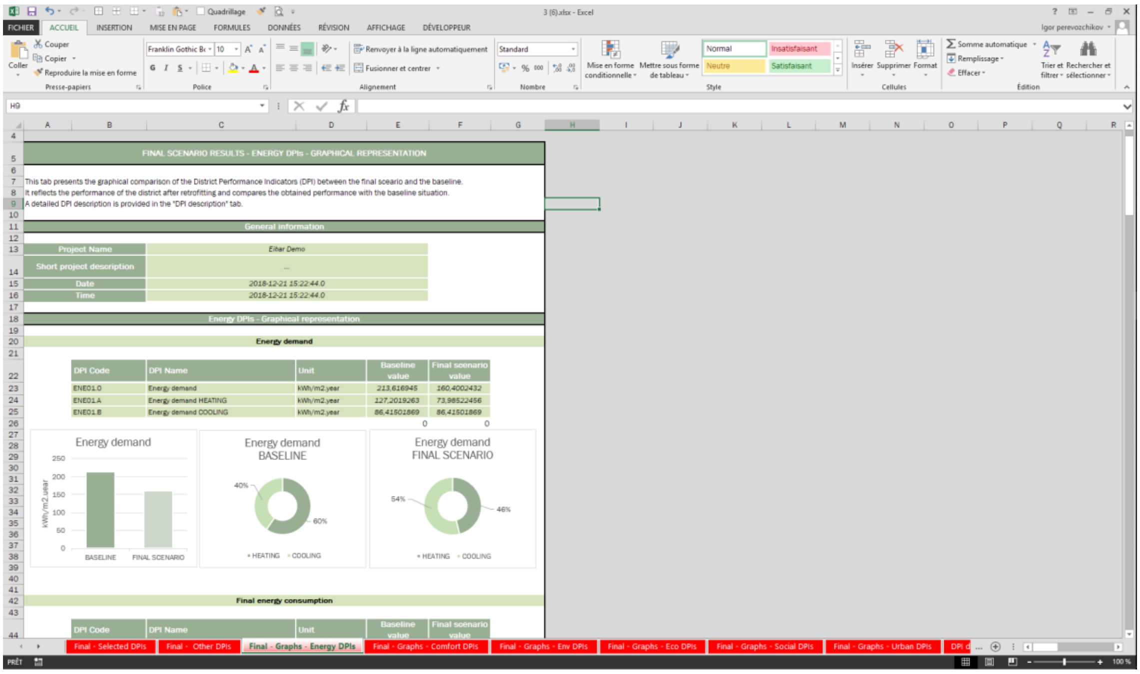


Figure 95: Final excel files exported from the platform (*Mogel* district)