OptEEmAL

OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

Optimised Energy Efficient Design Platform for Refurbishment at District Level
H2020-WORK PROGRAMME 2014-2015 – 5. Leadership in enabling and industrial technologies
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D6.4: Report on platform demonstration in the demo cases

WP6, Task 6.4

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Author(s): Maxime Pousse[1], Susana Martin Toral[2], Sonia Alvarez Diaz[2], Miguel Á. García-Fuentes[2], Victor Serna[2], Juan Pedrero Alegria[3], Belen Gomez Uribarri Serrano[4], Hassan El-Ridouane[5], Luciano De Tommasi[5], Iker Martinez[6], Elin Dalaryd[7], Micol Mattedi[8]

([1]NBK, [2]CAR, [3]TEC, [4]ACC, [5]UTRC-I, [6]FSS, [7]LUND, [8]DTTN)

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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

Following the same exercise done in deliverable D6.2, this document describes the validation activities of the OptEEmAL platform but in this case towards the achievement of a TRL7, that is, demonstration of the OptEEmAL platform in operational environments. With this aim three demonstration sites with different "district profile" are considered with a twofold objective:

- Demonstrate that the prototype fulfils the technical requirements for new retrofitting designs. That is, the districts under evaluation have not been previously assessed in any study or project, therefore OptEEmAL recommendations are only based on the target, boundaries, barriers and prioritization criteria inserted by the end-user into the platform.
- Analyse that the prototype suggests "optimal" solutions that fulfils the end-user expectations and that improves the baseline conditions of the district. This evaluation was done together with the demo-site leaders (DTTN, LUND and FSS).

With both objectives in mind, data from all the demonstration sites have been collected together with the end-user expectations for the three refurbishment proposals (IFC and CityGML files elaborated, Building Energy System information available, targets and boundaries and barriers defined, etc.). Several elaborations have been made for the different demo sites in order to investigate the influence of input data on the results provided by the platform.

From these activities, the following conclusions can be made:

- The OptEEmAL platform has been demonstrated at TRL7 on the different demo sites.
- The future technical improvements for the platform have been identified and listed (to go from TRL7 to TRL9). Those technical improvements are listed in this deliverable together with the more general improvements obtained from trainings and demonstration activities reported in D6.3.
- Results provided by the platform are coherent with the available data and the recommendations appears to be also in line with the user requirements and existing information. This point has to be further developed in the upcoming development phases of the platform to ensure the usefulness of the platform for its targeted users.
- The performance of the platform, in terms of time needed to use it on the different demo sites, has been evaluated.
- Potential impacts of the platform have been evaluated. However, as they are aligned with the one reported in D6.2, they are not reported in this document.

1 Introduction

1.1 Purpose and target group

This document presents the work performed in task 6.3 “TRL7 Platform ready for demonstration in operational environment”. The purpose of this task is to demonstrate the platform on real demonstration sites where district retrofitting projects are currently being implemented/to be implemented. This task constitutes the second testing of the platform on real districts (after TRL6 validation). Overall, this task is also the last part of the whole testing process implemented in this project. The overall TRL7 validation objective can be specified into the following sub-objectives regarding this deliverable:

- The platform fulfils its technical requirements (following TRL6 validation activities)
- The platform provides useful information to its end-users in the design of district energy retrofitting projects.

Two deliverables are related to T6.3 (D6.3 and 6.4). While D6.3 is focused on end-users experience, this deliverable is focused on the technical aspects of the platform at TRL7. Also, this deliverable complements D6.3 in the sense that D6.3 includes feedbacks from “external end-users” (outside the project consortium) while D6.4 includes feedbacks from “internal end-users” (inside the project consortium).

This document starts with a description of the demo sites used to demonstrate the platform providing the context and the objectives of the different retrofitting projects. Then, a section describes how the data related to these demo sites 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. After this analysis, impacts of the platform are discussed in comparison to the ones mentioned in the proposal. Finally, a list of feedbacks for the future steps of the platform development are presented and discussed to pave the way for a proper market uptake of the OptEEmAL platform.

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. Assistance to task leader in the implementation of the different activities. Improvement of the IFC files for San Bartolomeo and Polhem districts.
TEC	Elaboration of input data (in particular CityGML files). Participation in all activities related to the Txomin Enea district.
NBK	Deliverable leader. Elaboration of (part of the) input data and related sections for the San Bartolomeo and Polhem districts. Elaboration of sections 4 to 8.
ACC	Follow up of the IPD methodology implementation (and associated feedbacks) in TRL7 activities.

UTRC-I	Contribution to the BES questionnaire fulfilment for all demo sites. Validation of the proper validation of energy systems.
FSS	Participation in all activities related to the Txomin Enea district.
DTTN	Participation in all activities related to the San Bartolomeo district.
LUND	Participation in all activities related to the Polhem district.

1.3 Relation to other activities in the project

This work aims at validating the whole OptEEmAL platform at its last development step within the project (TRL7). As a consequence, it is 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).

2 Description of the demo sites

The demo sites used in the OptEEmAL project are presented in the section below and their location is mentioned in Figure 1. As a reminder, this section aims at describing, from a general perspective the demo sites of the project. More technical information, especially in terms of input data for the OptEEmAL platform, are reported in the next section.

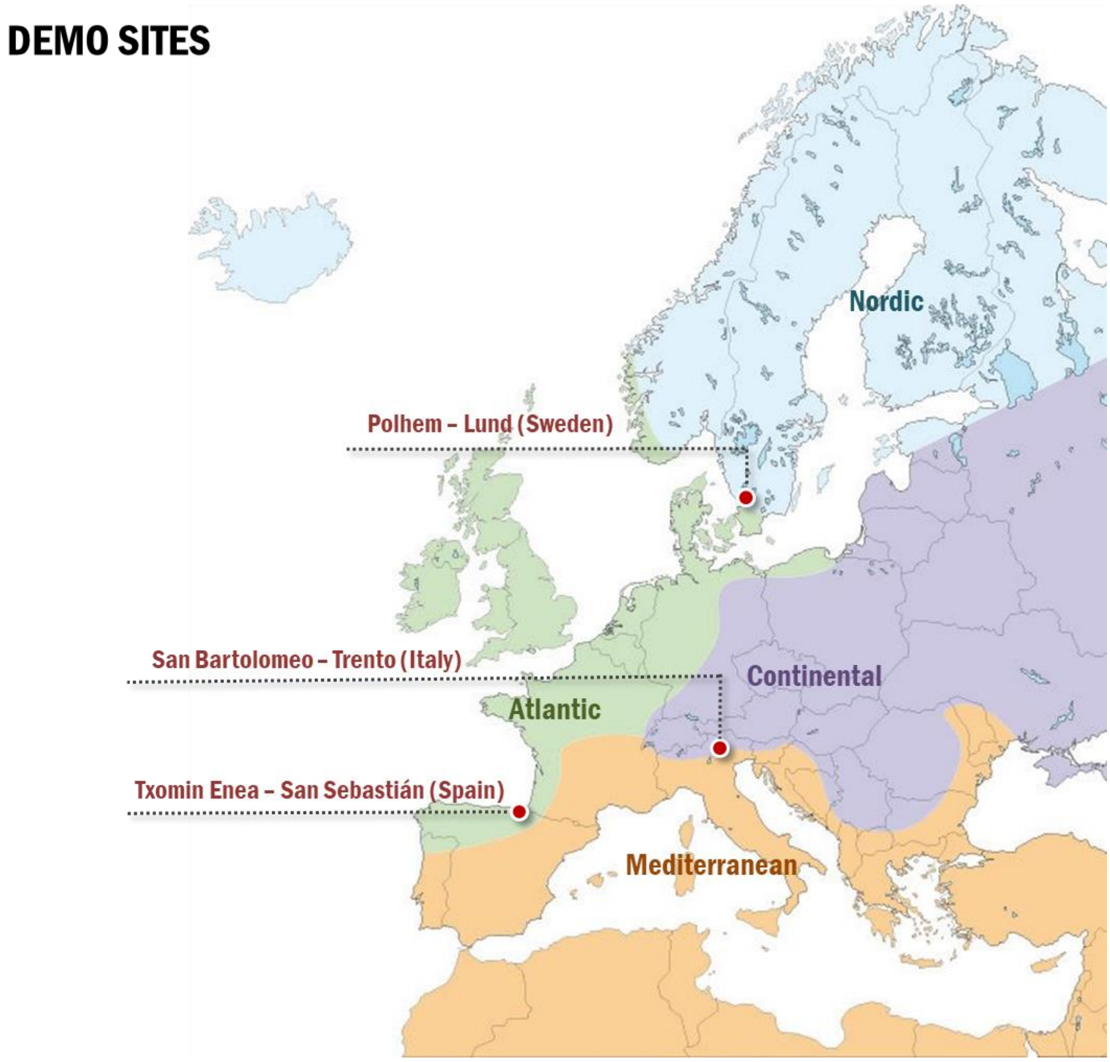


Figure 1: Location of the demo sites according to climatic zones

2.1 Txomin Enea district, San Sebastian (Spain)

2.1.1 General introduction

The building retrofitting project in Txomin Enea is part of a larger and ambitious project towards a smart city model for the Urumea Riverside district. San Sebastian has an integrated strategy aiming for a smart district in the Urumea Riverside with the particular objective of getting a nearly zero energy district. The Urumea Riverside district has a surface of approximately 200 hectares, which is made up of the Txomin Enea residential neighbourhood, the Ametzagaina Natual Park, which acts as a carbon reserve, and the Industrial Estate 27 with over 350 companies and almost 4,500 people.

The retrofitting project is an opportunity to improve the quality of life of the neighbours in Txomin Enea. The aim of the retrofitting is to achieve both reduction in energy demand of dwellings around 35%, as well as reducing the energy cost for residents and, therefore, the CO_2 emissions. Currently, these households do not have insulation on facades or roofs, so an action of refurbishment in these elements will substantially improve the thermal conditions and comfort.

In total, 156 dwellings, distributed along 10 doorways and totalling 18,365 m², are concerned by the retrofitting project. The construction dates of the buildings range from 1967 to 1980.

Finally, it shall be mentioned that, in agreement with FSS, only 8 doorways have been studied using the OptEEmAL platform (see Figure 4 for more details).

Figure 2: *Txomin Enea* district location (@GoogleMaps)

Figure 3: Whole project for the *Txomin Enea* district (@Fomento de San Sebastian/Ayuntamiento de San Sebastian)

2.1.2 Objectives of the retrofitting project

As mentioned previously, the objectives of the project are:

- To reduce the energy demand
- To reduce the final energy consumption
- To improve quality of life
- To reduce operational energy costs
- To reduce CO_2 emissions
- To achieve a nearly zero energy district.

2.1.3 Buildings under study

The buildings concerned by the retrofitting project are the ones highlighted in the Figure 4 below. They are also visible on the Figure 2 above (detailed buildings in the figure). All the buildings under study are used for residential purpose.

Figure 4: Buildings under study in the *Txomin Enea* district

2.2 San Bartolomeo district, Trento (Italy)

2.2.1 General introduction

The district of San Bartolomeo in Trento is one of the biggest public residential districts devoted to the living of both students and professors: the area of approximately 20,000 square meters is divided in different buildings with varying types of use serving different needs: dorms, a board with gymnasium, an auditorium, a bar and offices.

Despite the fact that the buildings have been built quite recently, the owner has the objective to verify which could be the main interventions that could bring energy benefits to the buildings themselves. The retrofitting project is an opportunity to, on the one hand, improve the quality of life of the inhabitants of the buildings, and on the other hand, to reduce the energy consumption and verify which technologies – software and hardware – will support this goal.

In total, 2 building blocks are part of the district (with 6 buildings in total) to be studied. They are all used for students and teachers housing. Due to time constraints, only one block (with 3 buildings in total) has been studied in the field of the OptEEmAL project.

Figure 5: *San Bartolomeo* district location (@GoogleMaps)

2.2.2 Objectives of the retrofitting project

As mentioned previously, the objectives of the project are:

- To improve quality of life
- To reduce operational energy costs

2.2.3 Buildings under study

The buildings concerned by the retrofitting project are the ones highlighted in the Figure 6 below. All the buildings under study are used for residential purpose.

Figure 6: Buildings under study in the *San Bartolomeo* district

2.3 Polhem district, Lund (SE)

2.3.1 General introduction

The Polhem school is a high school located near the city center of Polhem. The buildings are in various ages, shapes and conditions. The construction years range from 1914 to 1991 and the total building area is approximately 24,000 m². The buildings are heated with district heating that is 100% renewable. However, the municipality sees many other advantages with energy efficiency measures. The municipality has no energy efficiency measures planned for the buildings at the moment.

Figure 7: *Polhem* district location (@GoogleMaps)

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 8). Building's uses are described in the Table 2 below. Due to time and technical constraints (especially data availability) only 3 buildings have been studied for this demo site (Buildings N°1, 2 and 8).

Figure 8: Buildings under study in the *Polhem* district

Table 2: Buildings' uses in the *Polhem* district

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

3 Introduction of the demo sites 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 demo sites 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 Txomin Enea district, San Sebastian (Spain)

3.1.1 BIM models

For the *Txomin Enea* district, 5 BIM models have been elaborated (Figure 9, Figure 10 and Figure 11) for OptEEmAL project by NBK. Indeed, considering the similarities between different buildings, it has been needed to elaborated “only” 5 models for the 8 buildings considered in the project. The link between the existing buildings and the elaborated IFC files are presented in Table 3 below.

Table 3: Link between existing buildings and elaborated IFC files for the *Txomin Enea* district

Portals	IFC files corresponding to portals n°
11	11
12	12
13	13
14	14
15	12
16	11
22	23
23	23

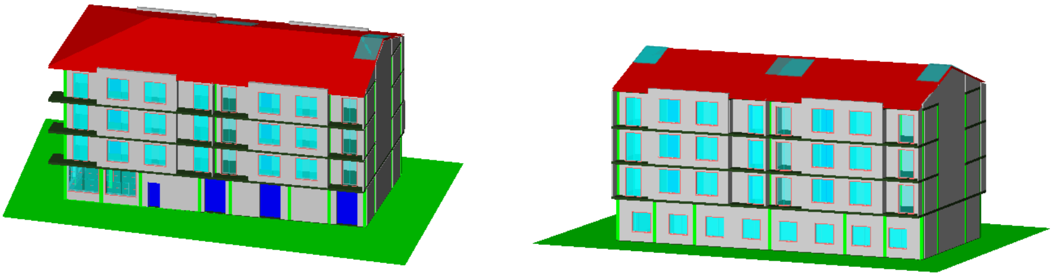


Figure 9: BIM models for portals 11 (left) and 12 (right) of the *Txomin Enea* district

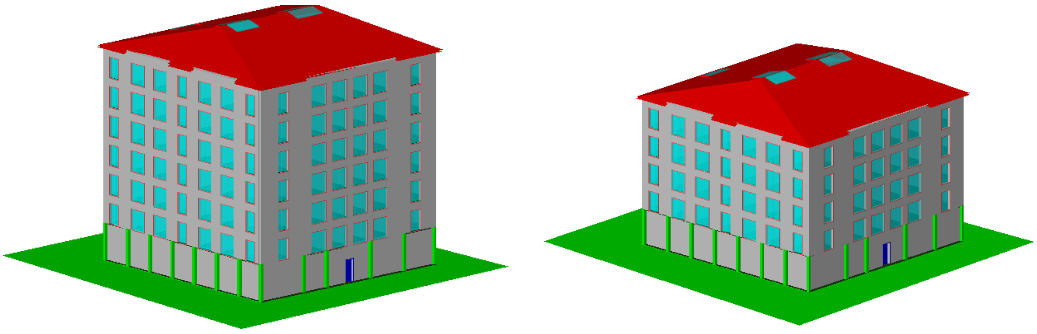


Figure 10: BIM models for portals 13 (left) and 14 (right) of the *Txomin Enea* district

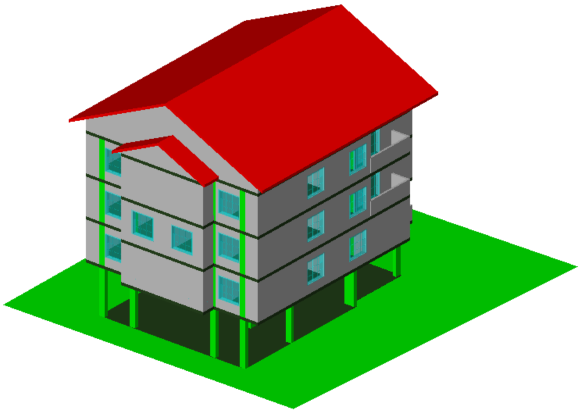


Figure 11: BIM model for portal 23 of the *Txomin Enea* district

3.1.2 CityGML model

The CityGML model of the district has been 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 and DSM of the same area). An illustration of the model is provided in the figure below (Figure 12). Considering the significant topography in the area, it has been 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.

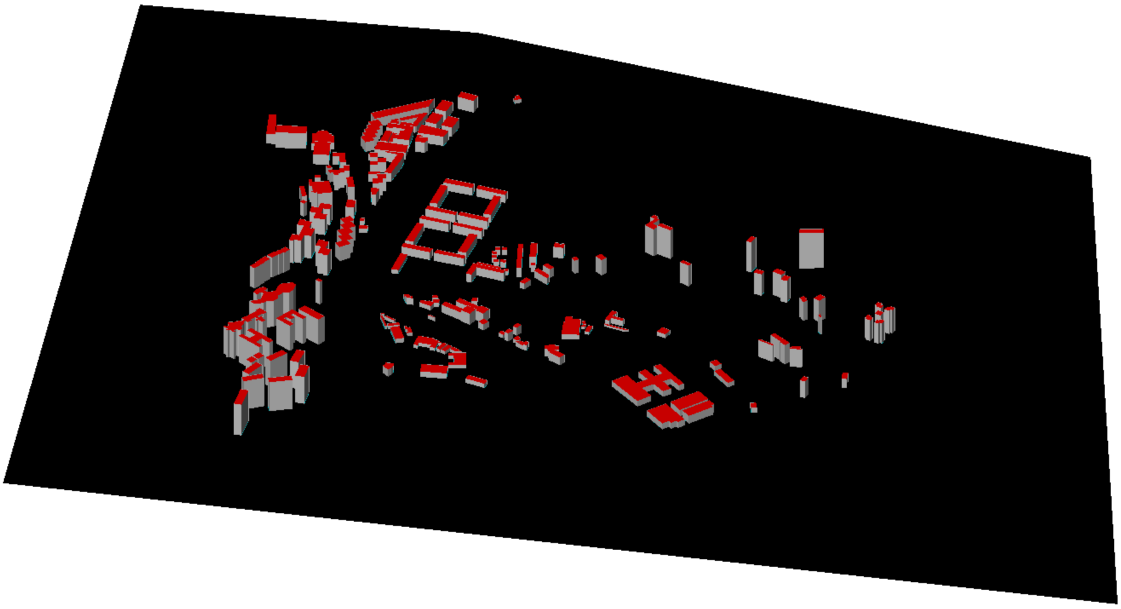


Figure 12: CityGML model of the *Txomin Enea* district

3.1.3 Baseline Energy Systems

Using information provided by FSS and TEC, the Baseline Energy Systems questionnaire from the platform has been answered as illustrated below. Only applicable questions from the BES questionnaire are reported below for ease of understanding.

BES questionnaire – *Txomin Enea* district, San Sebastian (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 except the total boiler capacity)**

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? **300 kW for portals 11, 12, 15, 16, 22 and 23 / 400 kW for portal 14 / 600 kW for portal 13**

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? **0.65**

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? **70°C**

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 ECM questionnaire

ECM questionnaire – *Txomin Enea* district, San Sebastian (Spain)

1_District

1.1_Will you connect building to a District Heating & Cooling network? **YES**

2_Buildings

2.1_Can you modify building façades? **YES**

2.1.1_Can they be refurbished externally? **YES**

2.1.2_Can they be refurbished internally? **YES**

2.1.3_Do you know the thickness of the air chamber of your façades? **No**

2.2_Can you modify building windows? **YES**

2.3_Can you modify buildings roofs? **YES**

2.3.1_Can you apply external roof insulation? **YES**

2.3.2_Can they be internally refurbished? **YES**

2.3.3_Can you consider the implementation of renewable generation systems on the roofs? **YES**

2.3.3.1_Can you use the roof for thermal energy production? **NO**

2.3.3.2_Can you use the roof for electricity production? **YES**

2.4_Can you modify building floors? **NO**

2.5_Can you change the energy generation system? **YES**

2.5.1_Do the buildings have functional space to implement biomass boilers? **NO**

2.6_Can you replace or implement the energy control system? **YES**

3.1.4.2 Targets and boundaries

TB questionnaire – *Txomin Enea* district, San Sebastian (Spain)

1.a_Investment (ECO02.2): **5.000.000 €**

1.b_Payback period (ECO05): **30 years.**

1.c_Energy Payback Time (ENV06): **50 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 – *Txomin Enea* district, San Sebastian (Spain)

Prioritisation criteria have been defined using manual weighting schemes. The following inputs have been introduced in the platform.

3.1.6 Biomass prices

- Local current value of biomass: 82.78 €/ton
- Annual increase: 3%

3.2 San Bartolomeo district, Trento (Italy)

3.2.1 BIM models

For the *San Bartolomeo* district, 1 BIM model (Figure 14) has been elaborated representing three buildings (from the “F” block in Figure 13). This BIM model has been elaborated by DTTN subcontractor with support from NBK and CAR.

Figure 13: Building locations in the *San Bartolomeo* district

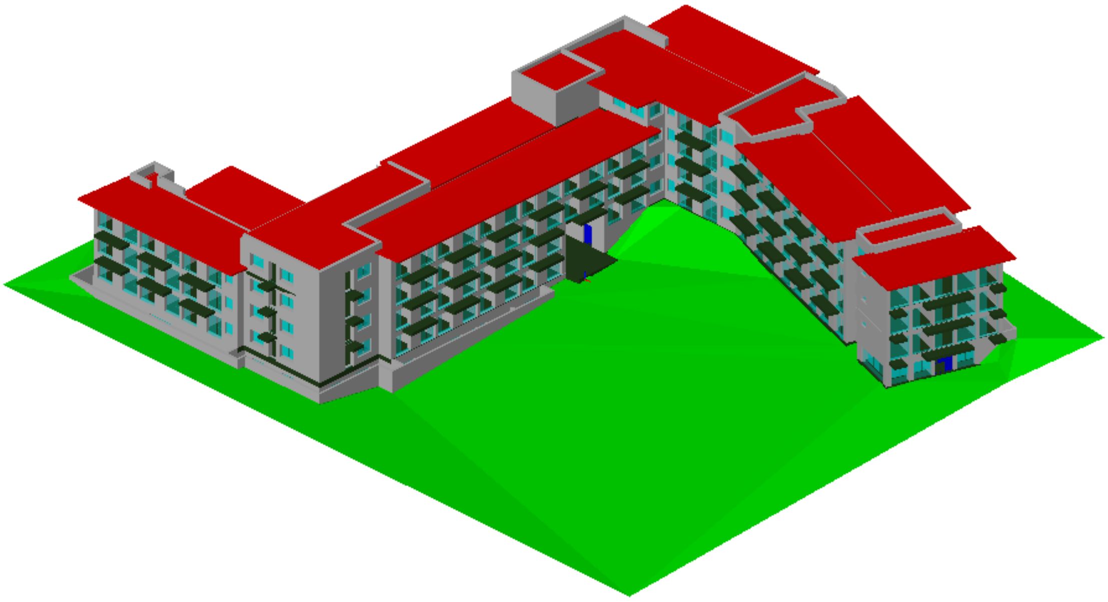


Figure 14: BIM model for the *San Bartolomeo* district (Building F)

3.2.2 CityGML file

The CityGML model of the district has been 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 and DSM of the same area). An illustration of the model is provided in the figure below (Figure 15). This model has been elaborated as part of the OptEEmAL project.

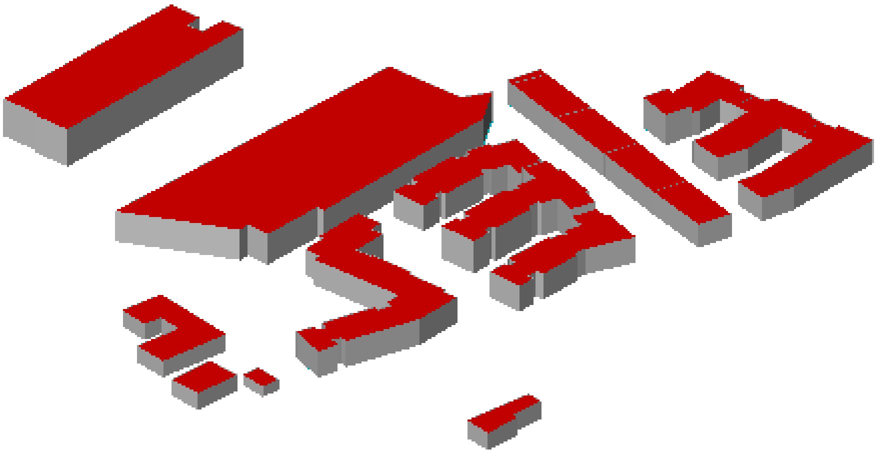


Figure 15: CityGML model of the *San Bartolomeo* district

3.2.3 Baseline Energy Systems

BES questionnaire – *San Bartolomeo* district, Trento (Italy)

1_District

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

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

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

1.1.1.1.1_If a, then

1.1.1.1.1.i_How many boilers do you have? **1**

1.1.1.1.1.ii_What is the total boiler capacity? **377 kW**

1.1.1.1.1.iii_What is the boiler type? **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? **0.974**

1.1.1.1.4_What is the district heating start and stop times? (hours) **Unknown**

1.1.1.1.5_What is the hot water set-point? (ºC) **Unknown**

2_Buildings

For each building of the district:

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? **YES**

2.3.1.1.1_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? (for all the HVAC zones)

2.3.1.1.1.1.5 **h. Underfloor heating**

3.2.4 Targets, boundaries and barriers

3.2.4.1 ECM questionnaire

ECM questionnaire – *San Bartolomeo* district, Trento (Italy)

1_District

1.1_Will you connect building to a District Heating & Cooling network? **YES**

1.1.1_Do you have useful land surface to implement renewables? **NO**

2_Buildings (same answers for all buildings)

2.1_Can you modify building façades? **YES**

2.1.1_Can they be refurbished externally? **YES**

2.1.2_Can they be refurbished internally? **YES**

2.1.3_Do you know the thickness of the air chamber of your façades? **NO**

2.2_Can you modify building windows? **YES**

2.3_Can you modify buildings roofs? **YES**

2.3.1_Can you apply external roof insulation? **YES**

2.3.2_Can they be internally refurbished? **YES**

2.3.3_Can you consider the implementation of renewable generation systems on the roofs? **YES**

2.3.3.1_Can you use the roof for thermal energy production? **YES**

2.3.3.2_Can you use the roof for electricity production? **YES**

2.4_Can you modify building floors? **NO**

2.5_Can you change the energy generation system? **YES**

2.5.1_Do the buildings have functional space to implement biomass boilers? **NO**

2.6_Can you replace or implement the energy control system? **YES**

3.2.4.2 Targets and boundaries

TB questionnaire – *San Bartolomeo* district, Trento (Italy)

1.a_Investment (ECO02.2): **Confidential**

1.b_Payback period (ECO05): **Confidential**

1.c_Energy Payback Time (ENV06): **Confidential**

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

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

3.2.5 Prioritisation criteria

Prioritisation criteria – San Bartolomeo district, Trento (Italy)

Considering the objectives of the retrofitting project in Trento, the choice has been made to select the pre-defined prioritisation criteria "To prioritise the reduction of operational energy costs" and including the prioritisation of economic aspects.

3.2.6 Biomass prices

- Local current value of biomass: 32.75 €/ton

- Annual increase: 2.65%

3.3 Polhem district, Lund (Sweden)

3.3.1 BIM models

For the Polhem district, 6 BIM models have been elaborated to represent the 6 buildings present in the district (see Figure 16, Figure 17, Figure 18 and Figure 20). It has been 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 4 below. Those models have been 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.

It has to be mentioned that finally, only three buildings have been used all along the platform (Buildings N°1, 2 and 8). The reason for discarding the other buildings is that their complexity in terms of BIM modelling was important and it was not possible to apply all the relevant ECMs (issues were faced with the platform when applying some ECMs).

Table 4: Relationship between the buildings and the IFC files for the Polhem district

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

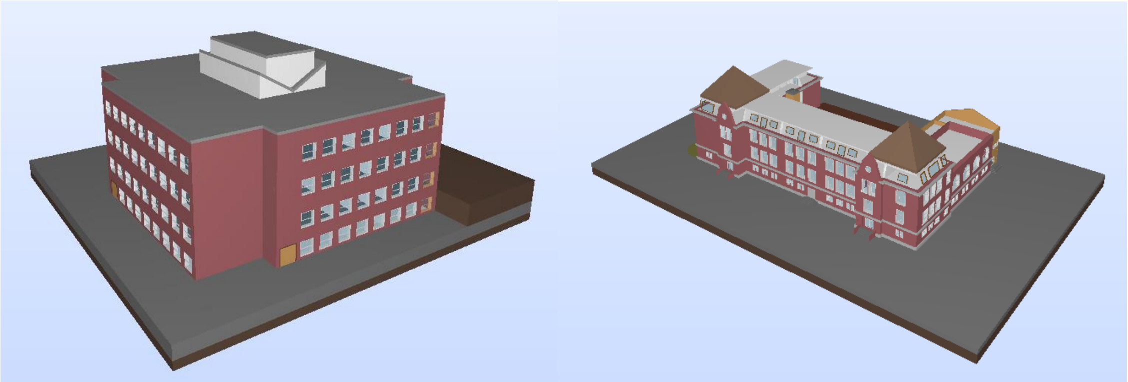


Figure 16: “Polhem_1” (left) and “Polhem_3” (right) IFC files

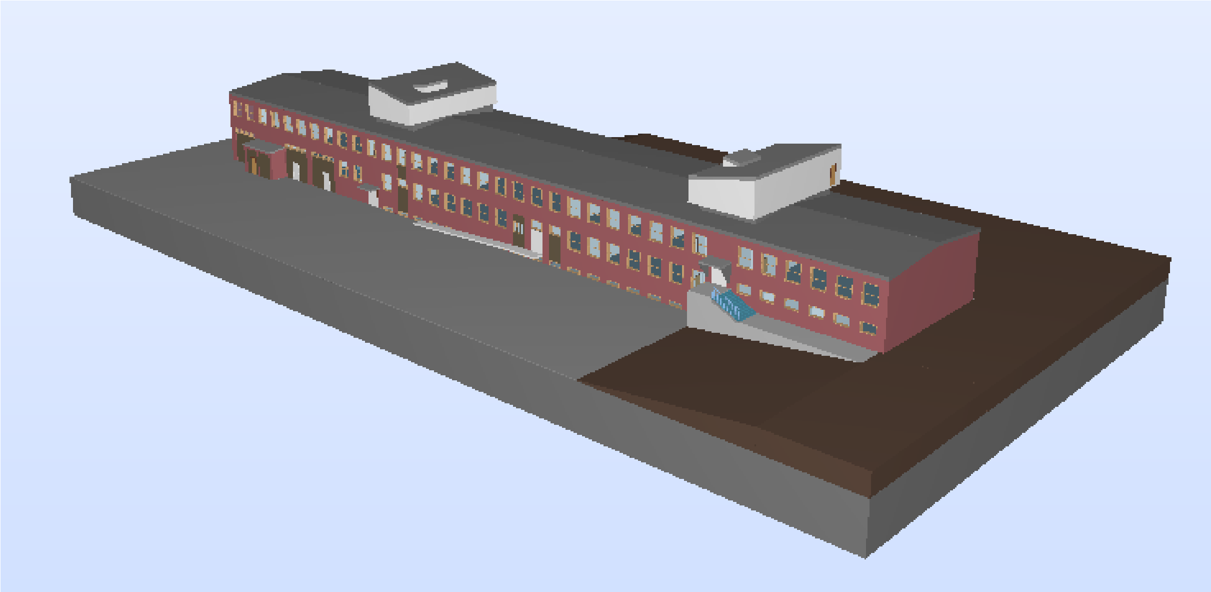


Figure 17: “Polhem_2” IFC file

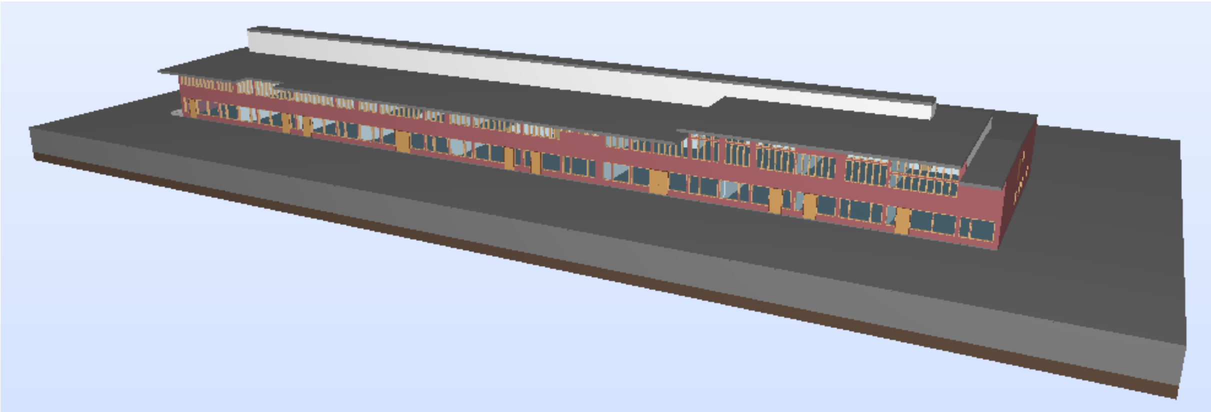


Figure 18: “Polhem_5” IFC file

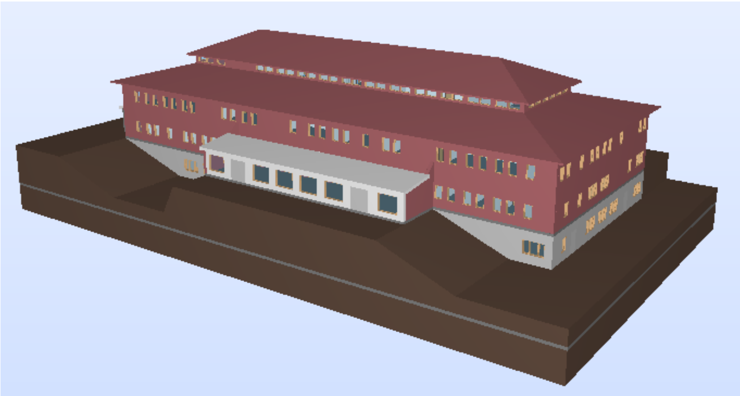


Figure 19: “Polhem_7” IFC file

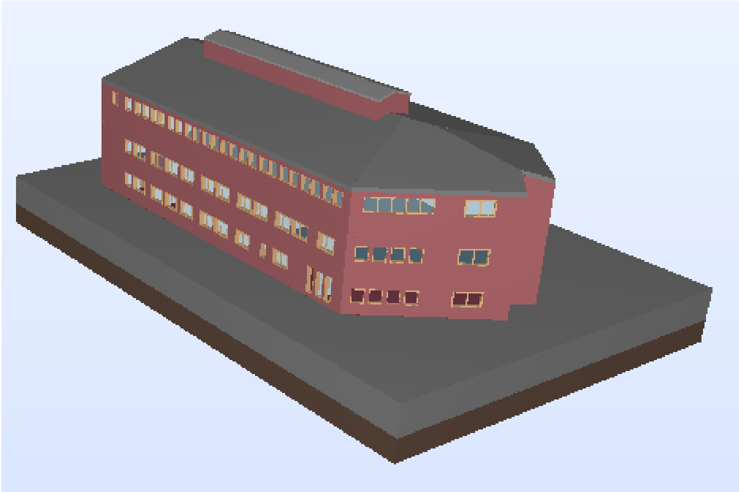


Figure 20: “Polhem_8” IFC file

3.3.2 CityGML model

The CityGML file for the Polhem district has been 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 has been elaborated as part of the OptEEmAL project.

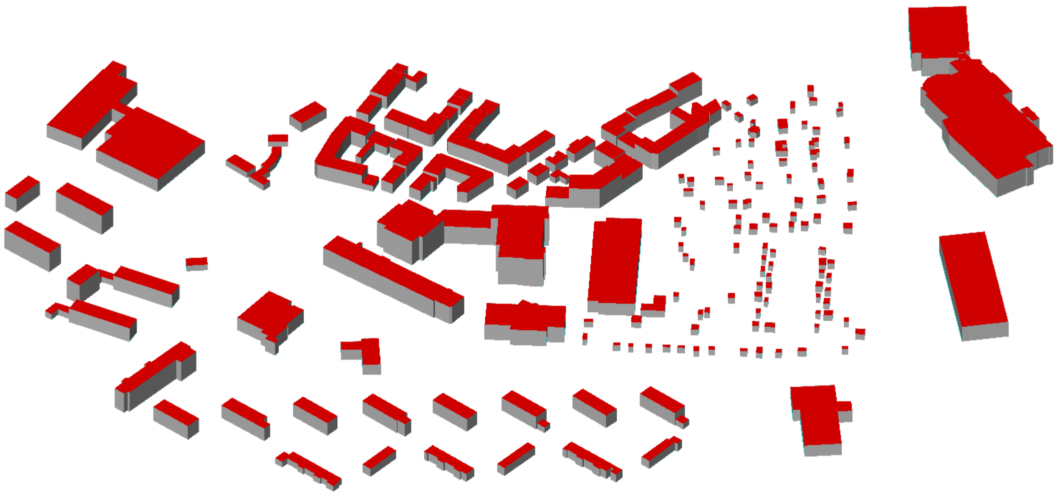


Figure 21: CityGML file for the Polhem district, Lund

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.

One important remark regarding the Polhem district BES questionnaire is that the energy systems and energy sources inserted into the platform are different than the ones used in reality. Regarding energy systems, the Polhem district is supply in reality by a complex regional/municipal district heating system supplied with different energy systems (boilers, CHPs, waste heat recovery systems, etc.). It was not possible to implement this complexity in the OptEEmAL platform at TRL7. As a consequence, simplification have been made. They are reported in the “boxes” below. Similarly, CHPs that are part of this complex system are using biomass. This option was not available in the platform (for CHPs only, biomass can be selected as an energy source for boilers). This has been also simplified while entering the data into the platform. Finally, for power related information, a ratio has been applied (based on the final energy consumed by the Polhem district in comparison to the total energy produced by the district heating system) to the power capacities of the regional/municipal district heating system.

The first box below mentions the real energy systems and associated energy sources of the Polhem district. The second bow presents the information introduced into the platform.

BES questionnaire – Polhem district, Lund (Sweden) – Real energy systems/sources

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 and Biogas**

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)**

BES questionnaire – Polhem district, Lund (Sweden) – Introduced energy systems/sources

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? **1** ***[14 (at regional level)***

1.1.1.1.1.ii. What is the total boiler capacity? **1100 kW** ***[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** ***[Natural gas and Biogas]***

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? **1** ***[2 (at regional level)***

1.1.1.1.2.ii. What is the CHP electrical capacity? **150 kW** ***[42 MW (at regional level)]***

1.1.1.1.2.iii. What is the CHP thermal capacity? **380** ***[102 MW (at regional level)]***

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

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 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/m^2.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. These kinds 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.

In D6.1, end-to-end tests have been performed in order to validate the proper integration of the different individual modules (and components) of the platform using a fictive example. In D6.2, end-to-end tests have been done to validate the proper integration of the different modules using real data from the case studies and thus investigate how the platform performed in conditions which are closer to the reality. In this section, and considering the development status of the platform, it has been decided to report the status of the demo sites for the different steps of the platform and not for the different individual tests reported in previous deliverables (D6.1 and D6.2).

The results of the different steps of the platform for the different demo sites are summarised in the Table 5 below and showed in details using screenshots for the *Txomin Enea* district in the following paragraphs. Screenshots for the other demo sites are provided in annex (see section 9.1).

4.2 Summary of the results

Results of the different tests are described in the Table 5 below for the different demo sites.

Table 5: Results of end-to-end tests

Step ID	Name	Txomin Enea, San Sebastian	San Bartolomeo, Trento	Polhem, Lund
1	IPD group creation	PASSED	PASSED	PASSED
2	Data upload	PASSED	PASSED	PASSED
3	Baseline Energy Systems	PASSED	PASSED	PASSED
4	Contextual data	PASSED	PASSED	PASSED
5	ECM questionnaire	PASSED	PASSED	PASSED
6	Check Strategies	PASSED	PASSED	PASSED
7	Baseline Performance	PASSED	PASSED	PASSED
8	Targets and Boundaries	PASSED	PASSED	PASSED
9	Prioritisation criteria	PASSED	PASSED	PASSED
10	Problem summary	PASSED	PASSED	PASSED
11	Optimisation progress	PASSED	PASSED	PASSED
12	Select optimal scenario	PASSED	PASSED	PASSED

13	Export	PASSED	PASSED	PASSED

4.3 Detailed results of end-to-end tests

This section describes the results obtained for each step of the platform for the *Txomin Enea* district. Same results for other demo sites are provided in annex (see section 9.1).

Step 1: IPD group creation

The IPD group is successfully created with several users (Figure 22). It has to be noted that in this project, all users (internal to the consortium) have been assigned the same role of "Prime Designer". This was done for testing purposes.

This test is PASSED.

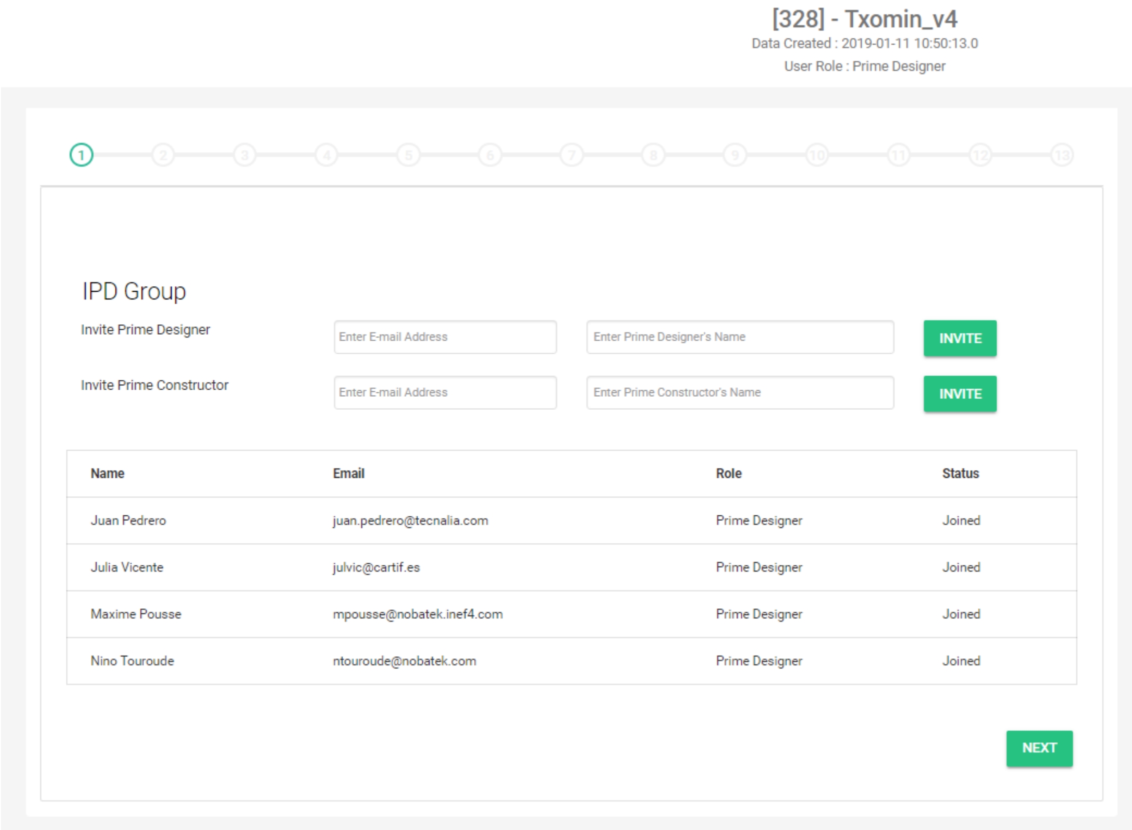


Figure 22: IPD group creation – *Txomin Enea* district, San Sebastian

Step 2: Data upload

Considering its importance, this step has been in two sub-steps "Upload" and "BIM-CityGML matching".

Upload

Using the GUI, the CityGML file has been properly uploaded and checked (Figure 23).

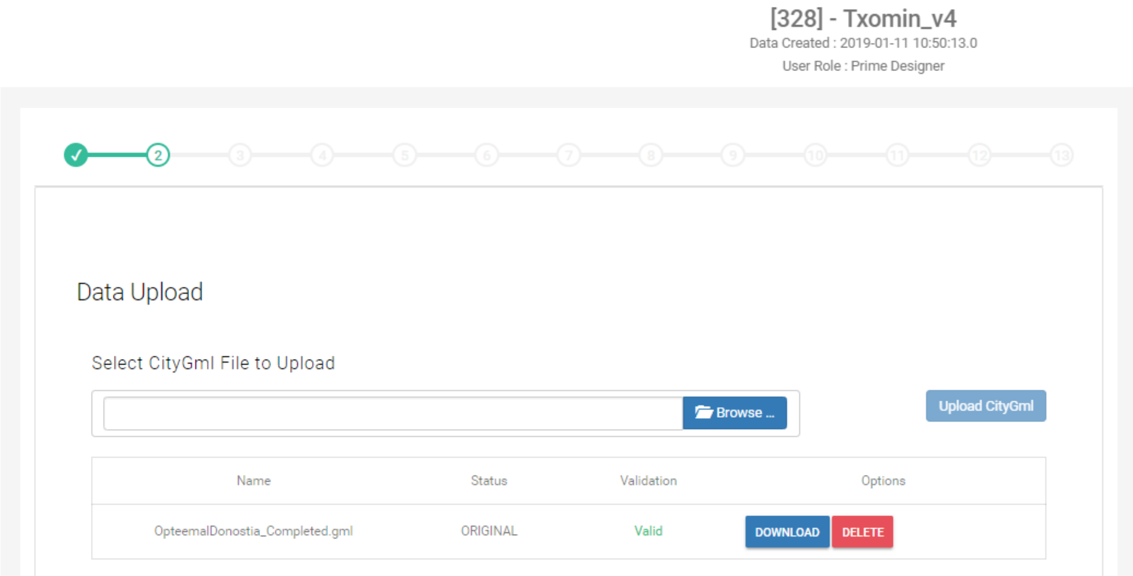


Figure 23: Uploaded and checked CItyGML file – *Txomin enea* district, San Sebastian

Similarly, all the IFC files have been properly uploaded and checked (Figure 24).

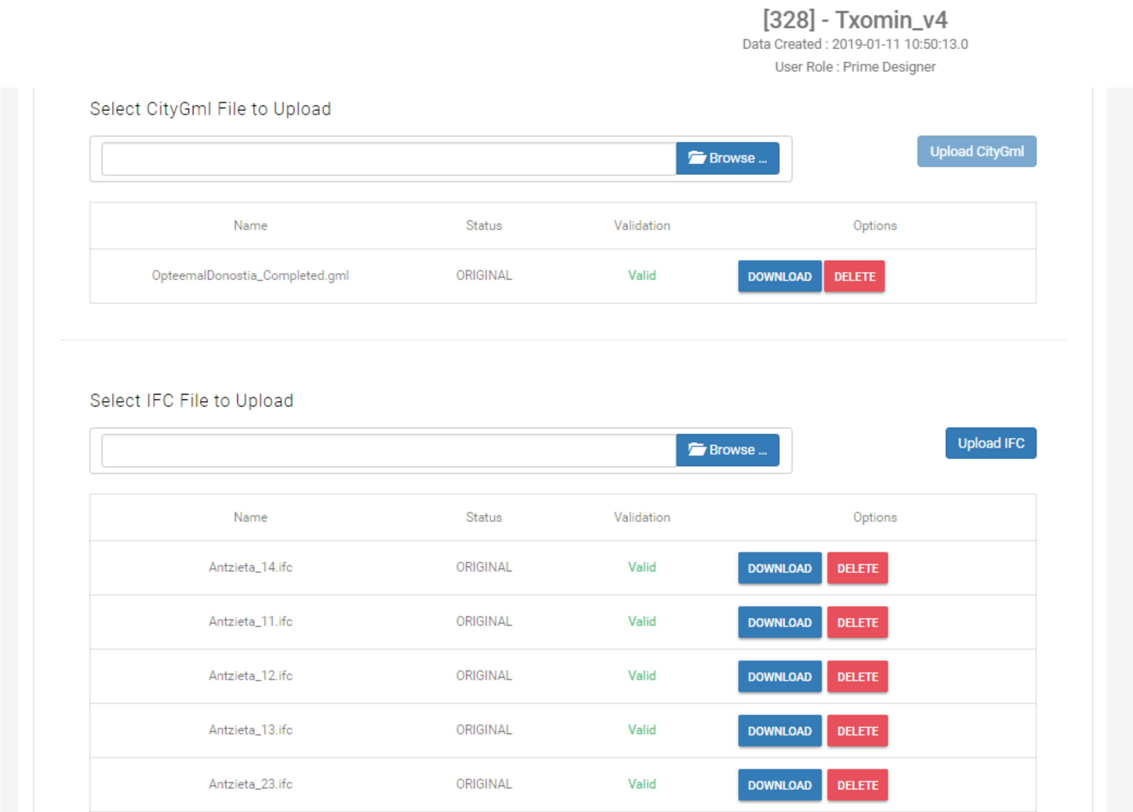


Figure 24: Uploaded and checked IFC files – *Txomin Enea* district, San Sebastian

BIM-CityGML matching

After their upload, the different IFC files have been matched with the CityGML file (Figure 25). This step is PASSED.

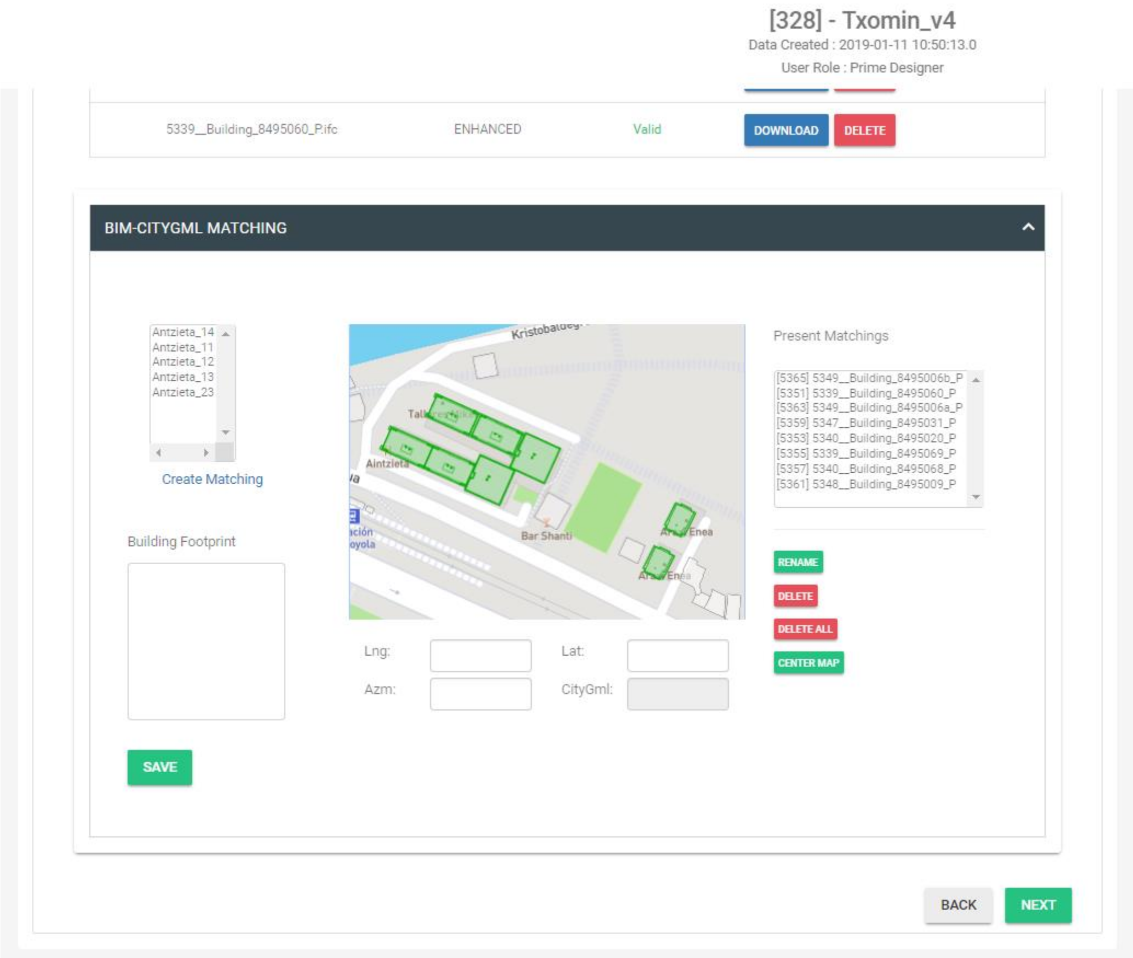


Figure 25: BIM and CityGML files matched – *Txomin Enea* district, San Sebastian

Step 3: Baseline Energy Systems

The Baseline Energy Systems questionnaire has been successfully answered at the district (Figure 26) and building (Figure 27 and Figure 28) levels. This step is PASSED.

Figure 26: BES questionnaire at district level – *Txomin Enea* district, San Sebastian

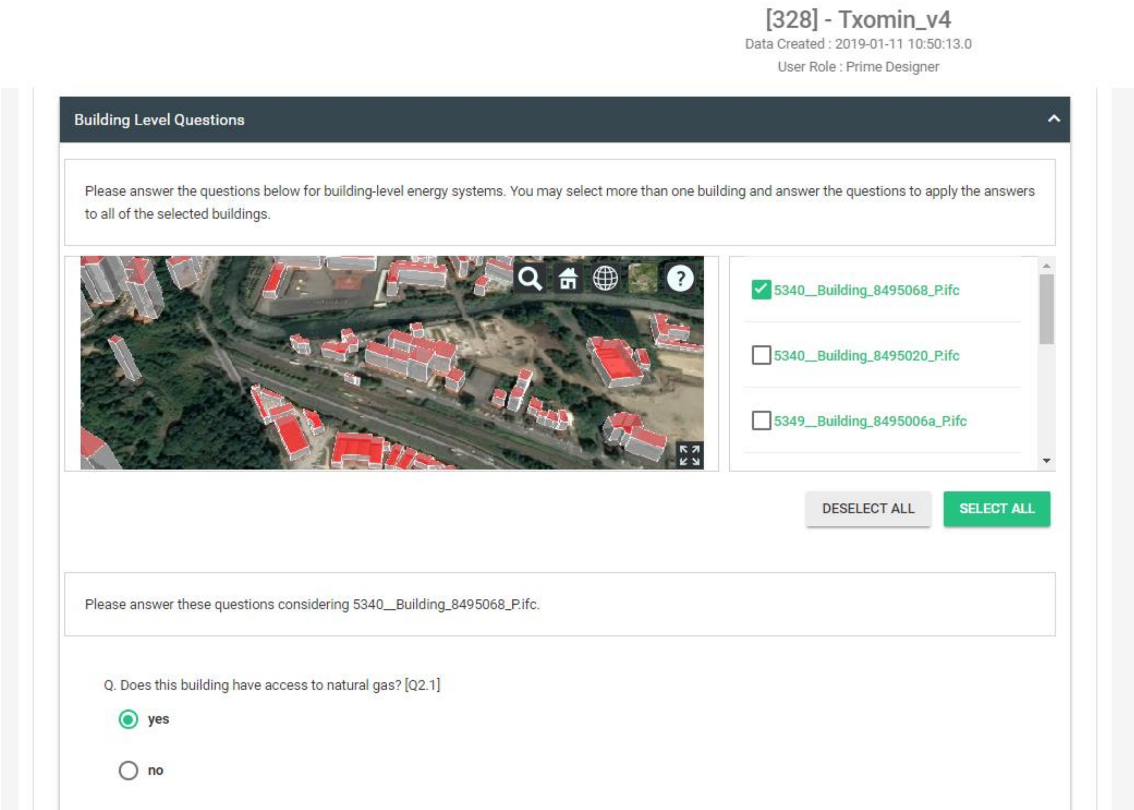


Figure 27: BES questionnaire at building level (1) – *Txomin Enea* district, San Sebastian

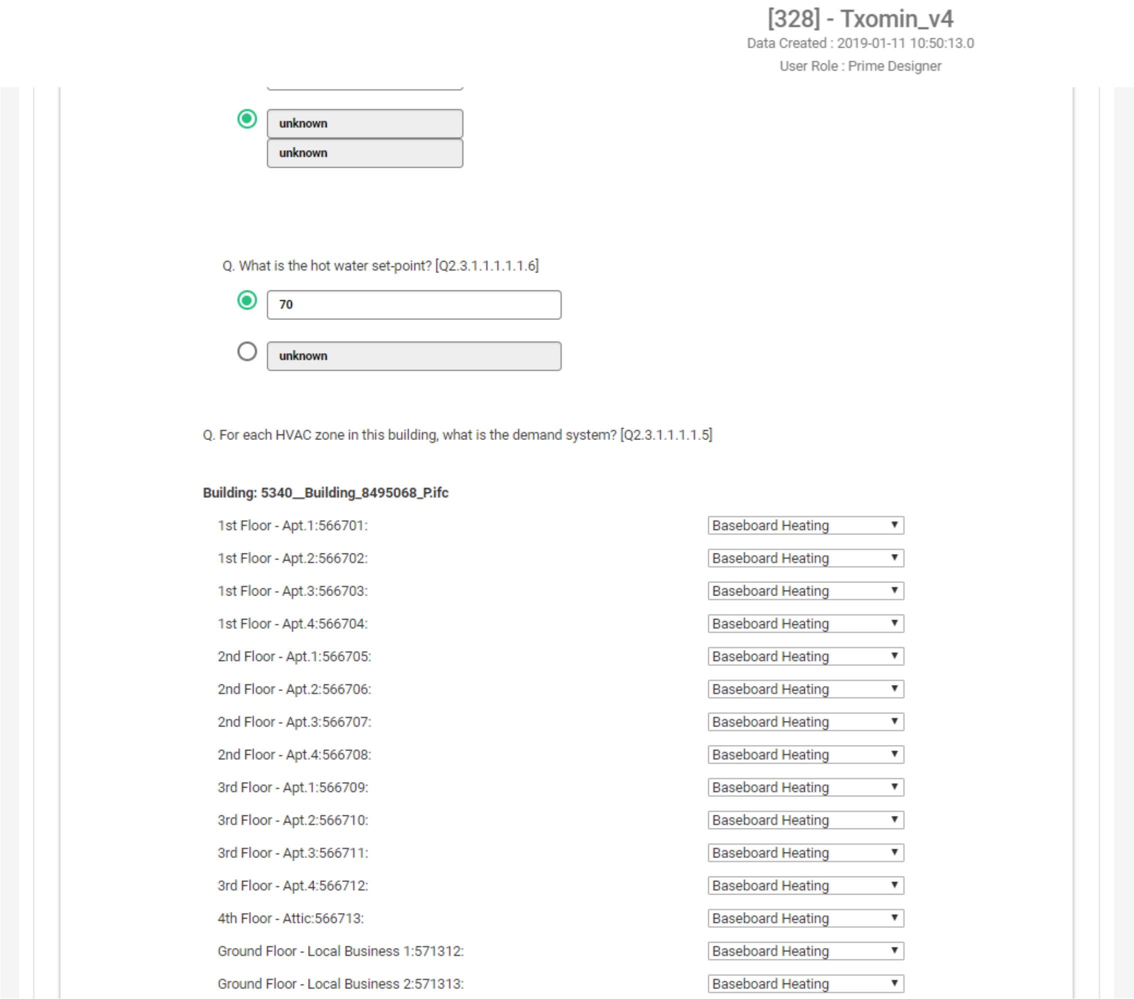


Figure 28: BES questionnaire at building level (2) – *Txomin Enea* district, San Sebastian

Step 4: Contextual data

The contextual data are properly retrieved from the different databases (Figure 29). They can be downloaded and modified by the user if needed. Biomass related information has also been inserted. It has to be noticed that site-related data (gathered using the unstructured data gathering service but not used in the calculations) are not presented properly in the platform (but properly retrieved). This last point is PARTIALLY PASSED. Otherwise, this step is PASSED.

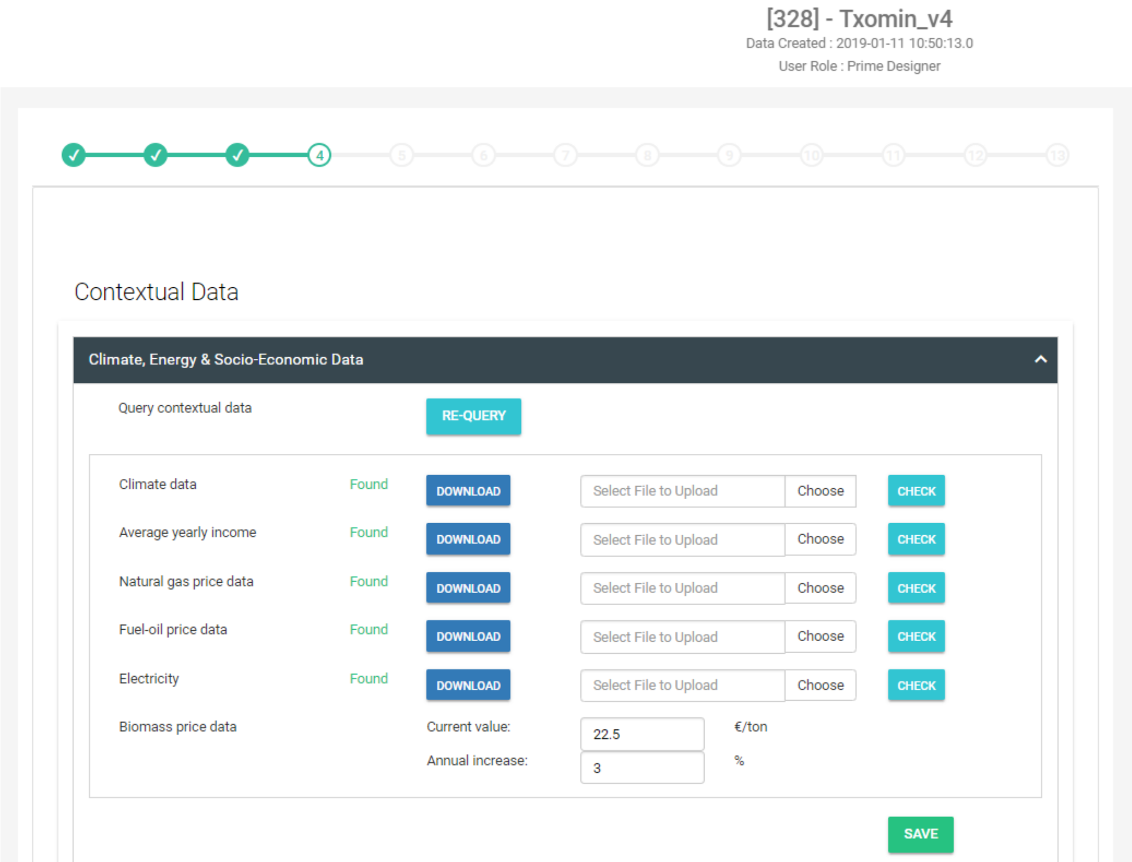


Figure 29: Contextual data gathered – *Txomin Enea* district, San Sebastian

ECM questionnaire

The ECM questionnaire has been answered at district (Figure 30) and buildings (Figure 31 and Figure 32) levels. This test is PASSED.

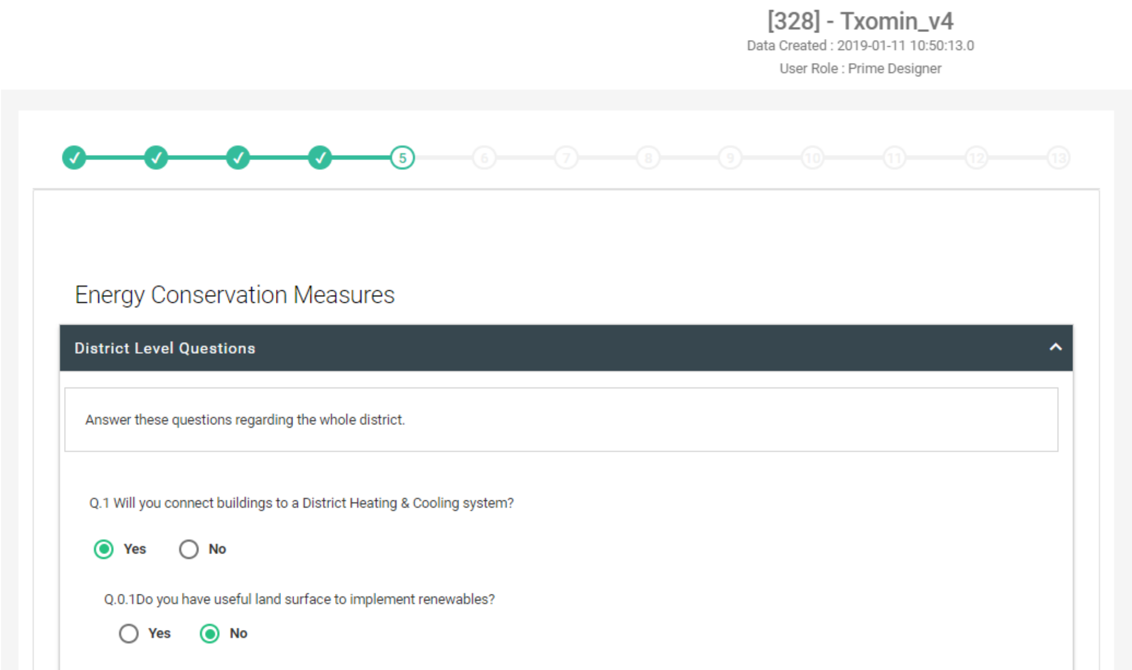


Figure 30: ECM questionnaire completed at district scale – *Txomin Enea* district, San Sebastian

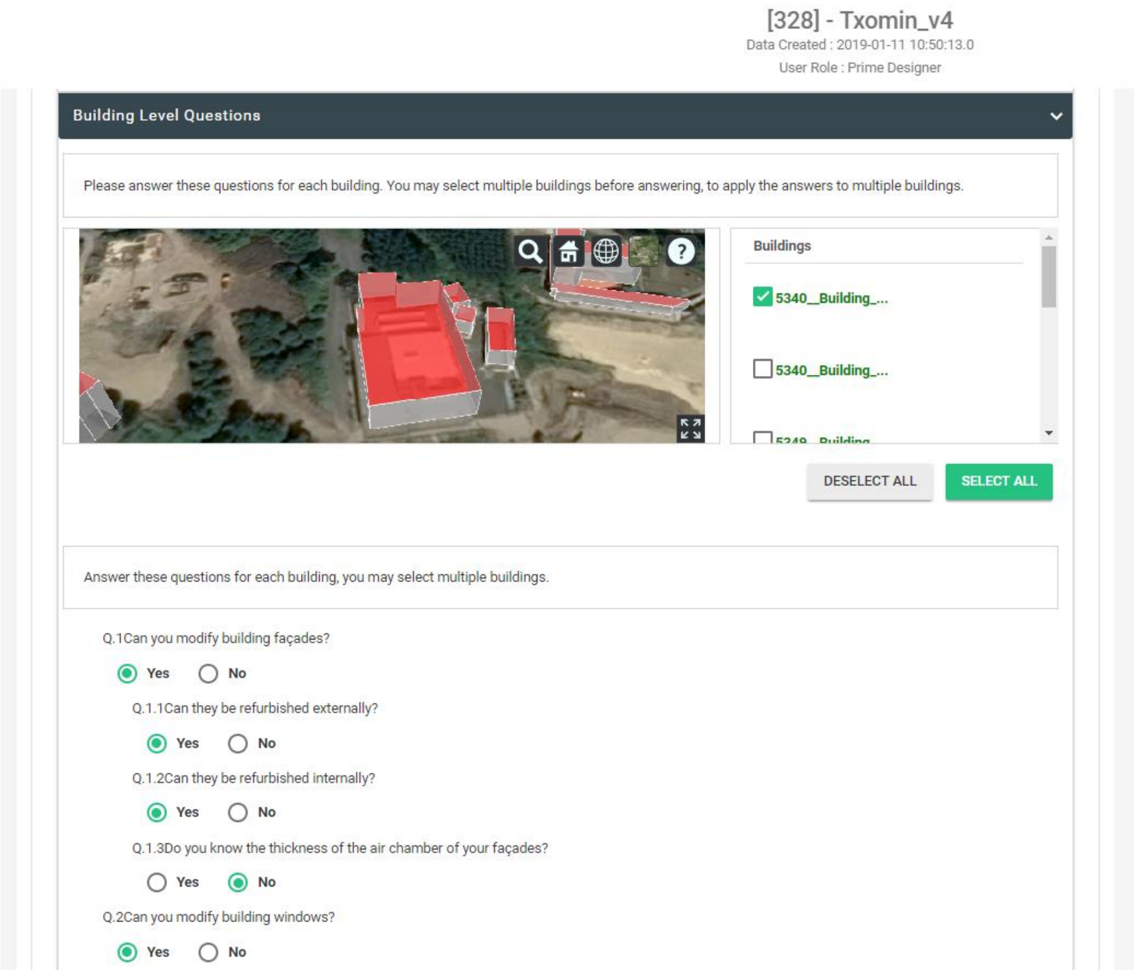


Figure 31: ECM questionnaire completed at building scale (1) – *Txomin Enea* district, San Sebastian

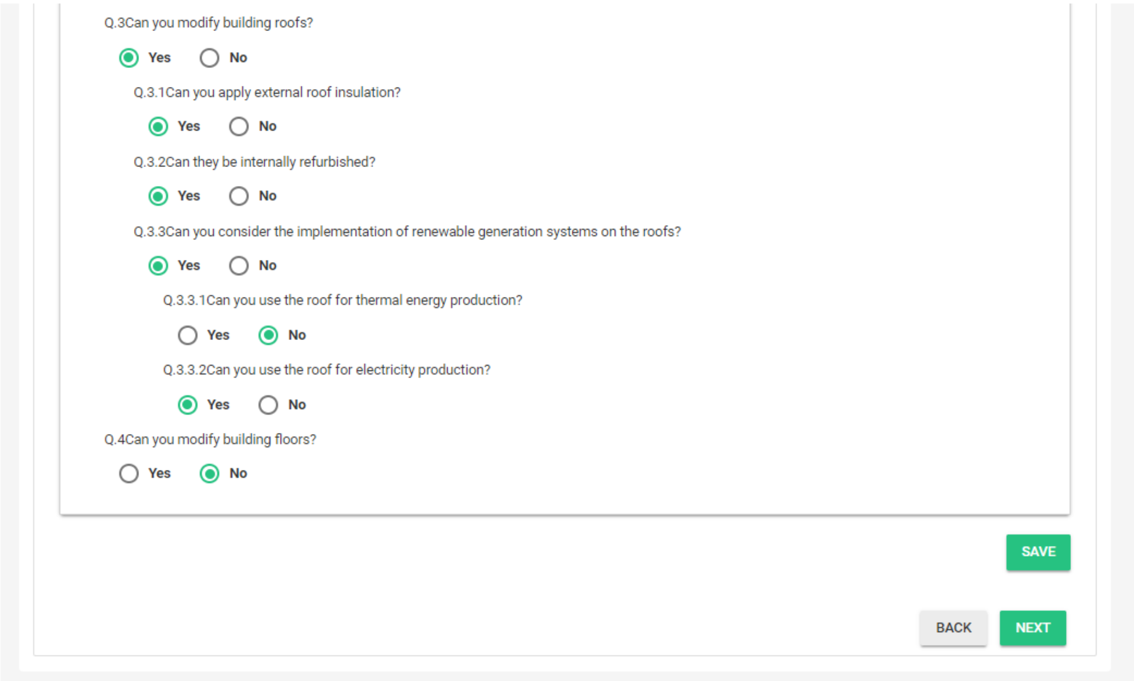


Figure 32: ECM questionnaire completed at building scale (2) – *Txomin Enea* district, San Sebastian

Step 6: Check strategies

Following answers provided in the ECM questionnaire, the Check strategies shows the possible ECMs. They can be discarded and edited (cost information) (Figure 33). This step is PASSED.

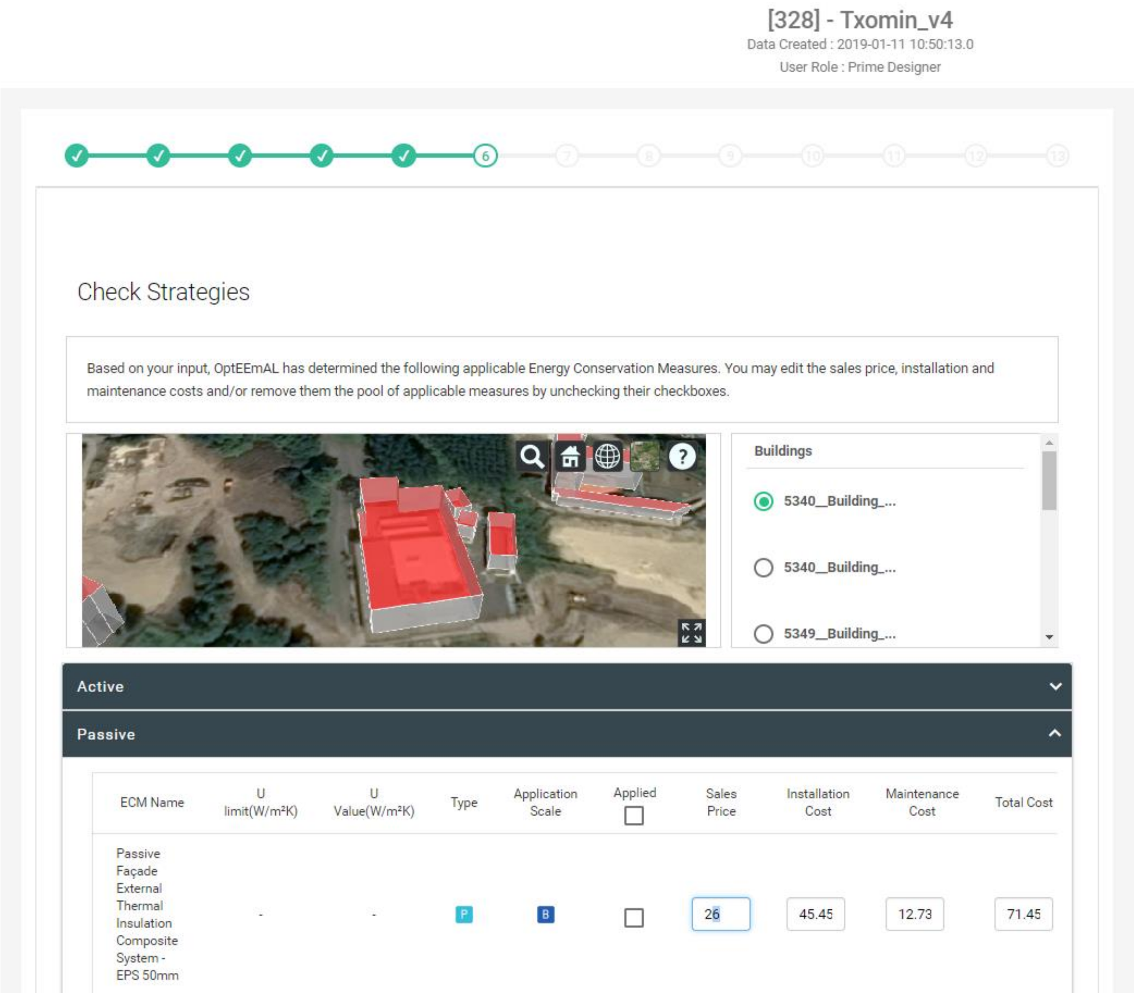
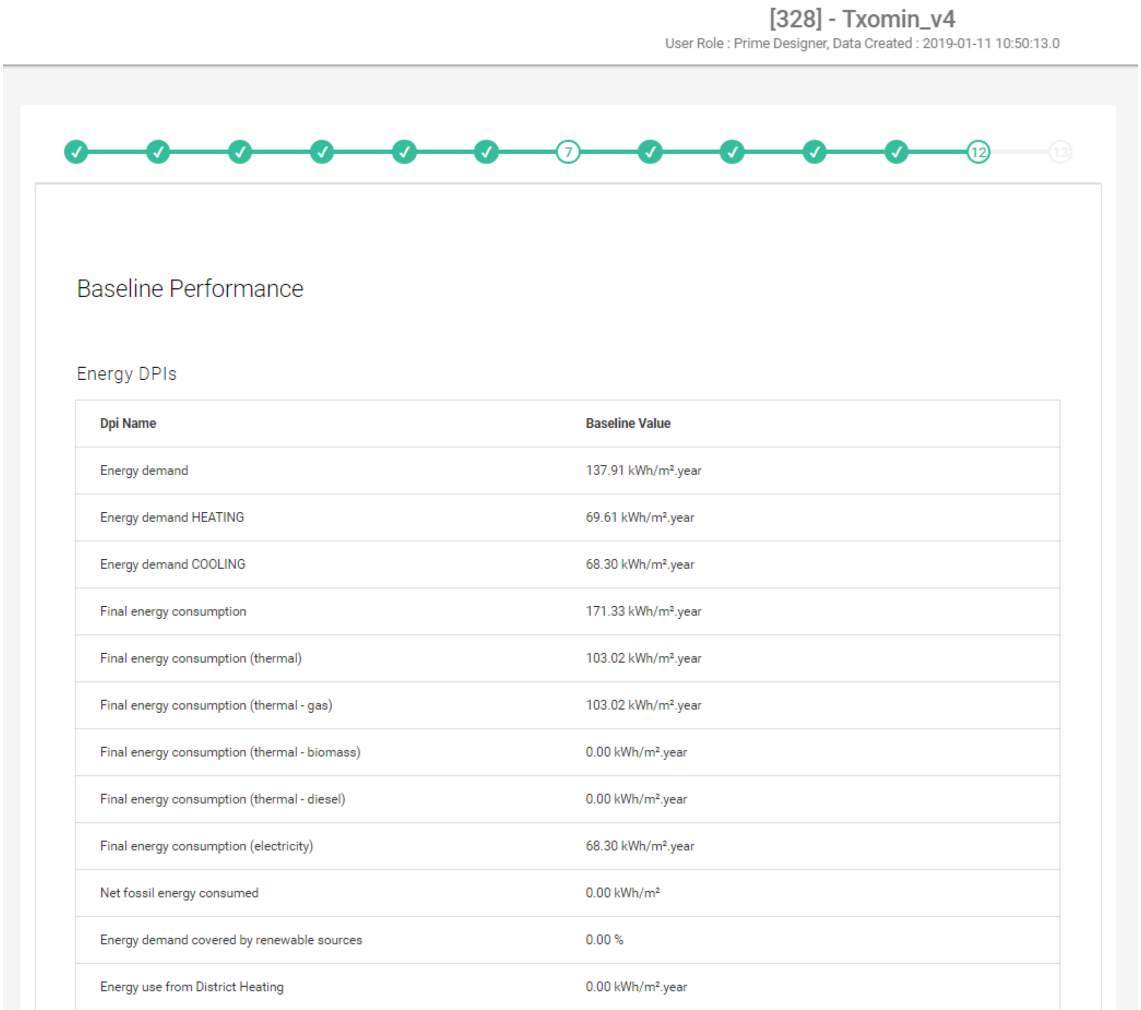


Figure 33: Discarded and edited ECM – *Txomin Enea* district, San Sebastian

Step 7: Baseline results

Based on the input data provided by the users, the platform has calculated the different DPIs for the baseline. The DPIs are presented to the user (Figure 34). This step is PASSED.


[328] - Txomin_v4

User Role : Prime Designer, Data Created : 2019-01-11 10:50:13.0

Baseline Performance

Energy DPIs

Dpi Name	Baseline Value
Energy demand	137.91 kWh/m².year
Energy demand HEATING	69.61 kWh/m².year
Energy demand COOLING	68.30 kWh/m².year
Final energy consumption	171.33 kWh/m².year
Final energy consumption (thermal)	103.02 kWh/m².year
Final energy consumption (thermal - gas)	103.02 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)	68.30 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 34: Baseline DPIs – *Txomin Enea* district, San Sebastian

Step 8 – Targets and Boundaries

After the selection of the ECMs, the user continues the definition of the retrofitting project by entering the different target and boundary values (Figure 35). This step is PASSED.

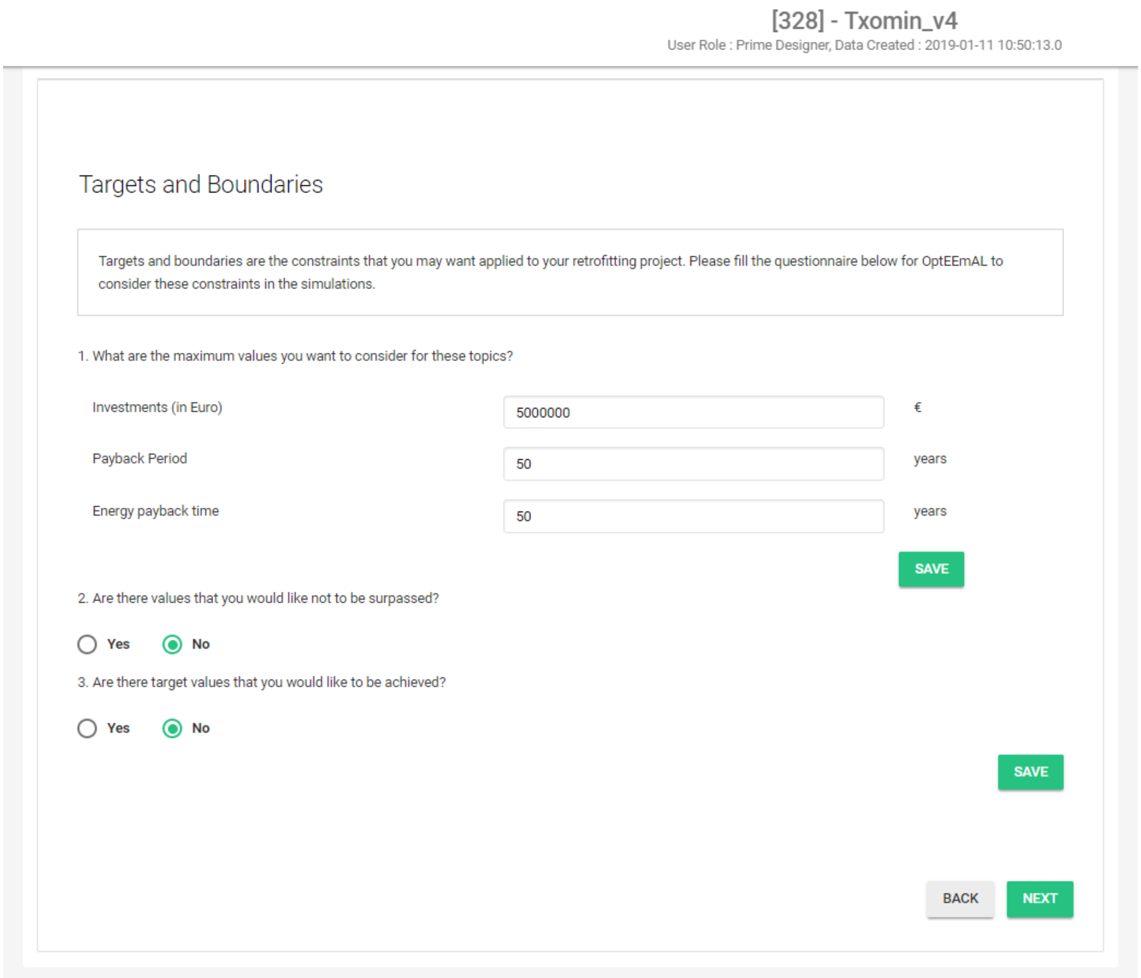


Figure 35: Targets and Boundaries – *Txomin Enea* district, San Sebastian

Step 9 – Prioritization criteria

The following step consists in entering the prioritisation criteria related information (Figure 36). This step is PASSED.

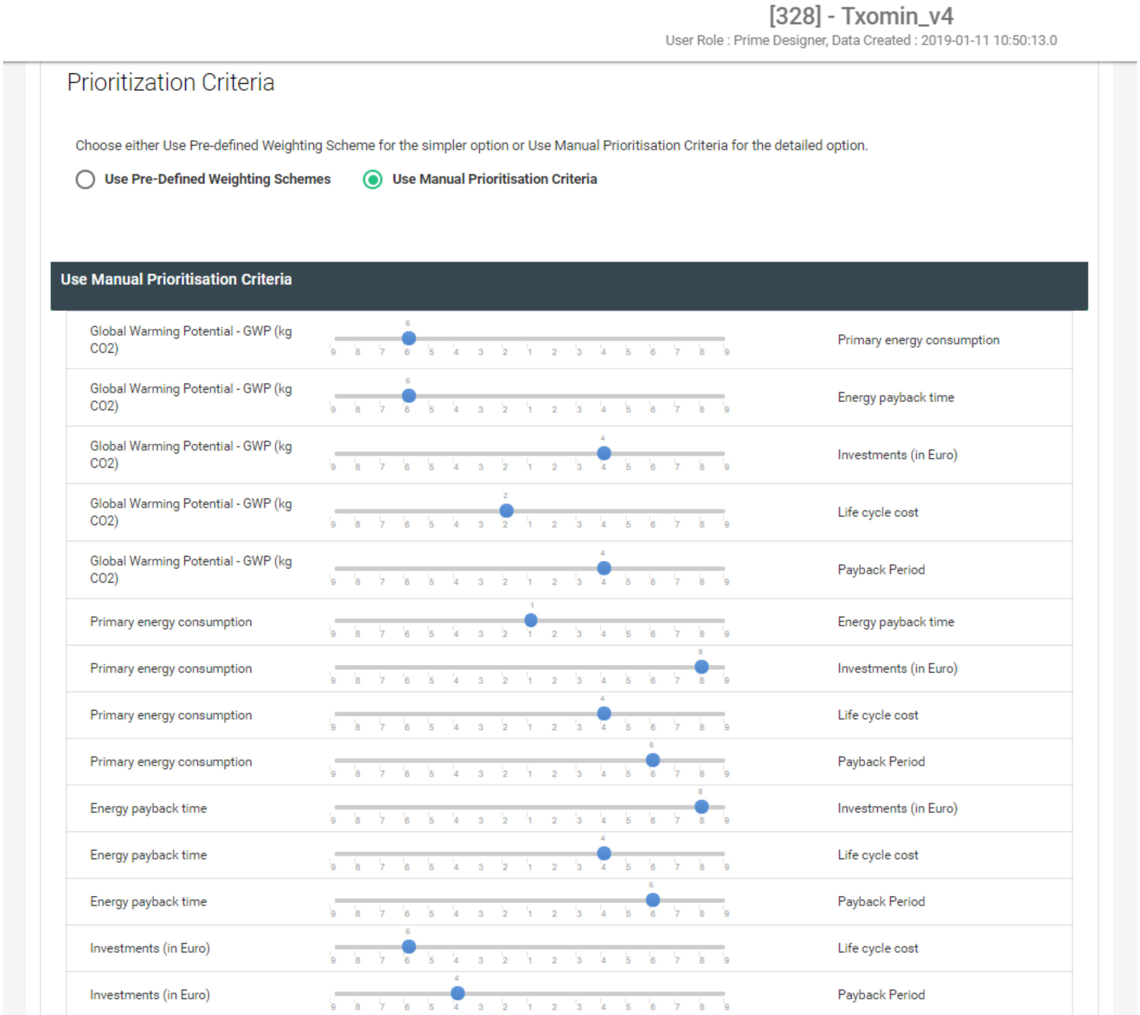


Figure 36: Prioritization criteria – *Txomin Enea* district, San Sebastian

Step 10 – Problem summary

In the following step, the user is able to see the baseline DPIs (Figure 37) and the selected ECMs (Figure 38) in the problem summary screen. This step is PASSED.

[328] - Txomin_v4

User Role : Prime Designer, Data Created : 2019-01-11 10:50:13.0

Problem Summary

Baseline Performance

Energy DPI's

DPI Name	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	137.91 kWh/m².year	n/a	n/a	n/a
Energy demand HEATING	69.61 kWh/m².year	n/a	n/a	n/a
Energy demand COOLING	68.30 kWh/m².year	n/a	n/a	n/a
Final energy consumption	171.33 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal)	103.02 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - gas)	103.02 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)	68.30 kWh/m².year	n/a	n/a	n/a
Net fossil energy consumed	0.00 kWh/m²	n/a	n/a	n/a
Energy demand covered by renewable sources	0.00 %	n/a	n/a	n/a
Energy use from District Heating	0.00 kWh/m².year	n/a	n/a	n/a
Energy use from Biomass	0.00 kWh/m².year	n/a	n/a	n/a
Energy use from PV	0.00 kWh/m².year	n/a	n/a	n/a

Figure 37: Baseline DPIs – *Txomin Enea* district, San Sebastian

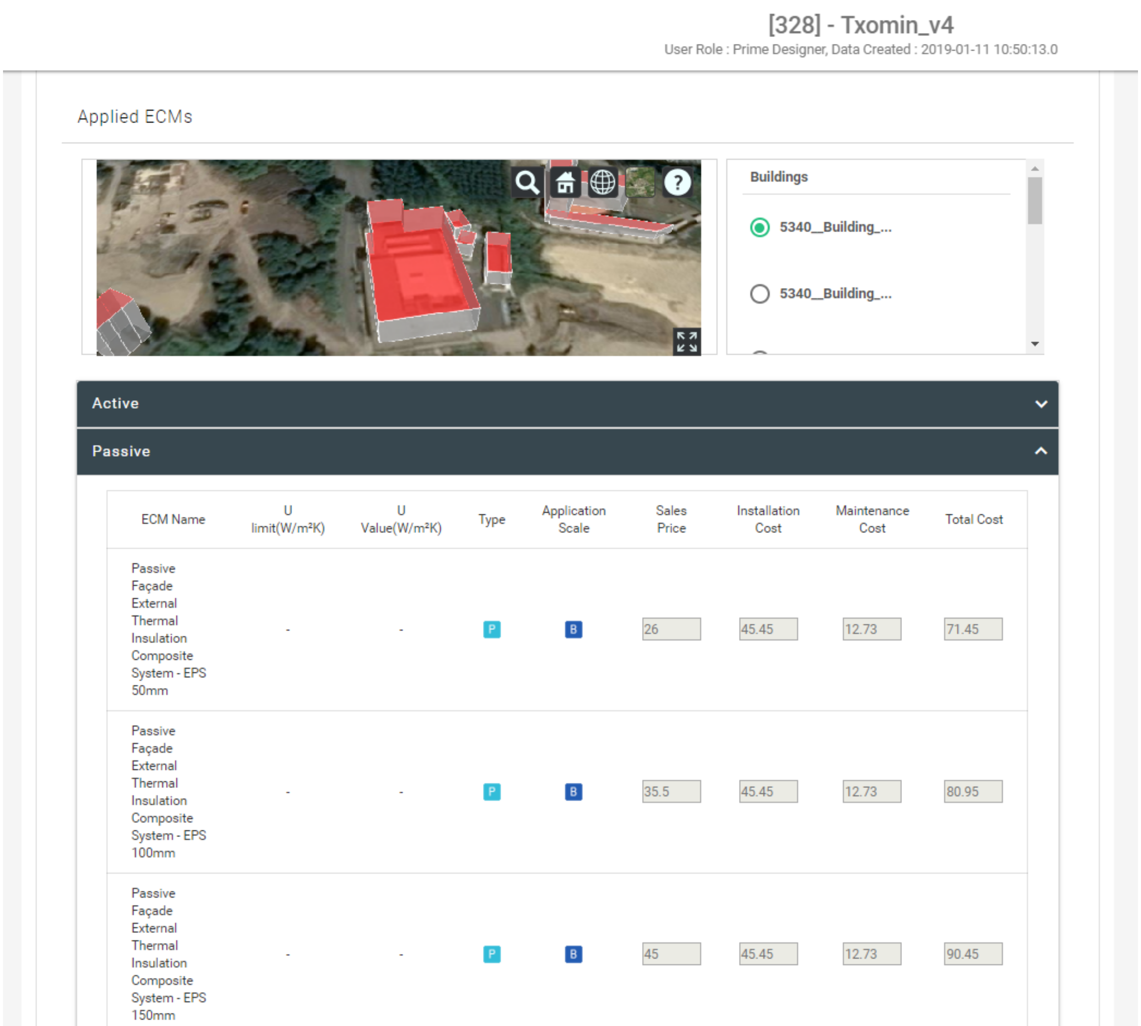


Figure 38: Problem summary (Applied ECMs) – *Txomin Enea* district, San Sebastian

Step 11 – Optimisation progress

After having launched the optimisation process at the end of the previous step, the user can track the status of the optimisation process using the Optimisation progress screen (Figure 39). This step is PASSED.

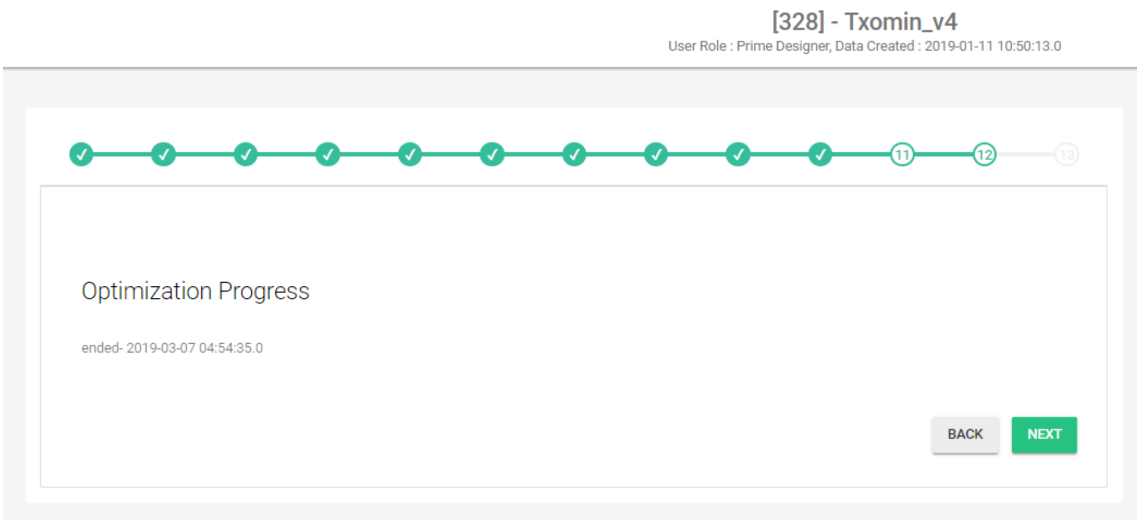


Figure 39: Optimisation progress – *Txomin Enea* district, San Sebastian

Step 12 – Select Optimal Scenario

The scenario selected through the optimisation process is presented in the Pareto Front (Figure 40). The user can check the different DPI values (and compare with the baseline) (Figure 41) and the associated applied ECMs (Figure 42).This step is PASSED.

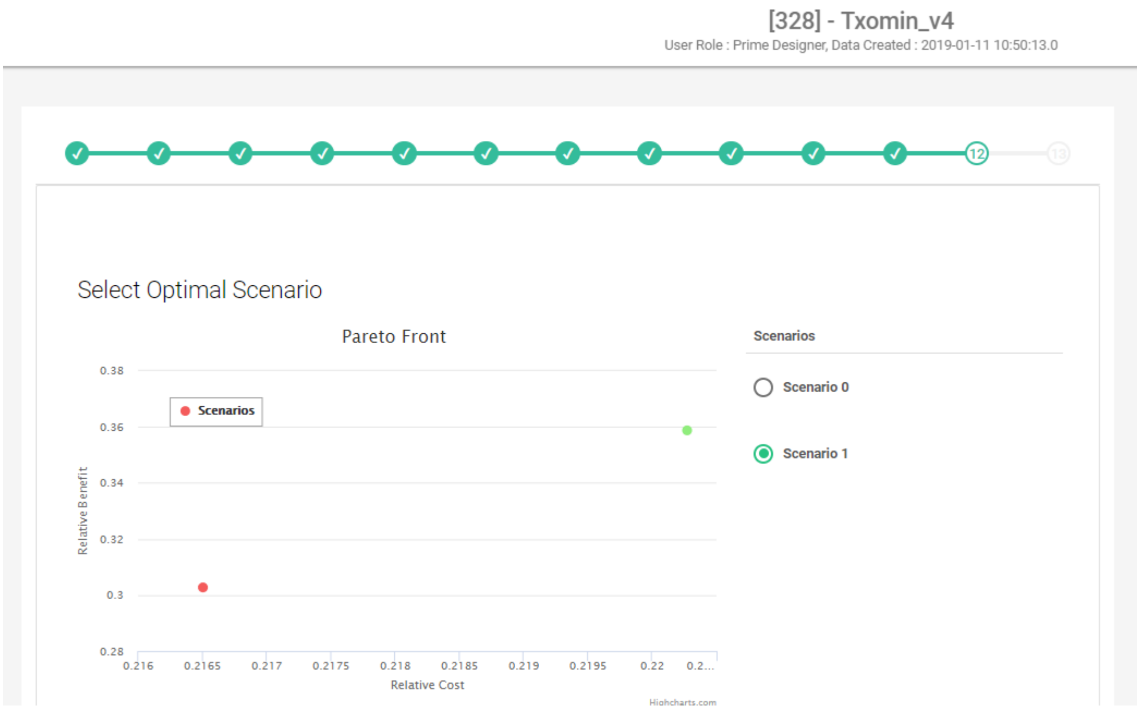
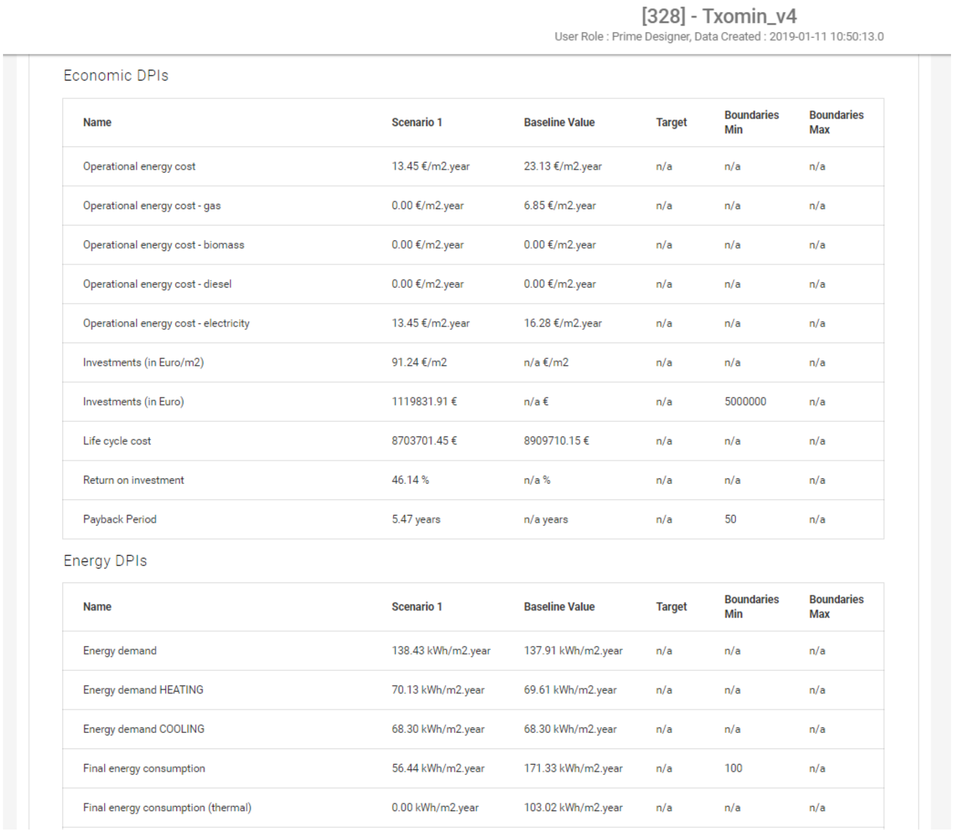


Figure 40: Pareto Front – *Txomin Enea* district, San Sebastian



[328] - Txomin_v4

User Role : Prime Designer, Data Created : 2019-01-11 10:50:13.0

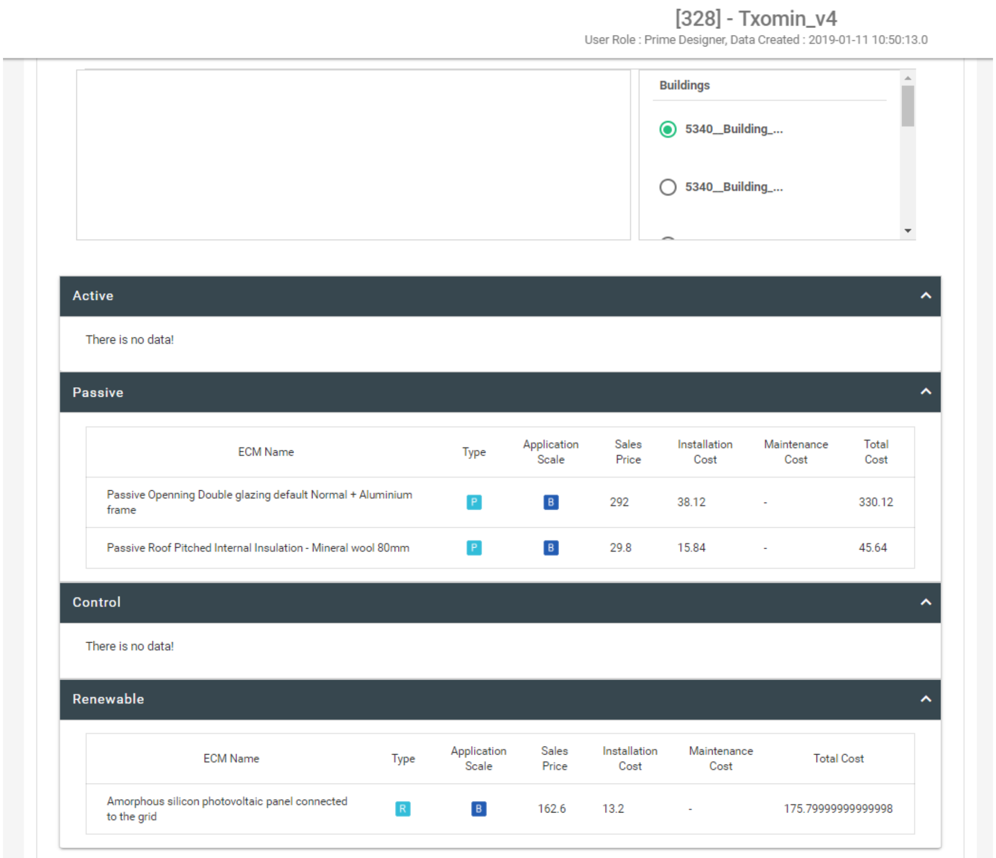
Economic DPIs

Name	Scenario 1	Baseline Value	Target	Boundaries Min	Boundaries Max
Operational energy cost	13.45 €/m2.year	23.13 €/m2.year	n/a	n/a	n/a
Operational energy cost - gas	0.00 €/m2.year	6.85 €/m2.year	n/a	n/a	n/a
Operational energy cost - biomass	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - diesel	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - electricity	13.45 €/m2.year	16.28 €/m2.year	n/a	n/a	n/a
Investments (in Euro/m2)	91.24 €/m2	n/a €/m2	n/a	n/a	n/a
Investments (in Euro)	1119831.91 €	n/a €	n/a	5000000	n/a
Life cycle cost	8703701.45 €	8909710.15 €	n/a	n/a	n/a
Return on investment	46.14 %	n/a %	n/a	n/a	n/a
Payback Period	5.47 years	n/a years	n/a	50	n/a

Energy DPIs

Name	Scenario 1	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	138.43 kWh/m2.year	137.91 kWh/m2.year	n/a	n/a	n/a
Energy demand HEATING	70.13 kWh/m2.year	69.61 kWh/m2.year	n/a	n/a	n/a
Energy demand COOLING	68.30 kWh/m2.year	68.30 kWh/m2.year	n/a	n/a	n/a
Final energy consumption	56.44 kWh/m2.year	171.33 kWh/m2.year	n/a	100	n/a
Final energy consumption (thermal)	0.00 kWh/m2.year	103.02 kWh/m2.year	n/a	n/a	n/a

Figure 41: Baseline and scenario DPIs – *Txomin Enea* district, San Sebastian



[328] - Txomin_v4

User Role : Prime Designer, Data Created : 2019-01-11 10:50:13.0

Buildings

5340_Building_...

5340_Building_...

Active

There is no data!

Passive

ECM Name	Type	Application Scale	Sales Price	Installation Cost	Maintenance Cost	Total Cost
Passive Openning Double glazing default Normal + Aluminium frame	P	B	292	38.12	-	330.12
Passive Roof Pitched Internal Insulation - Mineral wool 80mm	P	B	29.8	15.84	-	45.64

Control

There is no data!

Renewable

ECM Name	Type	Application Scale	Sales Price	Installation Cost	Maintenance Cost	Total Cost
Amorphous silicon photovoltaic panel connected to the grid	R	B	162.6	13.2	-	175.79999999999998

Figure 42: Applied ECMs – *Txomin Enea* district, San Sebastian

Step 13 – Export

Once the best scenario has been selected, the user is able to export all the useful information from the platform in the form of Excel, xml, IFC and CityGML files (Figure 43). For instance, the user can access the detailed results provided by the platform through the different excel files (Figure 44). This step is PASSED

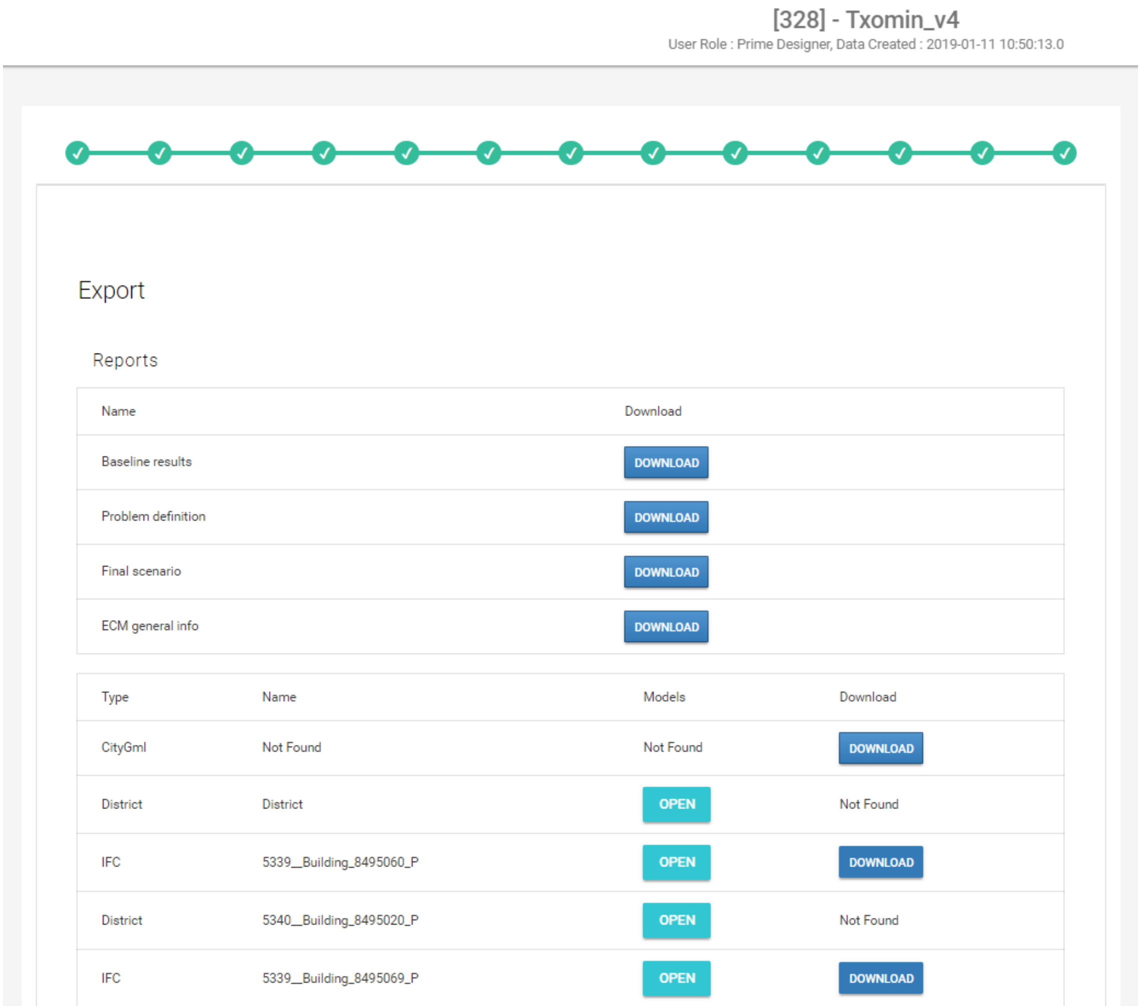
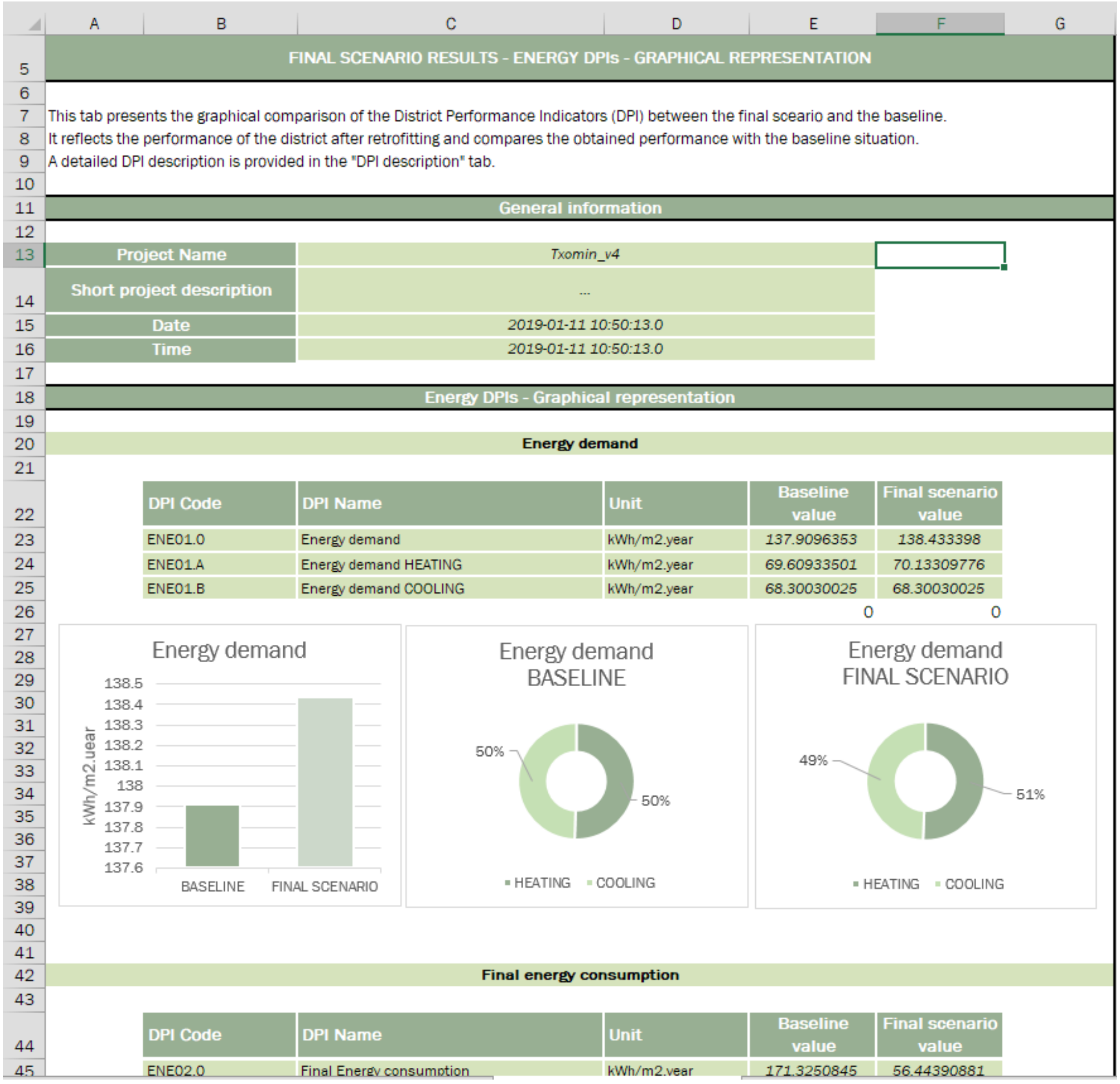


Figure 43: Information to be exported – *Txomin Enea* district, San Sebastian



FINAL SCENARIO RESULTS - ENERGY DPIs - GRAPHICAL REPRESENTATION

This tab presents the graphical comparison of the District Performance Indicators (DPI) between the final sceario and the baseline.
It reflects the performance of the district after retrofitting and compares the obtained performance with the baseline situation.
A detailed DPI description is provided in the "DPI description" tab.

General information

Project Name	*Txomin_v4*
Short project description	...
Date	*2019-01-11 10:50:13.0*
Time	*2019-01-11 10:50:13.0*

Energy DPIs - Graphical representation

Energy demand

DPI Code	DPI Name	Unit	Baseline value	Final scenario value
ENE01.0	Energy demand	kWh/m2.year	*137.9096353*	*138.433398*
ENE01.A	Energy demand HEATING	kWh/m2.year	*69.60933501*	*70.13309776*
ENE01.B	Energy demand COOLING	kWh/m2.year	*68.30030025*	*68.30030025*
			0	0

Final energy consumption

DPI Code	DPI Name	Unit	Baseline value	Final scenario value
ENE02.0	Final Energy consumption	kWh/m2.year	*171.3250845*	*56.44390881*

Figure 44: Exported Excel file – *Txomin Enea* district, San Sebastian

5 Results obtained

5.1 Result discussions

5.1.1 *Txomin Enea* district, San Sebastián

5.1.1.1 Presentation of available data

First of all, it is important to mention that the results presented in this section are different than the ones presented in the screenshots showed in the previous section. The difference between the two elaborations is the **configuration of the IFC files**.

After the final review meeting with the EC, new elaborations for all the demo cases have been launched in order to complete end-to-end test, correct values and obtain more accurate results. Indeed, in the case of *Txomin Enea* district, and for the results presented in this section, "air tightness" parameters have been modified in the IFC files to consider a more correct air tightness of the buildings.

For information purpose, the project reported in the previous section is project 328 while the project reported in this section is project 387 (those numbers are the internal IDs used in the OptEEmAL platform).

For the *Txomin Enea* district, two different types of information are available for the baseline situation (before retrofitting):

- Energy simulation results (from the CE3X2.3 software) mentioned as "Simulated data" in this section
- Measured data from measurements

For the situation after retrofitting, only simulated data are available.

This information is summarised in the Table 6 (before retrofitting) and Table 7 (after retrofitting) below. All this information has been provided by FSS and has been elaborated in the frame of the REPLICATE project[1].

Table 6: Simulated and measured data for the *Txomin Enea* district, San Sebastian (Spain) – Before retrofitting

Txomin Enea district, San Sebastián	SIMULATED		MEASURED
	Heating energy demand (kWh/m2.yr)	Total non-renewable primary energy consumption (kWh/m2.yr)	Final energy consumption (kWh/m2.yr)
Value	174.3	265.5	Between 100 and 175

For measured data before retrofitting, a range is given has the obtained data is varying between measured households according to user's behaviour.

Table 7: Simulated data for the *Txomin Enea* district, San Sebastian (Spain) – After retrofitting

Txomin Enea district, San Sebastián	SIMULATED	
	Heating energy demand (kWh/m2.yr)	Total non-renewable primary energy consumption (kWh/m2.yr)
Value	41.1	81.2

[1] https://replicate-project.eu/, this project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement N°691735.

Although TRL7 is not designated to compare the results of the OptEEmAL platform with already existing information to do fine tuning (because this information is not available for all the demo sites), for the *Txomin Enea* district the consortium has taken advantage of this existence to analyse and improve, one more time, the results obtained with the platform, and compare this results with Fomento de San Sebastian (FSS) expectations for the refurbishment under execution.

5.1.1.2 Discussion of available data

Before retrofitting

First of all, it has to be mentioned that the simulated data are obtained using the CE3X tool which is used for energy certification in Spain. This tool is specific to the Spanish context. Before comparing the data obtained with OptEEmAL with this data, it is important to remind the differences between CE3X and EnergyPlus software/calculation engines:

- In CE3X, there is no need to enter any kind of 3D model (detailed geometrical aspects are calculated using key parameters such as floor area, floor height, etc. and default parameters already included in the software. In EnergyPlus, detailed geometrical information is used based on the information included in the IFC models (in OptEEmAL).
- Similarly, most of the technical characteristics of building materials are considered through default values in CE3X. In EnergyPlus, it is possible to consider the detailed characteristics of the materials.
- As a conclusion, we can say that the CE3X software is easier and faster to use but maybe less precise than EnergyPlus which is more flexible and complicated (for an end-user perspective). A recent study[2] has showed that CE3X tends to overestimate the heating energy demand of buildings in comparison to other existing tools.

Another comment that can be made on available data is that the heating demand (simulated) and the final energy consumption (measured) are not necessarily in line. Indeed, if we consider that the heating demand (simulated) is correct, then the final energy consumption should be higher than the one currently measured (energy system efficiencies, etc.). As already mentioned, all this data has not been elaborated within the OptEEmAL project and it was thus difficult to investigate in more depth this data. Those limits shall be reminded when reading the following section (0).

Regarding measured data, they are showing important variations. These variations are mainly explained by user behaviour differences as two apartments in the same building (so having normally close thermal characteristics) with the same number of occupants are showing important differences. As previously mentioned, this is why a range is presented in Table 6. User behaviour is accounted for in OptEEmAL (schedules, internal gains, etc.) but are not representative of real behaviours. This is a limit of OptEEmAL but also a limit of all simulation tools. As a consequence, this has not been investigated in this section.

After retrofitting

Only simulated data is available for the situation after retrofitting. Same comments as the one made for the situation before retrofitting can be made for this data (differences between CE3X tool and the EnergyPlus calculation engine).

[2] Análisis y estudio de la simulación energética de edificios residenciales con programas reconocidos, Carnero Melero Pablo, 09/2018, https://riunet.upv.es/bitstream/handle/10251/108970/48674824Q_TFM_15361375659575617724787295760418.pdf?sequence=1&isAllowed=y

5.1.1.3 Comparison with OptEEmAL results

Before retrofitting

Having in mind the limits presented in the previous section, the comparison between OptEEmAL results and available data is provided in the Table 8 below for the situation before retrofitting.

Table 8: Comparison of available data and OptEEmAL results for the *Txomin Enea* district, San Sebastián (Spain) – Before retrofitting

Txomin Enea district, San Sebastián	SIMULATED		MEASURED
	Heating energy demand (kWh/m².yr)	Total non-renewable primary energy consumption (kWh/m².yr)	Final energy consumption (kWh/m².yr)
Available data	174.3	265.5	Between 100 and 175
OptEEmAL	75.77	216.0	138.8
Rel. difference	57%	19%	-1%[3]

The results obtained are discussed in the paragraphs below. First, the heating energy demand is discussed, followed by the final energy consumption and finally the total non-renewable primary energy consumption. Although this order creates a mix between the comparison of simulated and measured data, it has been selected because it is the order the calculations are made (first energy demand, then final energy consumption and finally primary energy consumption).

- Heating energy demand: As showed in the above table, the simulated energy demand is much more higher (more than the double) using the CE3X software (available data) in comparison to OptEEmAL. As already mentioned, the CE3X software seems to overestimate the energy demand. In the previously mentioned study, this overestimation is consider to be 47.7%. This is close to the deviation observed when comparing with OptEEmAL information. The remaining difference can be explained by a lot of parameters and it was impossible to investigate in details (as done in D6.2) the exact parameters responsible for this difference. From the exercise performed in D6.2, we can mention some examples such as internal gains, air tightness, thermostat's set-points, detailed information about building materials (U-values), etc.
- Final energy consumption: The measured final energy consumption in reality and the simulated final energy consumption are really close (only 1% of relative difference). This is interesting as it shows that the OptEEmAL platform provides results which are in line with measured data. However, limits related to the comparison between measured and simulated data mentioned in the previous section have to be reminded and only limited conclusions can be elaborated from this comparison.
- Total non-renewable primary energy consumption: The difference between both tools on this indicator is 19% (CE3X being again higher than OptEEmAL). In order to understand the difference, it has to be reminded that the primary energy consumption is obtained by multiplying the final energy consumption values for the different energy sources by the primary energy conversion factors of the same energy sources. In OptEEmAL, primary energy conversion factors are based on Life Cycle Assessment information. In CE3X, it was not possible to identify the factors used. Usually, factors based on Life Cycle Assessment are higher than the ones based on energy regulations. It explains why the difference between CE3X and OptEEmAL has been reduced (from 57% to 19%) when going from heating energy demand to primary energy consumption (although CE3X being still higher).

[3] To calculate this relative difference, we have considered an average final energy consumption of 137.5 kWh/m².yr

- Conclusion: Comparing the results provided by OptEEmAL and other existing information is difficult because the tools (and associated methodologies) are different. However, the general conclusions below can be made:
  - The heating energy demand obtained with the platform seems to be in line with the correct heating energy demand (considering the characteristics of the CE3X tool) but more detailed investigations are required to make robust conclusions on this. Refer to the work make in D6.2.
  - The platform seems to provide relevant information in terms of final energy consumption when compared to measured data although this has to be considered with caution.
  - Primary energy consumption information provided by the platform seems to be coherent. Detailed information about the CE3X tool (primary energy conversion factors) would be needed to definitively validate this conclusion.

After retrofitting

For the situation after retrofitting, only simulated data is available. This data is compared with OptEEmAL results in the following table (Table 9). It has to be noted that for this specific configuration, the OptEEmAL platform has proposed 4 scenarios as outputs of the optimisation process. Based on the prioritisation criteria defined by FSS, it has been decided to select the scenario with the lowest heating energy demand. Results presented hereafter are related to this scenario.

Table 9: Comparison of available data and OptEEmAL results for the *Txomin Enea* district, San Sebastián (Spain) – After retrofitting

Txomin Enea district, San Sebastián	SIMULATED	
	Heating energy demand (kWh/m^2.yr)	Total non-renewable primary energy consumption (kWh/m^2.yr)
Available data	41.1	81.2
OptEEmAL	47.6	74.6
Rel. difference (%)	16%	8%

Considering the results presented above and the comments made to the situation before retrofitting, the following comments can be made:

- Heating energy demand: The results are closer than the situation before retrofitting (“only” 16% vs 57% relative difference). In addition, for the situation after retrofitting, OptEEmAL gives higher results than the available data (it was the contrary for the situation before retrofitting). Considering the comments made to the situation before retrofitting (CE3X software tending to overestimate the energy demand), those results are strange. To understand these results, it would have been needed to compare in detail the simulation performed by both tools but this has not been possible in the frame of the OptEEmAL project.
- Total non-renewable primary energy consumption: For this indicator, the same explanations as the ones provided for the situation before retrofitting can be given. Indeed, we can see that for this indicator, OptEEmAL gives lower results than the available data. As mentioned above, this is related to the conversion factors used to move from final energy consumption to primary energy consumption.

5.1.1.4 Recommended ECMs

The **ECMs implemented in the real retrofitting** project are presented in the Table 10 below.

Table 10: ECMs implemented in the real retrofitting project – *Txomin Enea* district, San Sebastian

Building ID	ECM Name	ECM Code in OptEEmAL
11	Ventilated facade (100 mm)	PA.FA.EX.VE.XX
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
12	Ventilated facade (100 mm)	PA.FA.EX.VE.XX
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
13	Ventilated facade (100 mm)	PA.FA.EX.VE.XX
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
14	ETICS (Rock wool, 100 mm)	PA.FA.EX.CS.02/10
	Double glazed windows (PVC or Aluminium frame)	PA.OP.DG.DE.01 PA.OP.DG.DE.02 PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
15	ETICS (Rock wool, 100 mm)	PA.FA.EX.CS.02/10
	Double glazed windows (PVC or Aluminium frame)	PA.OP.DG.DE.01 PA.OP.DG.DE.02 PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
16	ETICS (Rock wool, 100 mm)	PA.FA.EX.CS.02/10
	Double glazed windows (PVC or Aluminium frame)	PA.OP.DG.DE.01 PA.OP.DG.DE.02 PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)
22	ETICS (Rock wool, 100 mm)	PA.FA.EX.CS.02/10
	Double glazed windows (PVC or Aluminium frame)	PA.OP.DG.DE.01 PA.OP.DG.DE.02 PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the

		same material)
23	ETICS (Rock wool, 100 mm)	PA.FA.EX.CS.02/10
	Double glazed windows (PVC or Aluminium frame)	PA.OP.DG.DE.01 PA.OP.DG.DE.02 PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	PA.RO.PI.IN.04 (not the same material)

The **ECMs recommended by the OptEEmAL platform** are compared with the ones implemented in reality in the Table 11 below. As a preamble to this comparison, it shall be mentioned that Ventilated Facade ECMs have not been implemented in the OptEEmAL platform at this stage. As a consequence, all buildings were ventilated facades (buildings n°11, 12 and 13) have been implemented are not presented in the table below.

Table 11: ECMs recommended by the platform – *Txomin Enea* district, San Sebastian

Building ID	Implemented ECMs	OptEEmAL ECMs	
	ECM Name	ECM Name	ECM ID
14	ETICS (Rock wool, 100 mm)	ETICS (EPS 150 mm)	PA.FA.EX.CS.03
	Double glazed windows (PVC or Aluminium frame)	Double glazed windows (PVC with coat and gas)	PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	-	-
15	ETICS (Rock wool, 100 mm)	ETICS (EPS 150 mm)	PA.FA.EX.CS.03
	Double glazed windows (PVC or Aluminium frame)	Double glazed windows (PVC with coat and gas)	PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	-	-
16	ETICS (Rock wool, 100 mm)	ETICS (EPS 150 mm)	PA.FA.EX.CS.03
	Double glazed windows (PVC or Aluminium frame)	Double glazed windows (PVC with coat and gas)	PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	-	-
22	ETICS (Rock wool, 100 mm)	ETICS (EPS 150 mm)	PA.FA.EX.CS.03
	Double glazed windows (PVC or Aluminium frame)	Double glazed windows (PVC with coat and gas)	PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	-	-
23	ETICS (Rock wool, 100 mm)	ETICS (EPS 150 mm)	PA.FA.EX.CS.03

	Double glazed windows (PVC or Aluminium frame)	Double glazed windows (PVC with coat and gas)	PA.OP.DG.DE.03
	Internal roof insulation (XPS, 100 mm)	-	-

Analysing the ECMs recommended by the platform and the ones implemented in the real project shows that:

- For façade: the platform recommends the proper ECM technology (i.e. ETICS). The difference lies in the thickness of the insulation material and the type of material used. Overall, also it cannot be checked in detail (we cannot access the U-value of the whole façade system in the current version of the OptEEmAL platform, only implemented for some ECMs), the U-value of the two ECMs are close.
- For windows: OptEEmAL recommends the ECM implemented in reality (double glazed PVC windows)
- For roof: OptEEmAL does not recommend any ECM. This is because in the ECM questionnaire, the “can you modify building roofs” question has been answered “No”. As a consequence, the platform has not “looked for” roof-related ECMs in the optimisation process.
- District scale: the platform is proposing a biomass district heating system as the one implemented in the real project.

As a conclusion, we can note that the OptEEmAL platform is proposing ECMs that are quite in line with the ones implemented in reality. However, it would have been interesting to make a new elaboration answering differently the ECM questionnaire regarding roof insulation. This new elaboration was not possible in the frame of the OptEEmAL project.

5.1.2 *San Bartolomeo* district, Trento

The *San Bartolomeo* district has been the last demo site under study due to several reasons:

- Priority has been given to those districts with existing or elaborated input data (CityGML and IFC files, among others).
- Priority has been given to those districts with available simulated or measured data to compare OptEEmAL results.
- Priority has been given to those districts with district ECMs in the baseline.

Due to the previous reasons and the fact that the IFC for this district is the most complex one (because it includes in a unique file 3 buildings and the total number of spaces is bigger than 520), the order of elaborations towards TRL7 has been *Txomin Enea* (initial CityGML and IFC existing, data available before and after retrofitting), *Polhem* (more simple IFC, data available before retrofitting and district ECMs in the baseline) and *San Bartolomeo* districts (complex IFC, no data available, but district ECMs in the baseline).

The end-to-end test have been executed under the context of the OptEEmAL project and the 13 steps have been passed correctly for *San Bartolomeo* district. These tests have demonstrated a proper behaviour when checking and enhancing the CityGML and IFC files, in the matching process, baseline calculation, ECMs configurations, optimisation process, select optimal scenario and with the data exportation. The optimisation process has been finalized correctly and the Pareto Front has been obtained with good results.

5.1.2.1 Presentation of available data.

No data is available for the *San Bartolomeo* district in Trento. This is because the owner of the building is not willing to share energy data about its building.

5.1.2.2 San Bartolomeo BIM model

In the case of *San Bartolomeo* district, and taking into account the complexity of the IFC feeding the OptEEmAL platform, its validation for TRL7 can be seen as an opportunity to detect problems when creating the IFC and to improve the IFC guidelines with the proper solution for BIM modelling. Some of the problems detected are presented below.

The Trento model is the most complex model tested in the platform. One of the complexities is the dimension of the model, with 523 spaces. In this building we found new errors not identified before:

- External curtain wall included in more than one level and for that reason is touching more than one space (see Figure 45). This casuistry was not contemplated before because in the case studies there was not this type of curtain wall, the curtain wall was always included in a single level.

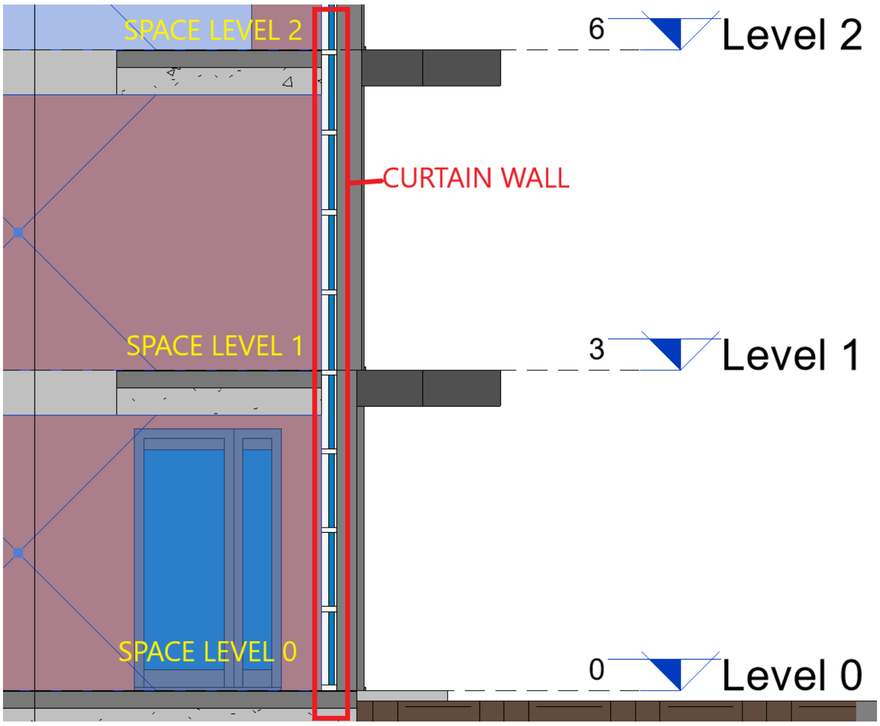


Figure 45: Curtain wall in the Trento building

- There was a problem with the original windows, it is not possible to have a window with opaque and glass panels (see Figure 46) because when you export to IFC the windows only has a material associated, the only way to have 2 panels of different materials is with a curtain wall.

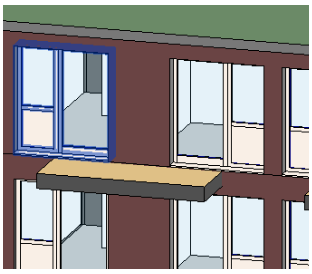


Figure 46: Windows with opaque and glass panels in the Trento model

- There was a problem with the libraries of Revit, because the model was modelled in the Italian language with the libraries in Italian. For the windows and doors families, the materials and finishes parameters must to be renamed using the OptEEmAL standardized parameter names and using the English language (see Figure 47). We have had to modify all the family names to export the model correctly. A specific guideline will be included in a new version of the BIM guidelines with this information.

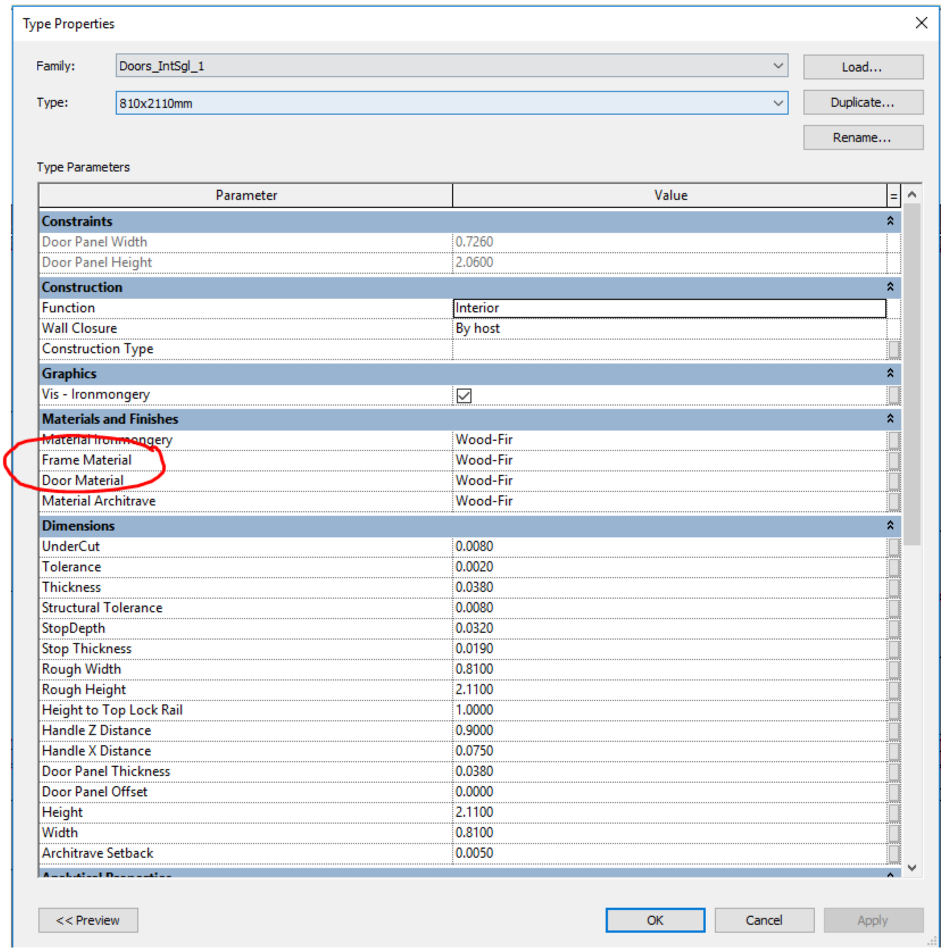


Figure 47: Path of the type properties for a door family. This door has the name of the materials correctly.

5.1.2.3 Baseline results

As already mentioned, there is no previous data available for the *San Bartolomeo* district. The data obtained in the OptEEmAL platform is shown in Table 12.

Table 12: OptEEmAL results for the *San Bartolomeo* district, Trento (Italy)

San Bartolomeo district, Trento (Italy)	OptEEmAL results
Final energy consumption – Heat (kWh/m2.yr)	56.60
Final energy consumption – Electricity (kWh/m2.yr)	102.37
Final energy consumption – Total (kWh/m2.yr)	158.97

5.1.2.4 Comparison baseline vs. "optimal" scenario results

For the situation after and before retrofitting only the OptEEmAL data is available. The baseline results obtained in the OptEEmAL platform is compared with the "optimal" scenario (scenario 0) selected in the Pareto Front generated by the platform. This comparison is shown in the following table (Table 13). It has to be noted that for this specific configuration, the OptEEmAL platform has proposed 2 scenarios as outputs of the optimisation process. Based on the prioritisation criteria defined by Trento municipality, it has been decided to select the scenario with the lowest energy payback time. Results presented hereafter are related to this scenario.

Table 13: Recommended ECMs for the *San Bartolomeo* district, Trento (Italy)

San Bartolomeo district, Trento (Italy)	OptEEmAL results	
	Baseline	"Optimal" scenario
Final energy consumption – Heat (kWh/m²·yr)	56.60	26.32
Final energy consumption – Electricity (kWh/m²·yr)	102.37	99.53
Final energy consumption – Total (kWh/m²·yr)	158.97	125.85

5.1.2.5 Recommended ECMs

As already mentioned, the *San Bartolomeo* district retrofitting project is not started yet. So no ECMs have been chosen for the retrofitting of the district. As a consequence, it is impossible to compare the one recommended by OptEEmAL and the ones implemented in reality. However, in order to give an idea of the possible interventions, the ECMs recommended by the OptEEmAL platform are presented in the Table 14 below.

For this project, the OptEEmAL platform has provided 2 optimised scenarios (scenario 0 and scenario 1). Considering the priority of the Trento municipality "to prioritise the reduction of operational energy costs" district, the scenario retained for the recommended ECMs is the one having the lowest "Energy payback time", and "Final energy consumption". This corresponds to the "scenario 0" provided by the platform.

Table 14: Recommended ECMs for the *San Bartolomeo* district, Trento (Italy)

Building ID:6488	Scenario 0	
	ECM code	ECM Name
Block F	PA.FA.EX.CS.09	Passive Façade External Thermal Insulation Composite System - MW 100mm
	PA.OP.DG.DE.02	Passive Opening Double glazing default Coat + PVC 3 Chambers
	PA.RO.TS.CI.04	Passive Roof Top slab insulation Chamber Insulation - MW 250mm
	RE.RO.SC.PV.03.25	Amorphous silicon photovoltaic panel connected to the grid
	RE.RO.SC.TC.02.5	Evacuated tube solar collector
District	AC.DE.BO.NG.04	Natural gas boiler with 143 kW of nominal capacity

5.1.3 Polhem district, Lund

5.1.3.1 Presentation of available data

For the *Polhem* district, only measured data is available. This data has been provided by two different sources. A first set of energy consumption data (heat final energy consumption) has been provided by the company managing the district heating network. A second set of energy consumption data (both heat and electricity) has been provided by the municipality of Lund through Energy Performance Certificates. All this information is presented in the Table 15 below. It has to be noted that in Sweden, Energy Performance Certificates are based on energy bills. Moreover, it has to be mentioned that collected Energy Performance Certificates are 10 years old while the data from the company managing the district heating network is an average on the 2014 – 2018 period.

Table 15: Measured data for the *Polhem* district, Lund (Sweden) – Before retrofitting

Polhem district, Lund (Sweden)	MEASURED DATA District Heating Company	MEASURED DATA Energy Performance Certificates
Final energy consumption – Heat (kWh/m².yr)	96.2	103.7
Final energy consumption – Electricity (kWh/m².yr)	-	65.0
Final energy consumption – Total (kWh/m².yr)	-	168.7

5.1.3.2 Discussion of available data

Considering the different periods of the different data sources, the completeness of the data and the fact that the heating final energy consumption are quite close between both sources (only 7% of relative difference), we consider that the data to be compared with OptEEmAL results are the one from the Energy Performance Certificates. One important comment here (as a preamble to the following section related to the comparison with OptEEmAL results) is that **OptEEmAL provides simulated results while those results are measured**.

5.1.3.3 Comparison with OptEEmAL results

The comparison between the available data and the OptEEmAL results are provided below (Table 16). It has to be noted that this comparison is related to the situation before retrofitting as the real retrofitting process is not yet started in the *Polhem* district.

Table 16: Comparison between available data and OptEEmAL results for the *Polhem* district, Lund (Sweden) – Before retrofitting

Polhem district, Lund (Sweden)	MEASURED DATA Energy Performance Certificates	OptEEmAL results	Relative difference (%)
Final energy consumption – Heat (kWh/m².yr)	103.7	110.2	6%
Final energy consumption – Electricity (kWh/m².yr)	65.0	50.3	23%
Final energy consumption – Total (kWh/m².yr)	168.7	160.5	5%

First of all, as already mentioned, it has to be highlighted that the comparison performed in this section should be handle with care considering that the available data are measured data while OptEEmAL results are simulated. It is not the purpose of this project to discuss the difference between simulated and measured energy performance of buildings but this is an important factor to have in mind. Moreover, this comparison is done because only measured data is available for the *Polhem* district.

Comparing the obtained results shows that the OptEEmAL platform provides results that are quite close to the available data. For the heating energy consumption, OptEEmAL results are higher by 6%. This can be explained by several parameters included in the IFC files (e.g. building air tightness, thermostat's set-points, and definition of building materials, as explained in D6.2). For the electricity consumption, the different is more important with OptEEmAL being lower than available data by 23%. As explained in D6.2, this can be related to the definition of internal gains and heat densities in the IFC files (information provided in the IFC files are not necessarily representing exactly the reality).

Finally, for the total final energy consumption, it appears that OptEEmAL provides results close to the available data (OptEEmAL being higher by "only" 5%), the difference being explained by the differences observed on the heating and electricity final energy consumptions.

As a conclusion, we can say that for the *Polhem* district, the OptEEmAL platform provides results that are close to the real measured energy consumption of the district. This conclusion is limited by the fact to compare simulated (from OptEEmAL) and measured (available) data. For the differences, all the parameters identified in D6.2 are likely to explain the differences observed in this section.

5.1.3.4 Recommended ECMs

As already mentioned, the *Polhem* district retrofitting project is not started yet. So no ECMs have been chosen for the retrofitting of the district. As a consequence, it is impossible to compare the one recommended by OptEEmAL and the ones implemented in reality. However, in order to give an idea of the possible interventions, the ECMs recommended by the OptEEmAL platform are presented in the Table 17 below.

For this project, the OptEEmAL platform has provided 3 optimised scenarios. Considering the priority of the Lund municipality to have a "carbon-neutral" district, the scenario retained for the recommended ECMs is the one having the lowest Global Warming Potential. This corresponds to the "scenario 1" provided by the platform.

Table 17: Recommended ECMs for the *Polhem* district, Lund (Sweden)

Building ID	Scenario 1	
	ECM code	ECM Name
Polhem_1	PA.FA.IN.CA.03	Passive Façade Internal insulation + plasterboard - Mineral wool 80mm
	PA.OP.DG.DE.02	Passive Opening Double glazing default Coat + PVC 3 Chambers
	PA.RO.PI.EX.01	Passive Roof Pitched External Insulation - Mineral wool 100mm
	PA.RO.TS.CI.03	Passive Roof Top slab insulation Chamber Insulation - MW 200mm
	CO.DE.TH.SS.01	System scheduling for heating
	RE.RO.SC.PV.01	Monocrystalline photovoltaic panel connected to the grid
	RE.RO.SC.TC.02	Evacuated tube solar collector
Polhem_2	PA.FA.IN.CA.03	Passive Façade Internal insulation + plasterboard - Mineral wool 80mm
	PA.OP.DG.DE.02	Passive Opening Double glazing default Coat + PVC 3 Chambers
	PA.RO.PI.EX.01	Passive Roof Pitched Internal Insulation - Mineral wool 80mm
	PA.RO.TS.CI.03	Passive Roof Top slab insulation Chamber Insulation - MW 150mm
	CO.DE.TH.SS.01	System scheduling for heating
	RE.RO.SC.PV.03	Amorphous silicon photovoltaic panel connected to the grid
	RE.RO.SC.TC.01	Flat plate solar collector

Polhem_8	PA.OP.DG.DE.01	Passive Opening Double glazing default Normal + Aluminium frame
	PA.RO.PI.EX.04	Passive Roof Pitched External Insulation - Mineral wool 250mm
	PA.RO.TS.CI.03	Passive Roof Top slab insulation Chamber Insulation - MW 150mm
	CO.DE.TH.OS.01	Optimal StartUp and ShutDown for heating
	RE.RO.SC.PV.01	Monocrystalline photovoltaic panel connected to the grid
	RE.RO.SC.TC.01	Flat plate solar collector

6 Identification of improvements

While using the platform at TRL7, several points of improvements have been listed by the different platform's users (inside the consortium). Those points are listed below (Table 18) and should be considered as the basis for the upcoming developments of the platform. The importance of the improvement is also given ("+++" indicates high priority improvements while "+" indicates low priority improvements). In the table below (in italic), improvements/new functionalities identified from D6.3 related activities (trainings and presentations of the platform outside the consortium) are also reported in order to provide a full list of improvements.

Table 18: Identified improvements for the upcoming TRL levels of the OptEEmAL platform

Development	Priority
Models elaboration	
Mention in all the documentation, and directly in the platform, the importance of the information included in the IFC files (and thus the importance of following the guidelines and make sure the materials and associated characteristics included in the IFC files are OK)	++
IPD group	
Give the possibility to have several users registered as "Owners"	+++
Data upload	
Continue to improve the user friendliness of the feedbacks from checking processes	++
Baseline energy systems	
Increase the number of possibilities (complex district heating systems, CHPs running on biomass…	+++
Ease the introduction of demand systems ("apply all" functionality)	++
Change the name of the buildings listed in the "Building" part of the questionnaire to ease their identification (eventually ask the user to provide a specific name)	++
Implement all demand systems (only the ones used in the case studies/demo sites are currently implemented in the platform)	+++
Contextual data	
Provide examples of data sources for biomass prices	+
ECM questionnaire	
Implement the missing ECMs (the ones present in the catalogue but which cannot be considered in the platform)	+++
Implement the defined methodology for the ECM catalogue update and expansion.	++
Check strategies	
Revise the name of some ECMS (e.g. "opening" and "openning", "Mineral Wool" instead of "MW", etc.)	++
Targets and Boundaries	
Provide definitions for the mandatory boundaries	+
Invert the "Maximum" and "Minimum" column (more logical)	+
Prioritisation criteria	

Provide, in the GUI, an explanation of why we have the “costs”, “benefits (level 1)” and “benefits (level 2)” columns and the associated %. Explain the relationship with the optimisation process.	+
Optimisation progress	
Provide the follow up information (as the one displayed in the “what’s going on” section) of the general page.	++
Results	
Provide, in the GUI, an explanation of the Pareto Front	+
Inverse the column for the baseline and optimisation results (actually results of the baseline are provided on the right while it would be more logical to have them on the left)	+
Display results at building level	+
Export results	
Finalise all excel reports including images of the district	++
Provide, in the GUI, an explanation of the different data models to be exported	+
Allow the import/export of idf files	++
Create a link with measured data and facility management tools	++
General	
Improve platform’s stability	+++
Continue results checking and testing of the platform on other projects	+++
Integrate in the simulation module the already implemented social, urban and global DPIs calculations	++
Link the platform with national regulation tools for energy analysis	++
Integration the planning of renovation works in time	++
Develop a tool and a methodology to gather inhabitants points of view and ease their acceptance of the retrofitting project	++

7 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. Overall, this section is similar to the one reported in D6.2. Only the time needed to run the platform has been reported for the demo sites (instead of the case studies in D6.2) in this section.

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 48 and Figure 49).

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. 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.

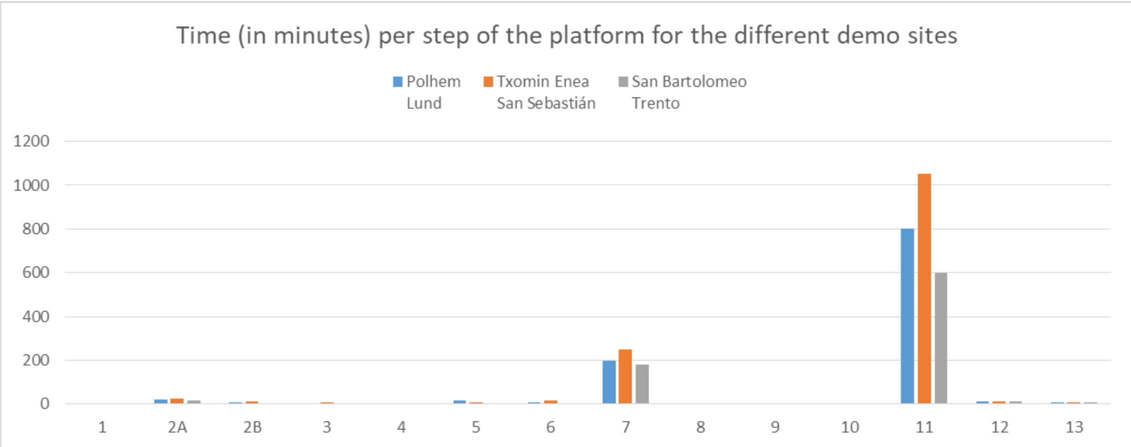


Figure 48: Time needed (in minutes) per step of the platform for the different demo sites

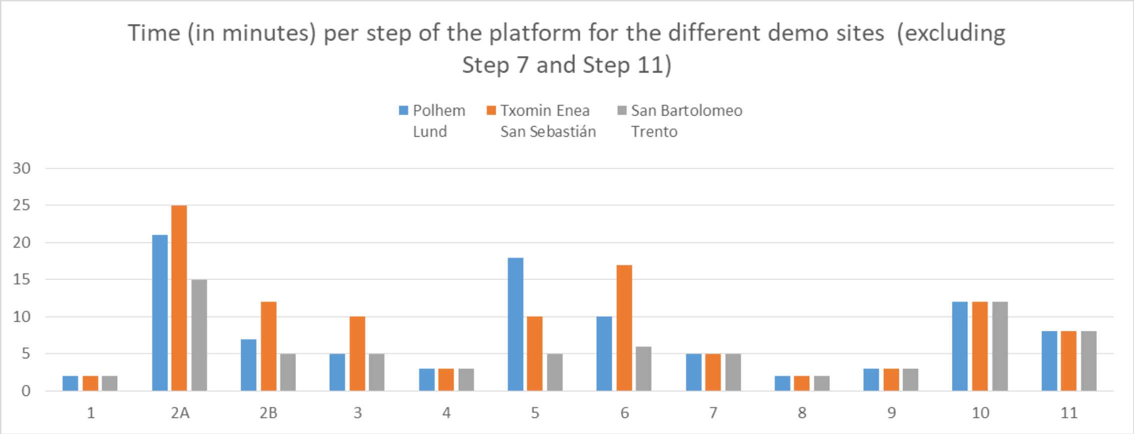


Figure 49: Time needed (in minutes) per step of the platform for the different case demo sites (excluding step 7 and step 11)

8 Conclusion

The work presented in this document is related to validation activities of the OptEEmAL platform at TRL7 “Platform ready for demonstration in operational environment” and the associated results. It shall be kept in mind that the outcomes presented in this document are complementary to the ones presented in D6.3 related to the feedbacks obtained from the trainings performed during the project.

The first activities related to this work has consisted in collecting and elaborating the data needed to run the OptEEmAL platform. The main outcome from this task is that the elaboration of the numerical models (both IFC and CityGML models) are probably one of the most time consuming and complicated step of the OptEEmAL process. This is related to the rare existence of such models for existing models and to the complexity of elaborating files that can be used for energy simulation purposes (despite the enrichment processes included in the platform).

Then, all the collected information has been used to demonstrate the platform on the three demo sites: *Txomin Enea* district in San Sebastián (Spain), *San Bartolomeo* district in Trento (Italy) and *Polhem* district in Lund (Sweden). This activity has showed that the OptEEmAL platform has reached the TRL7 and can be successfully used on the abovementioned districts. However, some improvement points have been listed in order to increase the platform’s robustness and provide additional functionalities. All those points (together with the ones identified as part of D6.3 activities, in *italic*) are listed in Table 18.

The work performed in order to elaborate this deliverable has not only consisted in validating that the platform was working but also in showing that the outputs provided are in line with the available existing information (this work is complementary to the one developed in D6.2) and the end-user requirements. Overall, the outputs provided by the platform are relevant and in line with the available data. However, these activities have also revealed the importance of the input data introduce by the user through the numerical models (especially the IFC files for parameters such as air tightness, building materials thermal characteristics, etc.) and directly through the Graphical User Interfaces of the platform (prioritisation criteria, targets, boundaries, etc.). This has been explained and added in the supporting information of the platform (IFC guidelines, “How to use” guide, etc.) but has to be kept in mind by future users of the platform.

Finally, the performance of the platform in terms of time needed to use it has been evaluated and reported and the potential impacts have been assessed (they are not reported in this deliverable as they are aligned with the ones reported in D6.2).Overall, the activities reported in this deliverable have been useful to 1) fine tune the final version of the platform which has been developed within the OptEEmAL project and 2) identify the future steps of the OptEEmAL platform development in order to ensure a proper market uptake.

9 Annex

9.1 Annex 1: End-to-end test screenshots

9.1.1 Polhem district, Lund

Step 1: IPD group creation

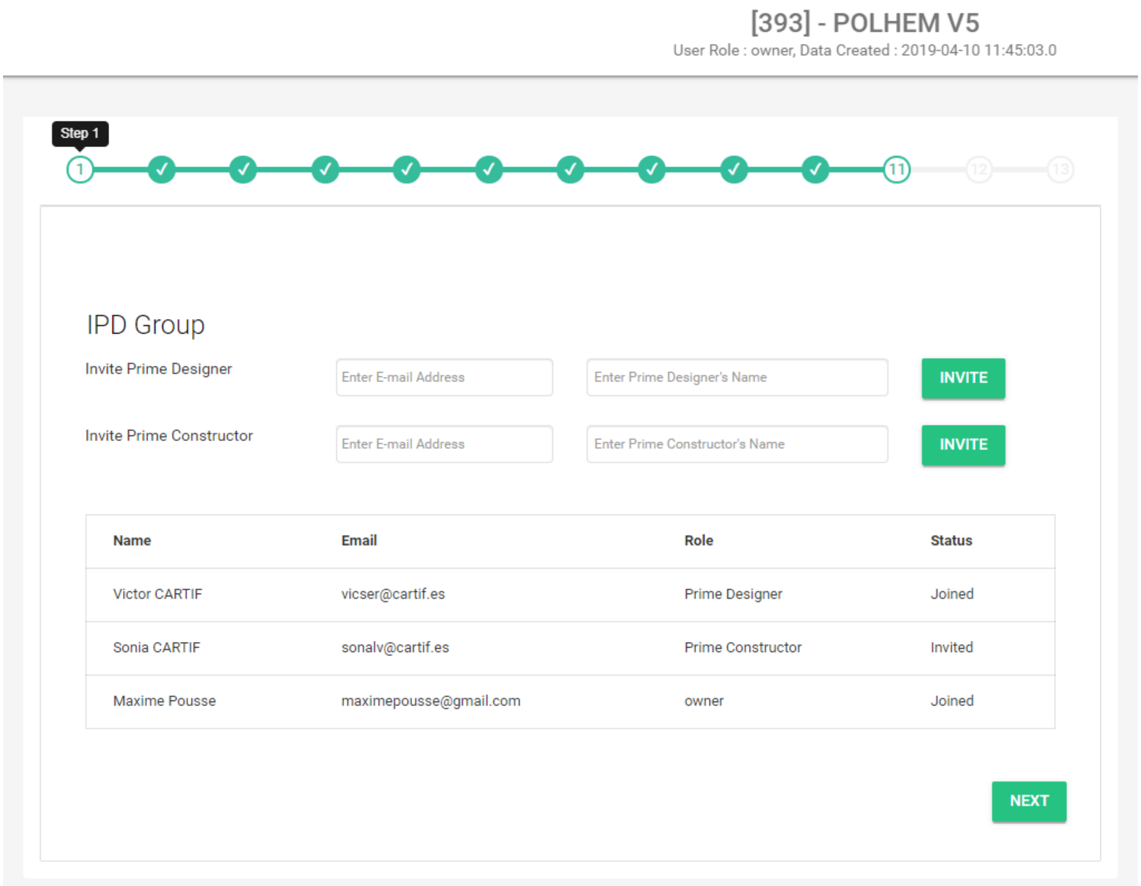


Figure 50: Uploaded and checked CItyGML file – *Polhem* district, Lund

Step 2: Data upload

Upload

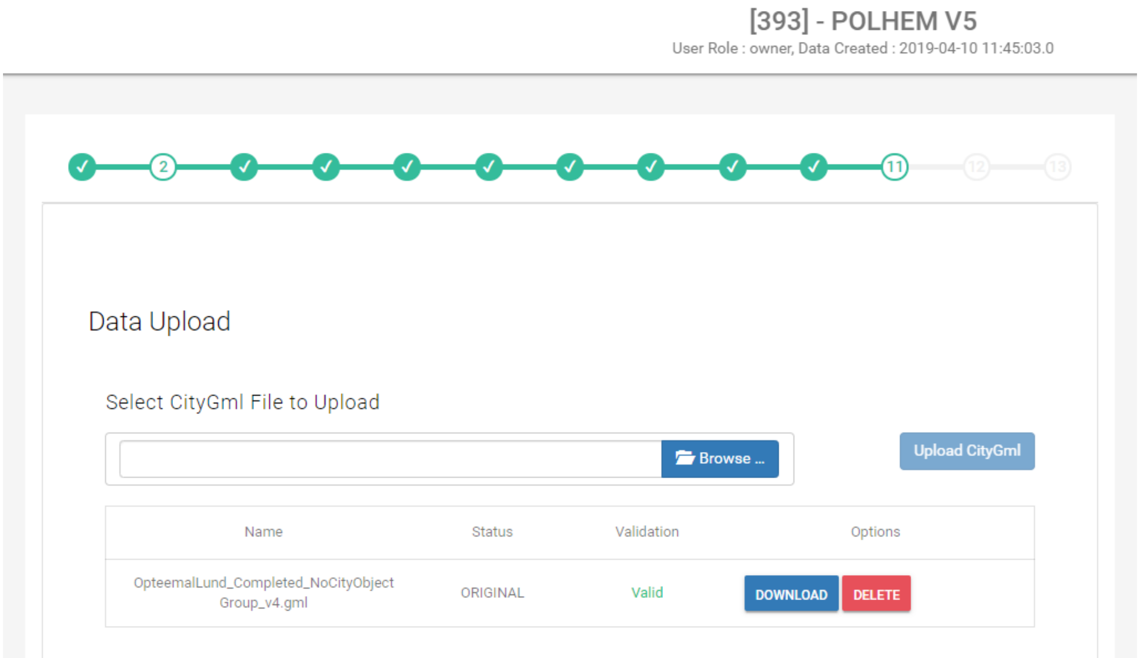


Figure 51: Uploaded and checked IFC files – *Polhem* district, Lund

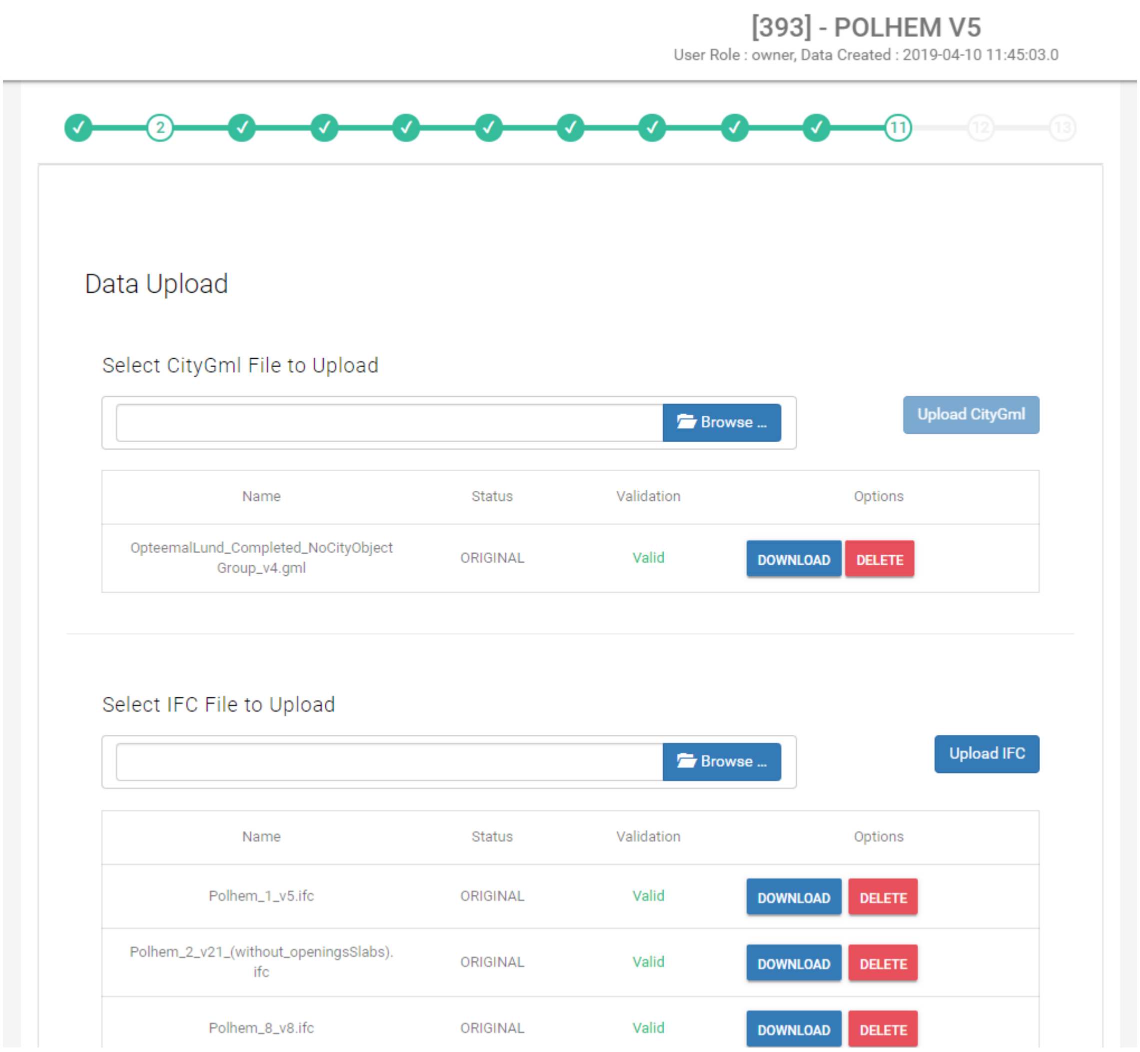


Figure 52: Uploaded and checked IFC files – *Polhem* district, Lund

BIM-CityGML matching

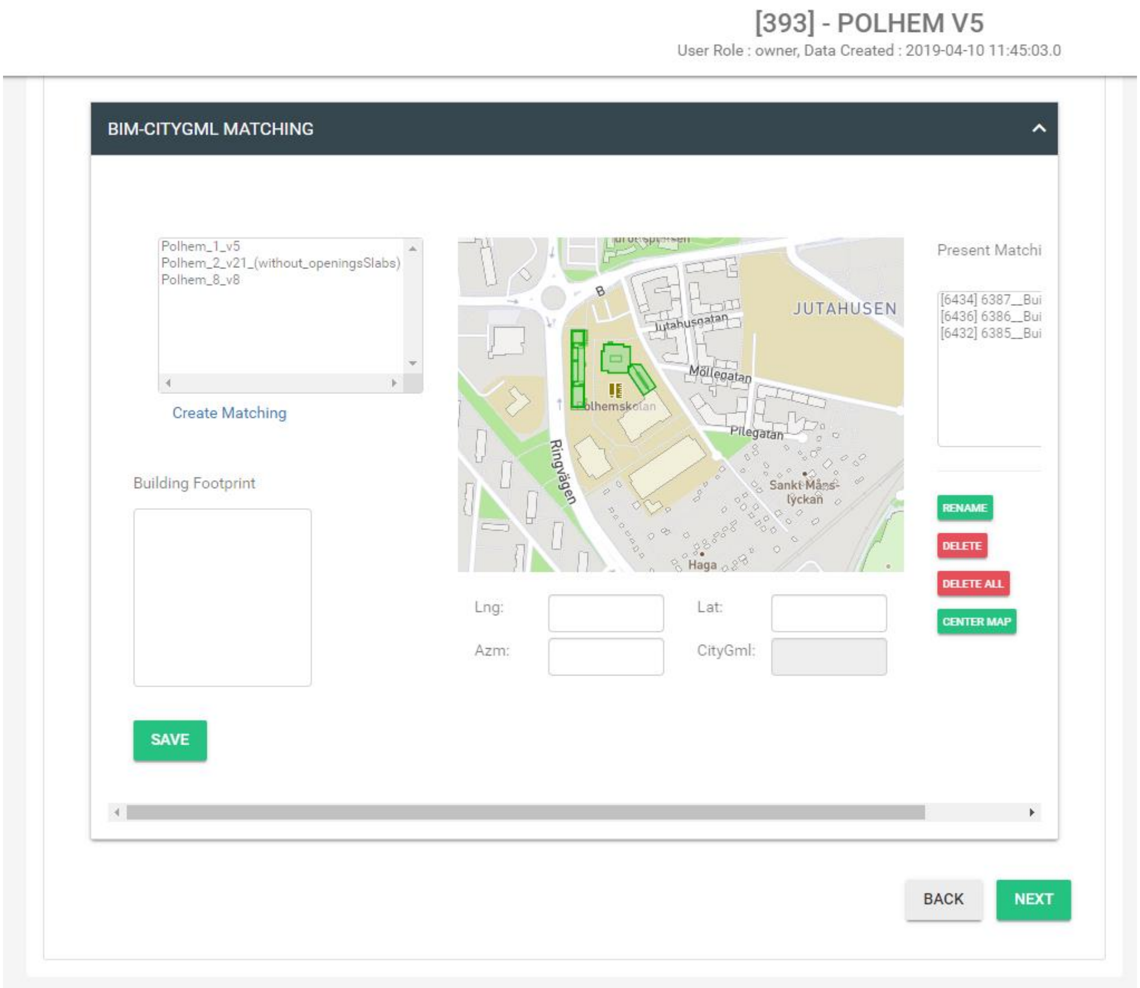


Figure 53: BIM and CityGML files matched – *Polhem* district, Lund

Step 3: Baseline Energy Systems

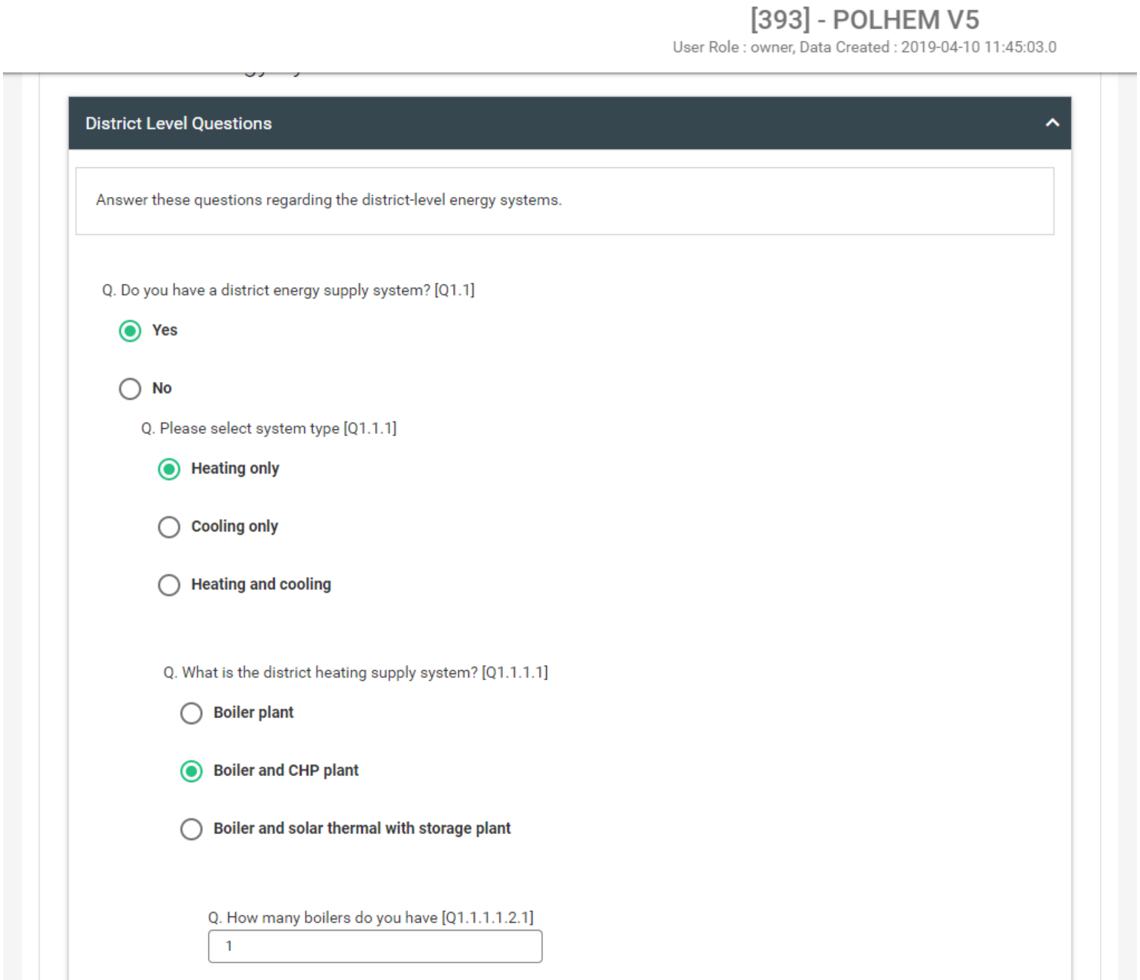


Figure 54: BES questionnaire at district level – *Polhem* district, Lund

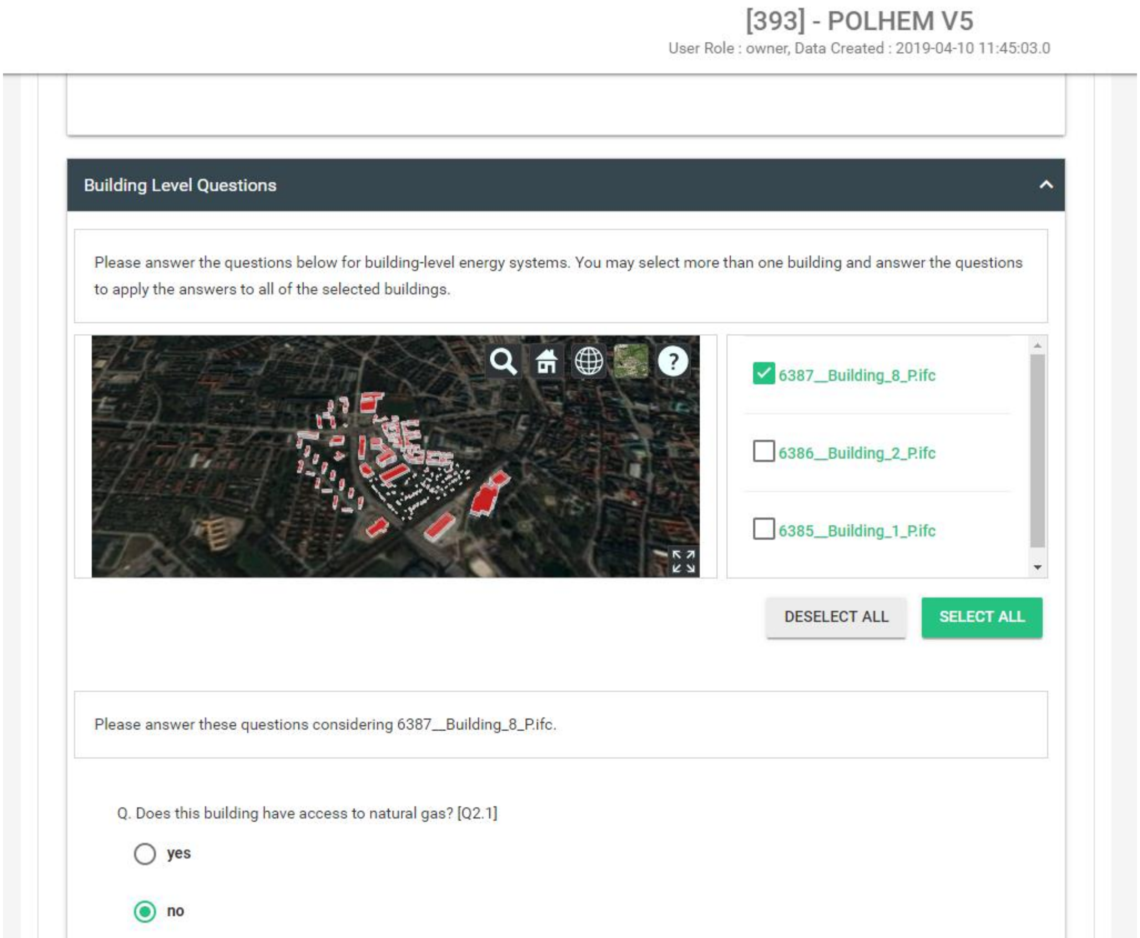


Figure 55: BES questionnaire at building level – *Polhem* district, Lund

Step 4: Contextual data

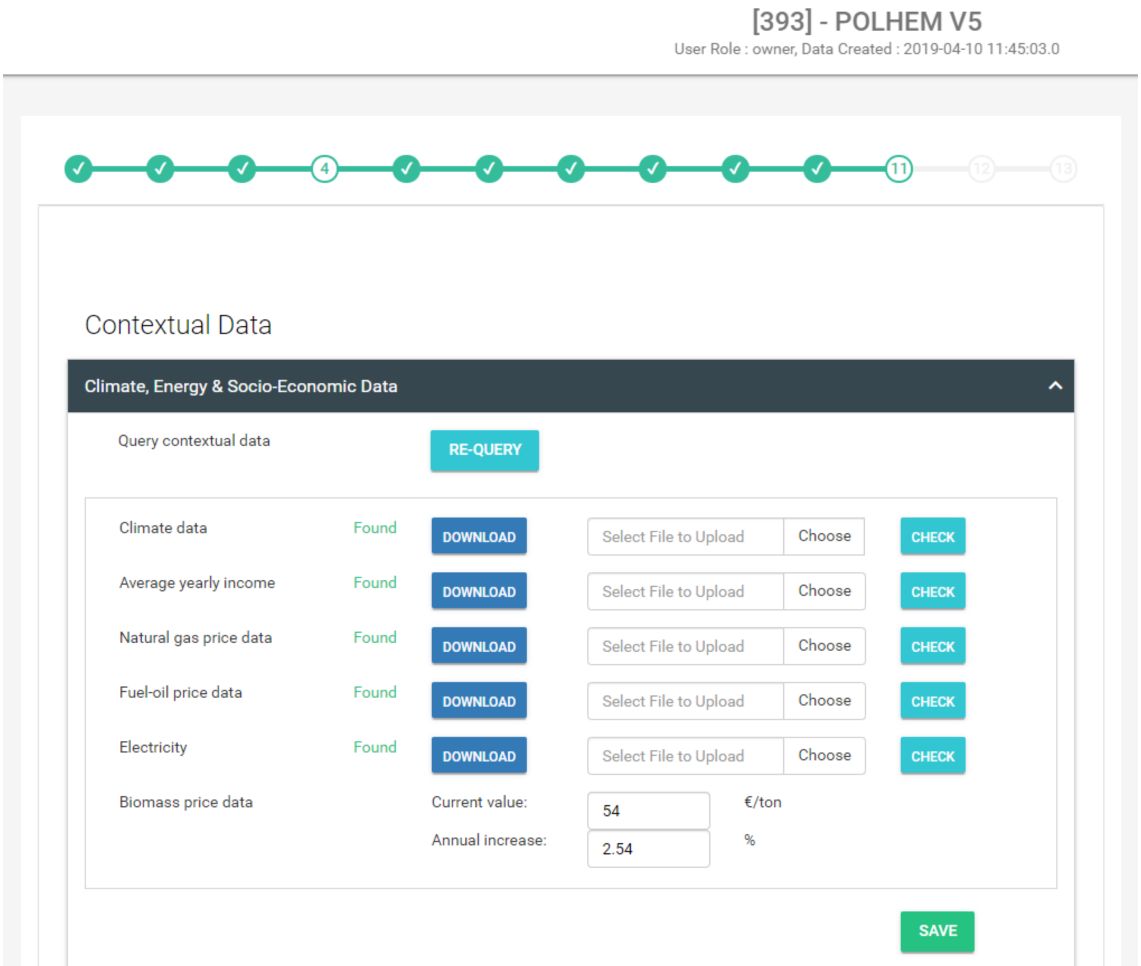


Figure 56: Contextual data gathered – *Polhem* district, Lund

Step 5: ECM questionnaire

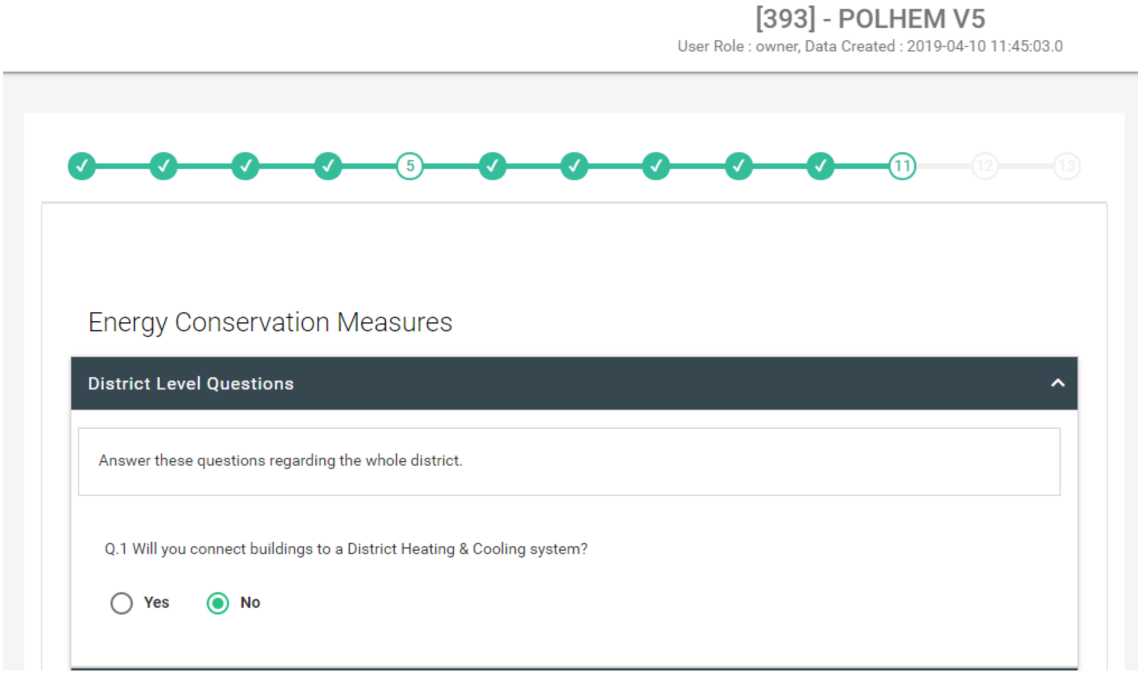


Figure 57: ECM questionnaire completed at district scale – *Polhem* district, Lund

Step 6: Check strategies

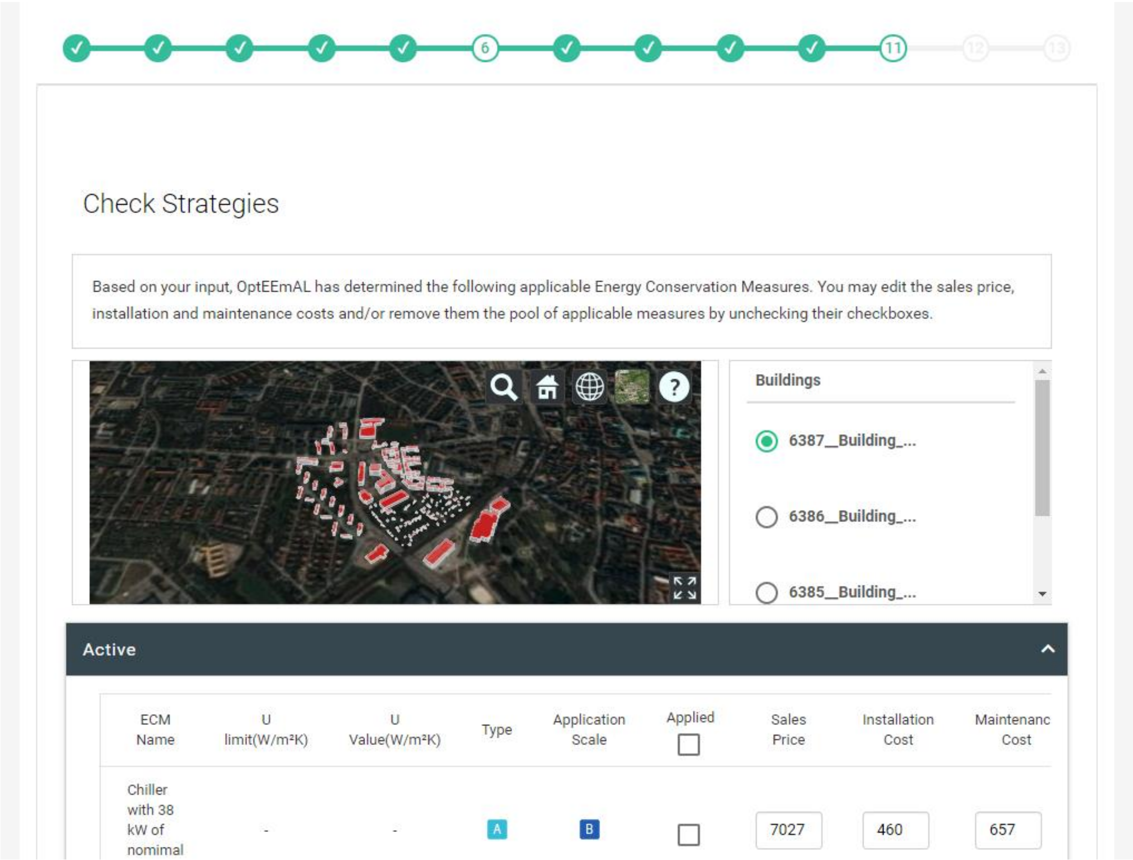
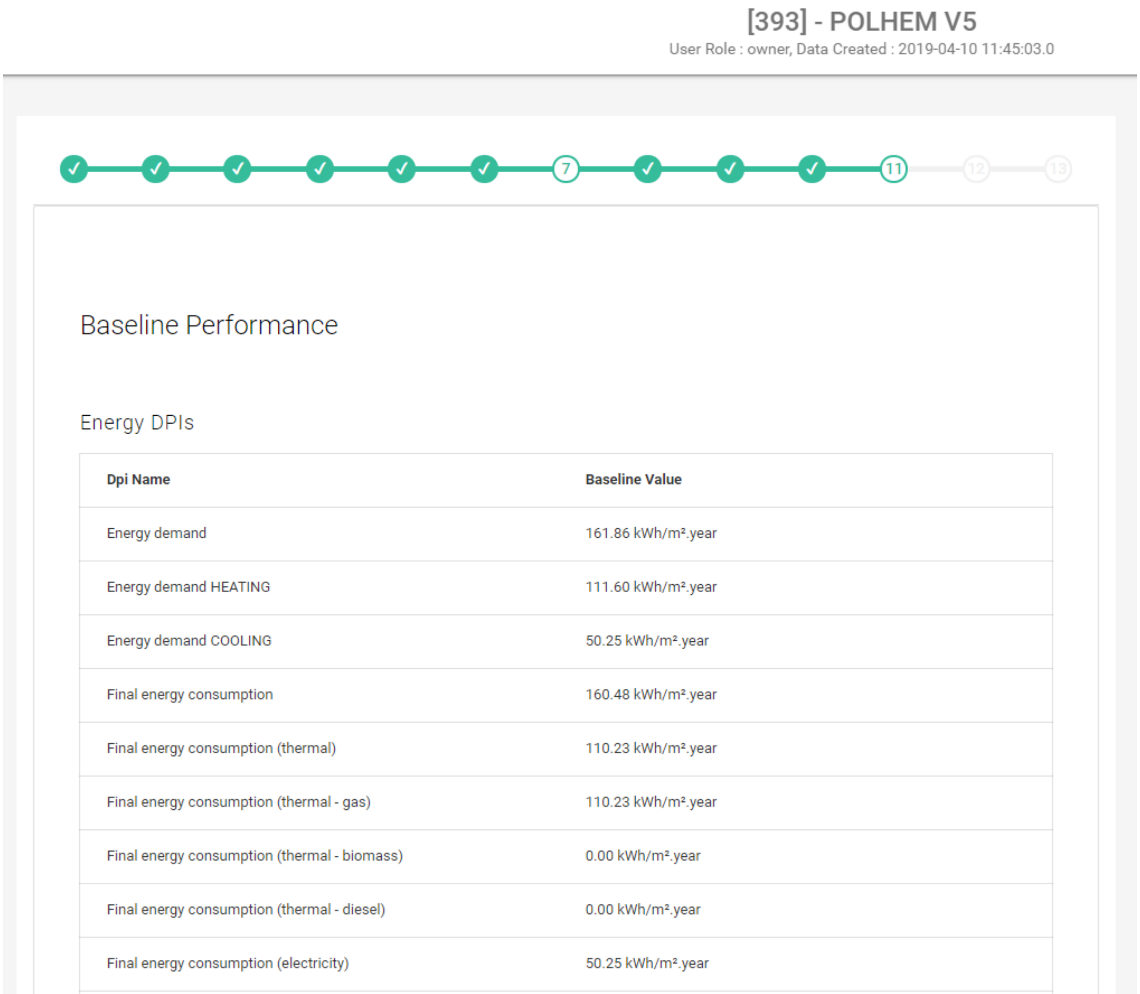


Figure 58: Discarded and edited ECM – *Polhem* district, Lund

Step 7: Baseline results



Dpi Name	Baseline Value
Energy demand	161.86 kWh/m².year
Energy demand HEATING	111.60 kWh/m².year
Energy demand COOLING	50.25 kWh/m².year
Final energy consumption	160.48 kWh/m².year
Final energy consumption (thermal)	110.23 kWh/m².year
Final energy consumption (thermal - gas)	110.23 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)	50.25 kWh/m².year

Figure 59: Baseline DPIs – *Polhem* district, Lund

Step 8: Targets and Boundaries

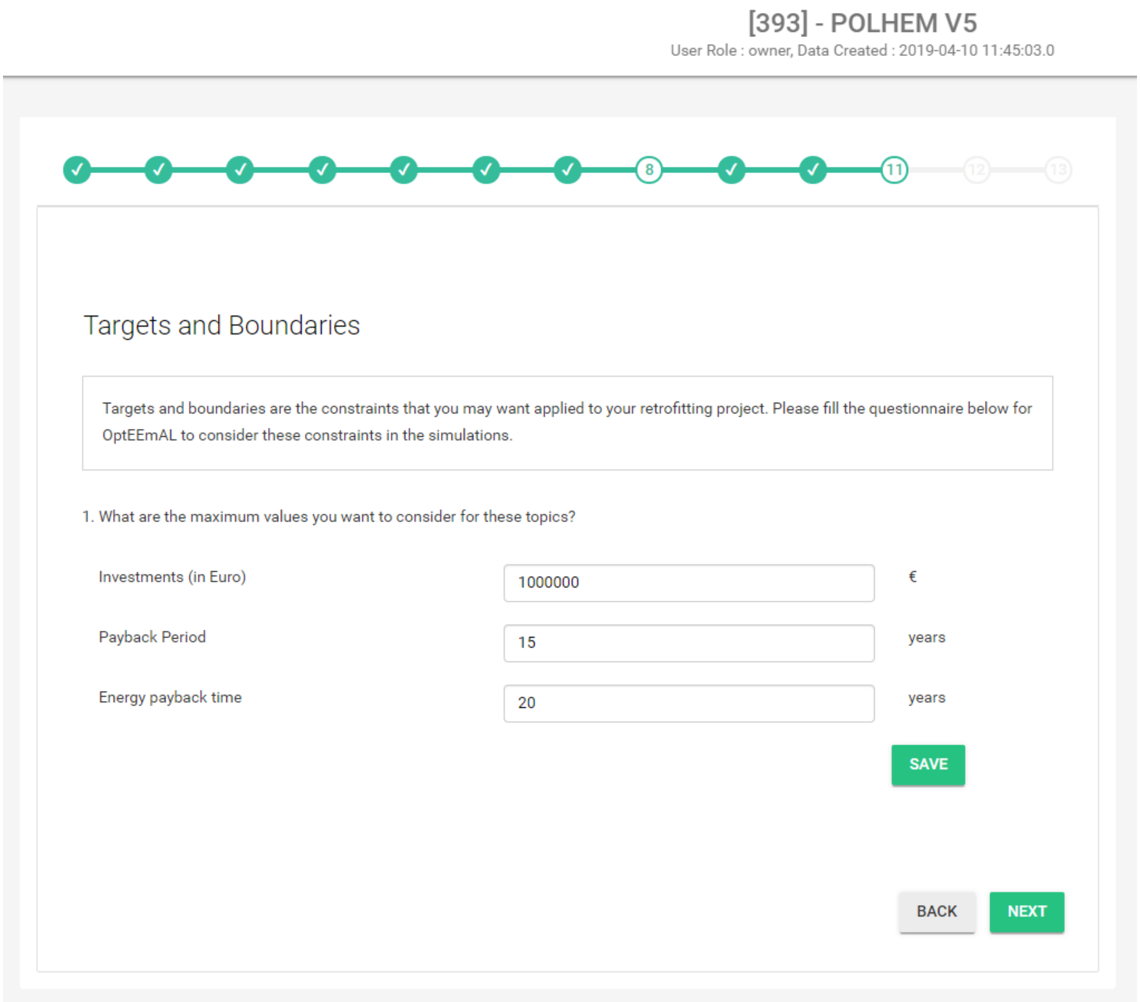


Figure 60: Targets and Boundaries – *Polhem* district, Lund

Step 9: Prioritization criteria

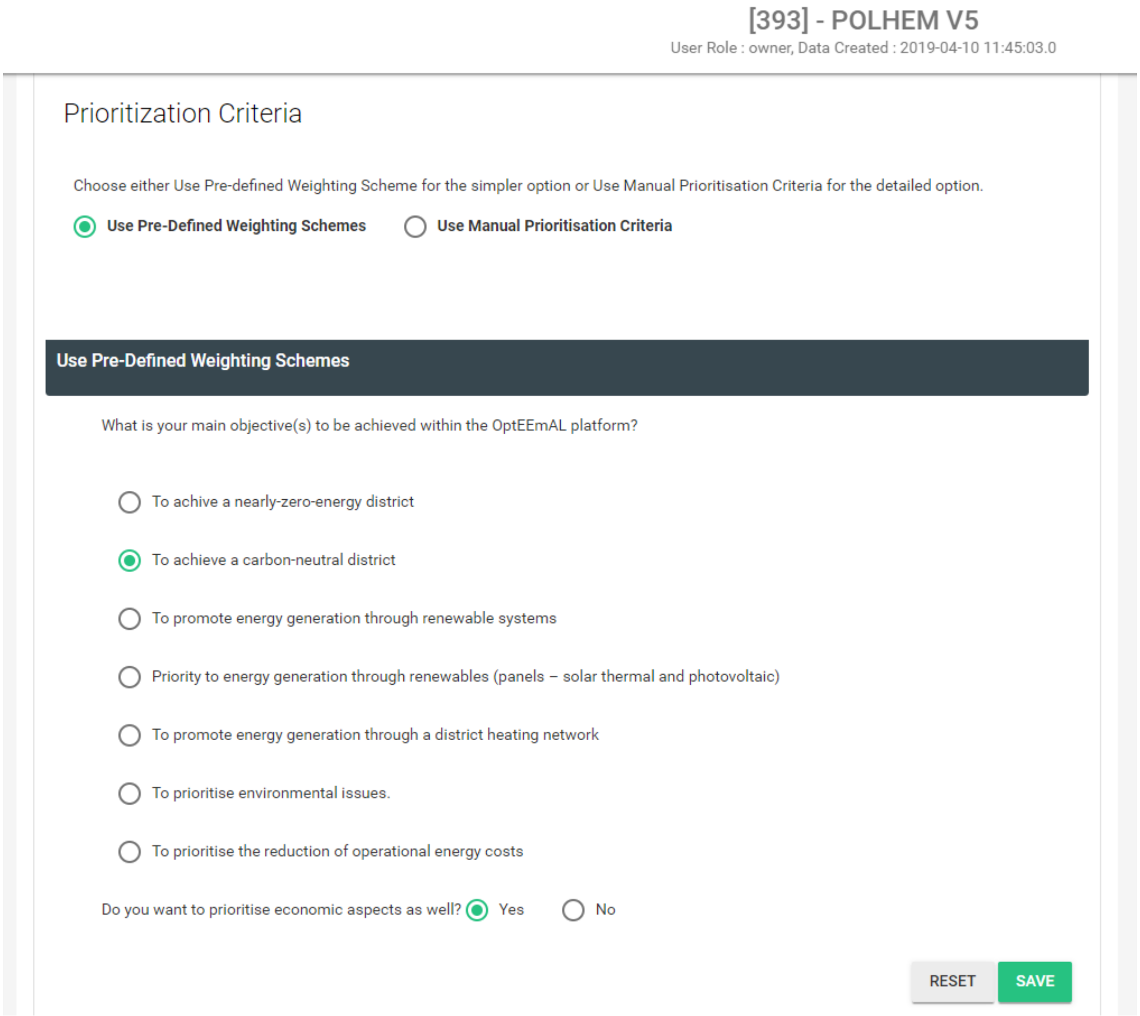
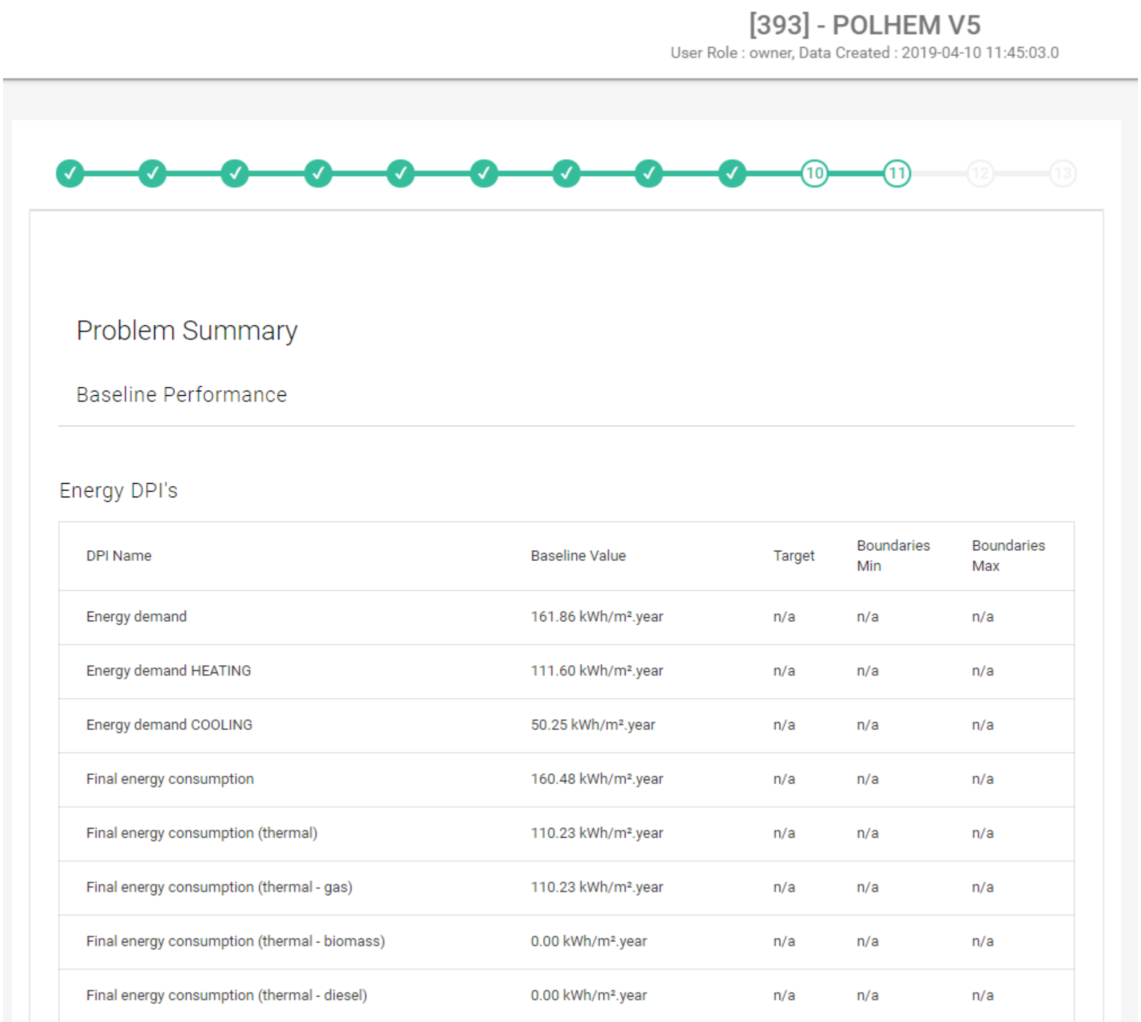


Figure 61: Prioritization criteria – *Polhem* district, Lund

Step 10: Problem summary



[393] - POLHEM V5

User Role : owner, Data Created : 2019-04-10 11:45:03.0

Problem Summary

Baseline Performance

Energy DPI's

DPI Name	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	161.86 kWh/m².year	n/a	n/a	n/a
Energy demand HEATING	111.60 kWh/m².year	n/a	n/a	n/a
Energy demand COOLING	50.25 kWh/m².year	n/a	n/a	n/a
Final energy consumption	160.48 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal)	110.23 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - gas)	110.23 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

Figure 62: Problem summary (baseline DPIs) – *Polhem* district, Lund

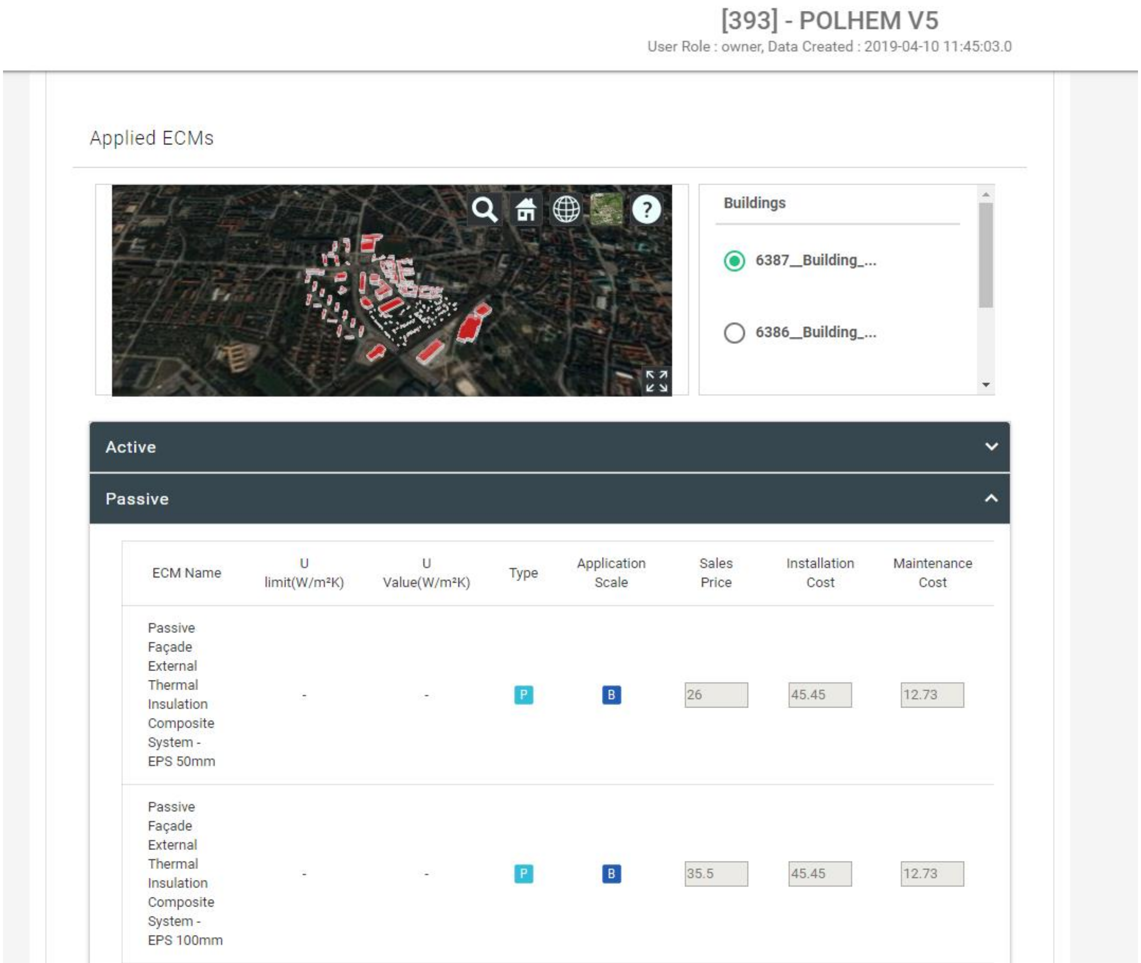


Figure 63: Problem summary (Applied ECMs) – *Polhem* district, Lund

Step 11 – Optimisation progress

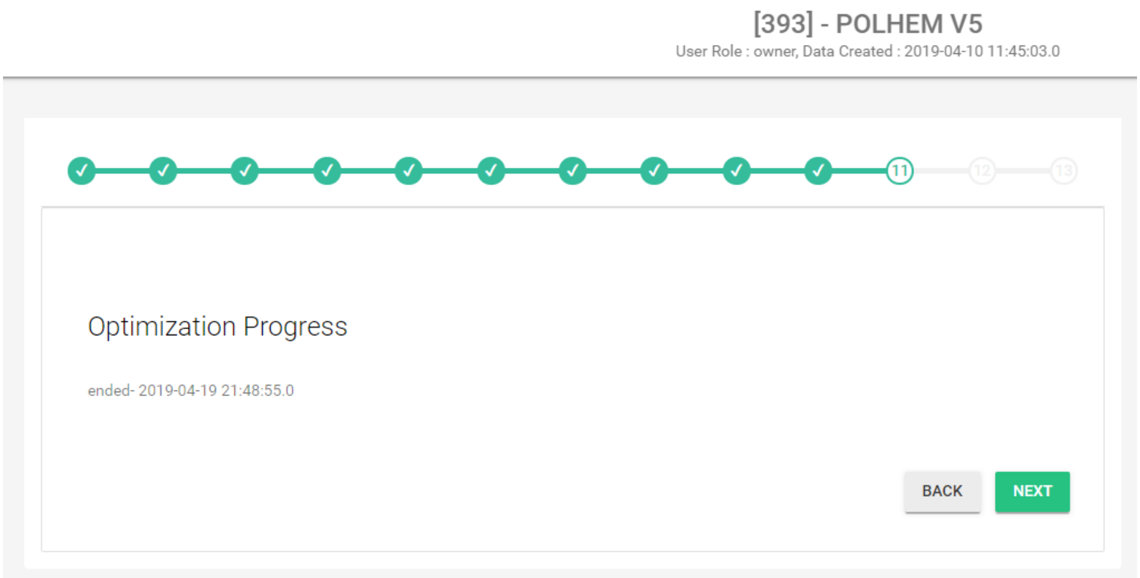


Figure 64: Optimisation progress – *Polhem* district, Lund

Step 12 – Select optimal scenario

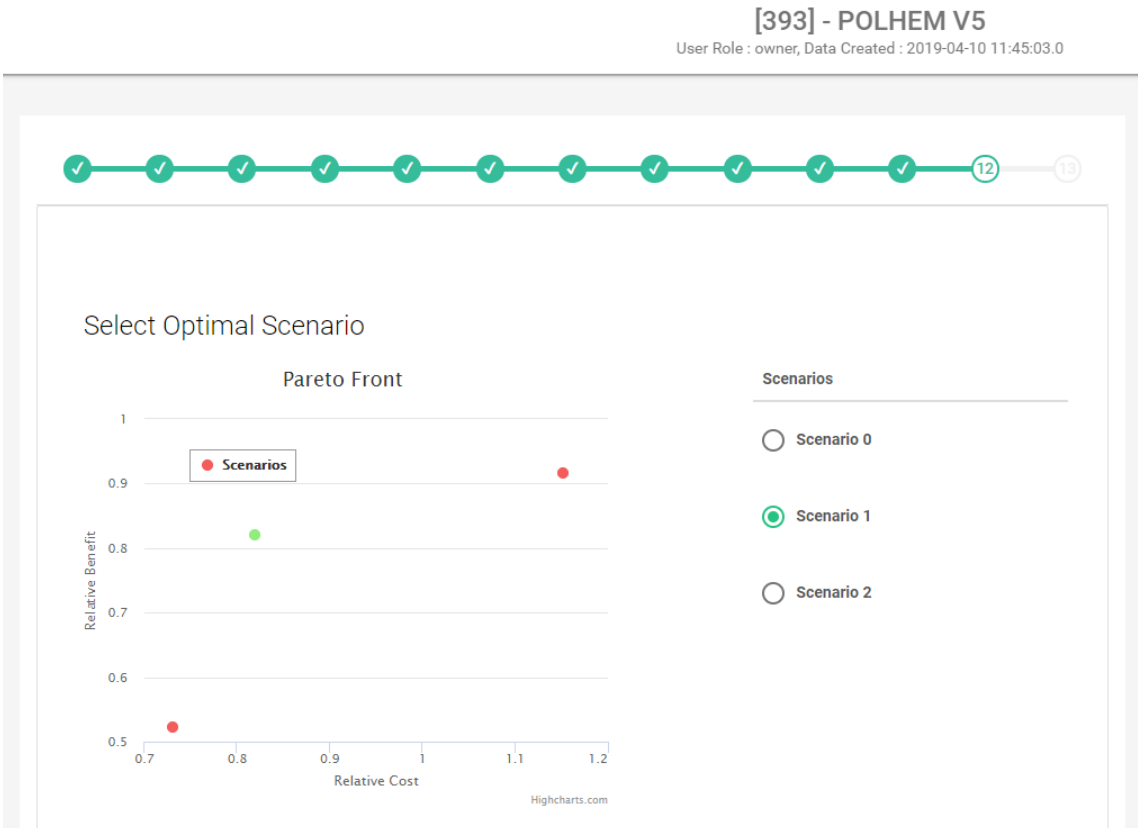


Figure 65: Pareto front – *Polhem* district, Lund

Economic DPIs

Name	Scenario 1	Baseline Value	Target	Boundaries Min	Boundaries Max
Operational energy cost	14.10 €/m2.year	25.76 €/m2.year	n/a	n/a	n/a
Operational energy cost - gas	3.90 €/m2.year	10.06 €/m2.year	n/a	n/a	n/a
Operational energy cost - biomass	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - diesel	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - electricity	10.20 €/m2.year	15.69 €/m2.year	n/a	n/a	n/a
Investments (in Euro/m2)	170.33 €/m2	n/a €/m2	n/a	n/a	n/a
Investments (in Euro)	1595412.19 €	n/a €	n/a	1000000	n/a
Life cycle cost	11378525.63 €	7572965.88 €	n/a	n/a	n/a
Return on investment	110.88 %	n/a %	n/a	n/a	n/a
Payback Period	7.67 years	n/a years	n/a	15	n/a

Energy DPIs

Name	Scenario 1	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	114.24 kWh/m2.year	161.86 kWh/m2.year	n/a	n/a	n/a
Energy demand HEATING	63.98 kWh/m2.year	111.60 kWh/m2.year	n/a	n/a	n/a

Figure 66: Baseline and scenario DPIs – *Polhem* district, Lund

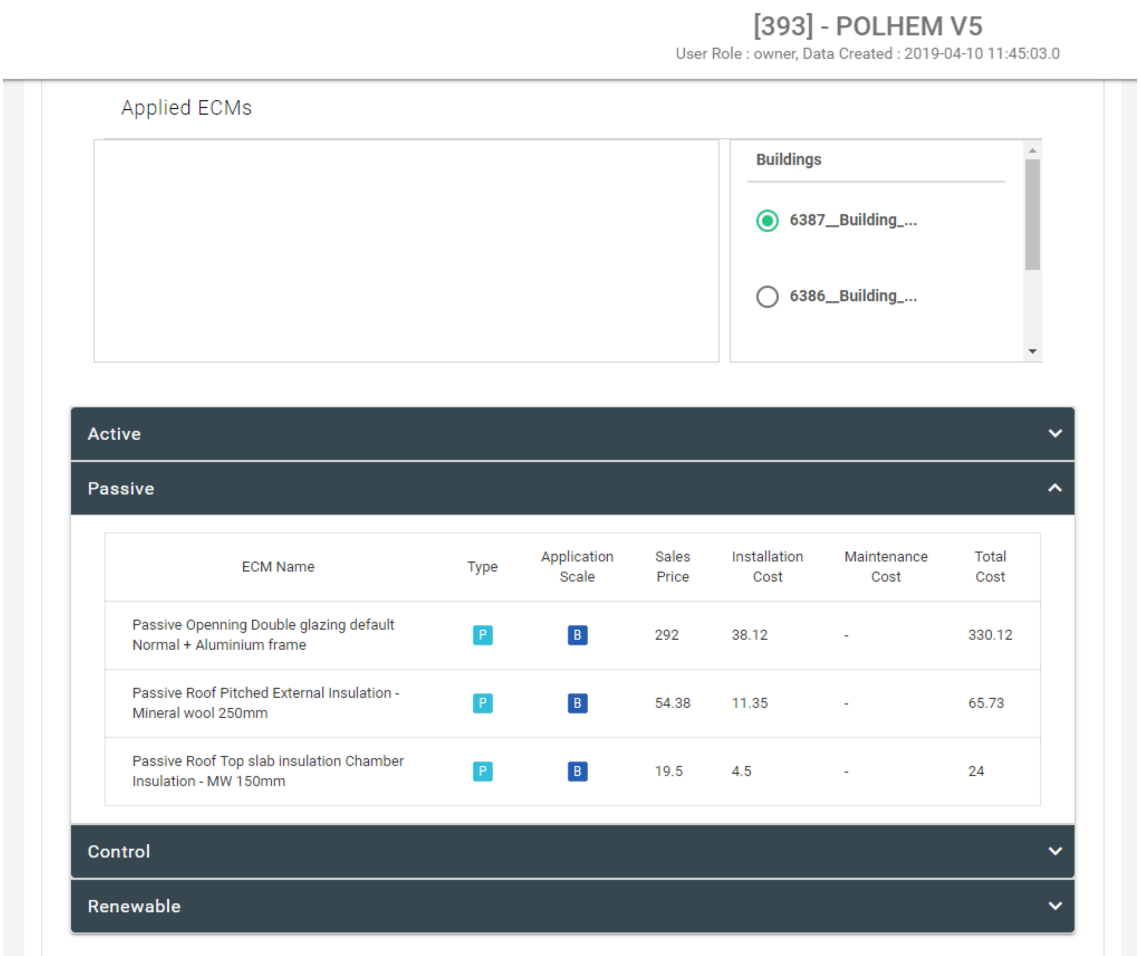


Figure 67: Applied ECMs – *Polhem* district, Lund

Step 13 – Export

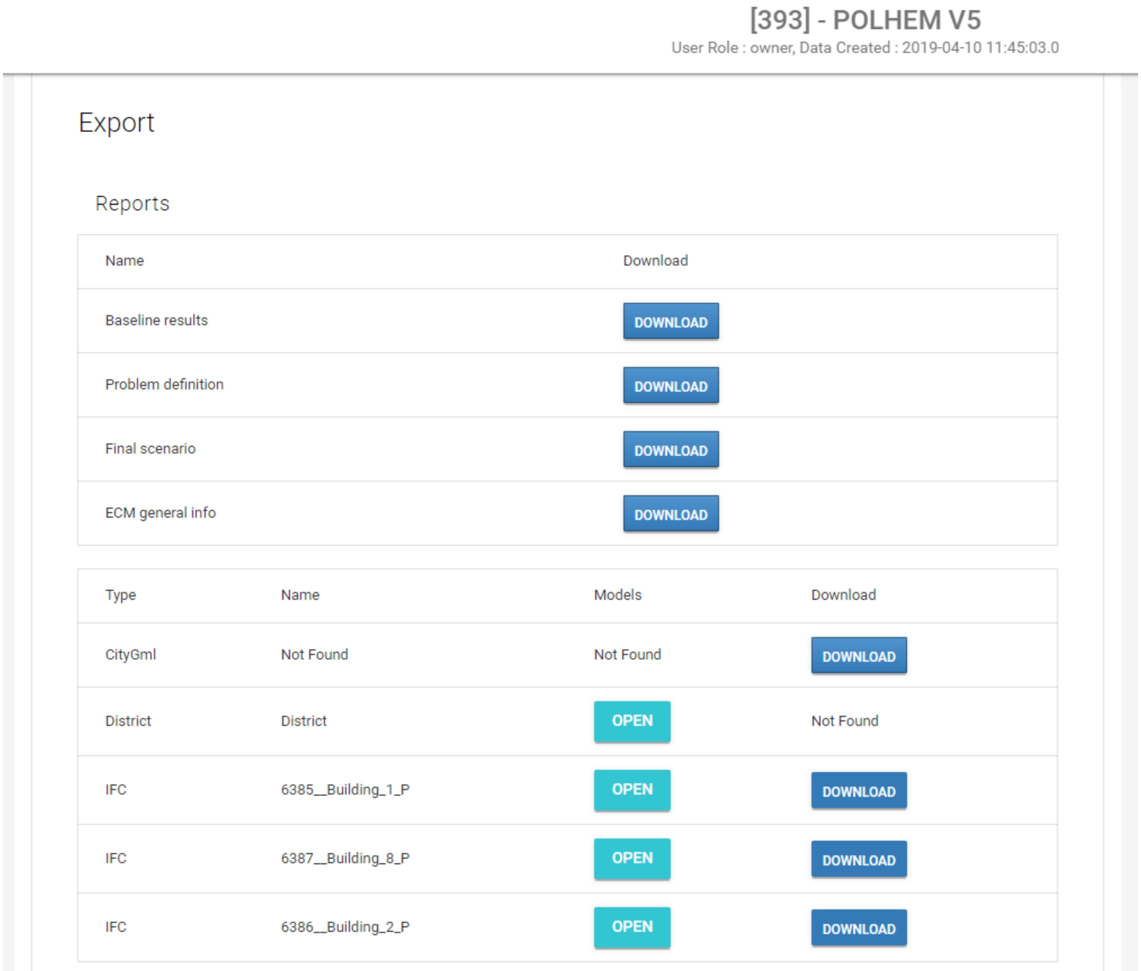


Figure 68: Information to be exported – *Polhem* district, Lund

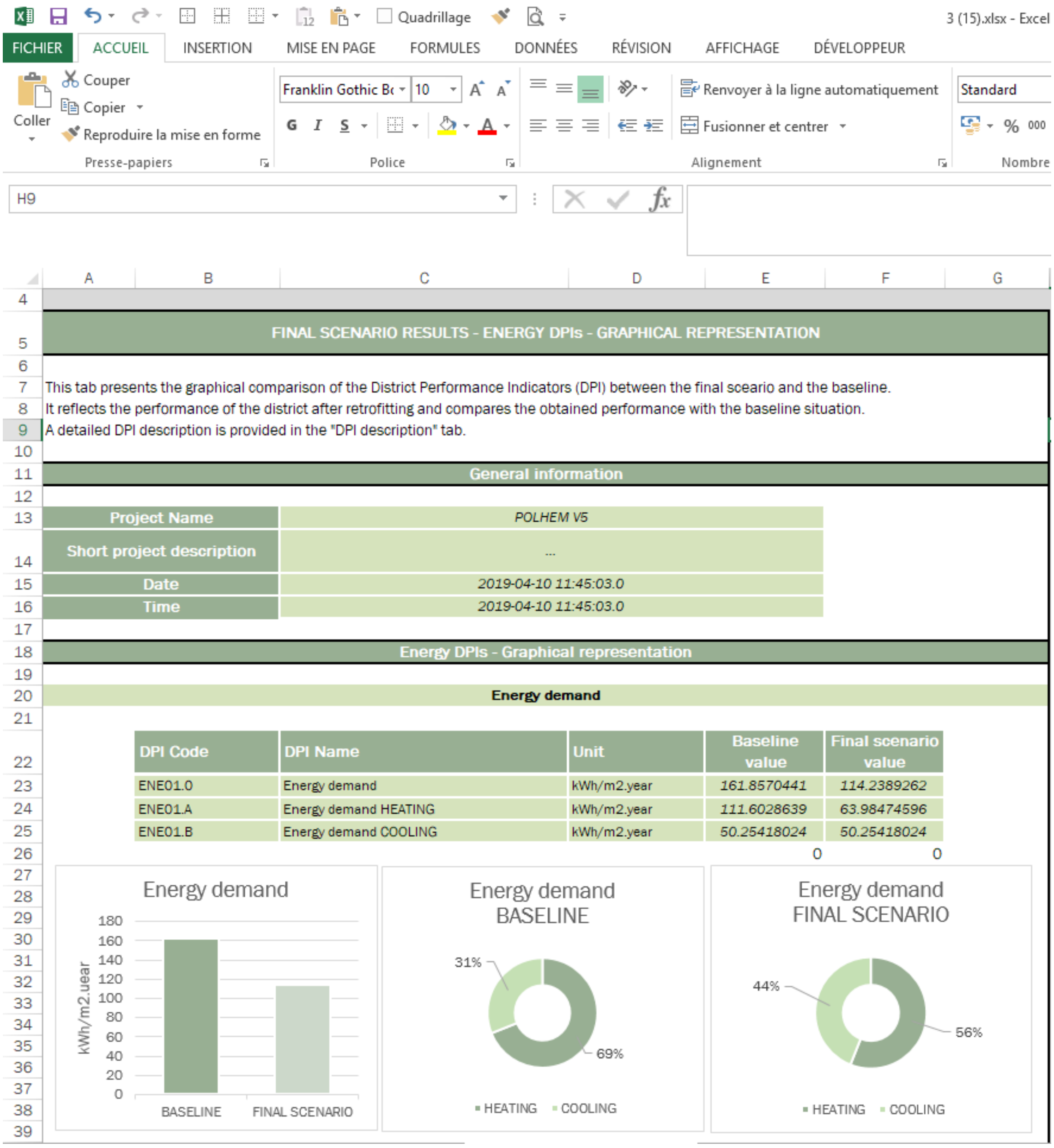


Figure 69: Exported Excel file – *Polhem* district, Lund

9.1.2 San Bartolomeo district, Trento

9.1.2.1 Step 1: IPD group creation

The IPD group is successfully created with several users (Figure 70). It has to be noted that in this project, all users (internal to the consortium) have been assigned the same role of “Prime Designer”. This was done for testing purposes.

This test is PASSED.

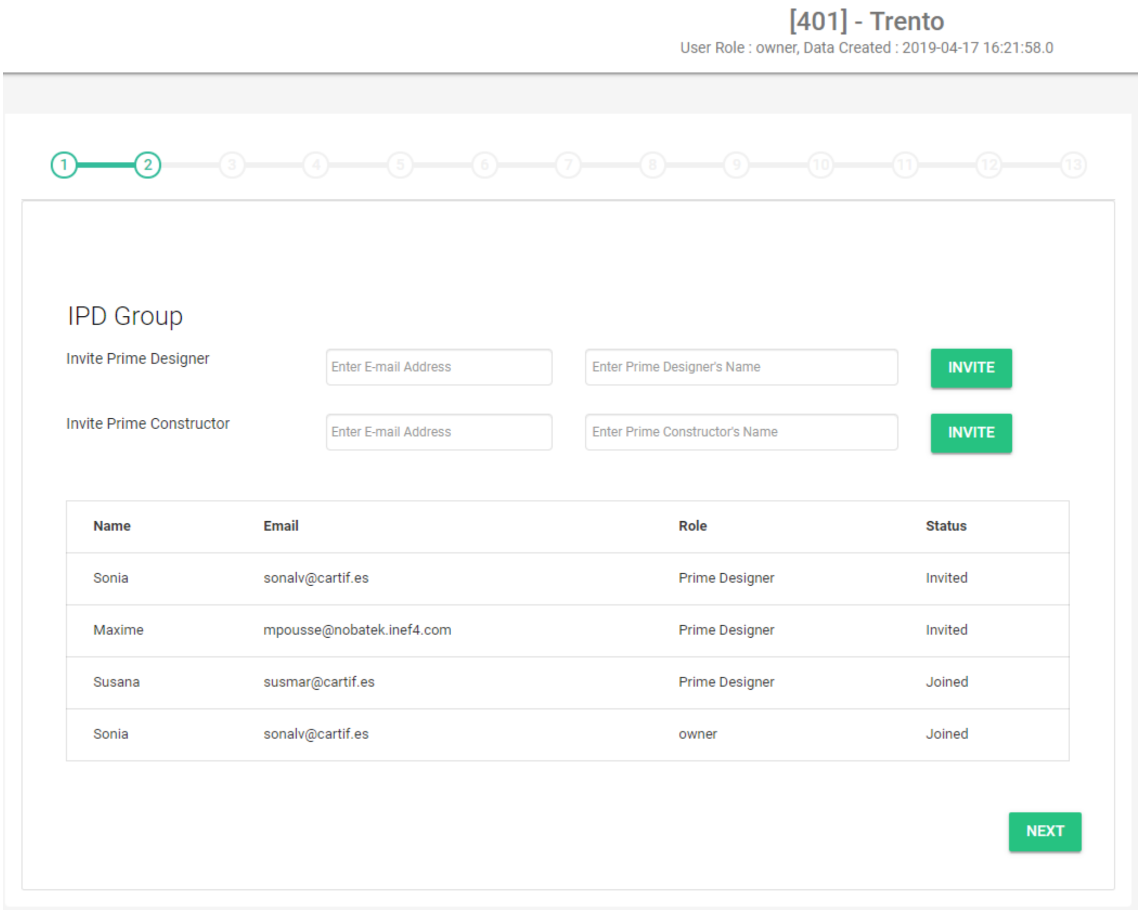


Figure 70: IPD group creation – *San Bartolomeo* district, Trento (Italy)

9.1.2.2 Step 2: Data upload

Considering its importance, this step has been in two sub-steps “Upload” and “BIM-CityGML matching”.

<u>Upload</u>

Using the GUI, the CityGML file has been properly uploaded and checked (Figure 71).

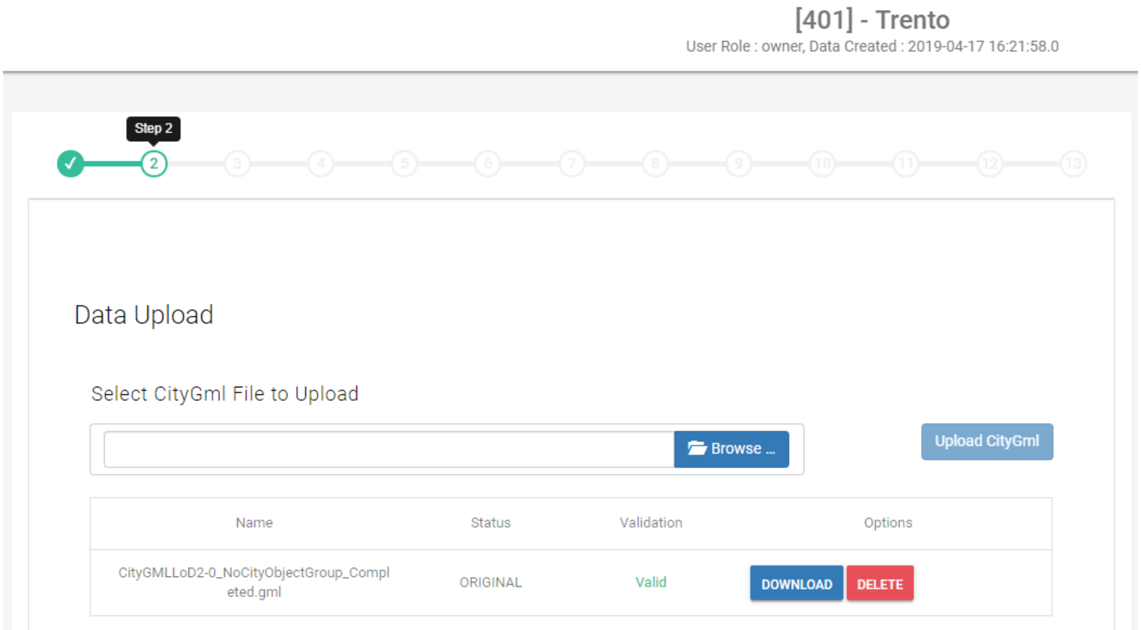


Figure 71: Uploaded and checked CItyGML file – *San Bartolomeo* district, Trento (Italy)

Similarly, the IFC file has been properly uploaded and checked (Figure 24).

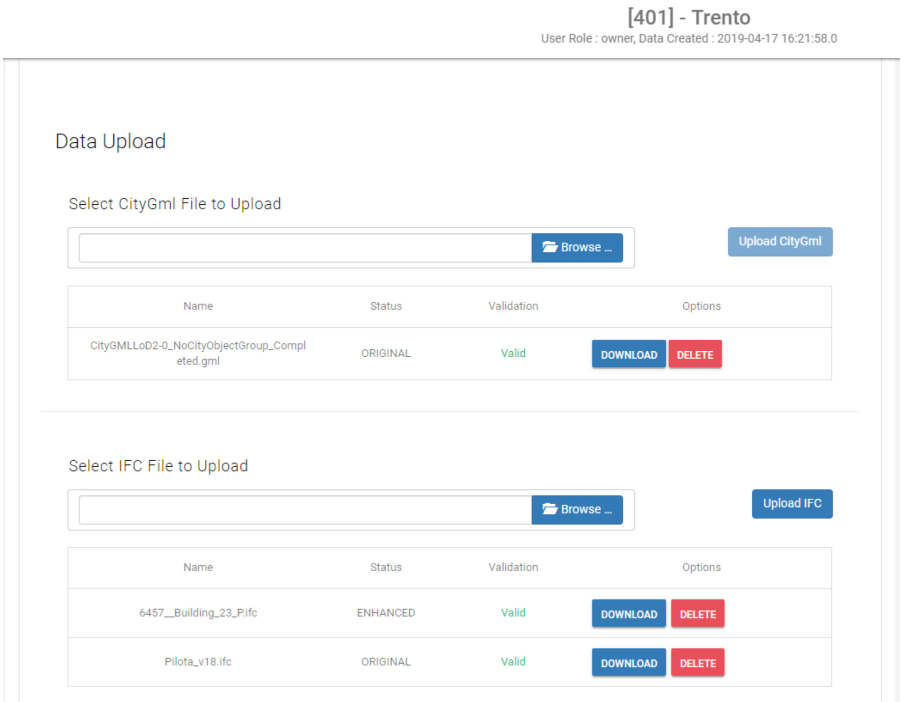


Figure 72: Uploaded and checked IFC files – *San Bartolomeo* district, Trento (Italy)

BIM-CityGML matching

After their upload, the different IFC files have been matched with the CityGML file (Figure 73). This step is PASSED.

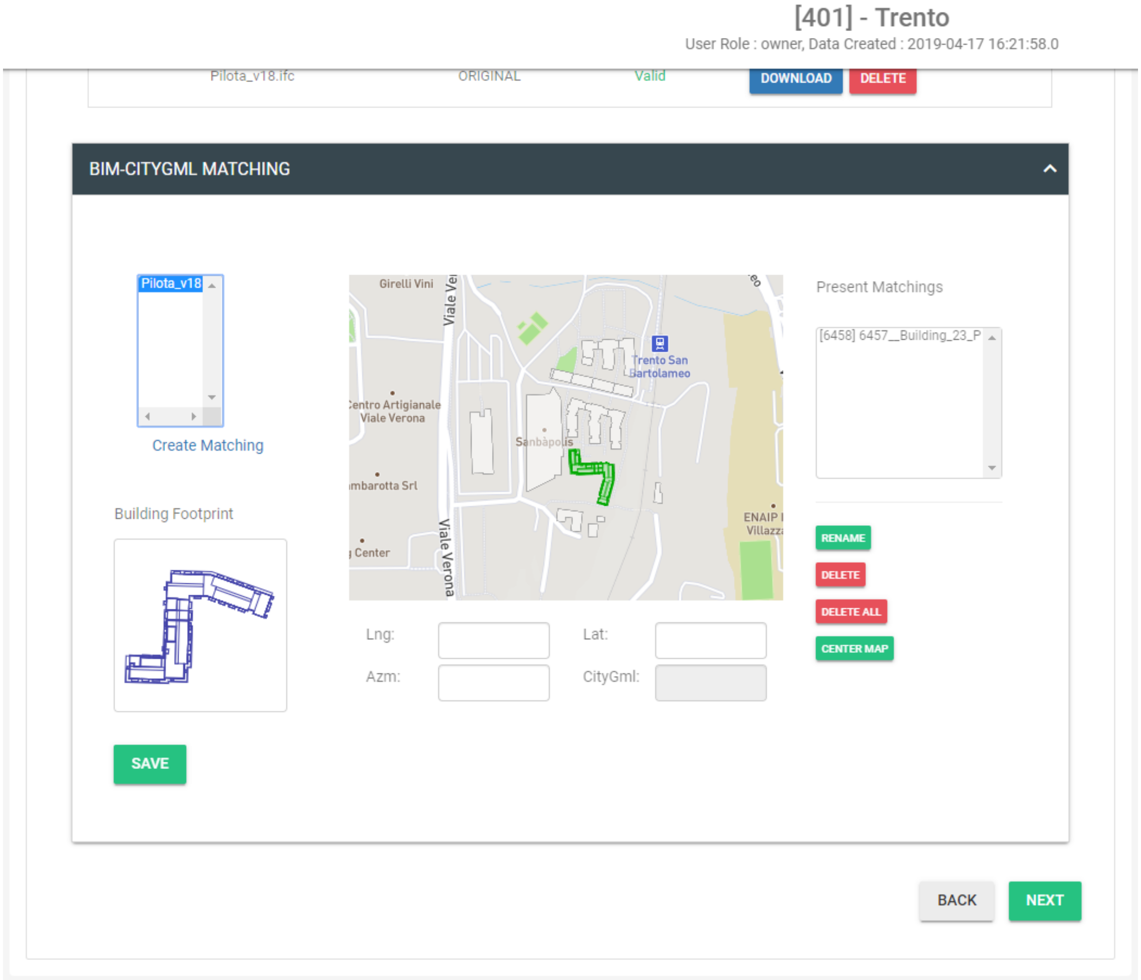


Figure 73: BIM and CityGML files matched – *San Bartolomeo* district, Trento (Italy)

9.1.2.3 Step 3: Baseline Energy Systems

The Baseline Energy Systems questionnaire has been successfully answered at the district (Figure 74 and Figure 75) and building (Figure 76 and Figure 77) levels. This step is PASSED.

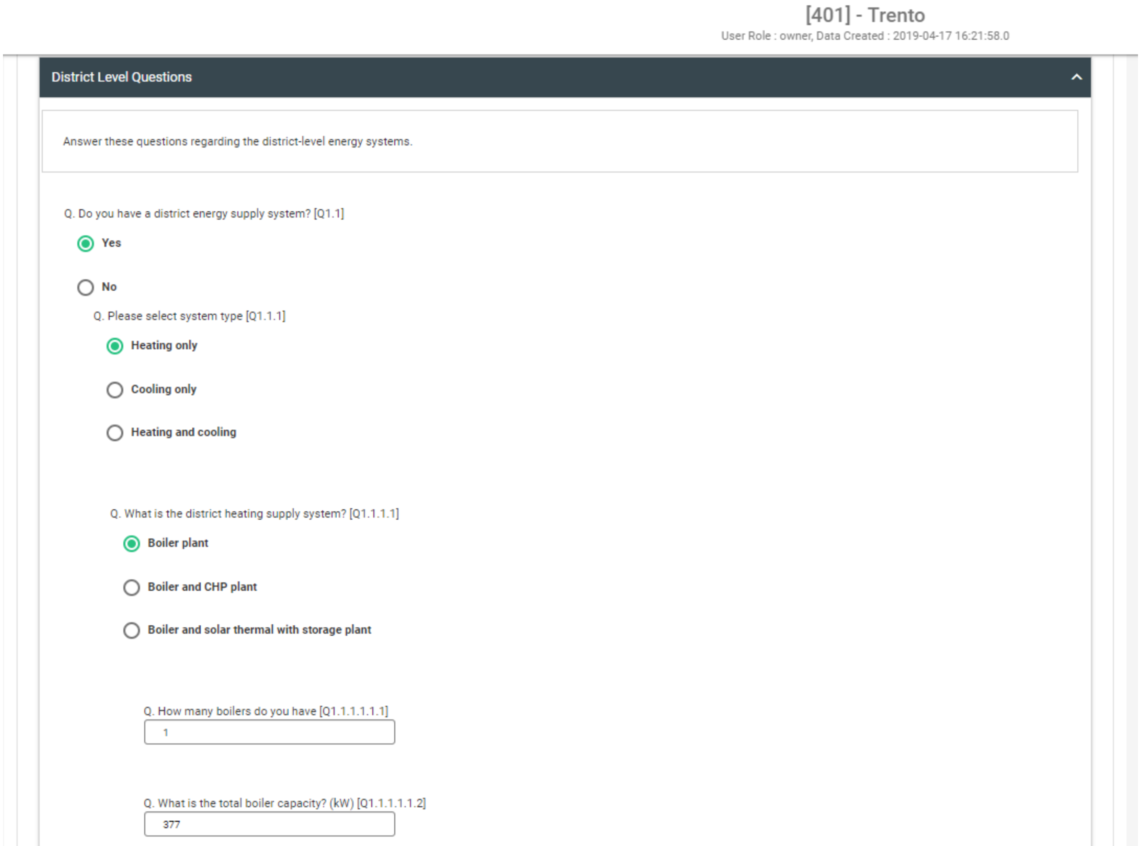


Figure 74: BES questionnaire at district level (1) – *San Bartolomeo* district, Trento (Italy)

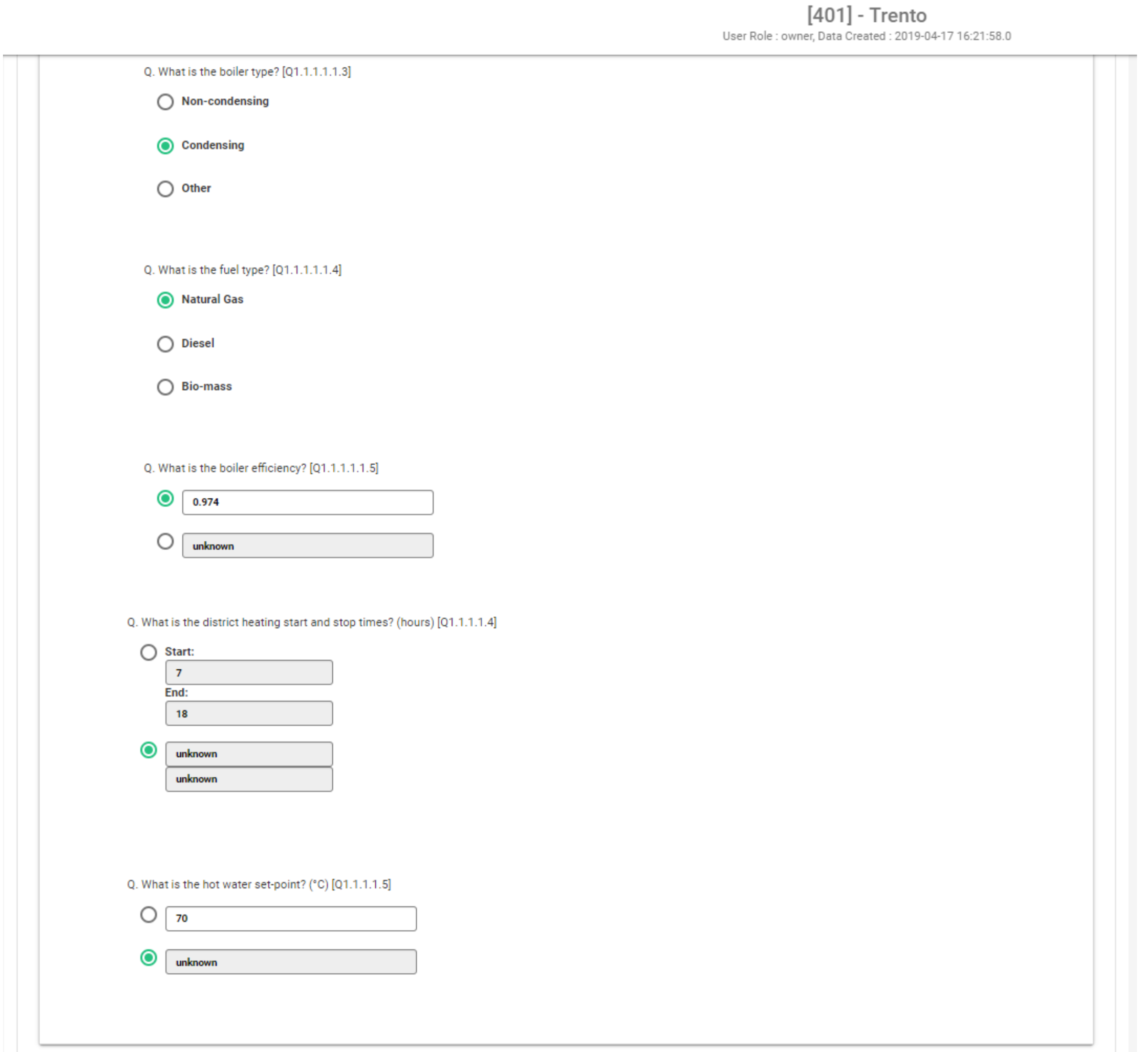


Figure 75: BES questionnaire at district level (2) – *San Bartolomeo* district, Trento (Italy)

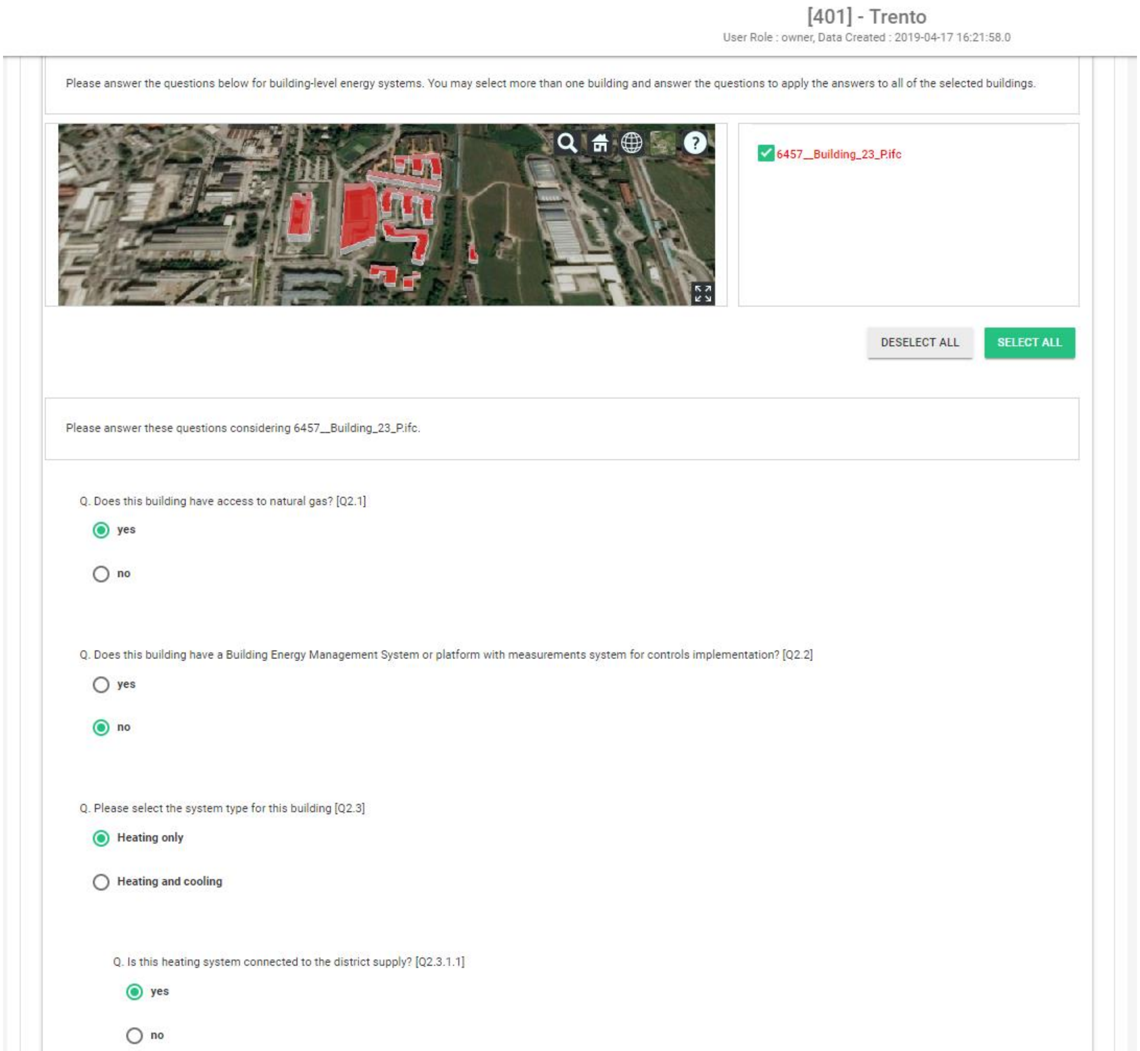


Figure 76: BES questionnaire at building level (1) – *San Bartolomeo* district, Trento (Italy)

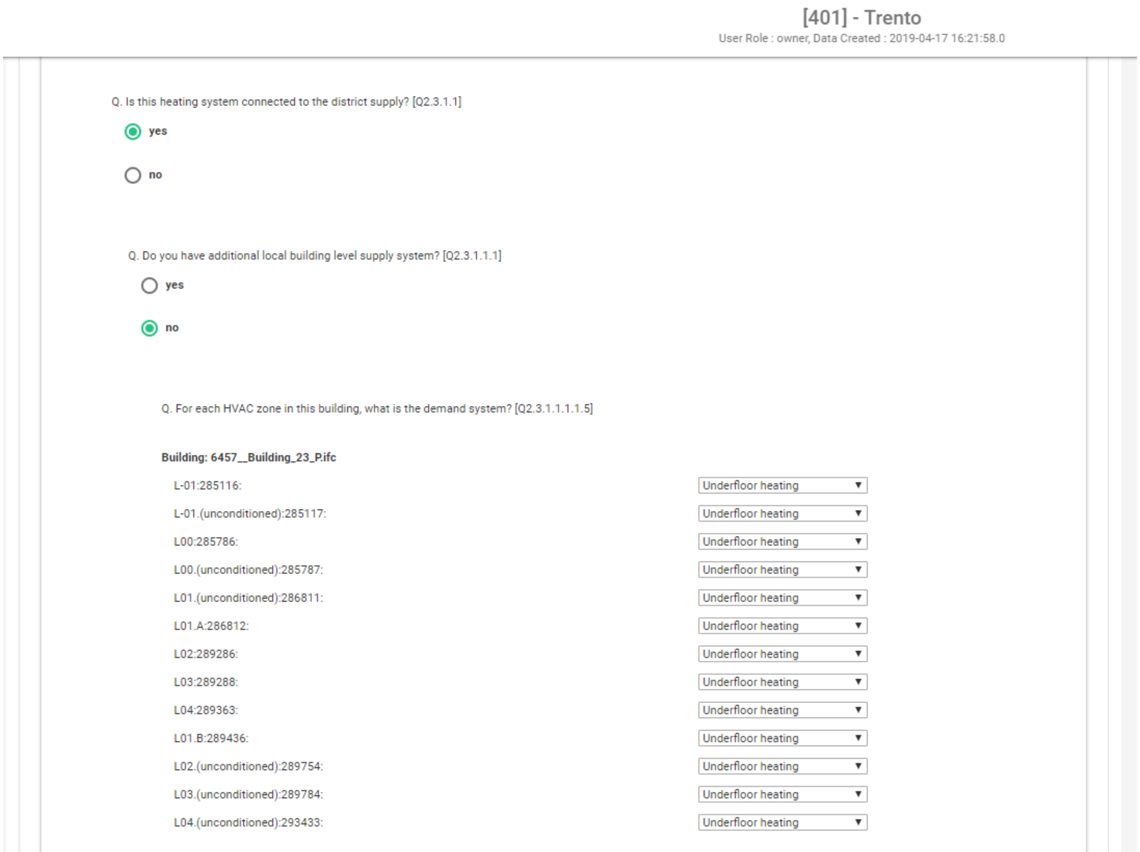


Figure 77: BES questionnaire at building level (2) – *San Bartolomeo* district, Trento (Italy)

9.1.2.4 Step 4: Contextual data

The contextual data are properly retrieved from the different databases (Figure 78). They can be downloaded and modified by the user if needed. Biomass related information has also been inserted. It has to be noticed that site-related data (gathered using the unstructured data gathering service but not used in the calculations) are not presented properly in the platform (but properly retrieved). This last point is PARTIALLY PASSED. Otherwise, this step is PASSED.

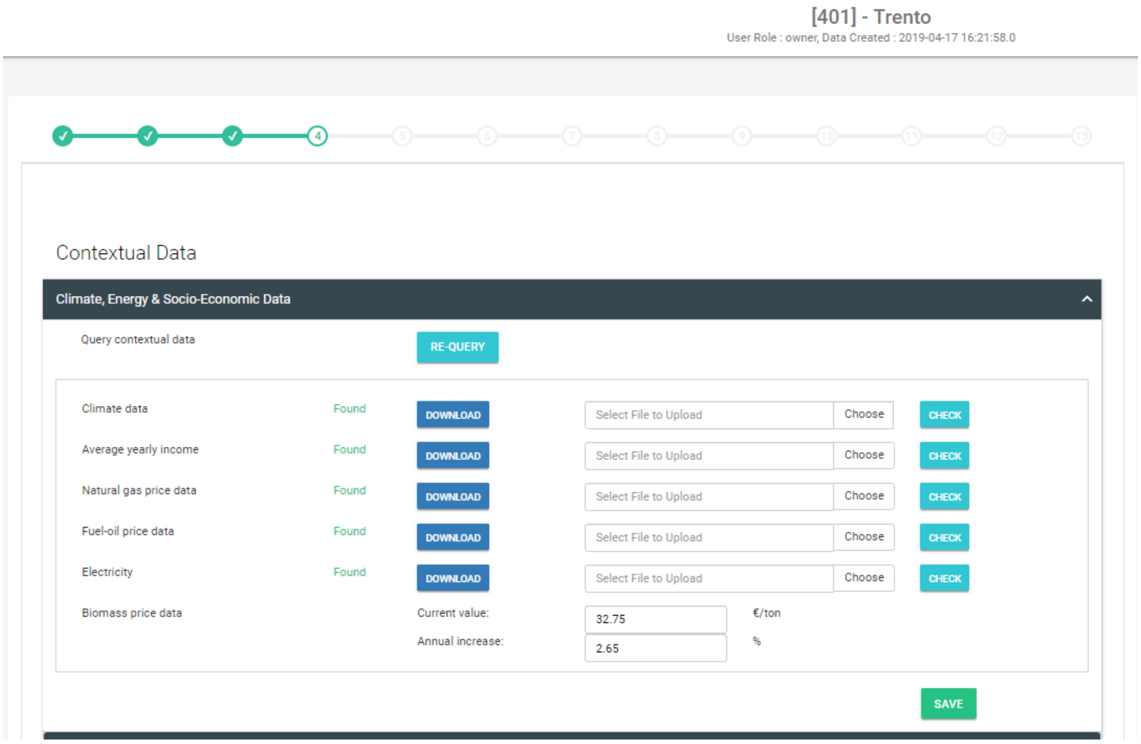


Figure 78: Contextual data gathered – *San Bartolomeo* district, Trento (Italy)

9.1.2.5 ECM questionnaire

The ECM questionnaire has been answered at district (Figure 79) and buildings (Figure 80 and Figure 81) levels. This test is PASSED.

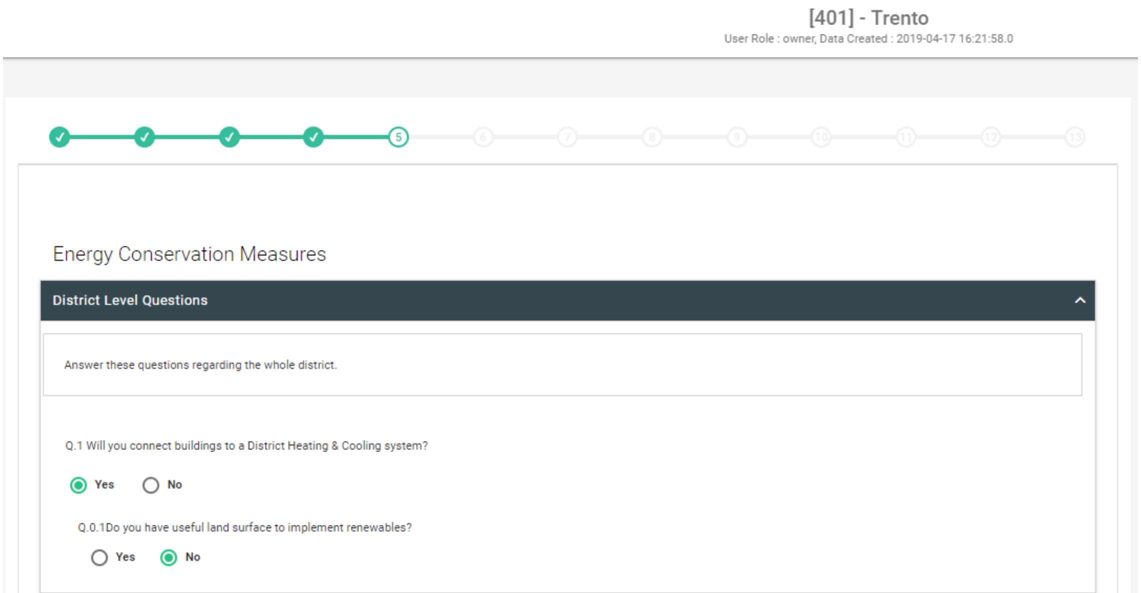


Figure 79: ECM questionnaire completed at district scale – *San Bartolomeo* district, Trento (Italy)

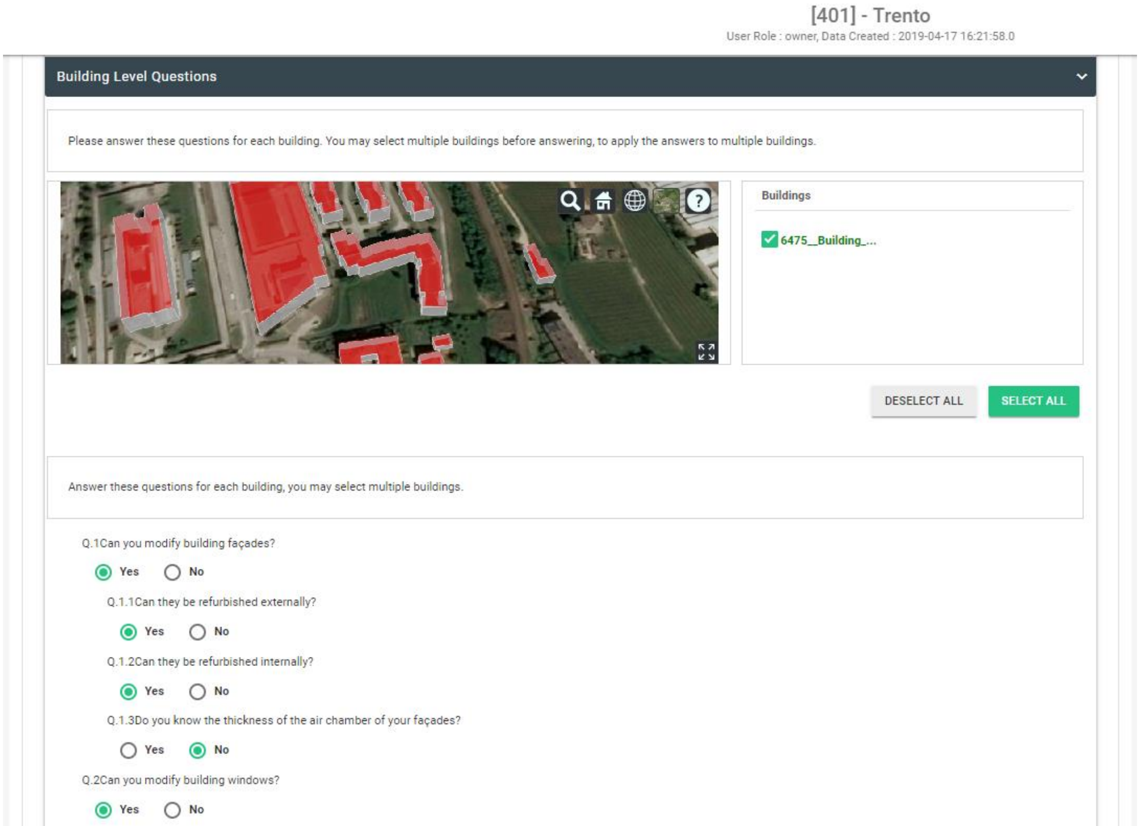


Figure 80: ECM questionnaire completed at building scale (1) – *San Bartolomeo* district, Trento (Italy)

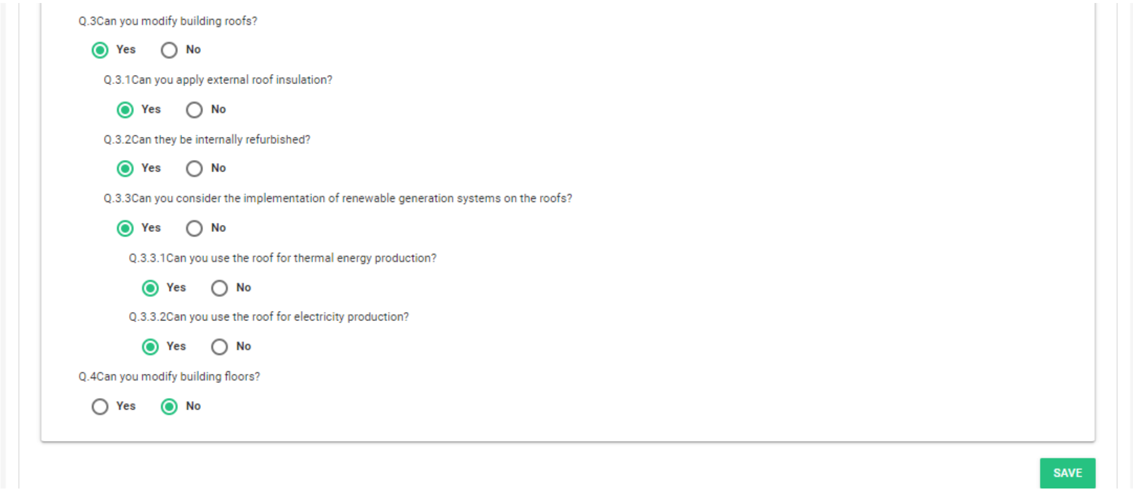


Figure 81: ECM questionnaire completed at building scale (2) – *San Bartolomeo* district, Trento (Italy)

9.1.2.6 Step 6: Check strategies

Following answers provided in the ECM questionnaire, the Check strategies shows the possible ECMs. They can be discarded and edited (cost information) (Figure 82). This step is PASSED.

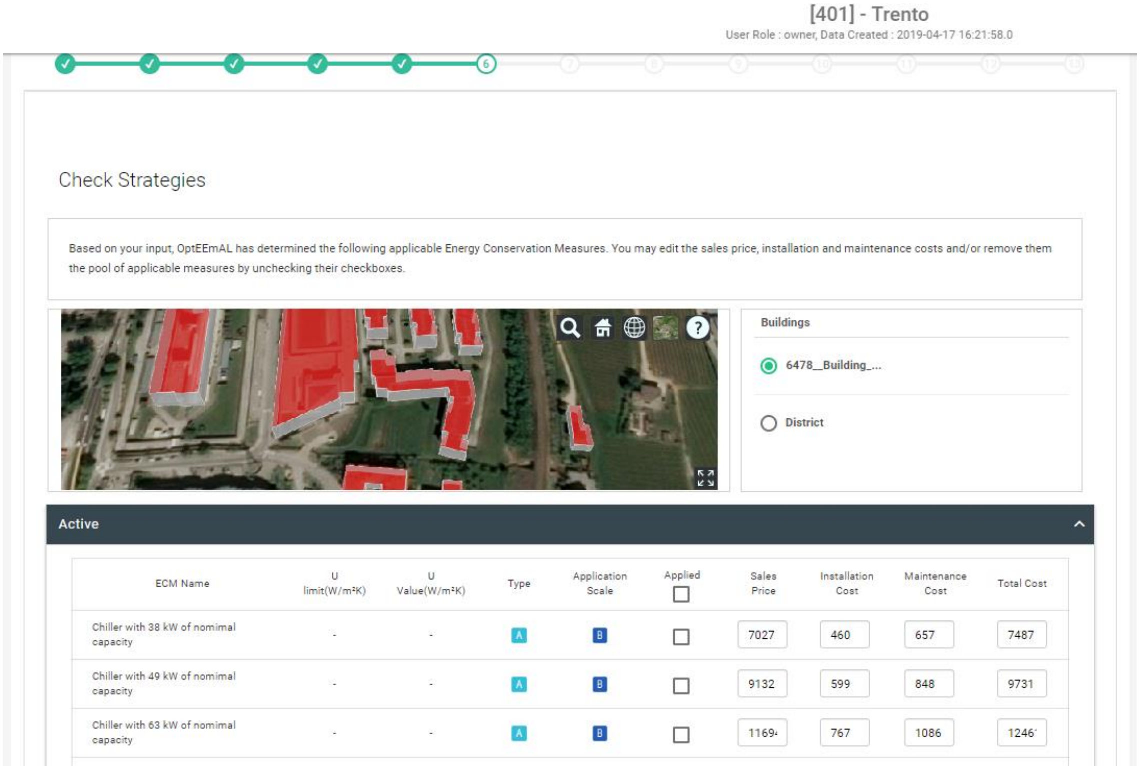


Figure 82: Discarded and edited ECM – *San Bartolomeo* district, Trento (Italy)

9.1.2.7 Step 7: Baseline results

Based on the input data provided by the users, the platform has calculated the different DPIs for the baseline. The DPIs are presented to the user (Figure 83). This step is PASSED.

[401] - Trento

User Role : owner, Data Created : 2019-04-17 16:21:58.0

Baseline Performance

Energy DPIs

Dpi Name	Baseline Value
Energy demand	189.62 kWh/m².year
Energy demand HEATING	87.25 kWh/m².year
Energy demand COOLING	102.37 kWh/m².year
Final energy consumption	158.97 kWh/m².year
Final energy consumption (thermal)	56.60 kWh/m².year
Final energy consumption (thermal - gas)	56.60 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)	102.37 kWh/m².year
Net fossil energy consumed	0.00 kWh/m²
Energy demand covered by renewable sources	0.00 %
Energy use from District Heating	55.00 kWh/m².year
Energy use from Biomass	0.00 kWh/m².year
Energy use from PV	0.00 kWh/m².year
Energy use from Solar Thermal	0.00 kWh/m².year

Figure 83: Baseline DPIs – *San Bartolomeo* district, Trento (Italy)

9.1.2.8 Step 8 – Targets and Boundaries

After the selection of the ECMs, the user continues the definition of the retrofitting project by entering the different target and boundary values[4] (Figure 84). This step is PASSED.

[4] These values are confidential and for that reason they have been blurred in the Figure 84.

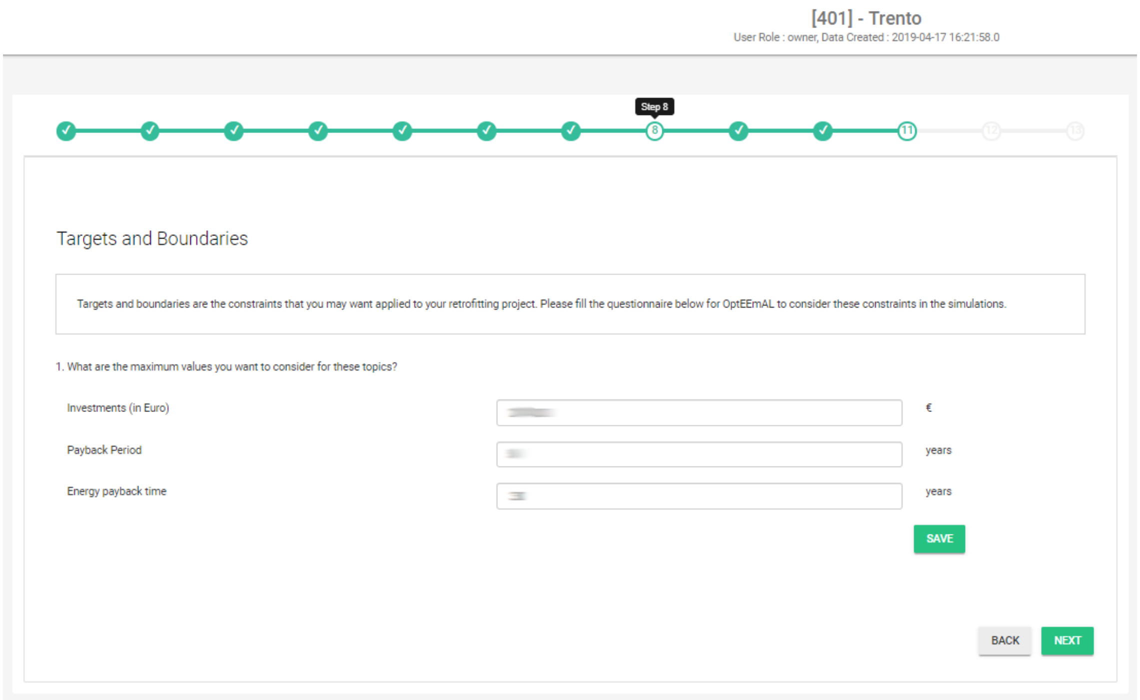


Figure 84: Targets and Boundaries – *San Bartolomeo* district, Trento (Italy)

9.1.2.9 Step 9 – Prioritization criteria

The following step consists in entering the prioritisation criteria related information (Figure 79). This step is PASSED.

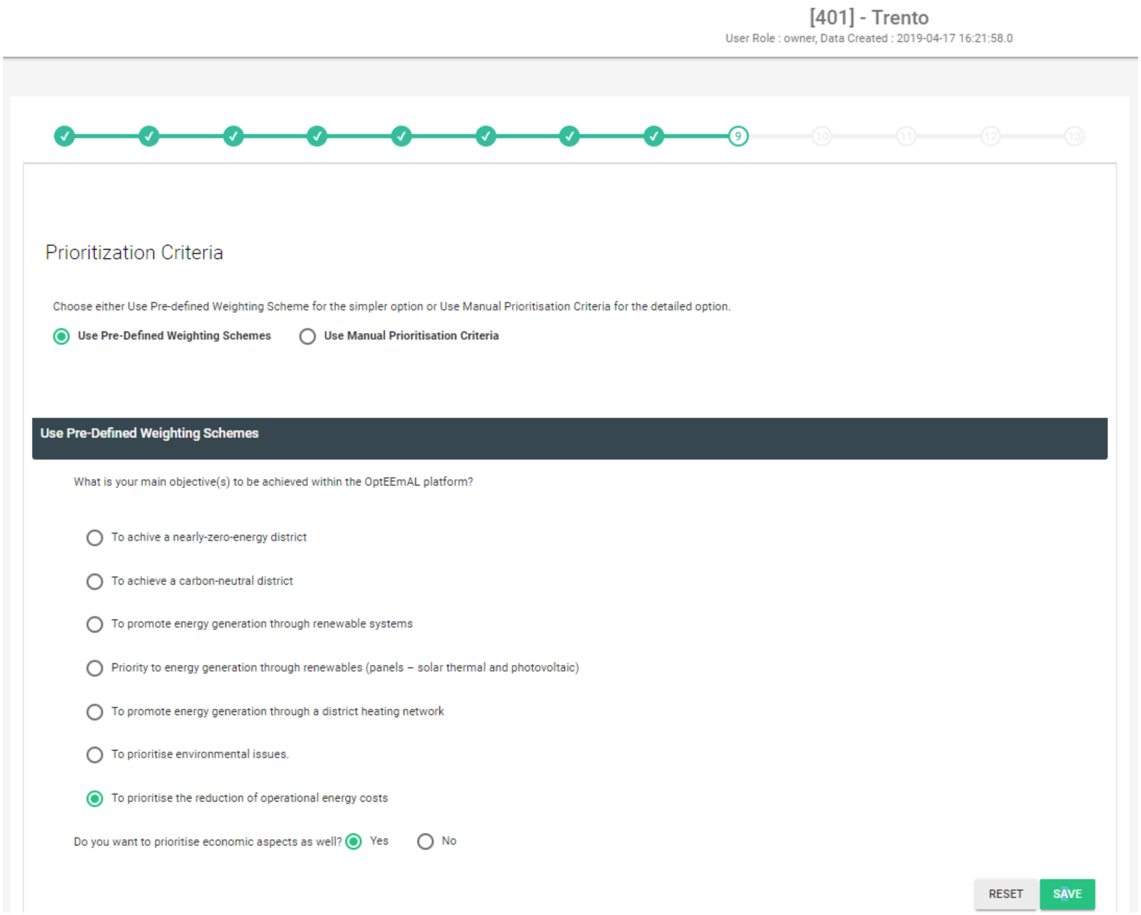
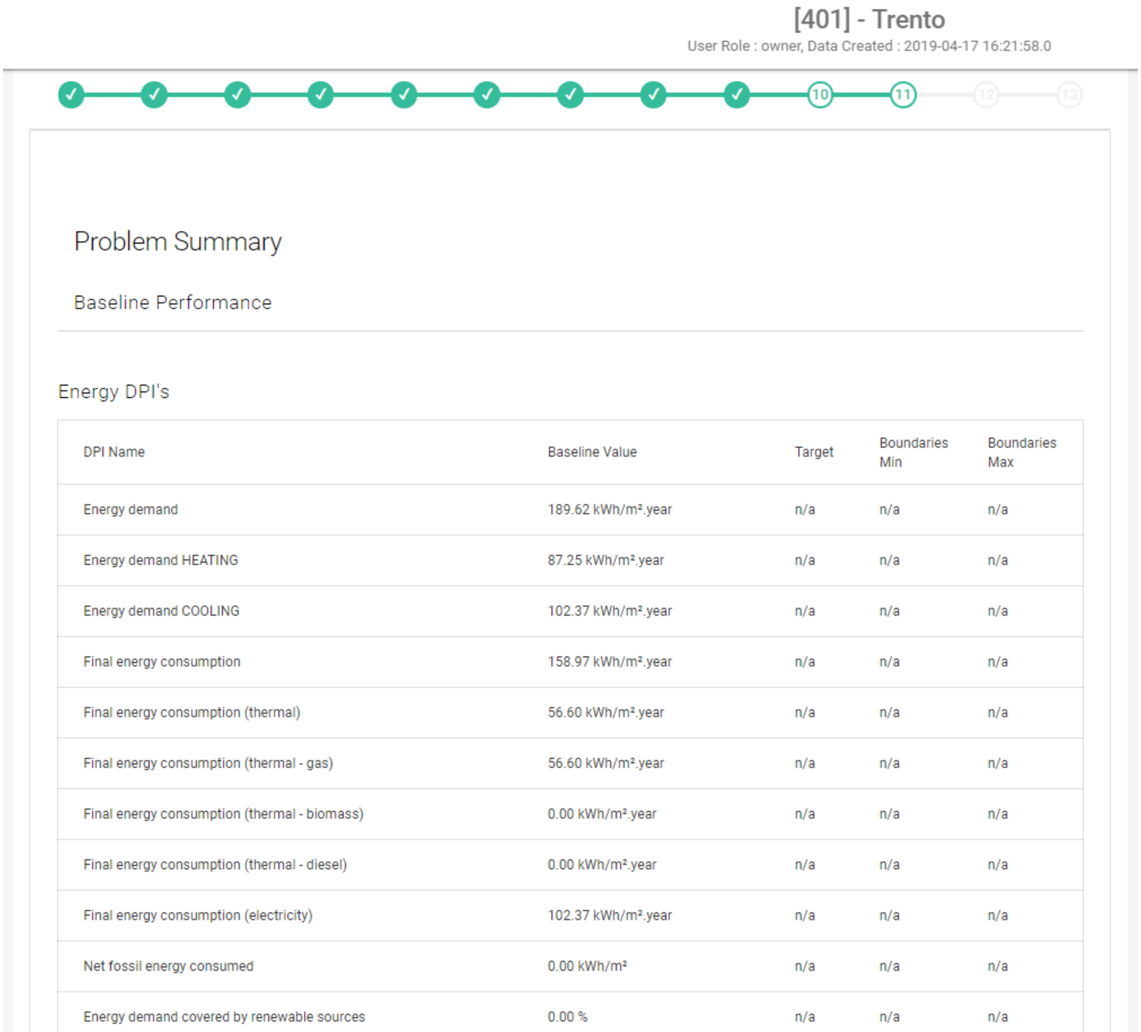


Figure 85: Prioritization criteria – *San Bartolomeo* district, Trento (Italy)

9.1.2.10 Step 10 – Problem summary

In the following step, the user is able to see the baseline DPIs (Figure 86) and the selected ECMs in the problem summary screen with active and control ECMs available for this project at district level (Figure 87) and passive and renewable ECMs available at building level (Figure 88). This step is PASSED.



[401] - Trento

User Role : owner, Data Created : 2019-04-17 16:21:58.0

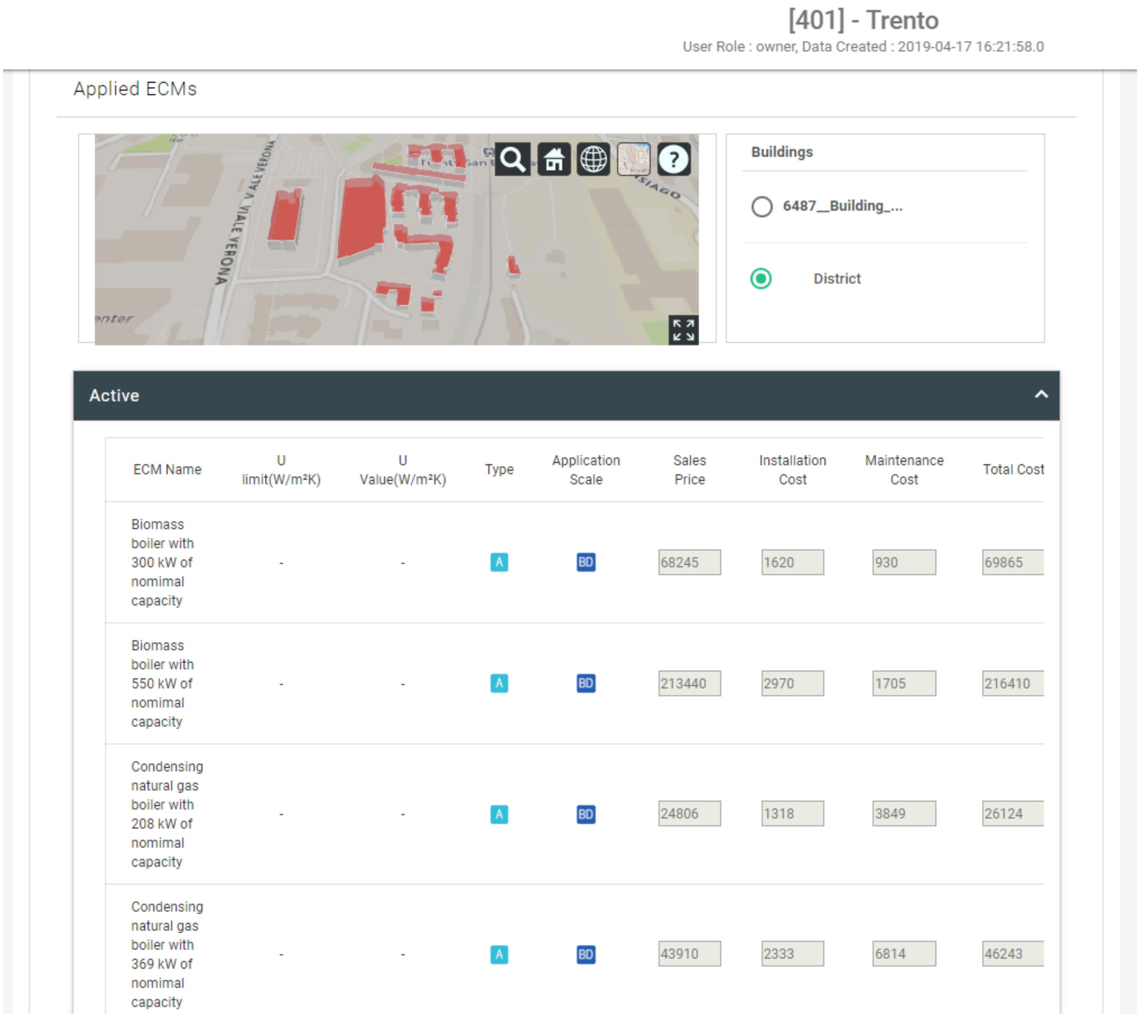
Problem Summary

Baseline Performance

Energy DPI's

DPI Name	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	189.62 kWh/m².year	n/a	n/a	n/a
Energy demand HEATING	87.25 kWh/m².year	n/a	n/a	n/a
Energy demand COOLING	102.37 kWh/m².year	n/a	n/a	n/a
Final energy consumption	158.97 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal)	56.60 kWh/m².year	n/a	n/a	n/a
Final energy consumption (thermal - gas)	56.60 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)	102.37 kWh/m².year	n/a	n/a	n/a
Net fossil energy consumed	0.00 kWh/m²	n/a	n/a	n/a
Energy demand covered by renewable sources	0.00 %	n/a	n/a	n/a

Figure 86: Problem summary (baseline DPIs) – *San Bartolomeo* district, Trento (Italy)



ECM Name	U limit(W/m²K)	U Value(W/m²K)	Type	Application Scale	Sales Price	Installation Cost	Maintenance Cost	Total Cost
Biomass boiler with 300 kW of nominal capacity	-	-	A	BD	68245	1620	930	69865
Biomass boiler with 550 kW of nominal capacity	-	-	A	BD	213440	2970	1705	216410
Condensing natural gas boiler with 208 kW of nominal capacity	-	-	A	BD	24806	1318	3849	26124
Condensing natural gas boiler with 369 kW of nominal capacity	-	-	A	BD	43910	2333	6814	46243

Figure 87: Problem summary (Applied ECMs for the district) – *San Bartolomeo* district, Trento (Italy)

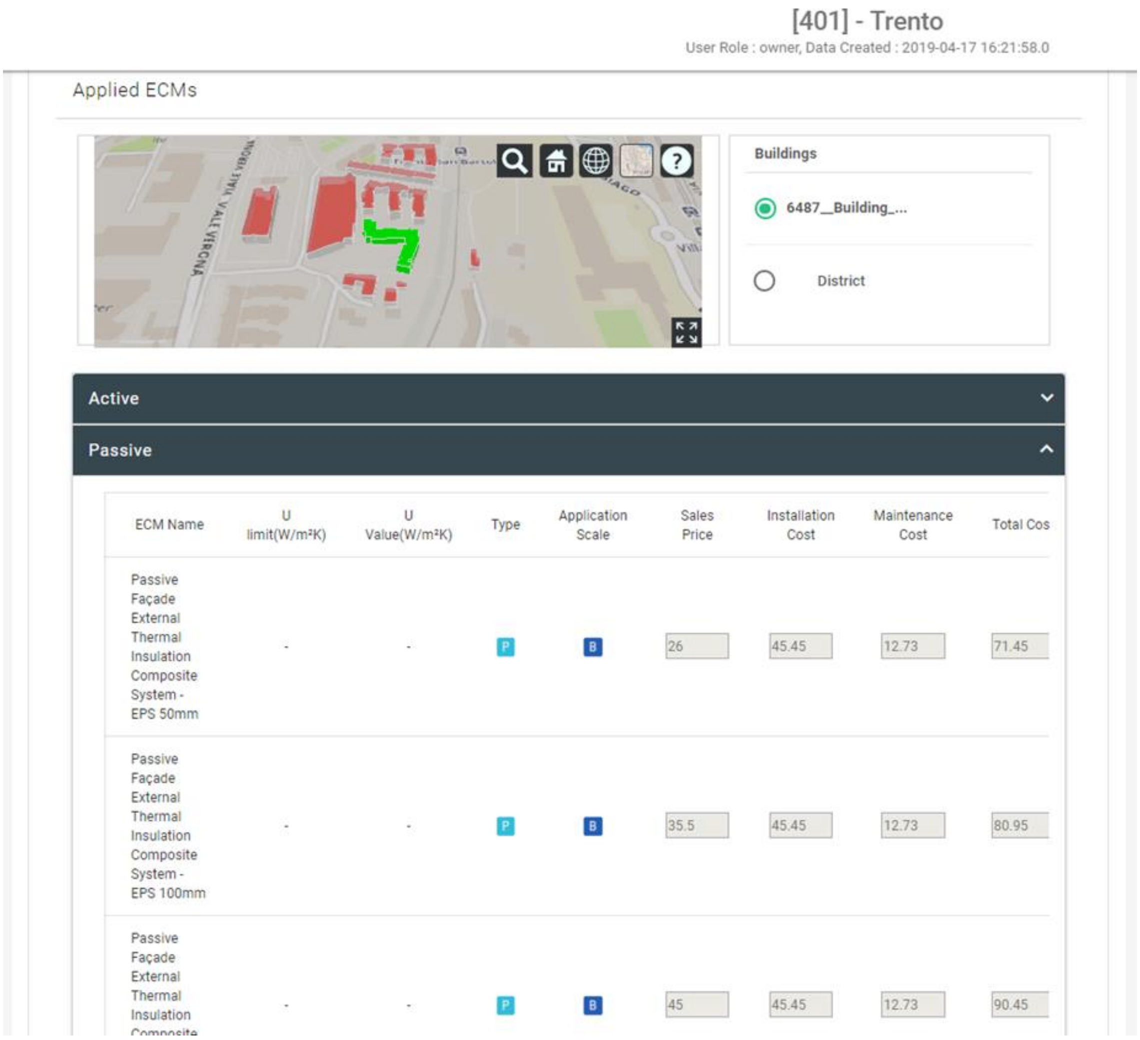


Figure 88: Problem summary (Applied ECMs for the building) – San Bartolomeo district, Trento (Italy)

9.1.2.11 Step 11 – Optimisation progress

After having launched the optimisation process at the end of the previous step, the user can track the status of the optimisation process using the Optimisation progress screen (Figure 89). This step is PASSED.

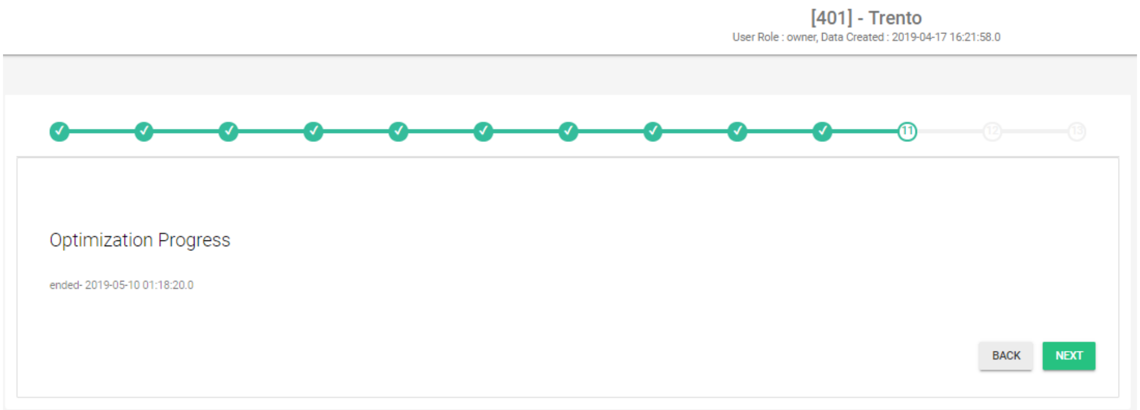


Figure 89: Optimisation progress – *San Bartolomeo* district, Trento (Italy)

9.1.2.12 Step 12 – Select Optimal Scenario

The scenario selected through the optimisation process is presented in the Pareto Front (Figure 90). The user can check the different DPI values (and compare with the baseline) (Figure 91) and the associated applied ECMs (Figure 92). This step is PASSED.

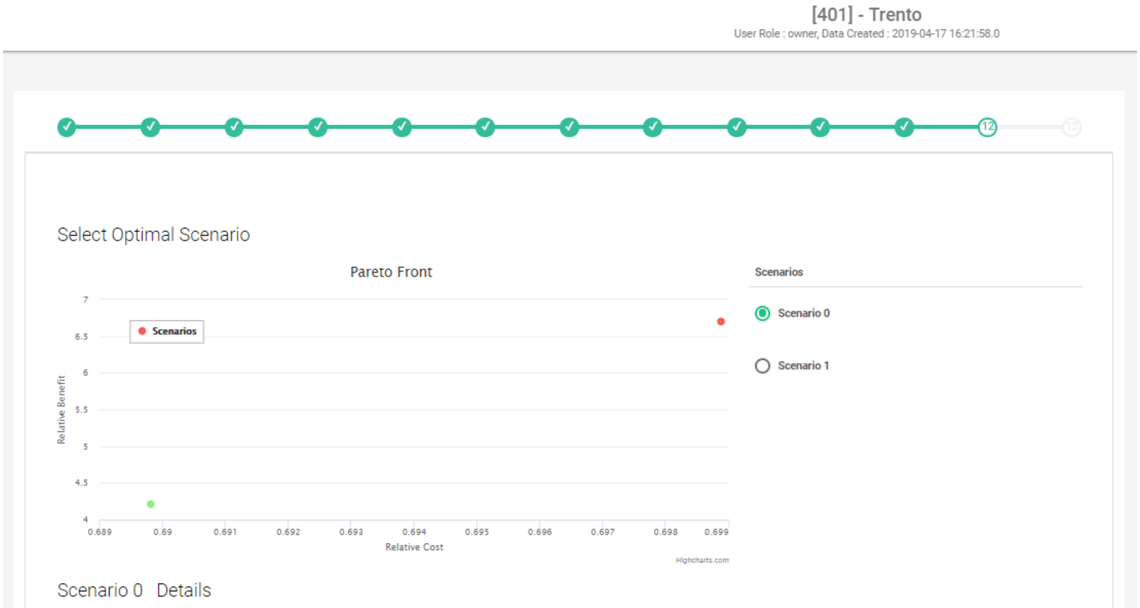


Figure 90: Pareto Front – *San Bartolomeo* district, Trento (Italy)

[401] - Trento

User Role : owner, Data Created : 2019-04-17 16:21:58.0

Scenario 0 Details

DPI Results

Comfort DPIs

Name	Scenario 0	Baseline Value	Target	Boundaries Min	Boundaries Max
Local thermal comfort	0.00 Level	0.00 Level	n/a	n/a	n/a

Economic DPIs

Name	Scenario 0	Baseline Value	Target	Boundaries Min	Boundaries Max
Operational energy cost	21.51 €/m2.year	27.50 €/m2.year	n/a	n/a	n/a
Operational energy cost - gas	0.00 €/m2.year	5.38 €/m2.year	n/a	n/a	n/a
Operational energy cost - biomass	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - diesel	0.00 €/m2.year	0.00 €/m2.year	n/a	n/a	n/a
Operational energy cost - electricity	21.51 €/m2.year	22.12 €/m2.year	n/a	n/a	n/a
Investments (in Euro/m2)	116.37 €/m2	n/a €/m2	n/a	n/a	n/a
Investments (in Euro)	656777.92 €	n/a €	n/a	2000000	n/a
Life cycle cost	4670059.35 €	4872704.29 €	n/a	n/a	n/a
Return on investment	-444.22 %	n/a %	n/a	n/a	n/a
Payback Period	100.00 years	n/a years	n/a	50	n/a

Energy DPIs

Name	Scenario 0	Baseline Value	Target	Boundaries Min	Boundaries Max
Energy demand	170.02 kWh/m2.year	189.62 kWh/m2.year	n/a	n/a	n/a
Energy demand HEATING	67.65 kWh/m2.year	87.25 kWh/m2.year	n/a	n/a	n/a
Energy demand COOLING	102.37 kWh/m2.year	102.37 kWh/m2.year	n/a	n/a	n/a
Final energy consumption	125.85 kWh/m2.year	158.97 kWh/m2.year	n/a	n/a	n/a

Figure 91: Baseline and scenario DPIs – *San Bartolomeo* district, Trento (Italy)

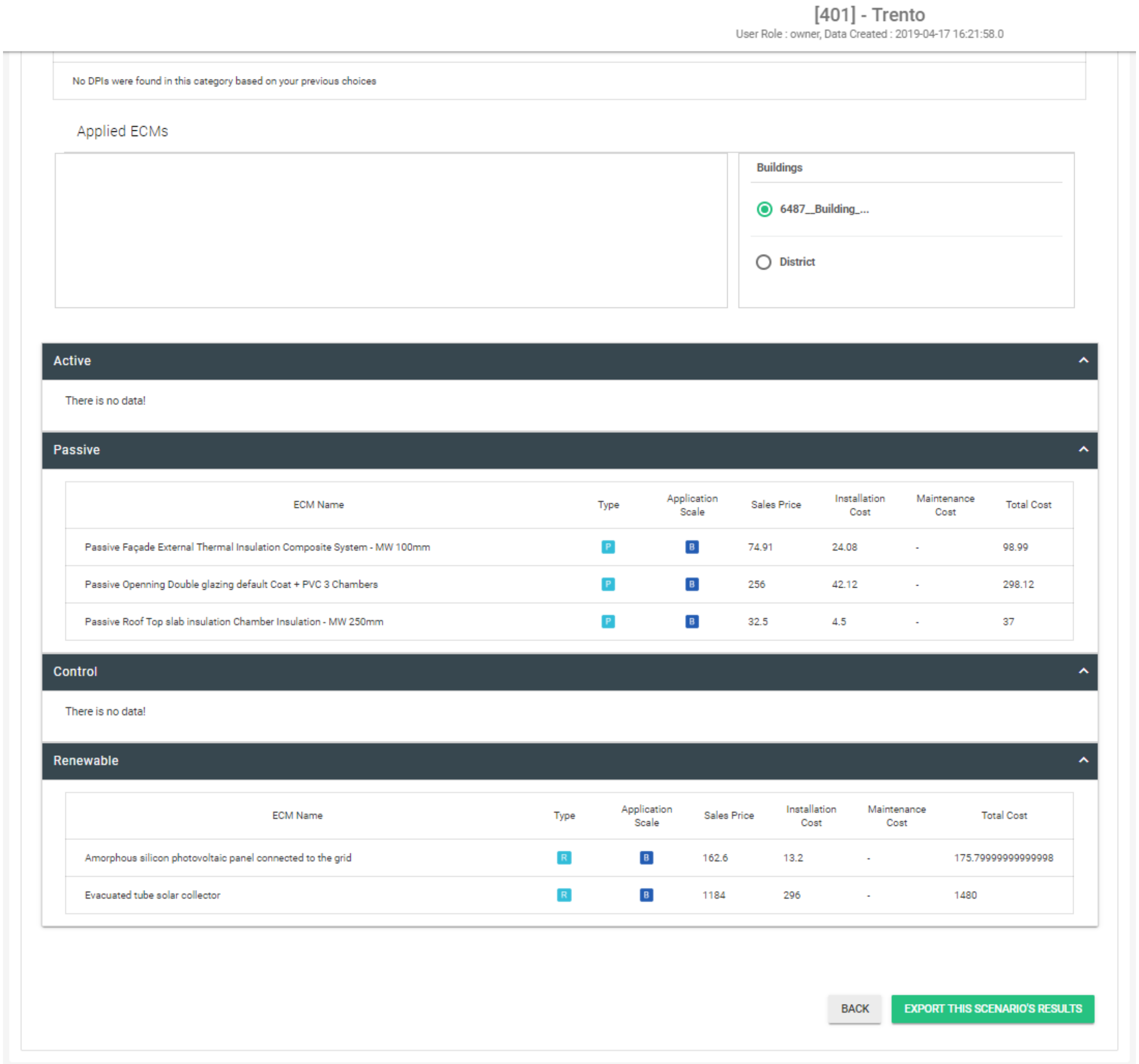


Figure 92: Applied ECMs – *San Bartolomeo* district, Trento (Italy)

9.1.2.13 Step 13 – Export

Once the best scenario has been selected, the user is able to export all the useful information from the platform in the form of Excel, xml, IFC and CityGML files (Figure 93). For instance, the user can access the detailed results provided by the platform through the different excel files (Figure 94). This step is PASSED.

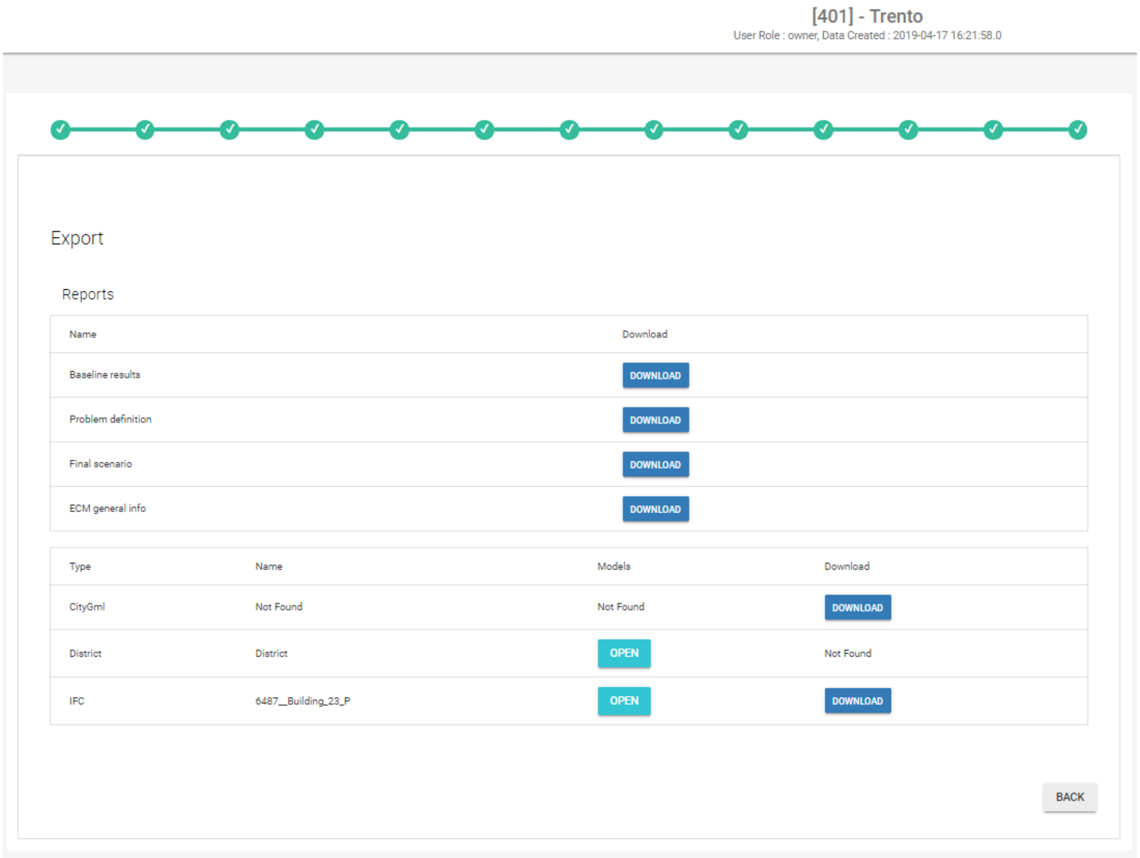
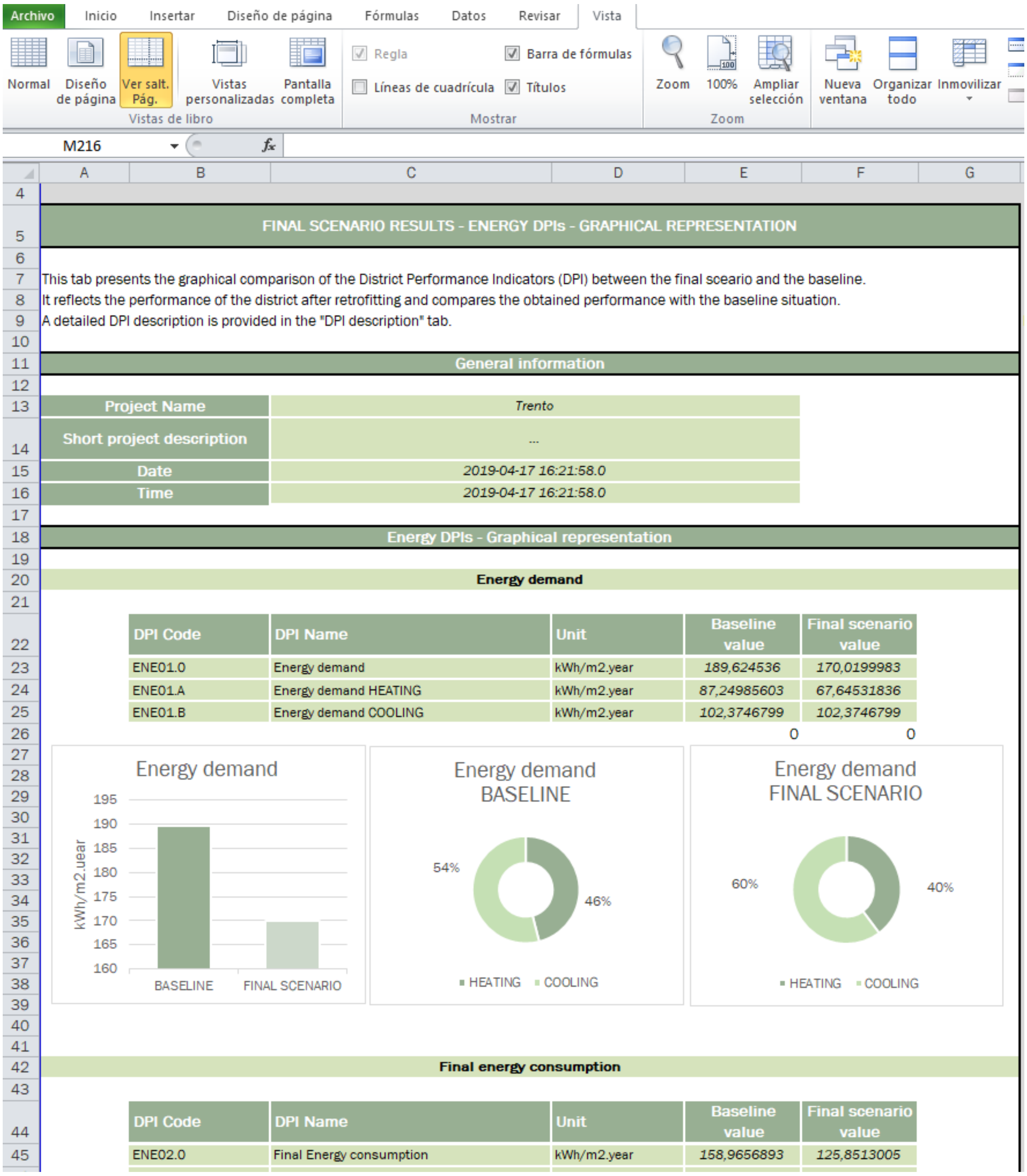


Figure 93: Information to be exported – *San Bartolomeo* district, Trento (Italy)


FINAL SCENARIO RESULTS - ENERGY DPIs - GRAPHICAL REPRESENTATION

This tab presents the graphical comparison of the District Performance Indicators (DPI) between the final seario and the baseline.
It reflects the performance of the district after retrofitting and compares the obtained performance with the baseline situation.
A detailed DPI description is provided in the "DPI description" tab.

General information

Project Name	Trento
Short project description	...
Date	2019-04-17 16:21:58.0
Time	2019-04-17 16:21:58.0

Energy DPIs - Graphical representation

Energy demand

DPI Code	DPI Name	Unit	Baseline value	Final scenario value
ENE01.0	Energy demand	kWh/m2.year	189,624536	170,0199983
ENE01.A	Energy demand HEATING	kWh/m2.year	87,24985603	67,64531836
ENE01.B	Energy demand COOLING	kWh/m2.year	102,3746799	102,3746799
			0	0

Final energy consumption

DPI Code	DPI Name	Unit	Baseline value	Final scenario value
ENE02.0	Final Energy consumption	kWh/m2.year	158,9656893	125,8513005

Figure 94: Exported Excel file – San Bartolomeo district, Trento (Italy)