D6.1: Established Baseline and DST for each FC

+CityxChange | Work Package 6, Task 6.1

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Authors	Nick Purshouse (IES RD) Olivier Neu (IES RD) Susan Pierce (IESRD)
Contributors	Liviu Stanciu (MAI), Milos Prokysek (MP), Andres Ernesto Bäcker (SB), Eftima Petkova (SMO), Siim Meeliste (VÕRU), Ina Karova (EAP).

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List of Acronyms

3D	3 Dimensional
API	Application Programming Interface
DST	Decisions Support Tool
DA	Demonstration Area
DD	Demonstration District
EV	Electric Vehicle
iCD	Intelligent Community Design (IES software)
IESVE	Integrated Environment Solutions Virtual Environment (IES Software)
iSCAN	Intelligent Systems Control and Analysis (IES software)
IESRD	Integrated Environmental Solutions Research and Development
iVN	Intelligent Virtual Network (IES software)
KPI	Key Performance Indicator
PEB	Positive Energy Block

Executive Summary

This document represents the work completed as part of Task 6.1 'Creating the Integrated Baseline Model for the Follower Cities', and as such the task will apply the Decision Support Tool (DST) developed in WP1 (D1.4: Demonstration of the +CityxChange Integrated Modelling Platform) to the Follower Cities.

The main area of demonstration is concerned with creating the baseline for the current energy and socio economic situation in the Follower Cities Demonstration Districts, Areas and potential PEB buildings. From this baseline, future potential scenarios can now be modelled to begin to guide the cities on the potential of achieving their PEBs and the most suitable approaches to creating a Bold City Vision.

To achieve an effective baseline, data was first gathered concerning the Follower Cities and their Demonstration Districts and potential PEBs. This data was imported into the DST and mapped to the building types and construction categories contained within it. Fuel types, carbon emissions of fuel and tariffs were also set and the baseline for energy demand in the cities were conducted. For the buildings in the potential PEB area, a more detailed energy baseline was formed by accessing certain parameters within IESVE software to increase the accuracy of the models prior to simulation.

Where complete building and energy usage data was available, it was possible to achieve the highly accurate results in terms of the simulations when compared to real life performance. For example, for the potential PEBs in Alba Iulia, Smolyan and Voru, the difference between the simulated baselines and actual energy consumption of the buildings was less than 4%, and in some cases less than 1%. However, a key lesson learned for the baseline simulations was regarding the use of assumed data and its validation. To ensure accuracy for the energy simulations, particularly of potential PEB buildings, it is important that assumptions are validated as much as possible. Efforts were made to reduce the amount of data collection required from the Follower Cities by using already available GIS data, deriving building data from national statistics and agreeing assumptions with cities. However, there were instances where hours of operations or heating set points for buildings were assumed, resulting in unacceptable variances (+-10% compared to actual energy usage) in the simulation results.

In terms of the energy supply baseline, where possible this was completed using a map of the electricity network within the potential PEB which showed the location of substations which was then replicated in the DST.

For the socio economic baseline, where possible, census data was available from each city at the lowest boundary level and added to the DST. It should be noted however, that as the lowest level of data available was much larger than the PEB boundaries, an analysis of the socio economic impacts of PEB creation will be difficult to achieve.

Although the data to baseline mobility was not available, it was confirmed by all cities that, currently, EV charging points are not installed in the Demonstration Districts which means this aspect is baselined at zero.

Following all baselines being completed, proposed energy interventions were produced as part of Task 6.4 Feasibility Studies, and these were reviewed to check how the DST could model these. Overall, it is positive that nearly all interventions can be modelled with little outside resources required.

In order to allow different users to view results and analyse potential future plans, online dashboards were set up and access can be given according to the user's needs. It needs to be agreed with each Follower City what content should be made public to ensure maximum non-technical stakeholders can be reached.

All Follower Cities have validated the DST results for their respective sites and have undergone initial training to be able to use the online Dashboards for further analysis and engagement amongst stakeholders. In terms of feedback to evaluate the DST from the cities perspective, whilst no formal process has taken place to gather this, anecdotal feedback has been positive, with cities eager to use the software and learn more about how they can use it to help with their future decarbonisation plans.

The next steps regarding the Follower City DSTs have been identified as follows:

- Further engagement and training to the relevant Follower City staff by IES RD is being planned and conducted via support for IES RD and the Online PEB Design Workflow Tool (see D1.4: Demonstration of the +CityxChange Integrated Modelling Platform and Section 2.2.4 in this document for more information). This will enable relevant people in the Follower Cities to run future energy simulations for themselves and to analyse the results.

- T6.2 BCVs - now the baselines are set, the DST for each Follower City can be used to help the city create its Bold City Vision. The DST can be used to replicate PEBs across the areas modelled and also show decarbonisation over time. As well as this, the impact of different measures on socio economic indicators can be modelled.

1. Introduction

1.1 Objectives

This document represents the work completed as part of Task 6.1 'Creating the Integrated Baseline Model for the Follower Cities', and as such the task will apply the Decision Support Tool (DST) developed in WP1 (D1.4: Demonstration of the +CityxChange Integrated Modeling Platform) to the Follower Cities. In the DoA, the task is described as follows:

"The task will aim to establish a baseline for the Follower Cities through the Integrated Modelling and Decision Support Tool. this will include: (i) the energy baseline, i.e. the primary energy end use of the various buildings and assets (renewables and storage) that exist in the city, (ii) the mobility baseline with respect to traffic patterns, congestion and movement as well as any e-vehicle charging points and (iii) the citizen baseline with respect to socio-economics, health, population, spatial, demographics etc. Upon these baselines, scenarios for the FCs' Bold City Vision 2050 will be developed and modelled. Based upon existing municipal databases, the DST and other tools in the ICT ecosystem will serve as a playground for simulating urban interventions, estimating their impacts, optimising scenarios, etc. Supported by IESRD, each FC will define a Smart City Baseline upon which scenarios for the Bold Smart City Vision 2050 will be developed and modelled in T6.2. The baseline will be used for all other tasks in the Follower Cities. Finally, training will be provided to FC staff with respect to the use of the DST so that it can be used beyond the +CityxChange project and its requirements."

It should be noted that whilst the energy and citizen baselines were achieved in this task, the mobility baseline as described was not. This was due to several factors. Firstly, as traffic movement, patterns, and congestion were not required for the lighthouse cities, this aspect was not developed within the DST and at the time of developing the tool for the Follower Cities resource was not available to make this addition. Secondly, in discussions with the Follower Cities, improved mobility as part of the Demonstration Areas was not shown as a priority and it was decided that resources should be focused elsewhere. That said, the DST is capable of showing the potential future locations of EV chargers and also of simulating the likely electricity demand from these as well as the constraints this may place on the network and the potential carbon reductions from a shift to cleaner vehicles.

1.2 Relationship with other tasks in the project

The inputs from other tasks into this task are as follows:

- T1.4: Creation of the +CityxChange Integrated Design and Decision Support Tool (DST) . This is the task that was the main input for the Follower Cities DST's. It brings together separate pieces of software into one integrated Tool to be used by the cities.

- T4.1 Limerick DST - The initial prototype for the DST was tested and validated in this task. Through the testing and feedback from Limerick, improvements and updates were completed so that the DST can be used in other cities.

- T5.1 Trondheim DST - This task furthered the work done for Limerick applying the DST to Trondheim. Updates to the software as part of the roll out to Trondheim, as well as the training and explanation of its functions also gave the IES RD team valuable feedback and learning to ensure a good roll out for the Follower Cities.

- T6.4 Feasibility Studies - The task will investigate the potential for energy reduction in the different Demonstration Areas and potential PEBs, and the actions which need to occur to represent a Energy Positive Block/District.. As an input, a large amount of energy related data was made available from the feasibility studies that was required for this task. As well as this, the feasibility studies confirmed the Demonstration Area and potential PEB buildings so that this task could ensure it was focussing on the same areas and also to confirm which energy related interventions could be modelled in the DST.

The outputs from this task into other tasks are as follows:

- T6.4 Feasibility Studies - Some of the data collected by cities for T6.1 is also used for T6.4.

- T6.2 BCVs - Once the baseline is set, the DST for each Follower City can be used to help the city create its Bold City Vision. The DST can be used to replicate PEBs across the areas modelled and also show decarbonisation over time. As well as this, the impact of different measures on socio economic indicators can be modelled.

2. Overview of the Decision Support Tool

This Chapter gives an explanation of the functions of the DST and the software which it is made up of. The subsections are a summarised version taken from the confidential D1.4: Demonstration of the +CityxChange Integrated Modelling Platform and in part from D4.1: Limerick DST (Integrated Modelling and Decision Support Tool) including training manuals/videos; or D5.2: +Trondheim DST including training manuals/videos.

2.2 Overview of Functions of the DST

The diagram below represents an overview of each function of the DST (termed here as 'Integrated PEB Decision Support Tool'), and is then followed by an explanation of each function, which partner it belongs to and how it was developed:

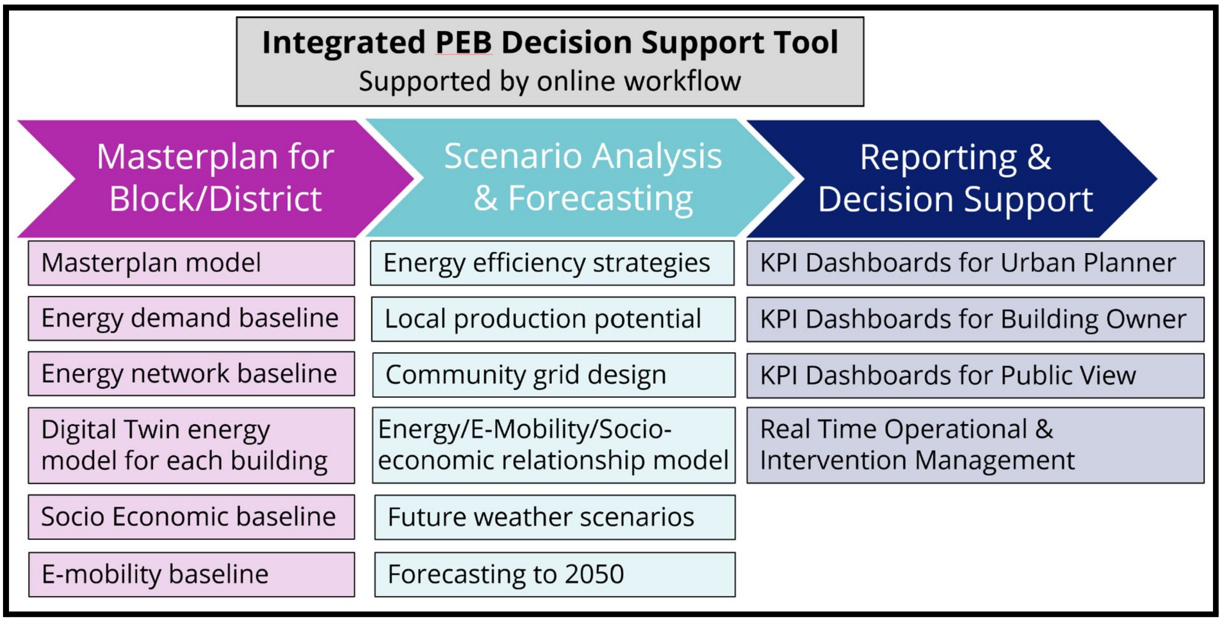


Figure 1: Overview of the DST functions (taken from D1.4)

2.2.1 Masterplan for Block/District

This module allows for a 3D master plan of the city/district/block to be created. Following some simple data collection and inputs, a quick but accurate energy demand baseline for the buildings in the city or district area can be simulated. However, greater accuracy for energy demand per building may be required in order to inform decisions at a PEB level and so a calibrated Digital Twin of the PEB can be produced. This is done by using metered energy data and aligning this with detailed building models created in IES VE to give a virtual representation of the building and its energy use which resembles the real world as closely as possible. This can still be viewed in the same way as the rest of the model. As well as this, an energy supply baseline can be modelled and viewed to show the current energy supply network for the PEB area.

The socio economic baseline of the PEB is formed by firstly understanding the available data from the most recent and relevant census and mapping this to the PEB/district areas. Other datasets that may not be available in the census such as crime or health should be obtained by the local authority where possible. Air pollution readings may also be available from air pollution sensors positioned around the city. The e-mobility baseline relates to showing the current status of e-charging options in the area, their charging capacity and usage.

2.2.2 Scenario Analysis and Forecasting

Using the baselines previously set, the software modules can next be used to simulate numerous scenarios over time so that a forecast for the next 5, 10, 20, etc. years can be analysed out to 2050 and a roadmap to creating a PEB can be made whilst taking into account potential changes and impacts on socio-economic aspects. The software is able to model potential energy efficiency strategies, as well as potential renewable energy solutions that could further contribute to the local energy supply. By adding new local production and analysing how this can be used within the PEB, a new community grid can be designed.

2.2.3 Reporting & Decision Support

This aspect of the PEB Design Tool allows the local municipality end users to view the results of their required scenarios to 2050 in a 3D map view overlaid with selected visual KPIs. These views are known as 'dashboards'. Three key stakeholder groups that would use the tool were identified as: Urban Planners, Building Owners and the Public, and so different dashboards were set up for these types of users. The Dashboards are entirely customisable in terms of the KPIs being viewed and can be changed depending on the users requirements. A view of each cities dashboard is given in the respective 'Reporting and Decision Support (Dashboard Views)' section for each city.

2.2.4 Online PEB Design Workflow

This is a freely available online tool that guides the user through a step by step process of using the different software modules to design a PEB for their chosen area. Where the software module is online, there are also direct links between the guidance and software so that the user can click on a step and be taken directly into the relevant part of the software. The online workflow can be used for training purposes and also as a way to ensure the different software can be used seamlessly together for the purposes of PEB design, creation and replication. The tool can be found at: https://cdp.iesve.com/calibr/1/13 with access granted on request to project partners. The full documentation for this tool can be found as part of D1.4: Demonstration of the +CityxChange Integrated Modelling Platform

3. Development, Modelling Approach and Launch for Follower Cities

3.1 Approach and Timeline of DST Development for the Follower Cities

The DST was developed iteratively as the project has progressed through ongoing engagement and feedback from Limerick and Trondheim Lighthouse Cities. An 'Agile Software Development' methodology was followed which takes a more collaborative and iterative discipline whereby software is specified and developed incrementally before being tested by the end users for feedback. The iterative, agile approach in terms of software design, initial implementation and refinement can be be seen in the rollout of the DST in the +CityxChange project as demonstrated below:

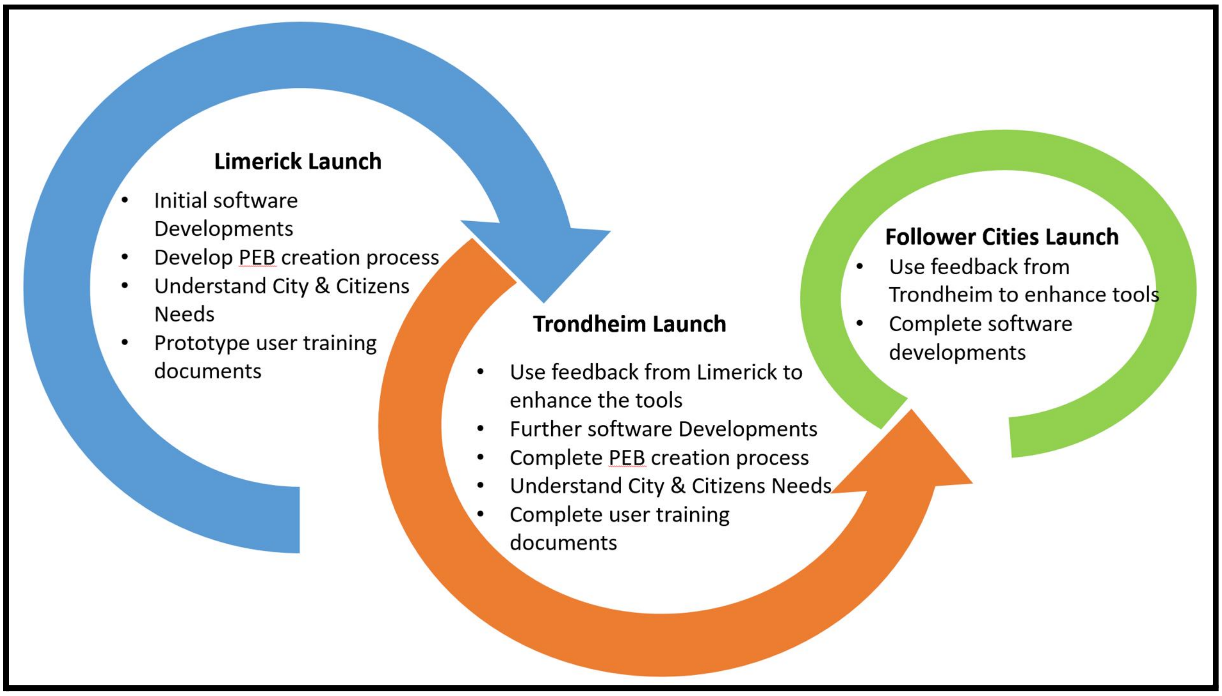


Figure 2: Rollout and iteration of the DST (taken from D1.4)

A high level timeline is shown below to accompany the above diagram and to demonstrate how the DST and the processes associated with it have been iteratively developed starting with Limerick. In the early stages of the DST development, it can be seen that all Follower Cities were engaged in order to explain the DST functions and begin the process of data collection. After there was a period where the focus need to be on development and completion of the DST for the lighthouse cities of Limerick and Trondheim, before then moving onto the Follower Cities. The launch for Limerick occurred in May 2019, the launch in Trondheim January 2021. The launch across all Follower Cities occurred throughout April/May 2021.The delay from the launch of the DST to the completion of the deliverable has been mainly due to resource constraints of IES RD in having to engage with all seven cities at the same time whilst they each complete their respective baselines and forward looking decarbonisation scenarios to 2050.

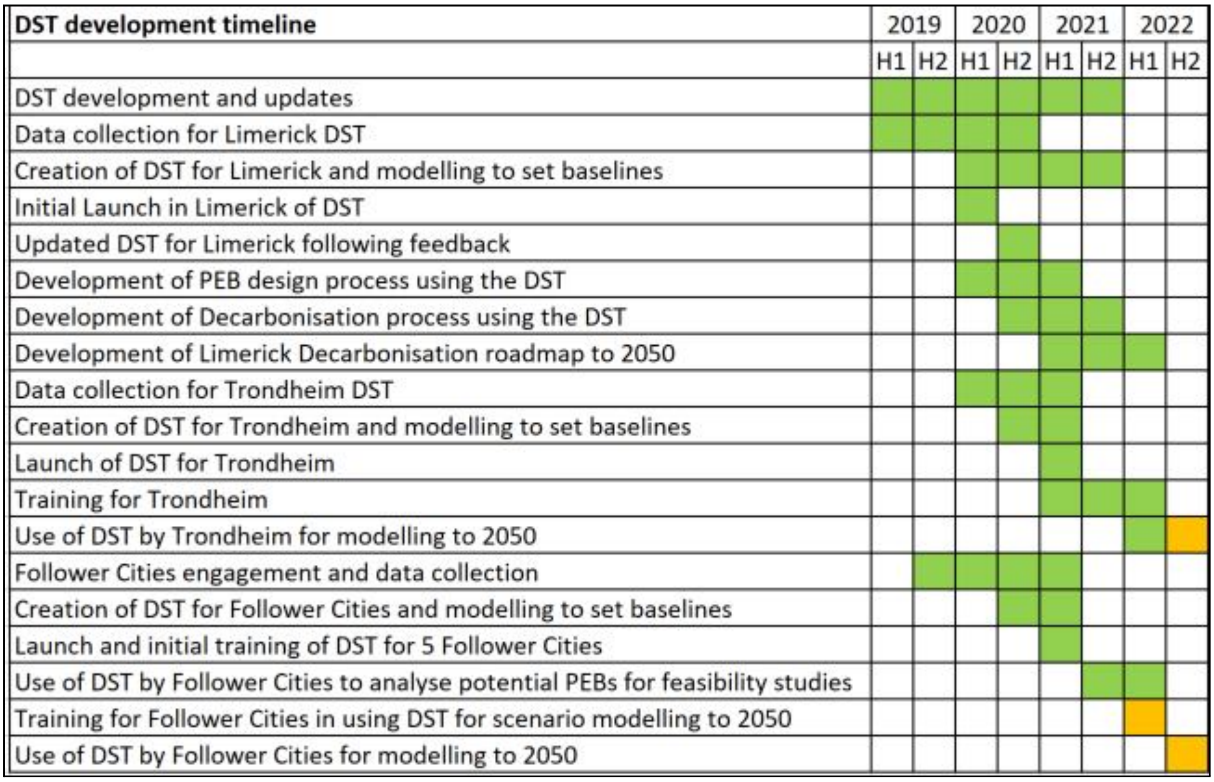


Figure 3 DST development, launch and use timeline

3.2 Modelling Approach and Data Collection

The following sections explain at a summary level the modelling process that was taken for all of the Follower Cities baseline modelling. The key aim for the activities of baseline modelling for the Following Cities was to use the learnings from Lighthouse City modelling to develop a more straightforward and less resource intensive method for data collection and data upload than was used for the Lighthouse Cities.

It should be noted that due to the setup of the project whereby Follower Cities PEBs were confirmed as potential only, with further feasibility studies required, the modelling for Follower Cities occurred at three different levels:

1. A City model - with basic data obtained from OpenStreetMap (OSM). Although data at this level was imported, as it was not the focus of the project, and there were no further efforts to conduct a city energy baseline. Instead, this model exists in the DST for the Follower Cities to extend their replication studies across the city if required.

2. Demo District (DD) model - the area within the city model that surrounds the potential PEB buildings, This area has been simulated for energy and carbon emissions. In some cases, as there were multiple potential PEBs to be investigated, the area modelled and simulated is relatively large. Further details of the data used for the modelling are explained in Section 3.2.1.
3. Demo Area and potential PEB model - these buildings are to be investigated as part of the feasibility studies in T6.4 for their potential to become PEBs and have undergone a more detailed modelling process. Further details of the data used for the modelling are explained in Section 3.2.2.

The process followed for the Lighthouse and Follower Cities was explained in detail in D1.4 'Demonstration of the +CityxChange Integrated Modelling Platform', however below is a brief summary of the modelling efforts to conduct accurate baselines for the Demonstration Districts and Areas/Potential PEBs.

3.2.1 Demonstration District Modelling

The baselining exercise aimed to model the Demonstration District defined by each Follower City at a minimum, whilst importing as wide to allow for further replication studies later in the project. For some cities, the demonstration districts were already well defined and relatively close together, whereas for others the area was much wider.

Firstly, the City model was created in the DST, specifically the IES iCD, through importing from OpenStreetMap (OSM). This differs from the Lighthouse Cities where more detailed GIS files were used due to (a) their availability and (b) the resources available to upload and adjust these files in order to correctly import them into the software.

While OSM provides the building footprints, more detailed information about the buildings must be collected by the relevant people in each city and assigned in the models. As the areas to be modelled for each Follower City were relatively large and contained a high number of buildings, the objective was to keep the process quick and simple. Statistics were obtained for each countries building stock in relation to the percentage breakdown of buildings characteristics as follows:

- Building construction year
- Building type
- Building height
- Building glazed area
- Building envelope U Values
- Building fuel types
- Building roof types

These attributes were assigned across the buildings in the demo districts, ensuring that the total frequency of occurrence of each parameter was close to the national target. For example, for Voru, national figures show that 75% of the building stock is residential, consisting of 26% single-family dwellings and 74% multi-family dwellings. The building type, construction year and fuel type were mapped across the buildings to achieve a breakdown similar to that reported in national statistics.

Data was also gathered on the storey height and glazed area of buildings of different types and ages in each city. Building heights and glazing ratios were then assigned based on this information. All data was supplied by the cities through the use of a 'building checklist' and regular calls/online meetings to track progress and answer queries.

As well as the building data, climate data for each location was obtained from International Weather Energy Calculations which enabled the relevant heating and cooling degree days to be applied to the buildings at each demonstration district[1].

3.2.2 Potential PEB Modelling

Within each Demonstration Area, the cities defined the collection of buildings to be investigated to become PEBs. The PEB buildings were also modelled and simulated within the city model using the IES iCD. However, as the PEB buildings required a more detailed analysis, the two-step simulation feature was used whereby the IES VE software was accessed for the PEB buildings. This allows for greater flexibility and detail in the information that can be assigned to the model during simulation, providing access to attributes such as setpoints, templates, internal gains and weather data to allow the internal systems modelled within the building to be correctly sized.

For each of the buildings to be included in a PEB, data was requested for the following categories in regards to building energy demand and supply:

- Fuel used for electricity and heating
- Building/site RES info
- Internal systems - HVAC type and details
- Lighting
- Equipment systems
- Zone/room set points
- Annual and monthly energy consumption meter readings and bills
- BMS data (if available/applicable)

In terms of accuracy of the PEB simulations using this approach, where actual energy consumption data has been received it is possible to compare the accuracy of the simulations to the real data. Where this approach has been used, and valid data received, it is the expert opinion of IES, that a value of plus or minus 10% for the simulation result against the actual energy consumption is acceptable as this is the value used for commercial clients also.

It should be noted that in a number of cases, cities were not able to provide the detailed information required for this approach, and in this case, the PEB areas were modelled in

[1] https://energyplus.net/weather/sources

the same way as the City approach above. In these cases, it is not possible to estimate the accuracy of the simulations due to the lack of data to compare them to.

As well as the building geometries and data for detailed characteristics, the following data sets were requested from the Follower Cities for their PEBs:

- Weather/Climate Data - As explained for the Demonstration Districts, the relevant climate data was applied for all buildings, however for the potential PEB buildings a further step was taken whereby Design Weather files from ASHRAE are accessed inside IES VE software to allow for the correct sizing of HVAC components in each building. This gives a more accurate energy simulation result.
- Electricity Network Map - each city was asked to provide an electricity network map for their PEB area, or to at least confirm that all of the buildings in the PEB were connected to the same sub station. This data will allow simulations for energy sharing/trading amongst the buildings to occur.
- Energy supply costs
- Socio Economic data - each city was asked to provide socio economic data for their PEB area in order to allow socio economic analysis to occur. The socio economic data requested at the lowest possible level available was:
    - Derelict/vacant buildings
    - Property values
    - Life expectancy
    - Premature death rate (under 75 yr old)
    - Crime rate
    - Disposable income
    - Job types for those employed
    - Employment rate (15-64 yr old)
    - Air quality sensor locations and if available, online access to data

Socio economic data was provided by each city from their latest census and local records. Unfortunately it was not possible with the time and resources available to conduct a full mobility baseline with respect to traffic patterns, congestion and movement. As regards to e-vehicle charging points, it was confirmed at all sites that no charging points existed.

All data was supplied by the cities through the use of a 'building checklist' and regular calls/online meetings to track progress and answer queries. The categories and data questions can be seen as an example in the Annex 'Building Checklist (example)'.

3.3 Follower City Demos and Training Sessions

A series of demo and training sessions on the DST Baselines developed for Follower Cities occurred starting April/May 2021. A first session took place on the 22nd of April 2021, in a joint manner for all the Follower Cities, in order to introduce the Follower Cities DST energy baseline. The agenda of this session was as follows:

- Overview of the DST
- Explanation of City/Demo Area/PEB model and baseline build

- Baseline Results and Visualisation for each city
- Discussion on future modelling of Follower City Smart City Interventions
- Plan individual training sessions on using the DST

Following on from this first session, individual sessions were organised with each Follower City, 27-28 May 2021, in order to discuss feedback and discuss specific questions. At this stage, it was considered that the Follower Cities had been trained in the baseline process and how they could use the online Decision Support Tool dashboards which had been set up for their city.

The next sessions to be conducted were regarding the process for setting up scenario modelling to 2050 and conducting the actual modelling so that each city could download the full DST software and also start to use it to understand how progress towards designing PEBs and further decarbonisation can best be achieved. Planning these sessions has taken some time due to firstly the need for Follower Cities to confirm their energy interventions to be modelled, secondly the need to complete the Roadmap to 2050 for Limerick and for Trondheim, and thirdly to update the process guidance and training manual to be in line with these experiences, and fourthly limited resource within IES RD to manage this workload. These final sessions are now planned to occur from end April to end June 2022.

4. DST Baseline for Alba Iulia

4.1 Introduction to the City, Demonstration District and potential PEBs

Alba Iulia Municipality is a medium-sized city in Romania with 74.000 inhabitants and an urban area 104km^2. As highlighted in the Grant Agreement the neighbourhood of Cetate was to be the main Demonstration Area, and where a DPEB was to be investigated. Details for all FCs PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC.

However, the area for the DPEB investigation was changed to two separate areas due to one of the aims in the project being to transfer renewable energy to and from buildings owned by the municipality. In order to make this possible, new areas outside of the original were sought. As well as this, the demonstration district area modelled for the baseline activities (including PEB modelling) was larger than originally anticipated due to ongoing discussions about a potential PEB on the other side of the city, and in order to provide as much potential for replication as possible. Details of any changes in the PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC. The area of the city eventually modelled was 12.4km2 and contained 2,850 buildings, as shown in the figure below.The 3D map images are taken from the Dashboard view for the Alba Iulia City model using the data imported from OSM and obtained from Alba Iulia Municipality.

Figure 4 The Alba Iulia City Area Modelled with potential PEBs highlighted

At the time of modelling, the city was considering two Demonstration Areas to be further analysed to see if they could become PEBs. Subsequent analysis as part of T6.4 has indicated that the PEB 2 shown in this document is likely to become the preferred PEB, with PEB 1 becoming the focus of replication activities.

The buildings included in the modelling for the potential PEBs for Alba Iulia are explained below, and shown in the respective figures.

4.1.1 Potential PEB 1 - Alba Iulia Municipality Buildings

This Demonstration Area (DA) for Alba Iulia requires further investigation to understand whether it has potential to become a PEB. Unfortunately, detailed geometry drawing and building characteristics were not available, and so the more accurate ' two step simulation' feature could not be used. Instead, the PEB was modelled in the same way as the rest of the wider city area (see Section 3 for more details).

The first PEB is situated in the central area. A number of five buildings will be envisaged in the Demonstration Area all belonging to the municipality. The size of the proposed PEB is of approximately 3 km^2, and the buildings are:

1. The Municipal Department of EU Programmes;
2. Former Social Assistance Dept. of Alba Iulia Municipality (ground+1st floor);
3. The Central Market;
4. The Municipality's HQ;
5. The Municipality`s Investments Department.

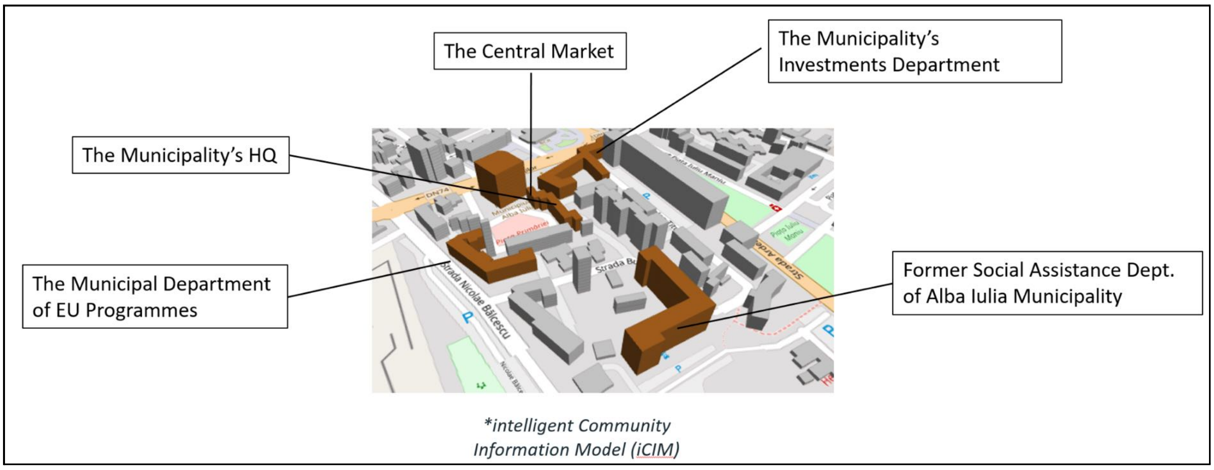


Figure 5 Potential PEB 1 Alba Iulia Municipality Buildings

4.1.2 Potential PEB 2 - Dorin Pavel Technical College

The second area to be investigated to potentially become a Positive Energy Block is also situated in the centre area of the municipality, approximately 1 km from the First PEB proposed. The size of the proposed PEB is approximately 2-3 km2. The list of the buildings:

1. The Dorin Pavel Technical College (HQ);

2. Post secondary school Henri Coandă;
3. Sports facilities within the Technical College;
4. The Dionisie Pop-Martian Economic College;
5. The Heating Plant of the Technical College;
6. The Canteen of the Technical College Dorin Pavel;
7. The secondary courses building of the D.P.Tech College.

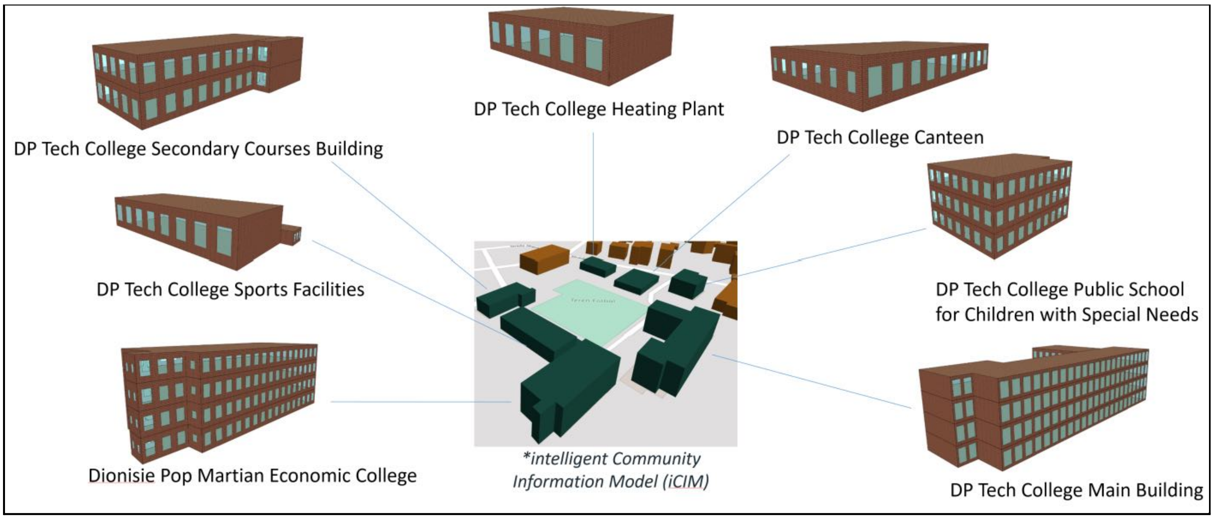


Figure 6 Potential PEB 2 Dorin Pavel Technical College

4.2 Data Collection for Baseline Model

In terms of data collection for Alba Iulia, the Data Checklist was filled in as requested with all of the necessary attributes for the district and demo area modelling.

The import from OSM was used for buildings and their geometries. This was then updated with applicable data from the data checklist. The data which was not in the checklist was that of roof types, so Google Maps was instead used to check the most common types which were used in the modelling.

As mentioned in the previous sub section, data was not received for PEB 1, hence this was modelled in the same way as the wider areas. For the PEB 2 buildings, all of the data requested in the checklist was obtained except for BMS data due to the buildings either not having this application, or it was not possible to download the information in the time requested. Also, actual energy usage was only received as a total for all buildings together and not individually.

For the supply side of electricity in the PEB, although no data was received, it was confirmed that all buildings in the PEB were connected to the same sub-station.

The IWEC weather file from the closest weather station, located in the city of Cluj-Napoca, was used for energy simulations and for the calculation of heating degree days

Socio economic data was received for 2020 at City level due to this being the lowest level available. All data for the categories requested was received except for derelict buildings and employment job types.

For energy supply costs, a flat unit rate of 0.08 €/kWh and 0.074 €/kWh have been considered for electricity and natural gas respectively.

4.3 Baseline Model Results

Once the buildings within the PEB and the demo district had been modelled, the baseline was simulated for the year 2021.

4.3.1 Demonstration District Modelling Results

The results of the baseline modelling for the city area, show the simulated buildings recorded a Total Annual Energy Usage of 1181.39 GWh, equating to an Average Energy Usage Intensity of 325 kWh/m^2. The associated Annual Carbon Emissions from the buildings was 365.7 ktCO_2e. This can be seen in the figures below which are taken from the Dashboard view (see Section 4.4) and shows each building's energy use and carbon emissions respectively.

Figure 7 Alba Iulia Demonstration District Baseline Model Building Energy Demand

Figure 8 Alba Iulia Demonstration Distric Baseline Model Building Carbon Emissions

4.3.2 Potential PEB Energy Demand and Supply Baseline

The potential PEB buildings were modelled and simulated within the city model using the IES iCD, and data supplied in the building data checklist completed by the city.

The energy models for each of the buildings in the two PEBs, along with their location, can be found below. A table for each PEB shows the results of the energy simulations.

4.3.2.1 Potential PEB 1 Alba Iulia Municipality Buildings Energy Demand Results

The figure below shows the PEB buildings as a reminder, with the following figures showing the energy demand results for each of the PEB buildings. It should be noted that the colour scheme does not necessarily indicate a ‘poor’ and ‘good’ performing buildings, but is merely representative of the higher energy use when compared to the other buildings (see the key in the Metric Viewer).

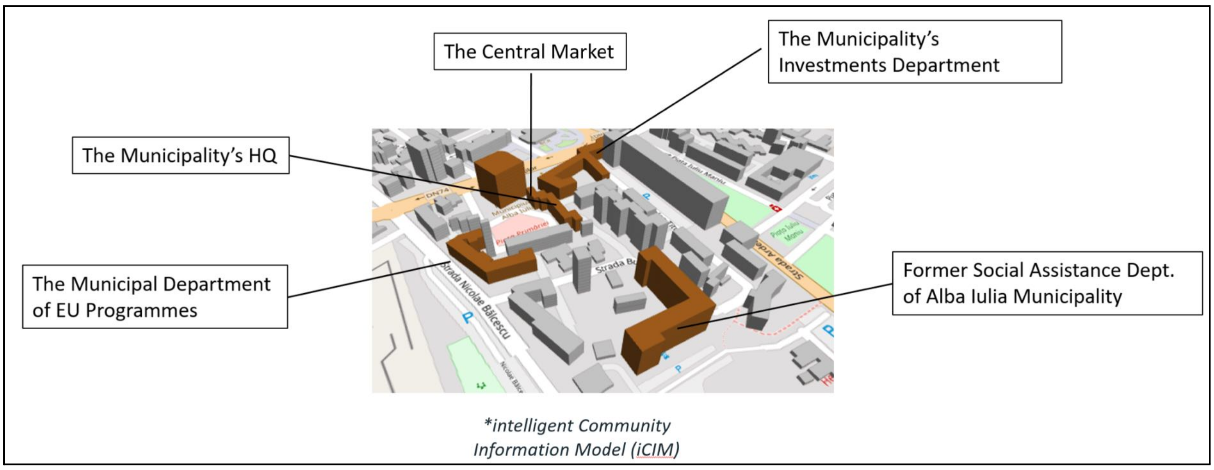


Figure 9 PEB 1 Alba Iulia Municipality Buildings

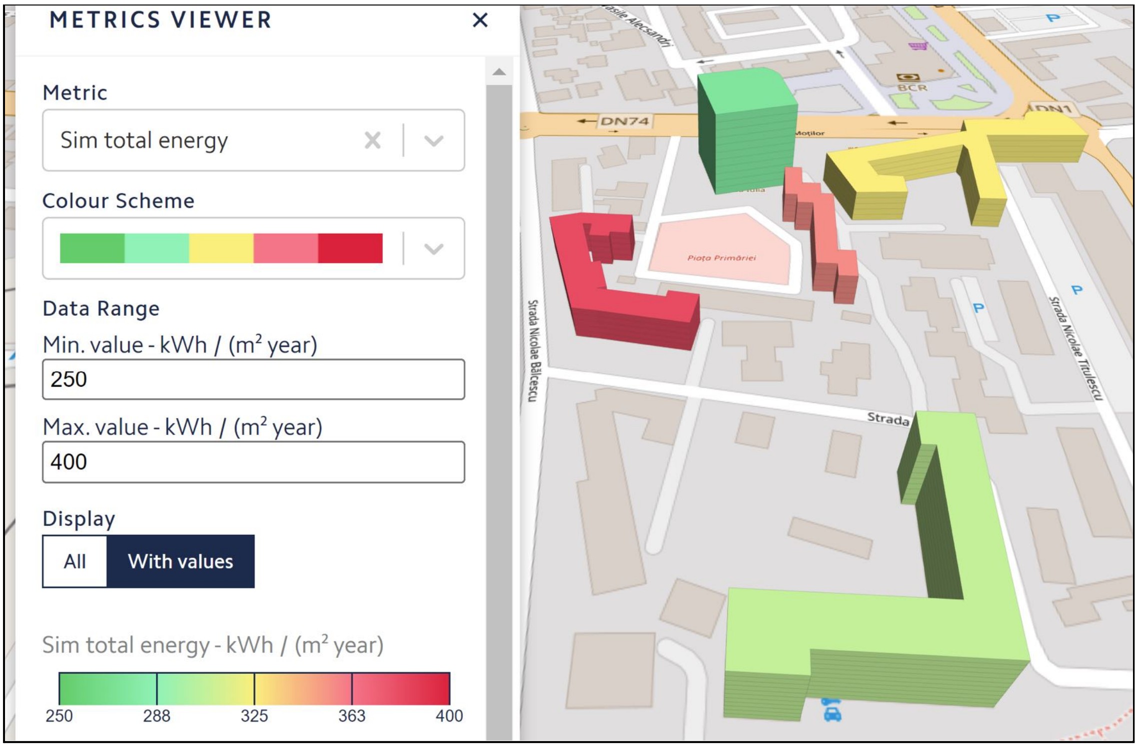


Figure 10 Potential PEB 1 Alba Iulia Municipality Buildings Energy Demand Baseline Model

The table below shows the annual result of the simulations, and these are also available by month. It was not possible to compare the simulated data against real data as this was not received.

PEB 1 Buildings	**Energy use (simulated) [kWh/m²/year]**
The Municipal Department of EU Programmes;	380.6
Former Social Assistance Dept. of Alba Iulia Municipality	306.5
The Central Market;	355.6
The Municipality's HQ;	275.5
The Municipality`s Investments Department.	325.3

Figure 11 Potential PEB 1 Alba Iulia Municipality Buildings Energy Demand Baseline Results

4.3.2.2 Potential PEB 2 Dorin Pavel Technical College Energy Demand Results

The figure below shows the PEB buildings as a reminder, with the following figures showing the energy demand results for each of the PEB buildings. It should be noted that the colour scheme does not necessarily indicate a 'poor' and 'good' performing buildings, but is merely representative of the higher energy use when compared to the other buildings (see the key in Figure 13).

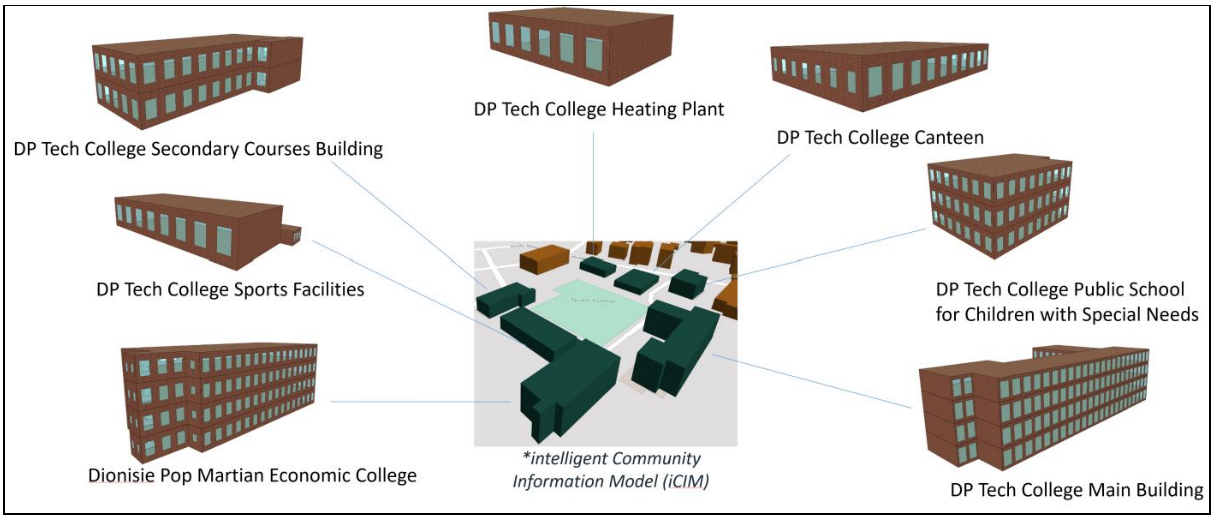


Figure 12 Dorin Pavel Technical College PEB

Figure 13 Dorin Pavel Technical College Potential PEB Energy Demand baseline results

PEB 2 Buildings	Energy use	Energy use	%

	(energy bills) [kWh/m²/year]	(simulated) [kWh/m²/year]	difference
The Dorin Pavel Technical College (HQ)	Actual energy usage only received as a total for all buildings.	126.8	N/A
Post secondary school Henri Coandă;		152.8	N/A
Sports facilities within the Technical College		143.6	N/A
The Dionisie Pop-Martian Economic College		114.59	N/A
The Heating Plant of the Technical College		30.8	N/A
The Canteen of the Technical College Dorin Pavel		2.3	N/A
The secondary courses building of the D.P.Tech College.		171.5	N/A
Total All buildings	**116.2**	**120.5**	**3.8**

Figure 14 Potential PEB 2 Alba Iulia Municipality Buildings Energy Demand Baseline Results compared to Actual Energy Demand

The data from the PEB buildings was imported into the IES iVN to create the energy supply baseline model. The figure below shows the 2D view of the baseline iVN model, where each of the PEB buildings is connected to the same electricity node, representative of their common substation.

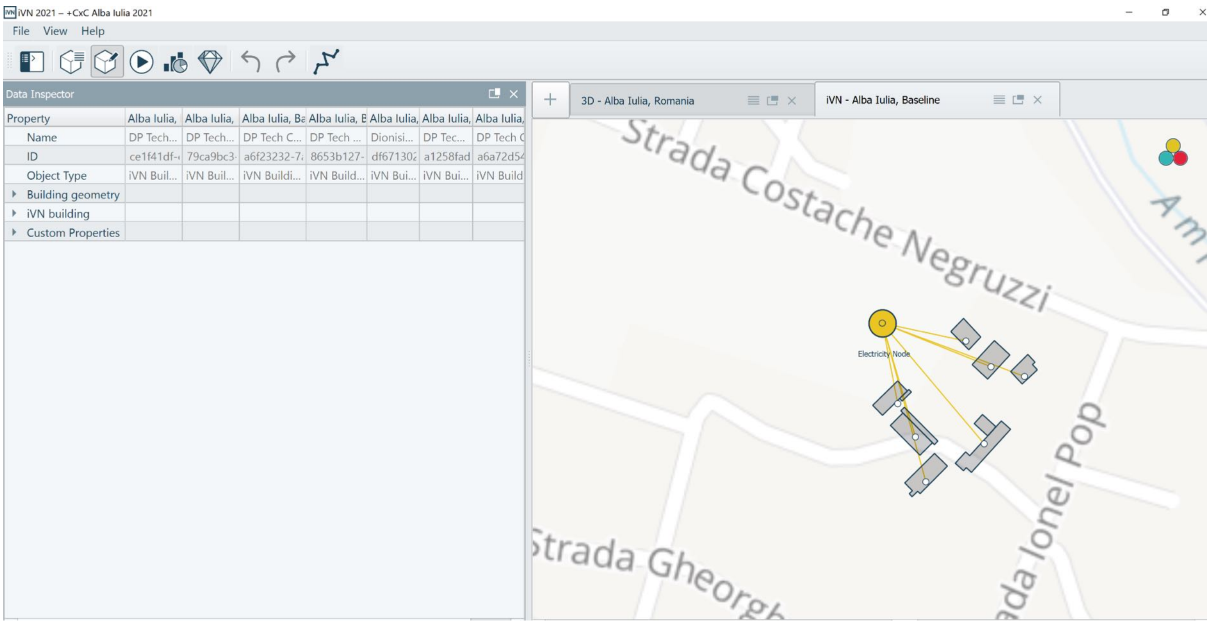


Figure 15 Alba Iulia Electricity Supply Potential PEB 2 Baseline

4.3.3 Socio Economic Baseline

As the data collected for socio economics was only at the city level, it was imported into the DST and can be visualised at boundary level as shown below.

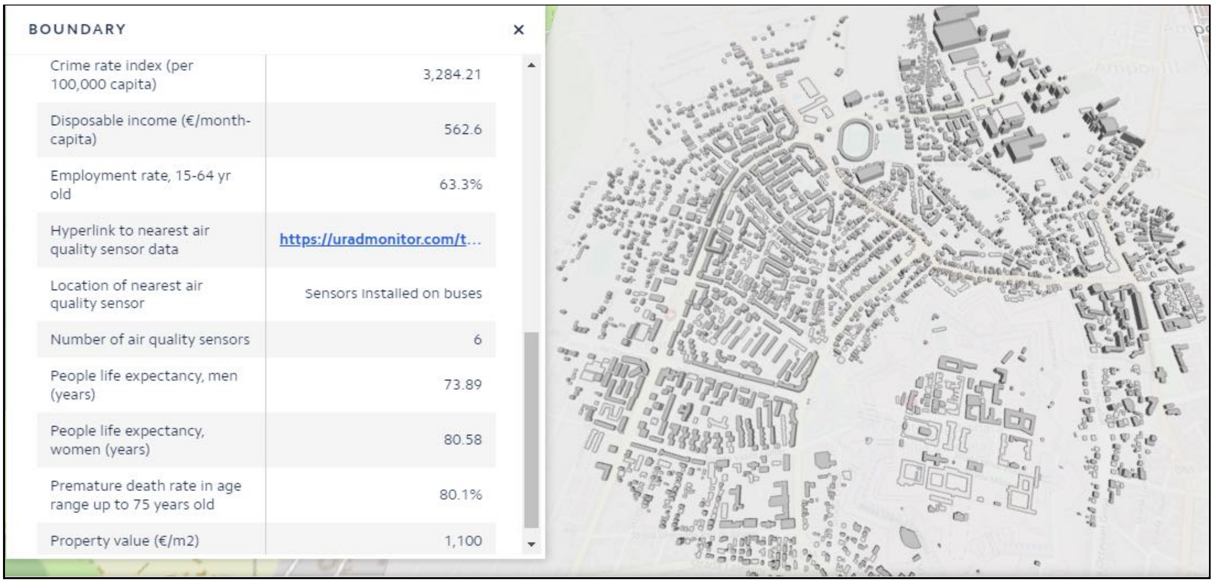


Figure 16 Alba Iulia Socio Economic Baseline Results

4.4 Reporting and Decision Support (Dashboard Views)

For the end user, the DST's main way to view the results of the demo district/PEB baseline and simulation is done through the use of online 'Dashboard' views that can be setup depending on the user's requirements. For Alba Iulia, a default Dashboard was set up to mirror what was provided to the Lighthouse Cities, and shows the Demonstration District and PEBs modelled in a 3D map view as well as some key energy related metrics. It should be noted that all of the images used in Section 4 have been taken from this Dashboard.

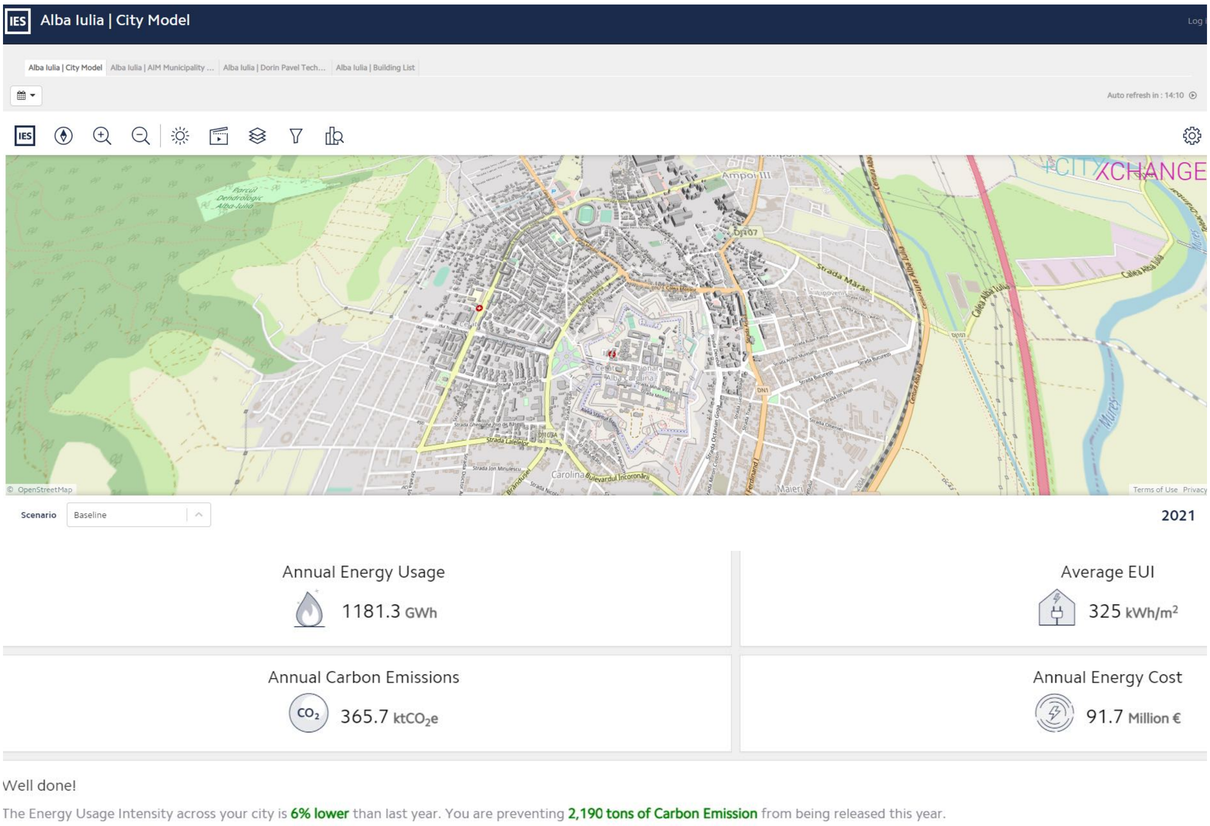


Figure 17 Alba Iulia DST Dashboard view

The User will have the ability to scroll around the map, click on any building to see the data relating to that building and view any simulation results. Various 'scenes' have also been pre-setup so the user can easily see on the map view:

- Energy Demand Results,
- CO_2 emissions
- PEB Results
- Building Primary Uses

Also available is a further tab showing the list of PEB buildings and their specific energy related results.

BUILDING NAME	PEB	EUI	POTENTIAL EUI
AIM HQ	1	- kWh/m^2	- kWh/m^2
AIM Investments Department	1	- kWh/m^2	- kWh/m^2
Central Market	1	- kWh/m^2	- kWh/m^2
Former AIM Social Assistance Department	1	- kWh/m^2	- kWh/m^2
Municipal Department of EU Programmes	1	- kWh/m^2	- kWh/m^2
Dionisie Pop-Martian Economic College	2	114.6 kWh/m^2	- kWh/m^2
DP Tech College Canteen	2	2.3 kWh/m^2	- kWh/m^2
DP Tech College Heating Plant	2	30.8 kWh/m^2	- kWh/m^2
DP Tech College Main Building	2	126.8 kWh/m^2	- kWh/m^2
DP Tech College Public School for Children with Special Needs	2	152.8 kWh/m^2	- kWh/m^2
DP Tech College Secondary Courses Building	2	171.5 kWh/m^2	- kWh/m^2
DP Tech College Sport Facilities	2	143.6 kWh/m^2	- kWh/m^2

Figure 18 Alba Iulia PEB Building List view

5. DST Baseline for Pisek

5.1 Introduction to the City, Demo District and PEB

Písek is a mid-size city with 30 000 inhabitants, situated in the South-Bohemian region of the Czech Republic. Písek originally defined two Demonstration areas, however, with further research, understanding and developments in the city have meant that a new Demonstration District and two new PEB areas have been proposed. Details for the DD and PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC.

The new Demonstration area – Inner City Area – surrounds the historical core of Pisek city and comprises 5 buildings (or building complexes) and one future construction project. Chosen buildings and the ongoing project are all in the ownership of the city and all buildings are currently connected to the central heating system. At the time of modelling, it was understood that there were to be two Demonstration Areas with two potential PEBs. However, through the feasibility study as part of D6.3, these have now been joined together to be considered as one Demonstration Area. The figure below shows a map of this area.

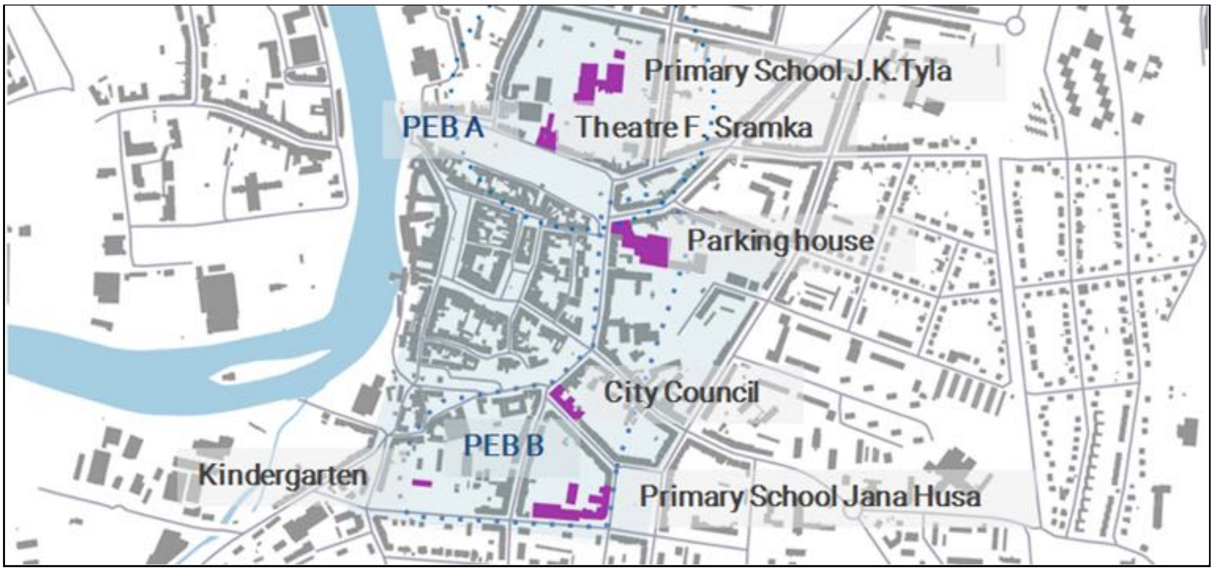


Figure 19 Map of the Demonstration Area with PEB A and PEB B in the City of Pisek

Below shows the overall city model of Pisek which was created in the IES iCD by importing from Open Street Map (OSM) and includes 2,209 buildings. The PEBs are also highlighted.

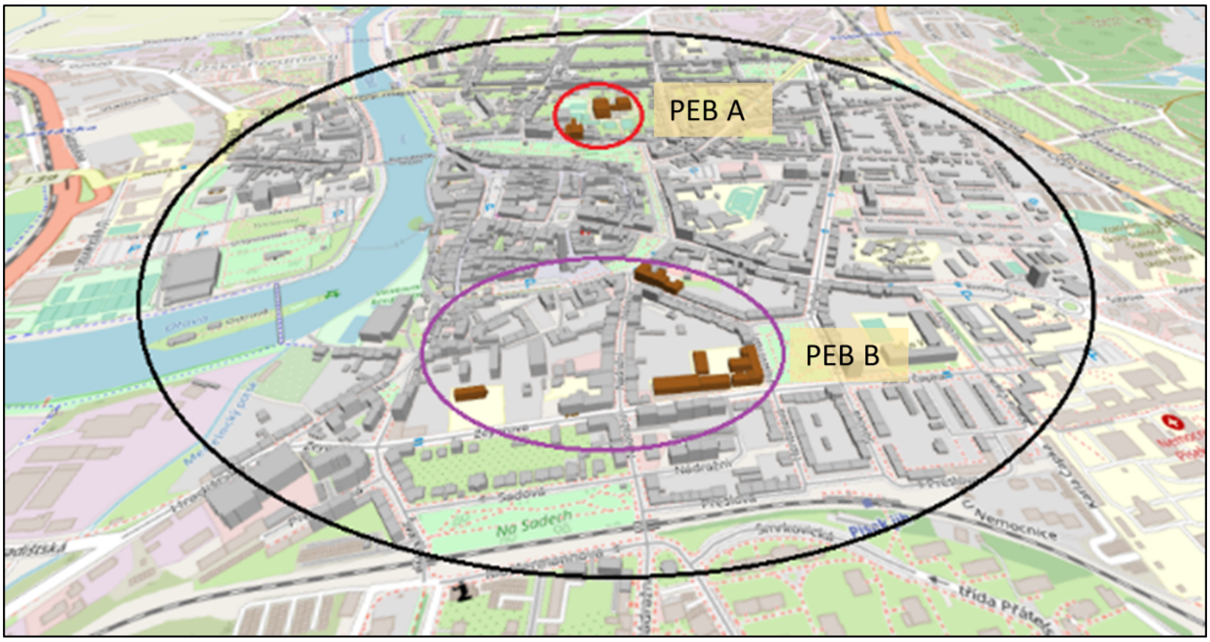


Figure 20 The Pisek Demonstration Area modelled with potential PEBs highlighted

The 3D map images above are taken from the Dashboard view for the Pisek City model using the data imported from OSM and obtained from Pisek Municipality.

5.1.1 Potential PEB A

The PEB area includes 2 buildings:

- Primary School J.K.Tyla
- Theatre Frana Sramek

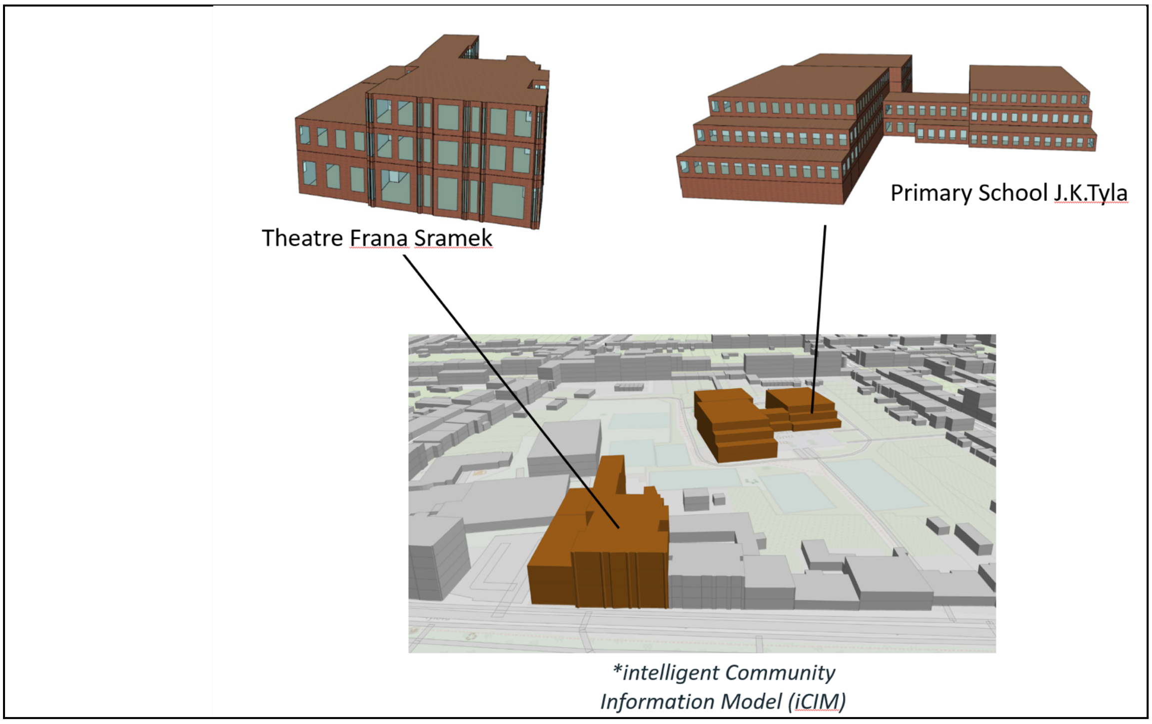


Figure 21 Pisek Potential PEB A

5.1.2 Potential PEB B

The PEB area includes 3 buildings:

- City Council
- Primary school Jana Husa
- Kindergarten

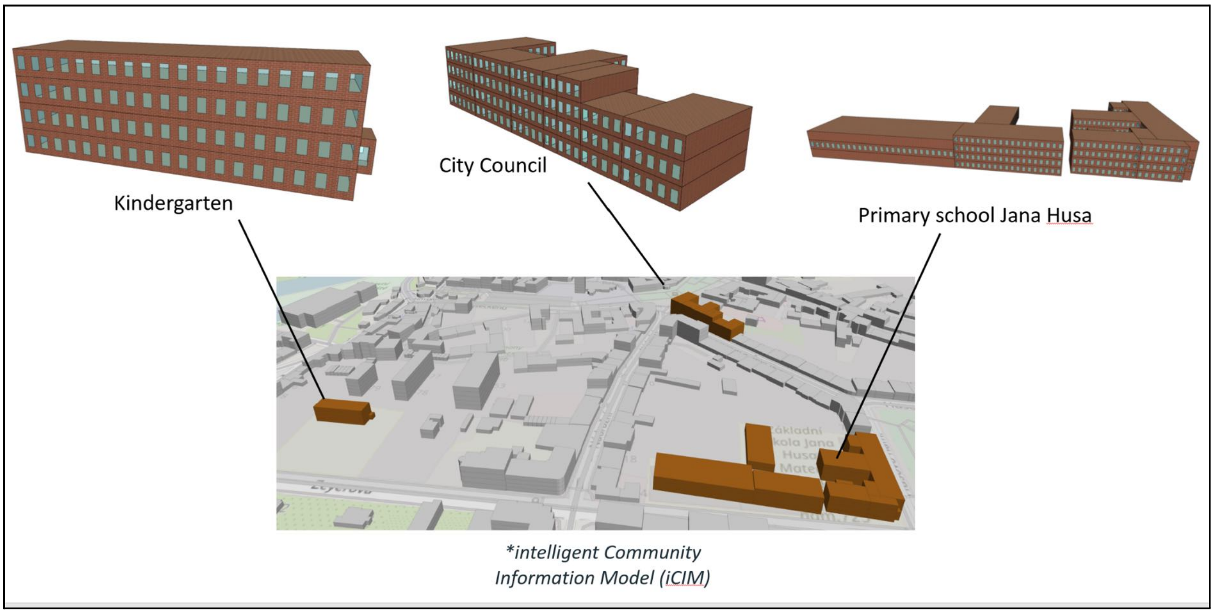


Figure 22 Pisek Potential PEB B

5.2 Data Collection for Baseline Model

In terms of data collection for Pisek, the Data Checklist was filled in as requested with all of the necessary attributes for the city and demo area modelling.

For the Demo Area model, the import from OSM was used for buildings and their geometries. This was then updated with applicable data from the data checklist. The data which was not in the checklist was that of roof types, so Google Maps was instead used to check the most common types and these were used in the modelling.

For the PEB buildings all of the data requested in the checklist was obtained except for:

- Renewable energy systems
- Internal systems - HVAC type and details
- Lighting
- Equipment systems
- Zone/room set points
- Monthly energy consumption metre readings and bills
- BMS data (if available/applicable

The missing data was due to the buildings either not having these applications, or it was not possible to download the information in the time requested. It should be noted that the amount of data missing for the PEBs may have affected the accuracy of the baseline modelling.

For the supply side of electricity in the PEBs, maps were received showing that all buildings in the PEBs were connected to the same sub-station.

The weather file from the closest weather station, located in the city of Prague, was used for energy simulations and for the calculation of heating degree days.

There was no socio economic data received, so this part of the baseline was not modelled for Pisek.

For energy supply costs, a flat unit rate of 0.165 €/kWh and 0.063 €/kWh have been considered for electricity and natural gas respectively.

5.3 Baseline Model Results

Once the buildings within the PEB and the demo area had been modelled, the baseline was simulated for the year 2021.

5.3.1 Demonstration Area Modelling Results

For the demo area, the simulated buildings recorded a Total Annual Energy Usage of 233.9 GWh, equating to an Average Energy Usage Intensity of 299 kWh/m^2. The associated Annual Carbon Emissions from the buildings was 85.52 ktCO_2e.

Figure 23 Pisek Demo Area Baseline Model Building Energy Demand

Figure 24 Pisek Demo Area Baseline Model Building CO2 Emissions

5.3.2 Potential PEB Energy Demand and Supply Baseline

The PEB buildings were modelled and simulated within the city model using the IES iCD, and data supplied in the building data checklist completed by the city.

The energy models for each of the buildings in the two PEBs, along with their location, can be found below. A table for each PEB shows the results of the energy simulations.

5.3.2.1 Potential PEB A Energy Demand Baseline

The figure below shows the PEB buildings as a reminder, with the following figures showing the energy demand results for each of the PEB buildings. It should be noted that the colour scheme does not necessarily indicate a 'poor' and 'good' performing buildings, but is merely representative of the higher energy use when compared to the other buildings.

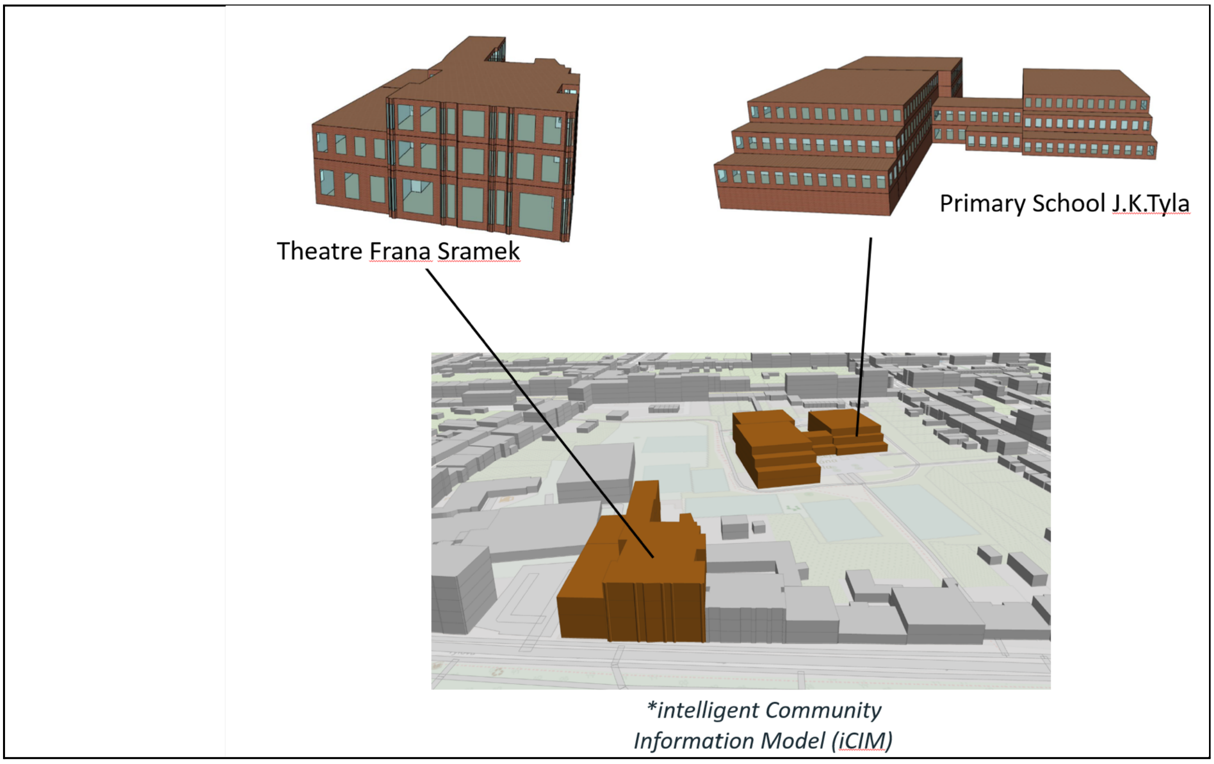


Figure 25 Pisek Potential PEB A

Figure 26 Potential PEB A Buildings Energy Demand Baseline Model

PEB A Buildings	Energy use (energy bills) [kWh/m²/year]	Energy use (simulated) [kWh/m²/year]	% difference
Primary School J.K.Tyla	103.2	129.7	25.7
Theatre Frana Sramek	71.2	75.5	6.1
Total	**79.8**	**90.2**	**12.9**

Figure 27 Potential PEB A Pisek Buildings Energy Demand Baseline Results compared to Actual Energy Demand

For the Primary School, there is a large difference between the actual energy use and the simulated energy use, which also creates a corresponding difference in the overall PEB energy consumption. Further data and investigation is required to come to a clear conclusion as to why this is the case, but it is felt that as actual data for internal heating/cooling set point temperatures were not received, the assumed temperatures used are likely to be incorrect and so cause the simulation results to be outside of the accepted accuracy range.

5.3.2.2 Potential PEB B Energy Demand Baseline

The figure below shows the PEB buildings as a reminder, with the following figures showing the energy demand results for each of the PEB buildings. It should be noted that the colour scheme does not necessarily indicate a 'poor' and 'good' performing buildings, but is merely representative of the higher energy use when compared to the other buildings..

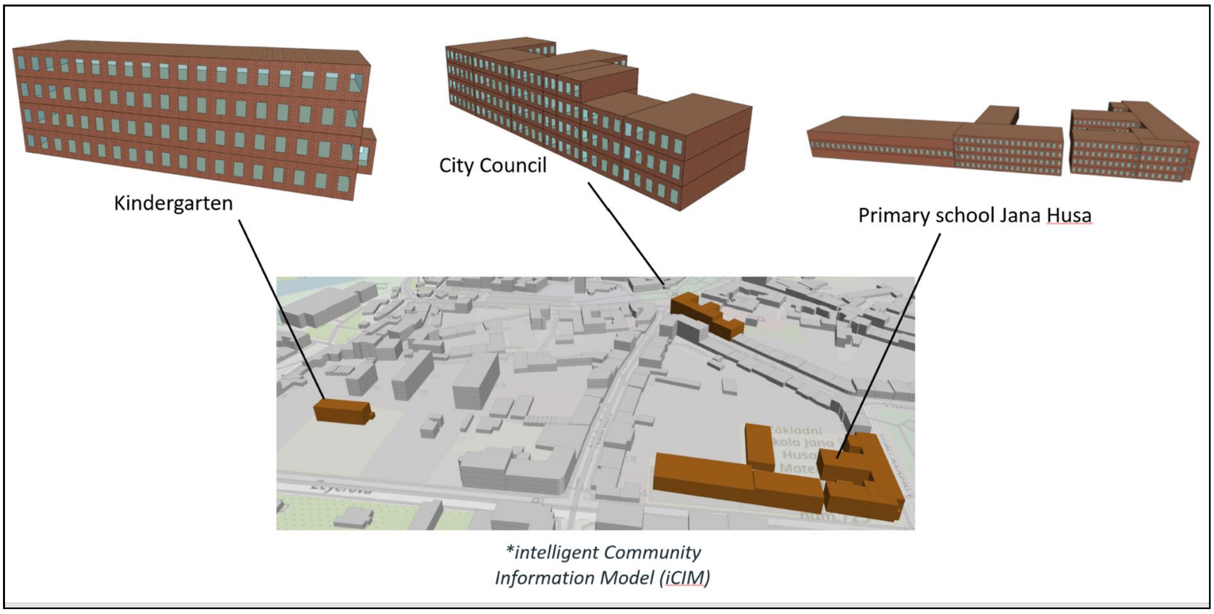


Figure 28 Pisek Potential PEB B

Figure 29 PEB potential Buildings Energy Demand Baseline Model

PEB B Buildings	**Energy use (energy bills) [kWh/m²/year]**	**Energy use (simulated) [kWh/m²/year]**	**% difference**
City Council	59.8	63.0	5.3
Primary school Jana Husa	131.0	152.1	16.1

Kindergarten	82.2	89.4	8.7
Total	**79.9**	**87.1**	**8.9**

Figure 30 Potential PEB B Pisek Municipality Buildings Energy Demand Baseline Results compared to Actual Energy Demand

For the Primary School, there is a large difference between the actual energy use and the simulated energy use, which also creates a corresponding difference in the overall PEB energy consumption. Further data and investigation is required to come to a clear conclusion as to why this is the case, but it is felt that as actual data for internal heating/cooling set point temperatures were not received, the assumed temperatures used are likely to be incorrect and so cause the simulation results to be so far out.

The data from the PEB buildings was imported into the IES iVN to create the energy supply baseline model.The figure below shows the 2D view of the baseline iVN model, where each of the PEB buildings is connected to the same electricity node, representative of their common substation.

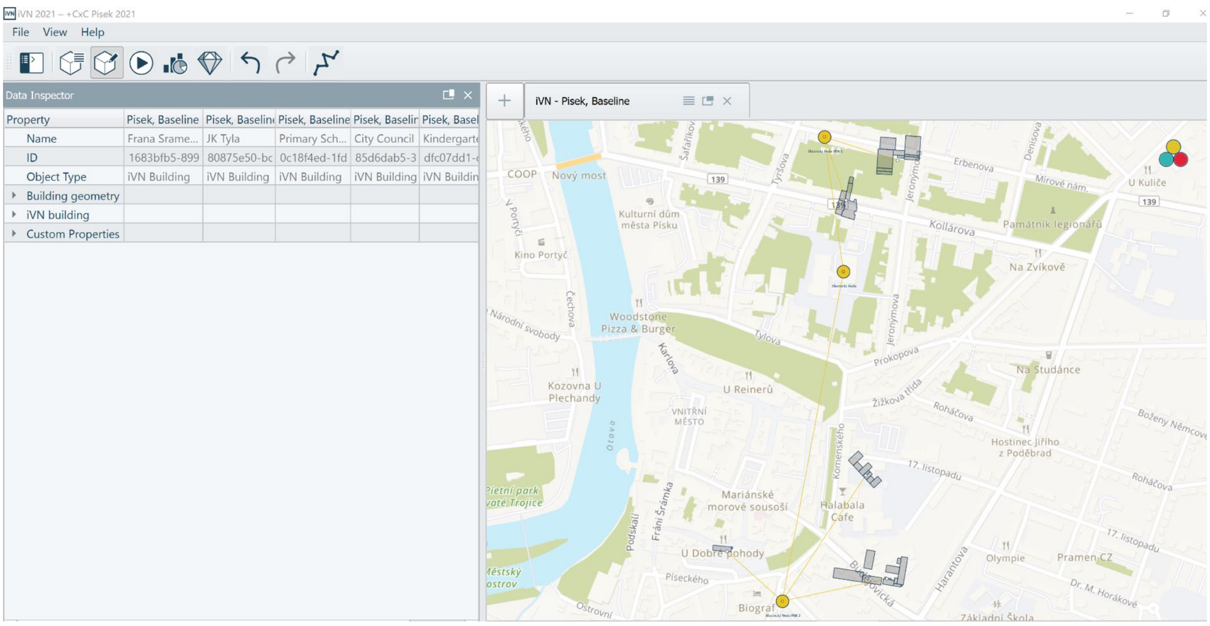


Figure 31 Pisek Electricity Supply Potential PEB Baseline

5.4 Reporting and Decision Support (Dashboard Views)

For the end user, the DST's main way to view the results of the demo area/PEB baseline and simulations is done through the use of online 'Dashboard' views that can be setup depending on the user's requirements. For Alba Iulia, a default Dashboard was set up to mirror what was provided to the Lighthouse Cities, and shows the City Area and PEBs modelled in a 3D map view as well as some key energy related metrics. It should be noted that all of the images used in Section 5 have been taken from this Dashboard.

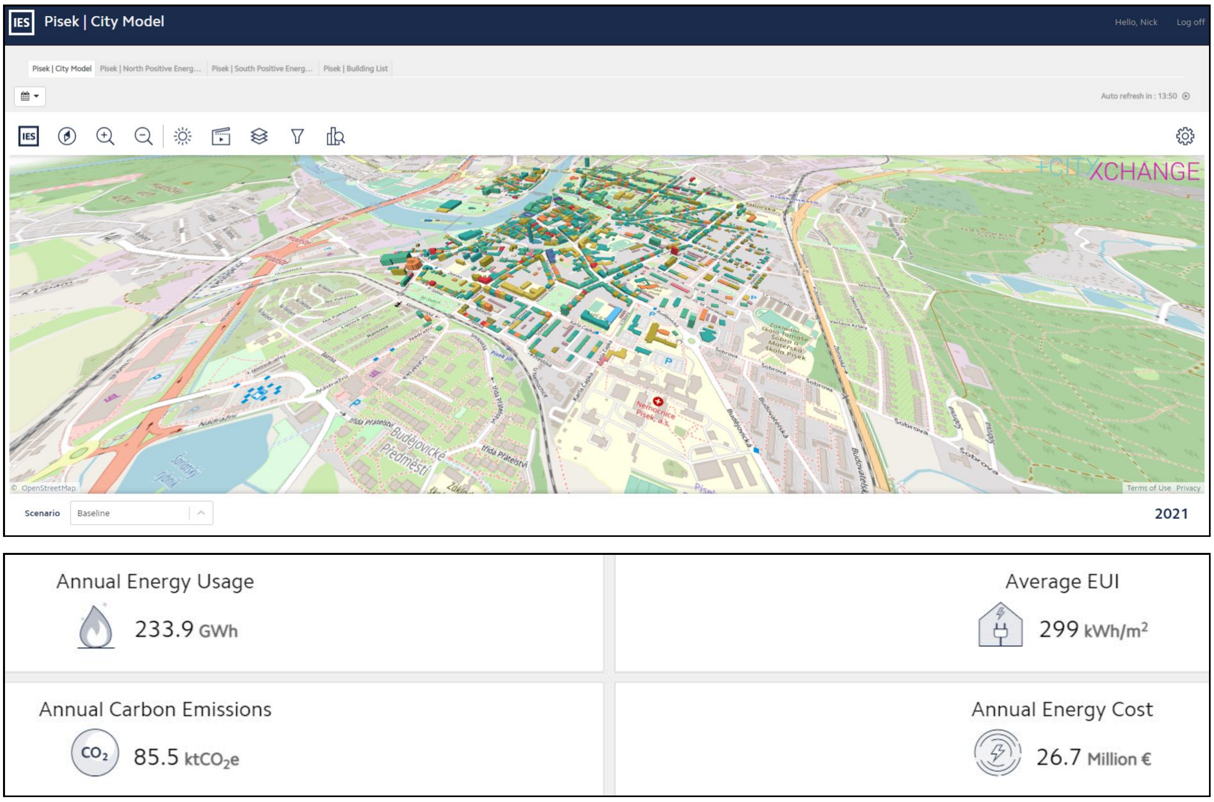


Figure 32 Pisek DST Dashboard view

The User can scroll around the map, and click on any building to see the data relating to that building and any simulation results. Various ‘scenes’ have also been pre-setup so the user can easily see on the map view:

- Energy Demand Results,
- CO2 emissions
- PEB Results
- Building Primary Uses

Also available is a further tab showing the list of PEB buildings and their specific energy related results.

BUILDING NAME	PEB	EUI	POTENTIAL EUI	POTENTIAL SAVINGS	PAST YEAR CONSUMPTION	ANNUAL COST
Frana Sramek Theater	1	129.7 kWh/m^2	- kWh/m^2	- %	530.34 MWh	€ 54,522
JK Tyla	1	75.5 kWh/m^2	- kWh/m^2	- %	829.2 MWh	€ 69,002
City Council	2	63 kWh/m^2	- kWh/m^2	- %	288.87 MWh	€ 22,820
Kindergarten Zayerova	2	152.1 kWh/m^2	- kWh/m^2	- %	196.32 MWh	€ 20,333
Primary School Jana Husa	2	89.4 kWh/m^2	- kWh/m^2	- %	1,012.58 MWh	€ 78,838

Figure 33 Pisek PEB Building List view

6. DST Baseline for Sestao

6.1 Introduction to the City, Demo Area and PEB

Sestao is a Basque municipality that belongs to the region of Gran Bilbao. At the end of 2018, the registered inhabitants in the census of the city council (7,926.86 hab./km^2) were 27 445 people. Details for the DD, DA and PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC. The Demonstration District, Areas and Sites are shown in the figure below.

The potential PEBs in Sestao are the same as originally intended in the Grant Agreement with a compilation of several buildings of around 15,000 m^2.

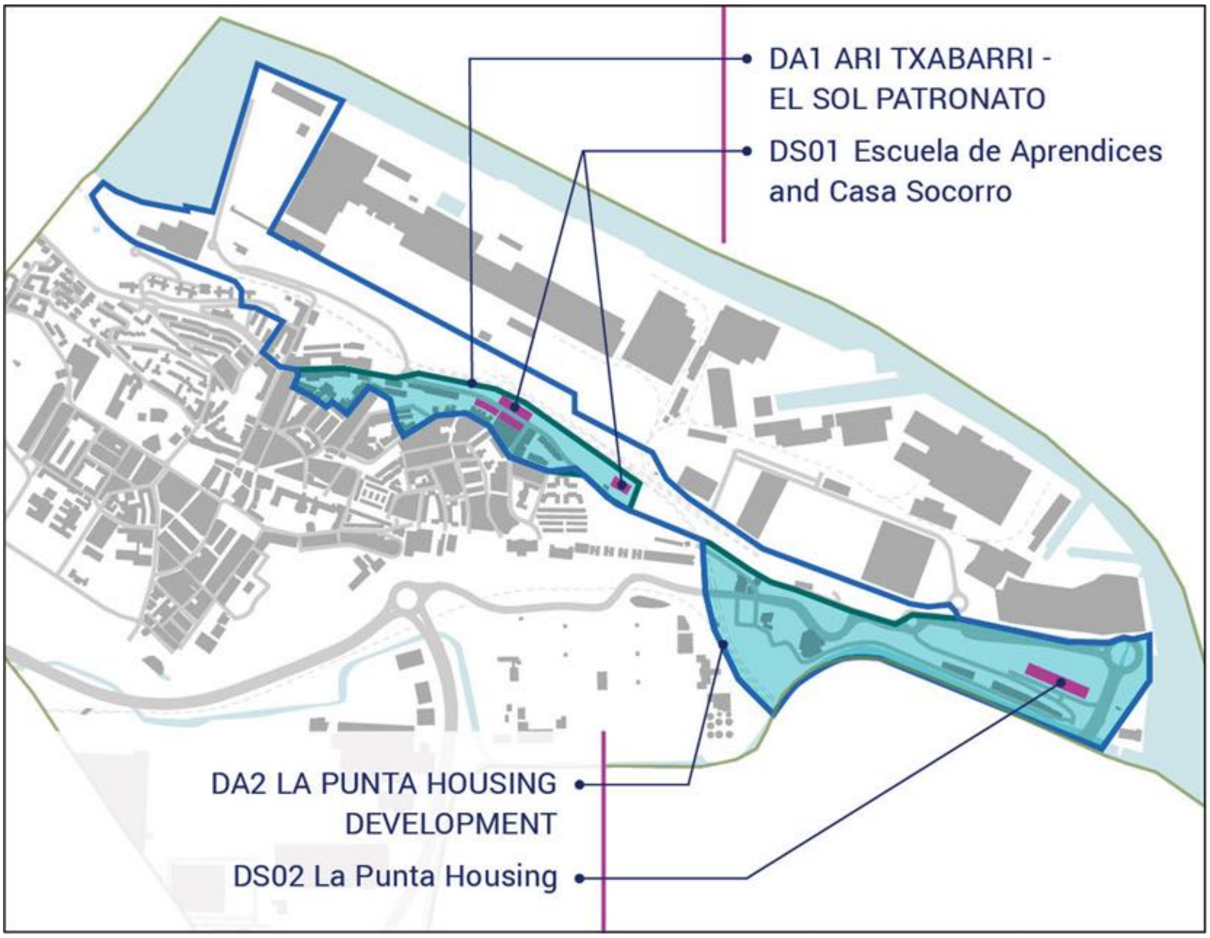


Figure 34 Sestao Demo District, Areas and Sites

The figure below shows the city area imported into the DST using OpenStreetMap, along with the PEB area highlighted. It includes 1,268 buildings, with 24 buildings in demo area one (DA1) and 14 in demo area two (DA2).

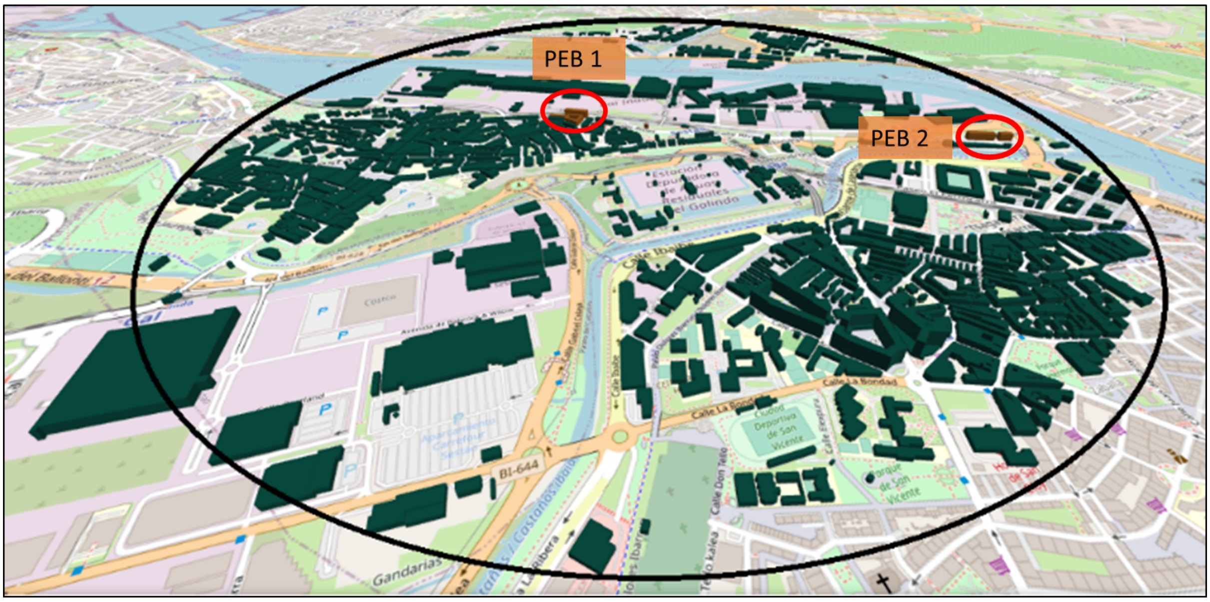


Figure 35 The Sestao Area Modelled with PEBs highlighted

The 3D map images above are taken from the Dashboard view for the Sestao City model using the data imported from OSM and obtained from Sestao Municipality.

6.1.1 Potential PEB 1

This consists of 4 buildings, 2 of which are currently not in use and need to be completely refurbished:

- Escuela de Aprendices (derelict)
- Casa Socorro
- Patronato/Txabarri 31-33
- Txabarri 25-27-29

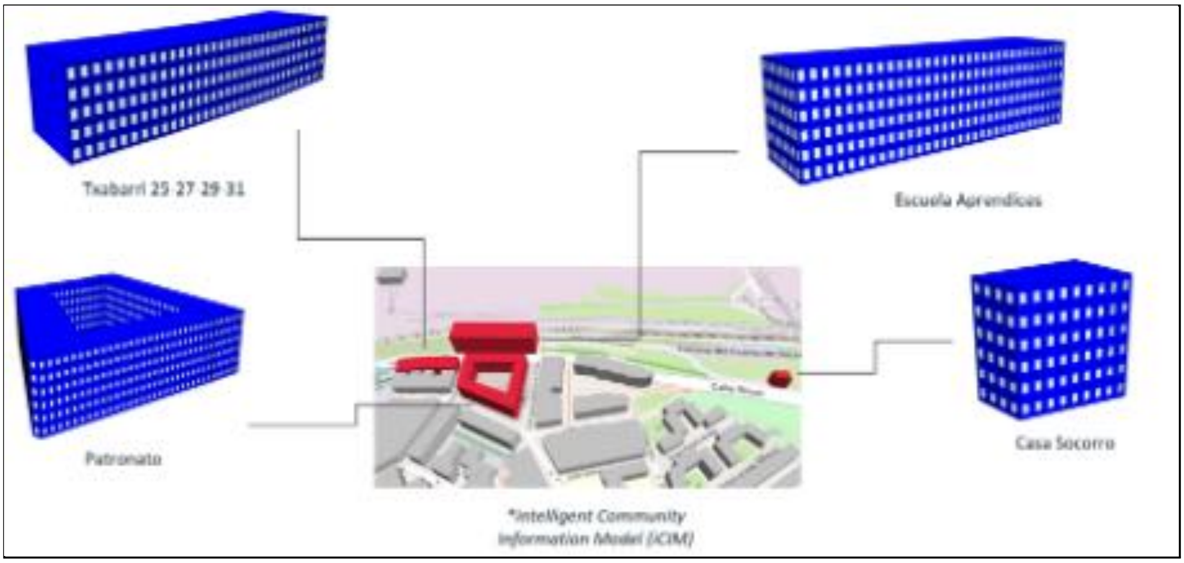


Figure 36 Sestao Potential PEB 1

6.1.2 Potential PEB 2

This consists of 2 buildings

- La Punta Housing 1
- La Punta Housing 2

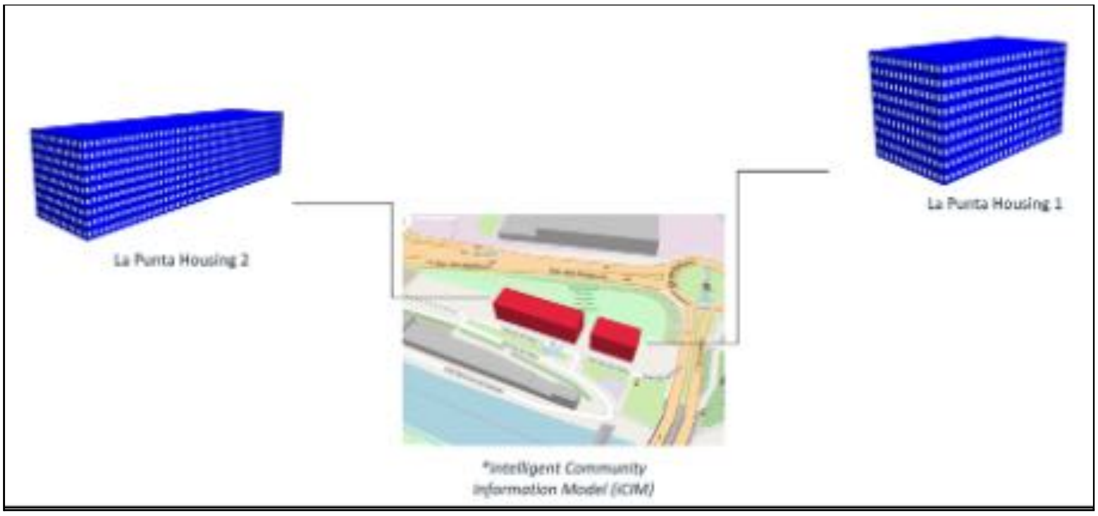


Figure 37 Sestao Potential PEB 2

6.2 Data Collection for Baseline Model

In terms of data collection for Sestao, the Data Checklist was filled in as requested with all of the necessary attributes for the city and demo area modelling.

For the Demonstration District model, the import from OSM was used for buildings and their geometries. However, data relevant to energy modelling was only received for the specific demo area, and not for that of the whole import. This is why although 1,268 buildings are shown in the 3D view, only 24 of those are within the designated demo area and have been modelled for energy performance.

For the PEB buildings, whilst all of the geometric and construction related data was received, there was very little for the following:

- Internal systems - HVAC type and details
- Lighting
- Equipment systems
- Zone/room set points
- Annual and monthly energy consumption metre readings and bills
- BMS data

Assumptions were made on data for the simulations for any derelict buildings. Although the building construction details were known, the future uses of the building, and the corresponding systems and settings were assumed and agreed with Sestao prior to the simulations.

For the supply side of electricity in the PEB, although no data was received it was confirmed that all buildings in the PEB were connected to the same sub-station.

The IWEC weather file from the closest weather station, located in the city of Santander, was used for energy simulations and for the calculation of heating degree days

Socio economic data was received for 2018 at City level due to this being the lowest level available. All data for the categories requested was received except for employment job types.

For energy supply costs, a flat unit rate of 0.289 €/kWh and 0.072 €/kWh have been considered for electricity and natural gas respectively. Both biomass and waste heat have been assigned a cost of 0.063 €/kWh.

6.3 Baseline Model Results

Once the buildings within the PEB and the demo area had been modelled, the baseline was simulated for the year 2021.

6.3.1 Demonstration District Modelling Results

For the city model of Sestao, the simulated buildings recorded a Total Annual Energy Usage of 66.4 GWh, equating to an Average Energy Usage Intensity of 240 kWh/m^2. The associated Annual Carbon Emissions from the buildings was 18.24 ktCO_2e.

The figure below shows the baseline model of Sestao where buildings within the demo areas are highlighted based on their total energy demand, followed by the same view but regarding the associated total carbon emissions.

Figure 38 Sestao Demo District Baseline Model Building Energy Demand

Figure 39 Sestao Demo District Baseline Model building Carbon emissions

6.3.2 Potential PEB Energy Demand and Supply Baseline

The PEB buildings were modelled and simulated within the city model using the IES iCD. Two PEBs were identified for the city of Sestao, one in each of the demo areas. Each of the buildings were modelled based on the building data checklist completed by the city.

The energy models for each of the buildings in the two PEBs, along with their location, can be found below. A table for each PEB shows the results of the energy simulations.

6.3.2.1 Potential PEB 1

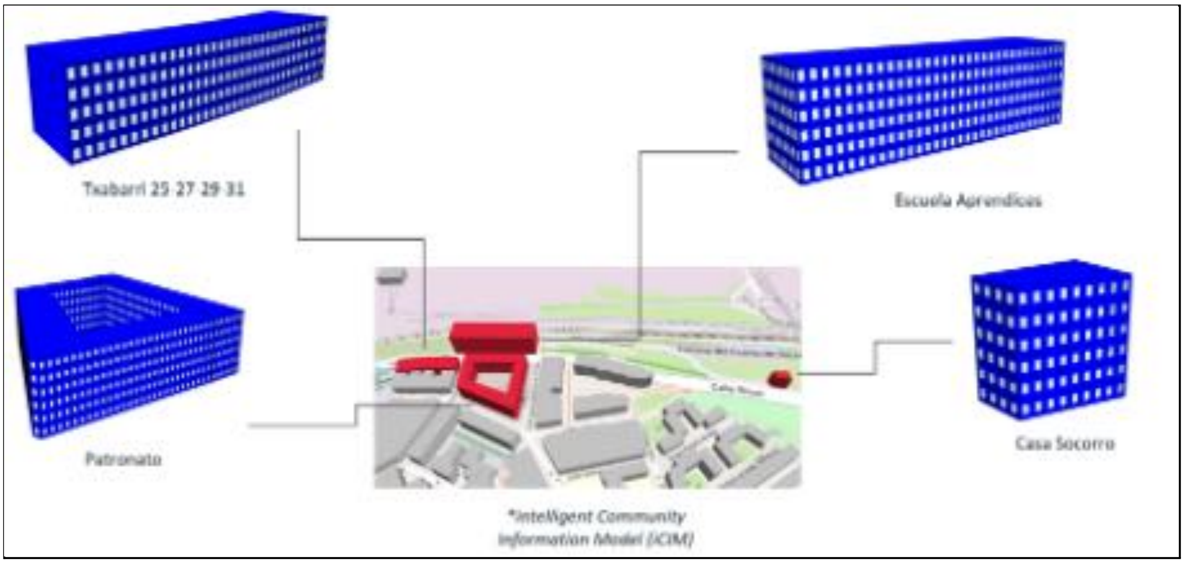


Figure 40 Sestao Potential PEB 1

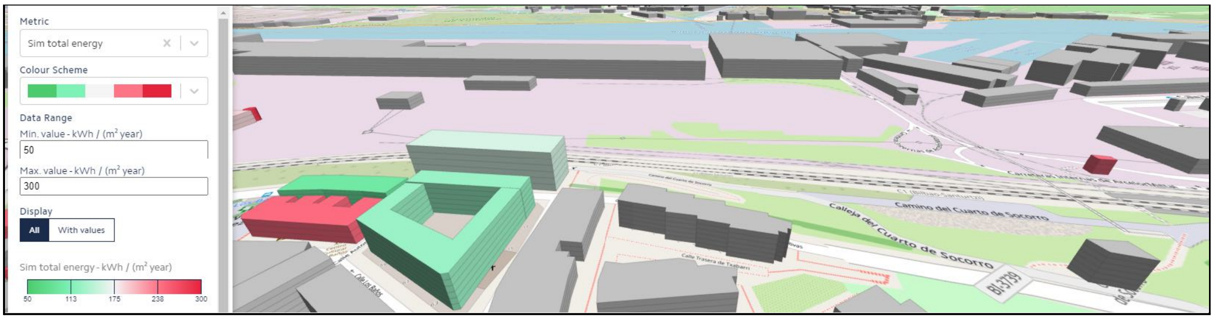


Figure 41 Sestao Potential PEB 1 Buildings Energy Demand Baseline Model

PEB 1 Building	**Energy use (simulated) [kWh/m²/year]**
Casa Socorro	595.5
Escuela Aprendices	160.2
Patronato	127.8
Txabarri 25-27-29-31	97.8

Figure 42 Potential PEB 1 Sestao Buildings Energy Demand Baseline Results

6.3.2.2 Potential PEB 2

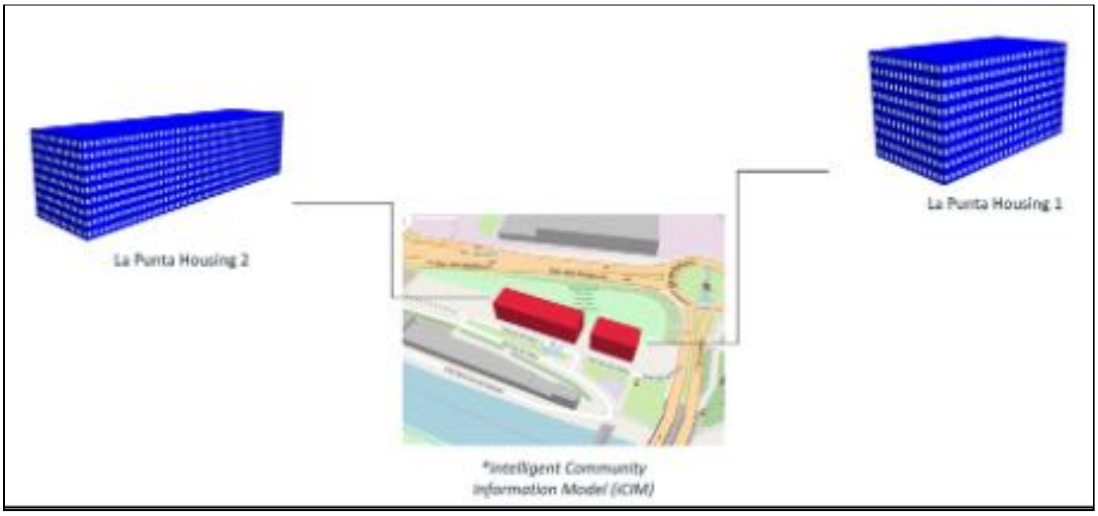


Figure 43 Sestao Potential PEB 2

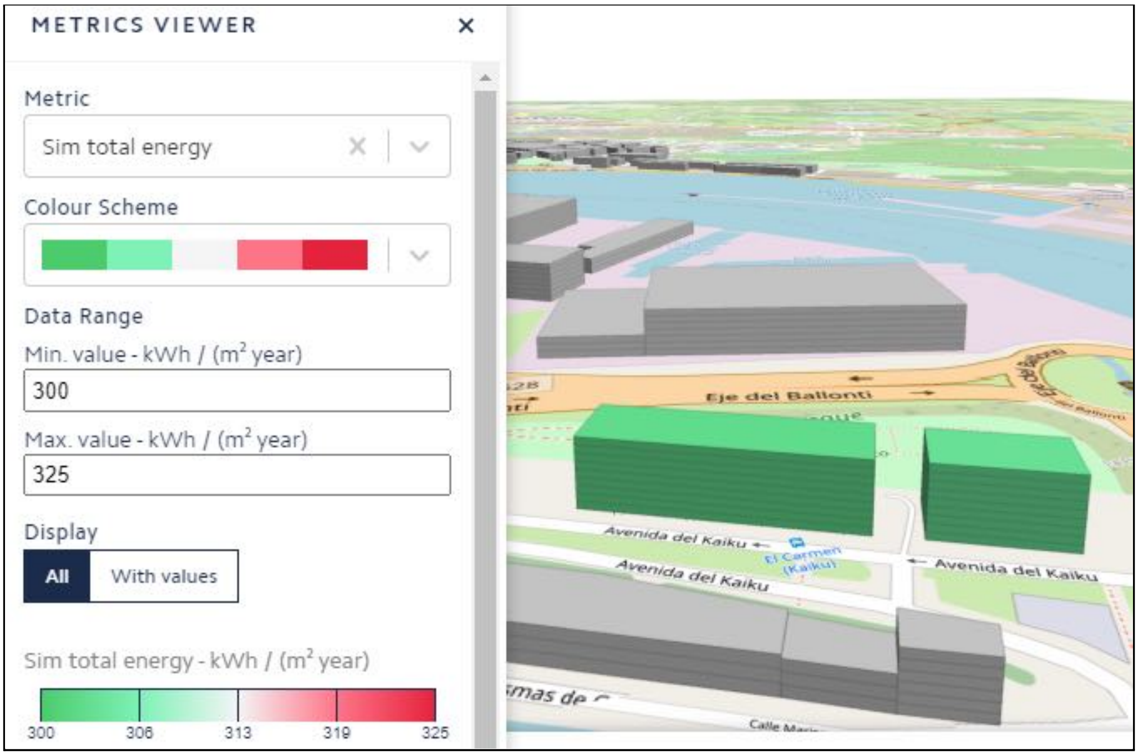


Figure 44 Sestao Potential PEB 2 Buildings Energy Demand Baseline Model

PEB 2 Building	Energy use (simulated) [kWh/m²/year]

La Punta Housing 1	303.6
La Punta Housing 2	302.7

Figure 45 Potential PEB 2 Sestao Buildings Energy Demand Baseline Results

The data from the PEB buildings was imported into the IES iVN to create the energy supply baseline model.The figure below shows the 2D view of the baseline iVN model, where each of the PEB buildings is connected to the same electricity node, representative of their common substation.

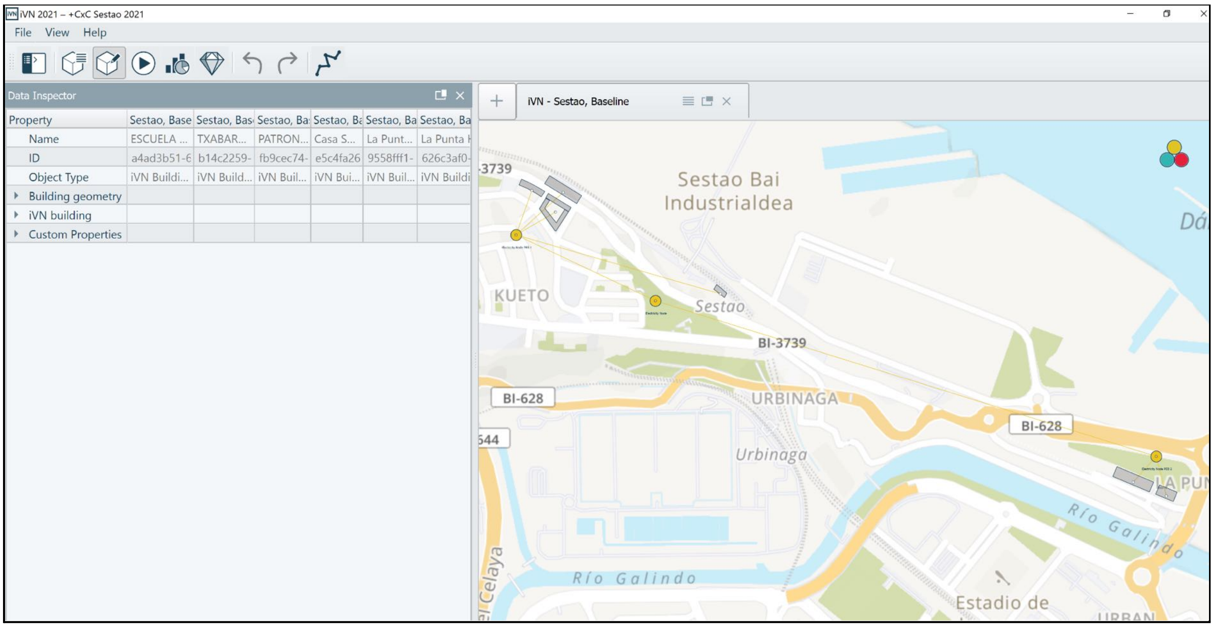


Figure 46 Sestao Electricity Supply PEB Baseline

6.3.3 Socio Economic Baseline

As the data collected for socio economics was only at the city level, it was imported into the DST and can be visualised at boundary level as shown below.

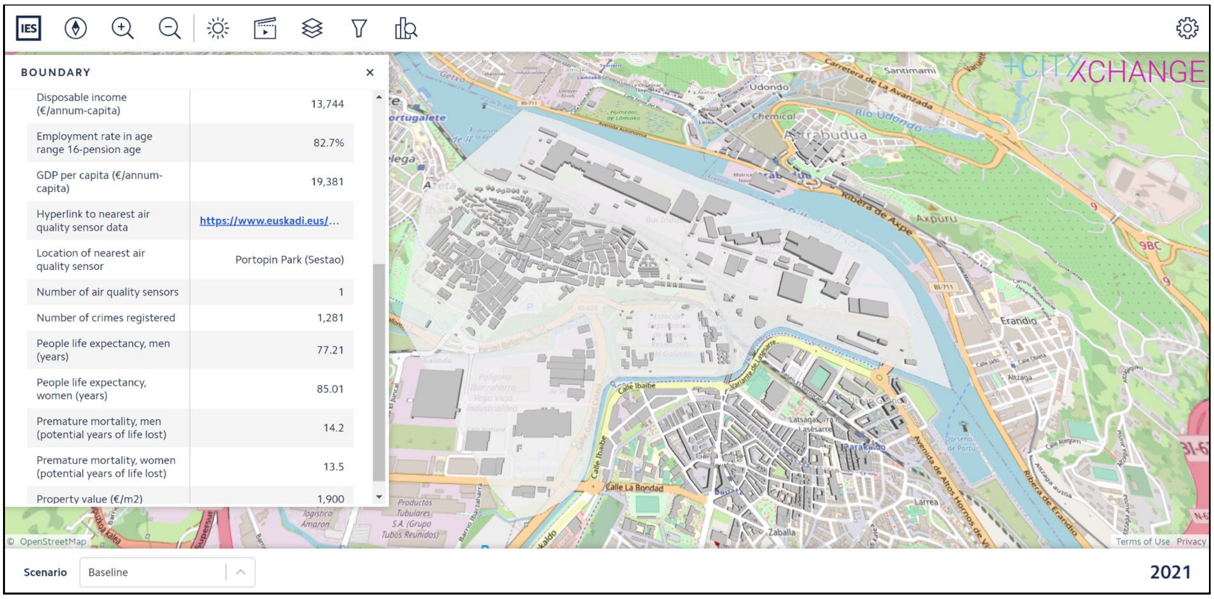


Figure 47 Sestao Socio Economic Baseline Results

6.4 Reporting and Decision Support (Dashboard Views)

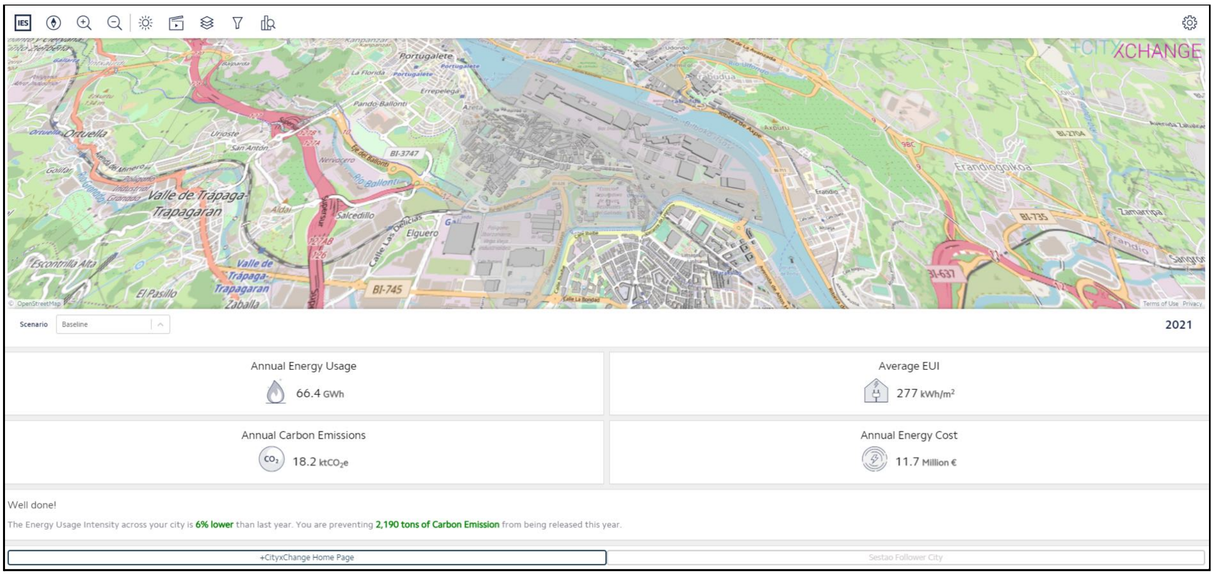


Figure 48 Sestao DST Dashboard view

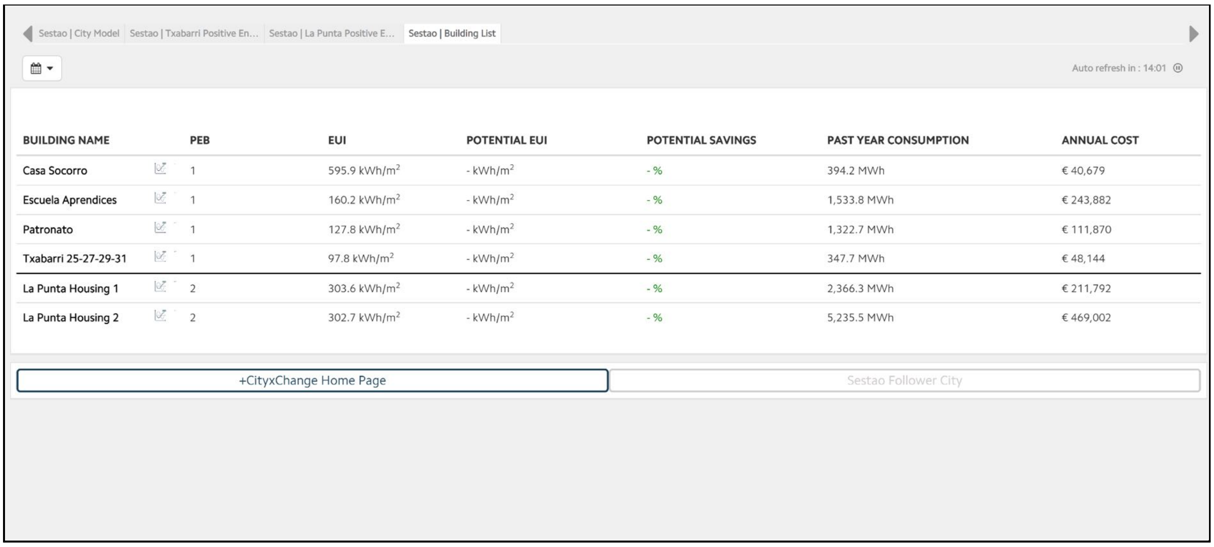


Figure 49 Sestao Potential PEB Building List view

7. DST Baseline for Smolyan

7.1 Introduction to the City, Demo Area and PEB

Municipality of Smolyan is situated in a mountainous region in South Bulgaria, on the Greek-Bulgarian border, and with a population of around 40 516. Details for the DD, DA and potential PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC.

The Demonstration areas to be covered within the city are: DA1 Old City Centre will be the main DA where most of the activities will be implemented, DA2 New City Centre and DA3 Raikovo are potential replication DAs where upscaling and replication could be achieved.

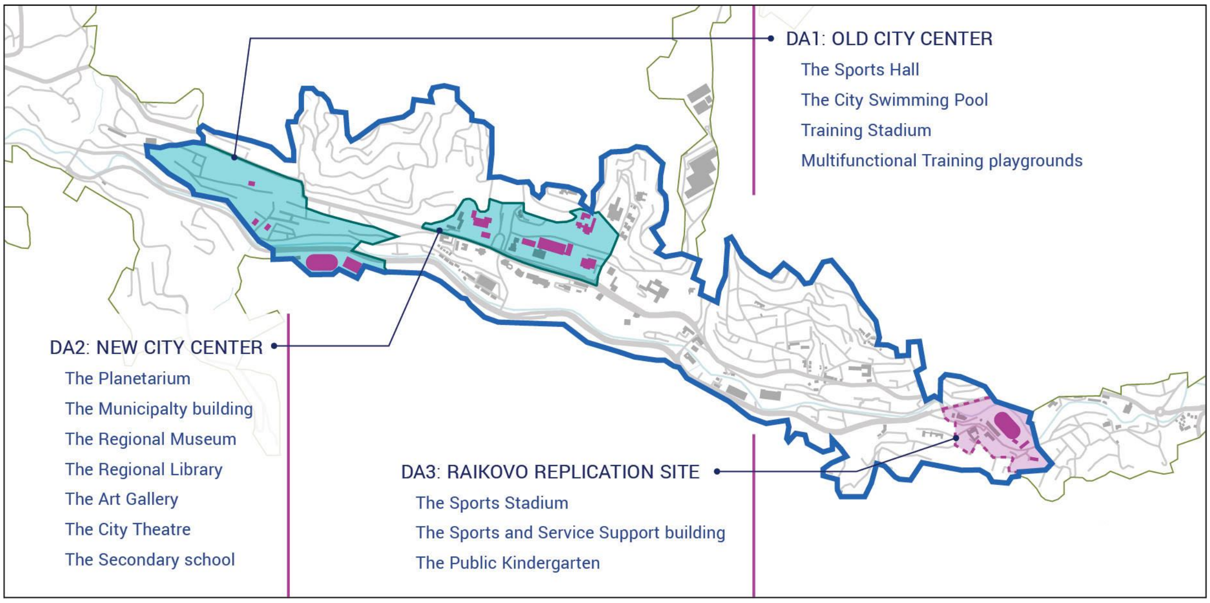


Figure 50 Smolyan Demo District, Areas and Sites

At the time of modelling, the city was considering three Demonstration Areas to be further analysed to see if they could become PEBs. Subsequent analysis as part of T6.4 has indicated that the PEB 1 shown in this document is likely to become the preferred PEB, with PEB 2 and 3 becoming the focus of replication activities.

The 3D map image below is taken from the Dashboard view for the Smolyan City model using the data imported from OSM and obtained from Smolyan Municipality.

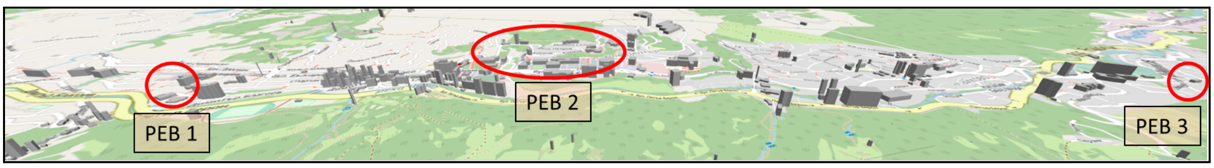


Figure 51 The Smolyan Area Modelled with Potneia PEBs highlighted

7.1.1 Smolyan Potential PEB 1

The PEB area includes 5 buildings:

- City Swimming Pool
- Kindergarten Buratino
- Secondary School SV.SV. Kiril I Metodiy
- Smolyan Training Stadium Service Building
- Sports Hall Velichko Cholakov

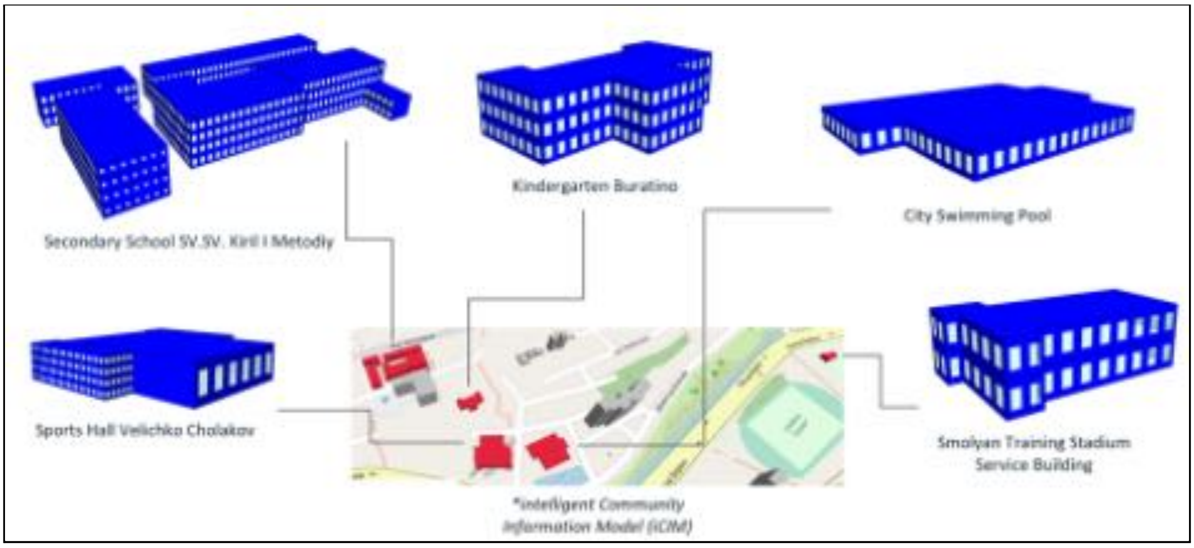


Figure 52 Smolyan Potential PEB 1

7.1.2 Smolyan Potential PEB 2

The PEB area includes 7 buildings:

- Art Gallery
- Municipality of Smolyan's Administrative Building
- Planetarium
- Regional Historical Museum Stoiyu Shishkov
- Regional Library Nikolai Haitov
- Rhodopean Dramatic Theatre Nikolai Haitov
- Secondary school Otetz Paisii

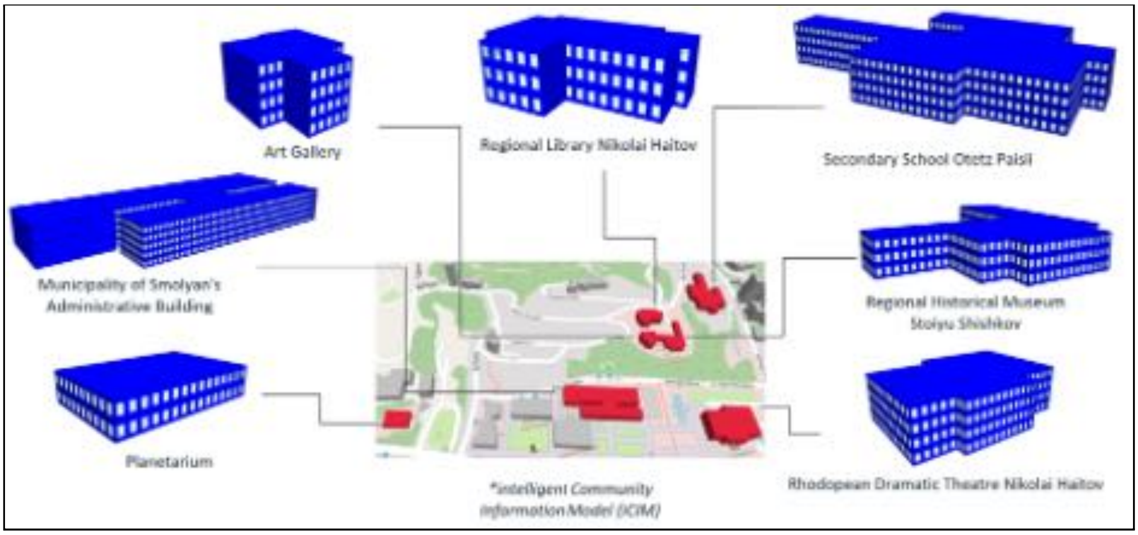


Figure 53 Smolyan PEB 2

7.1.3 Smolyan Potential PEB 3

The PEB area includes 2 buildings:

- Raikovo Stadium Building
- Slaveitche Kindergarten

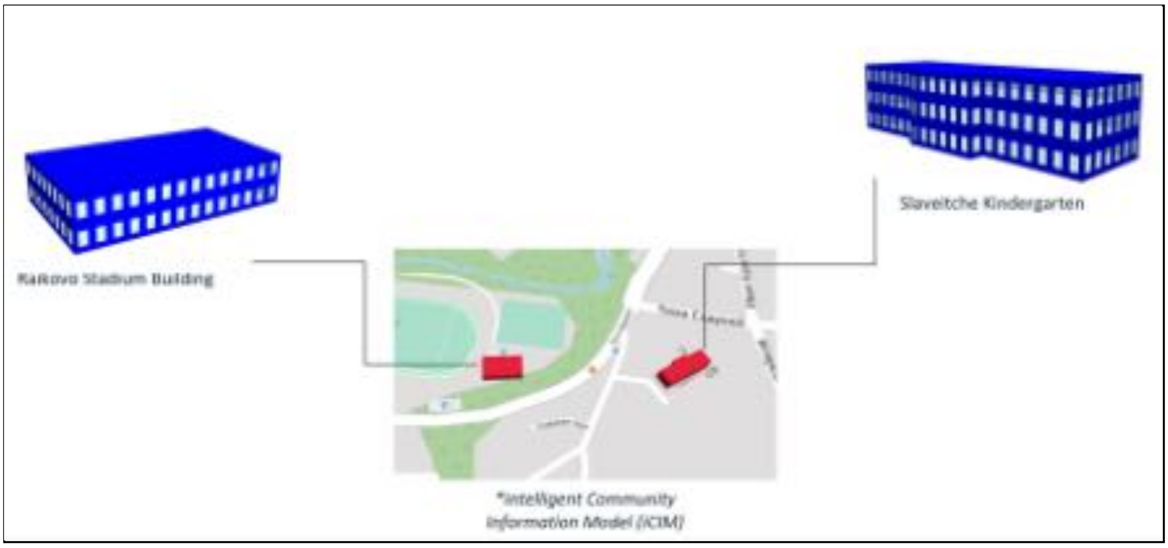


Figure 54 Smolyan PEB 3

7.2 Data Collection for Baseline Model

The Data Checklist was filled in as requested with all of the necessary attributes for the city and demo district modelling. However, the information available in OSM was limited, resulting in a model that includes only 366 buildings across the city. Missing buildings from OpenStreetMap import (OSM) will need to be added by future buildings of interest, making use of other sources of information. Nevertheless, it was possible to model the demo and

PEB area sufficiently using the data provided. The import from OSM was used for buildings and their geometries, and was then updated with applicable data from the data checklist. The data which was not in the checklist was that of roof types, so Google Maps was used instead to check the most common types and these were used in the modelling.

For the PEB buildings, all of the data requested in the checklist was obtained except energy consumption data for 1 building in PEB 2 (Otetz Paisii), and missing U-values for PEB 3. BMS data for all the buildings was also not available.

For the supply side of electricity in the PEBs, although no data was received it was confirmed that all buildings in the PEB were connected to the same sub-station.

The IWEC weather file from the closest weather station, located in the city of Plovdiv, was used for energy simulations and for the calculation of heating degree days

Socio-economic data was collected for Smolyan in the following categories:

- Derelict/vacant buildings
- Property values
- Employment
- Air quality

For energy supply costs, a flat unit rate of 0.08 €/kWh and 0.074 €/kWh have been considered for electricity and natural gas respectively. Both biomass and oil have been assigned a cost of 0.077 €/kWh.

7.3 Baseline Model Results

Once the buildings within the PEB and the demo area had been modelled, the baseline was simulated for the year 2021.

7.3.1 Demonstration District Modelling Results

For the city model, the simulated buildings recorded a Total Annual Energy Usage of 228.1 GWh, equating to an Average Energy Usage Intensity of 288 kWh/m^2. The associated Annual Carbon Emissions from the buildings was 135.74 ktCO$_2$e. The results of the city-scale simulation are limited by the number of buildings imported through OSM.

Figure 55 below shows the baseline model of Smolyan, where buildings within the demo area are highlighted based on their total energy demand. The associated total carbon emissions are shown in Figure 56.

Figure 55 Smolyan Demo Area Baseline Model Building Energy Demand

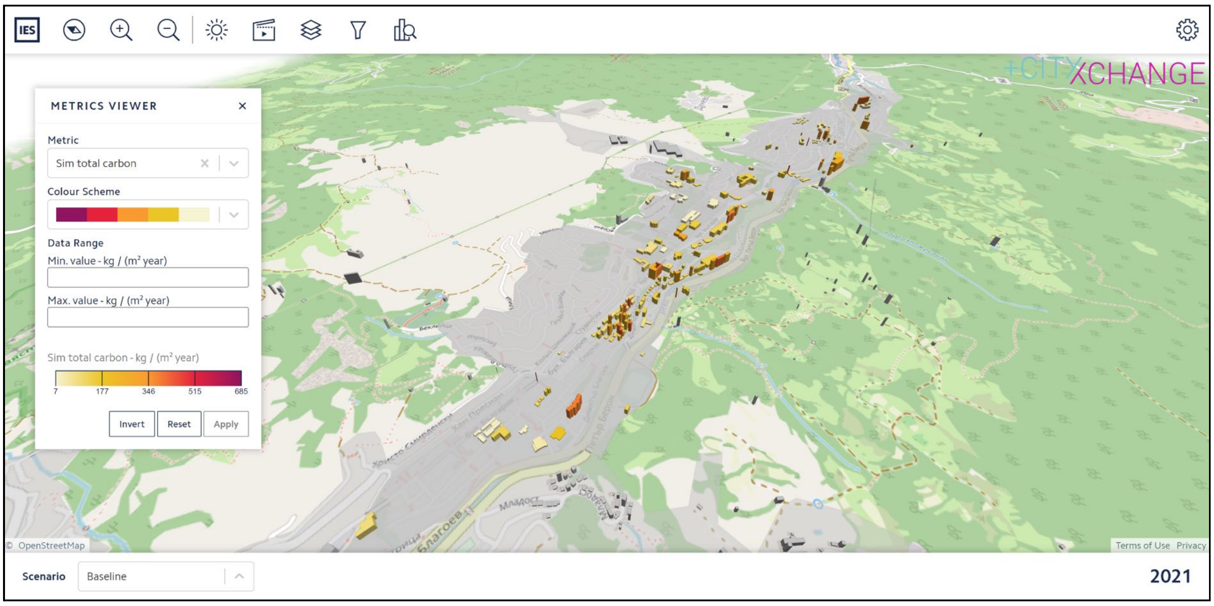


Figure 56 Smolyan Demo Area Baseline Model Building Carbon emissions

7.3.2 Potential PEB Energy Demand and Supply Baseline

The PEB buildings were modelled and simulated within the city model using the IES iCD. There are three PEBs distributed across the city of Smolyan. Each of the buildings were modelled based on the building data checklist completed by the city.

A table for each potential PEB shows the results of the energy simulations and the validation against the data provided.

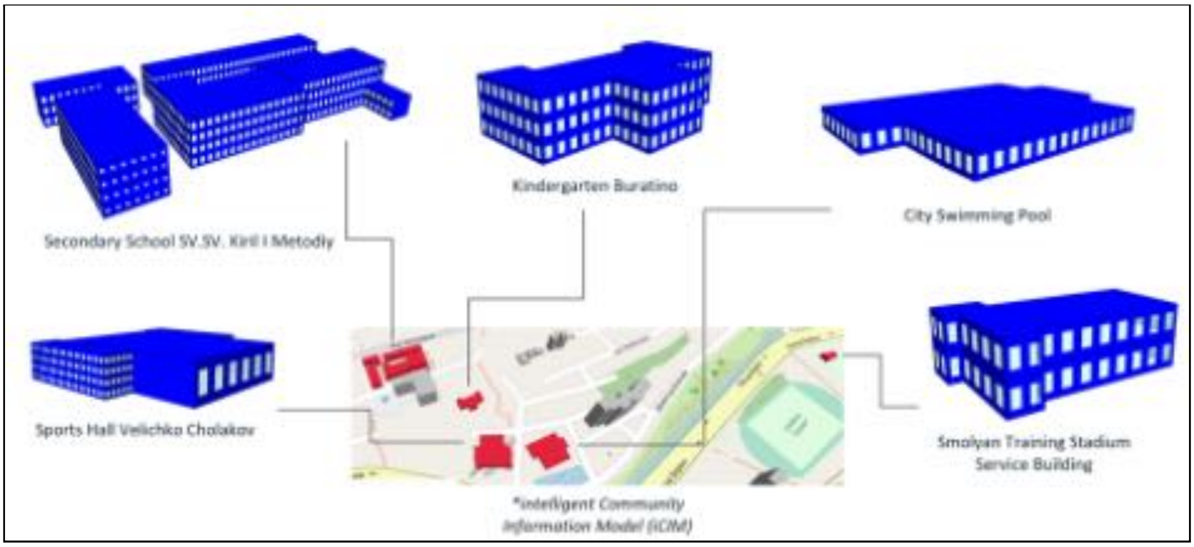


Figure 57 Smolyan Potential PEB 1

Figure 58 Smolyan Potential PEB 1 Buildings Energy Demand Baseline Model

PEB 1 Building	**Energy use (energy bills) [kWh/m²/year]**	**Energy use (simulated) [kWh/m²/year]**	**% difference**
City Swimming Pool	433.6	411.6	-5.1
Kindergarten Buratino	21.3	22.3	4.7
Secondary School SV.SV. Kiril I Metodiy	48.5	50.6	4.3
Smolyan Training Stadium Service Building	139.1	145.0	4.2

Sports Hall Velichko Cholakov	81.5	80.7	-1.0
Total	**93.9**	**92.9**	**-1.0**

Figure 59 Potential PEB 1 Smolyan Buildings Energy Demand Baseline Results

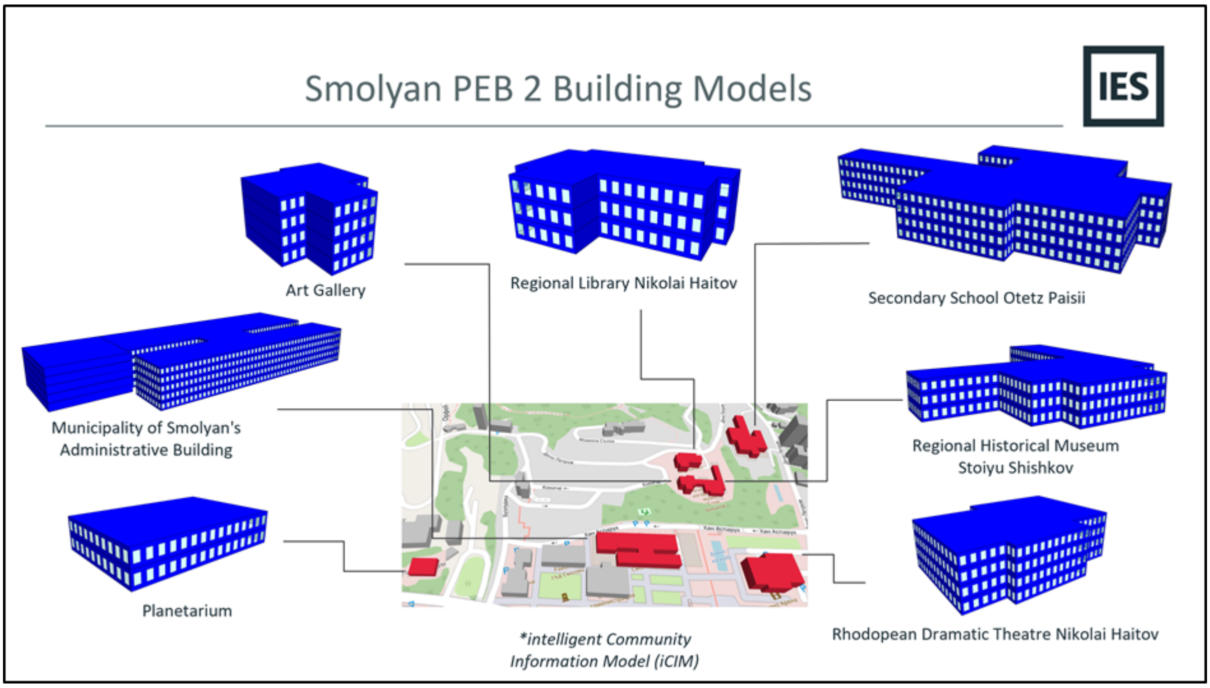


Figure 60 Potential Smolyan PEB 2

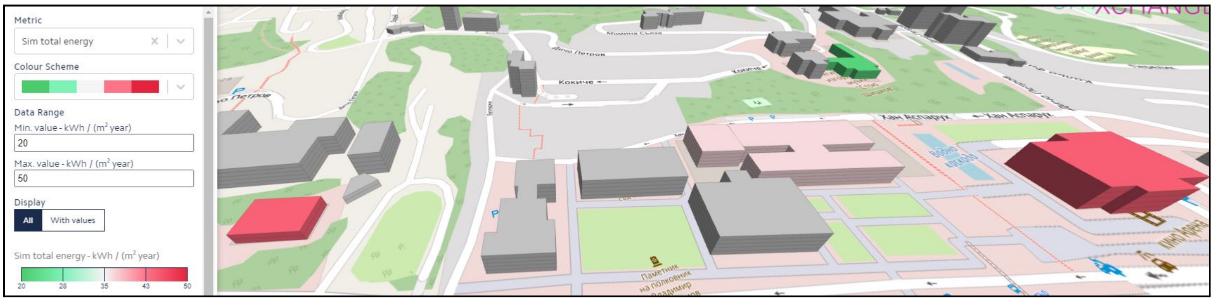


Figure 61 Smolyan Potential PEB 2 Buildings Energy Demand Baseline Model

PEB 2 Building	Energy use (energy bills) [kWh/m²/year]	Energy use (simulated) [kWh/m²/year]	% difference
Art Gallery	9.8	10.7	9.2
Municipality of Smolyan's Administrative Building	36.1	36.5	1.1

Planetarium	45.3	44.3	-2.3
Regional Historical Museum Stoiyu Shishkov	22.6	21.7	-4.2
Regional Library Nikolai Haitov	18.4	18.9	2.9
Rhodopean Dramatic Theatre Nikolai Haitov	44.0	44.4	1.0
Secondary School Otetz Paisii		117.6	N/A
Total	**29.3**	**29.4 (not inc. Secondary School)**	**0.3**

Figure 62 Potential PEB 2 Smolyan Buildings Energy Demand Baseline Results

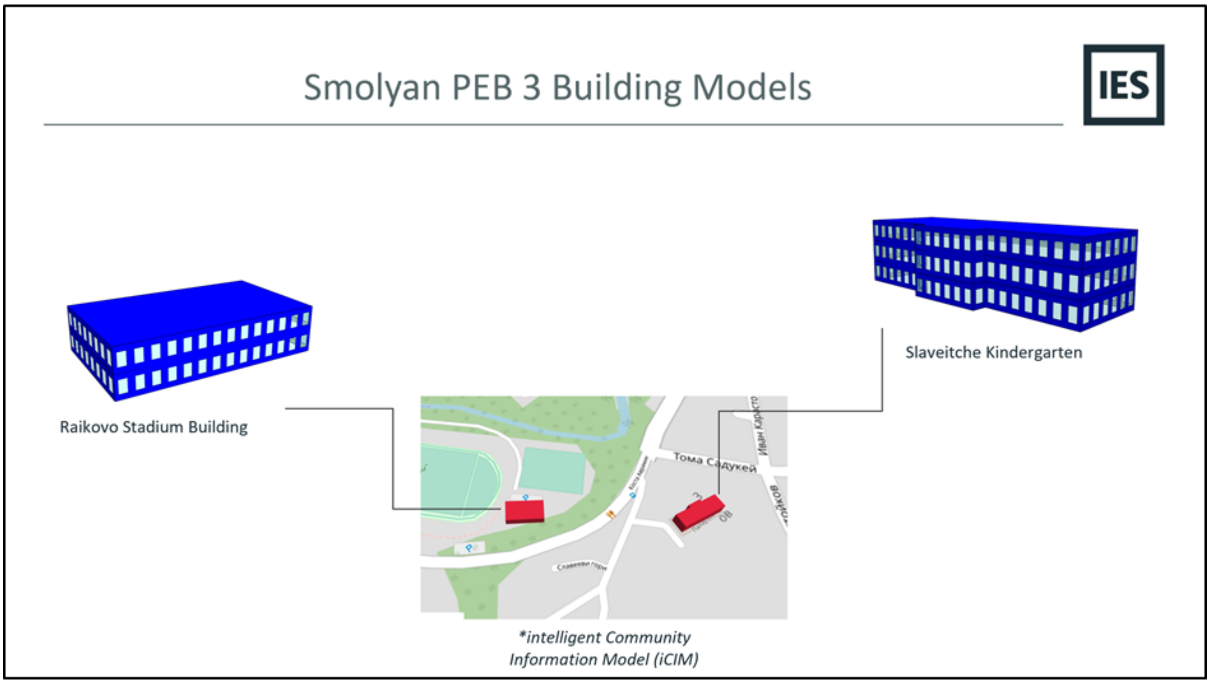


Figure 63 Smolyan Potential PEB 3

Figure 64 Smolyan Potential PEB 3 Buildings Energy Demand Baseline Model

PEB 3 Building	Energy use (energy bills) [kWh/m²/year]	Energy use (simulated) [kWh/m²/year]	% difference
Raikovo Stadium Building	9.3	9.1	-1.9
Slaveitche Kindergarten	103.8	106.5	2.6
Total	**65.1**	**66.7**	**2.4**

Figure 65 Potential PEB 3 Smolyan Buildings Energy Demand Baseline Results

The data from the three PEBs was imported into the IES iVN to create the energy supply baseline model. Within each PEB, the buildings are connected to the same substation.

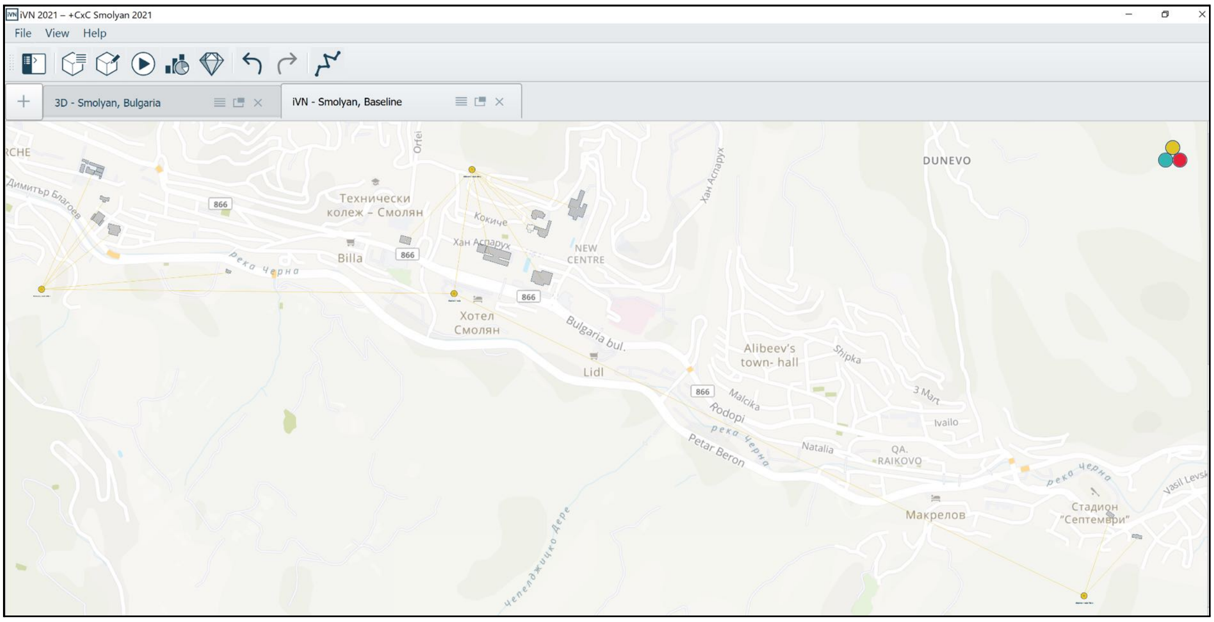


Figure 66 Smolyan Electricity Supply All Potential PEBs Baseline

The data from the +PEB buildings was imported into the IES iVN to create the energy supply baseline model.The figure below shows the 2D view of the baseline iVN model, where each of the PEB buildings is connected to the same electricity node, representative of their common substation.

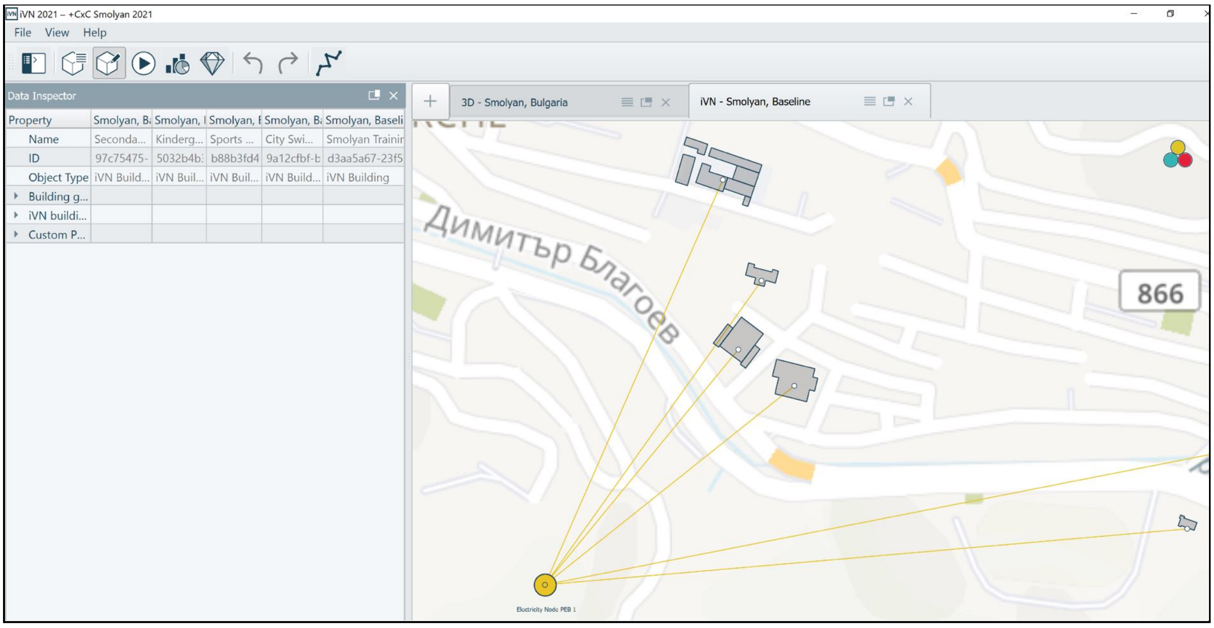


Figure 67 Smolyan Electricity Supply Potential PEB 1 Baseline

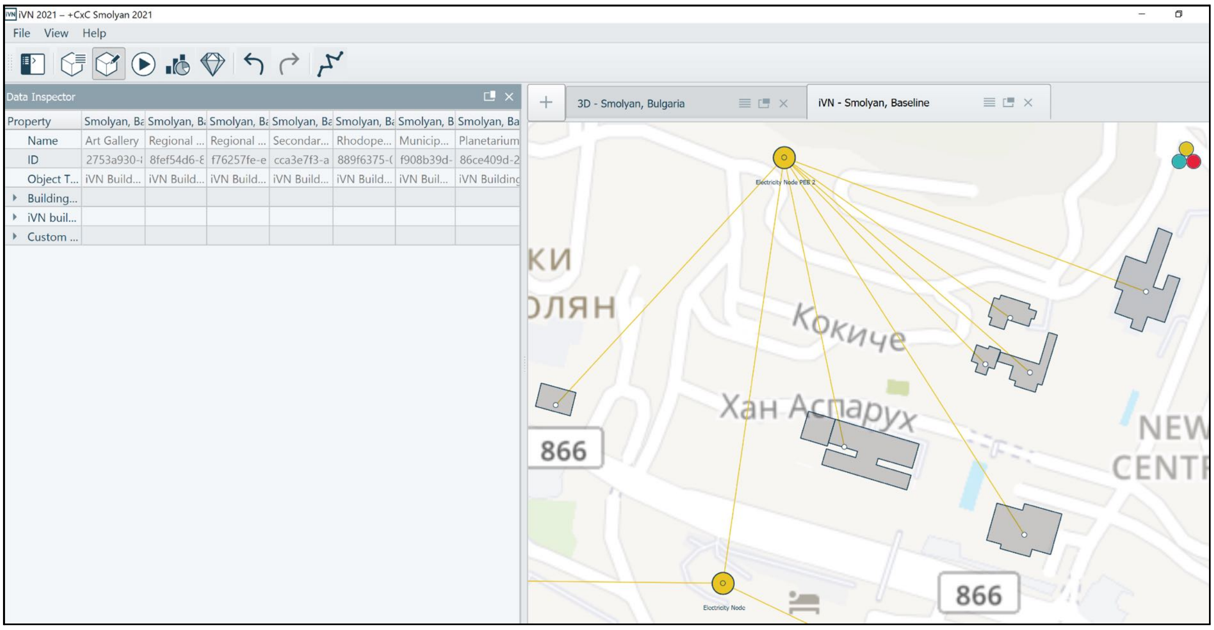


Figure 68 Smolyan Electricity Supply Potential PEB 2 Baseline

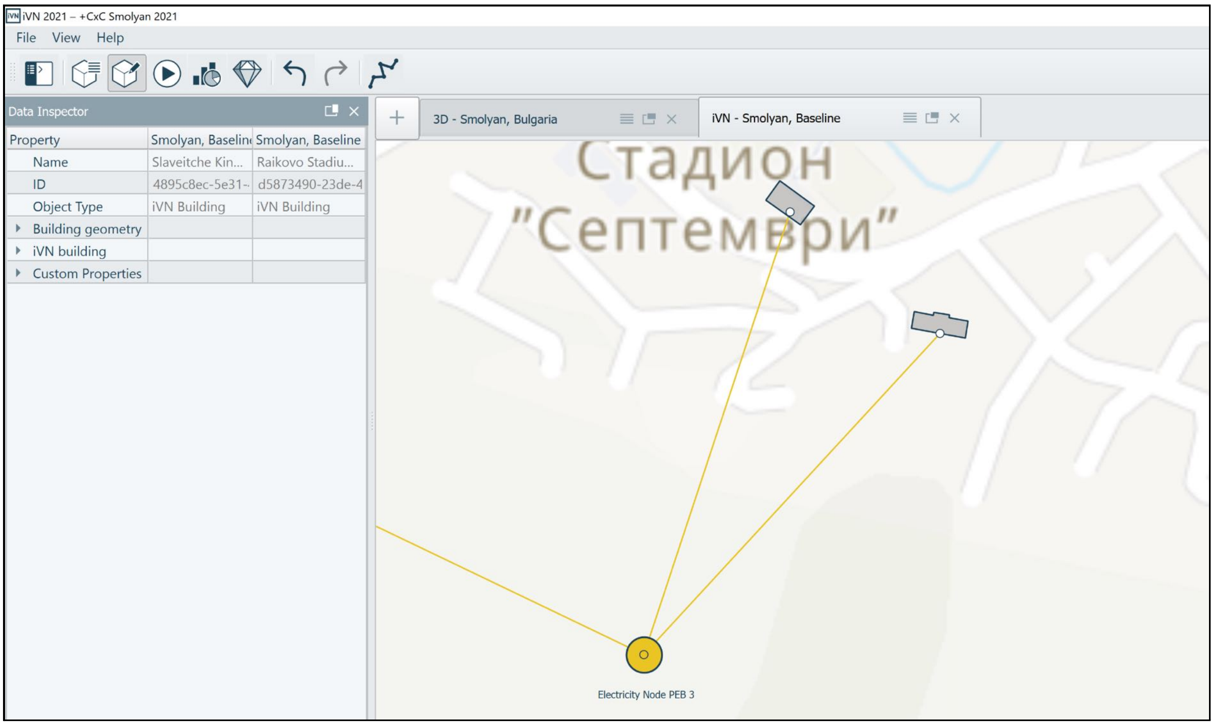


Figure 69 Smolyan Electricity Supply Potential PEB 3 Baseline

7.3.3 Socio Economic Baseline

The socio-economic data collected for Smolyan was imported into the DST and can be visualised at boundary level as shown below.

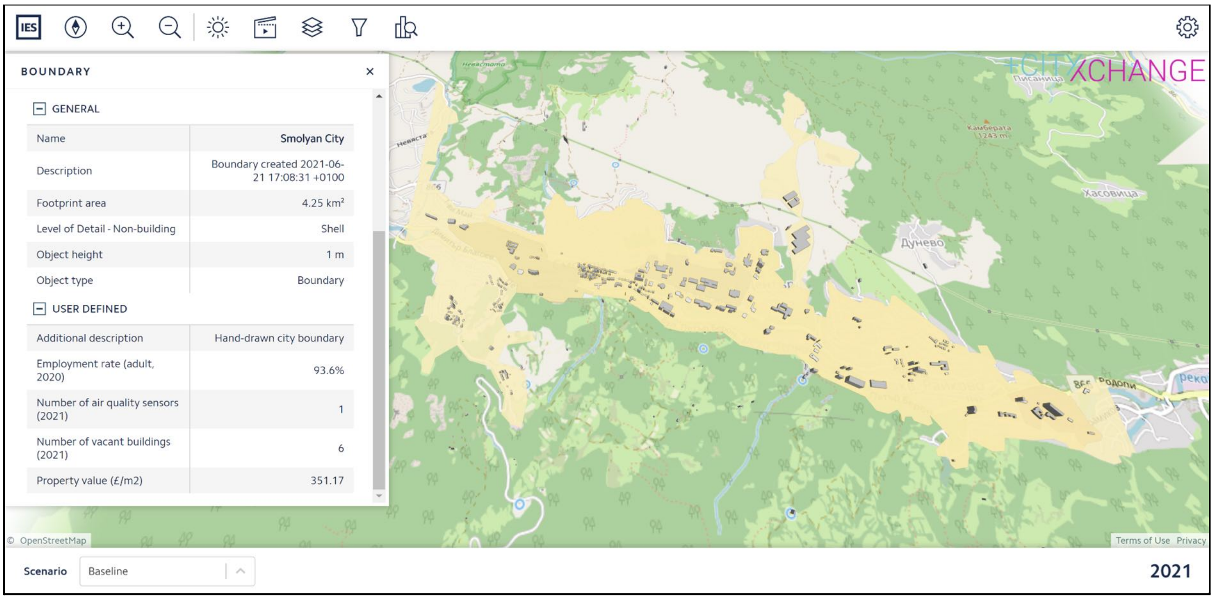


Figure 70 Smolyan Socio Economic Baseline Results

7.4 Reporting and Decision Support (Dashboard Views)

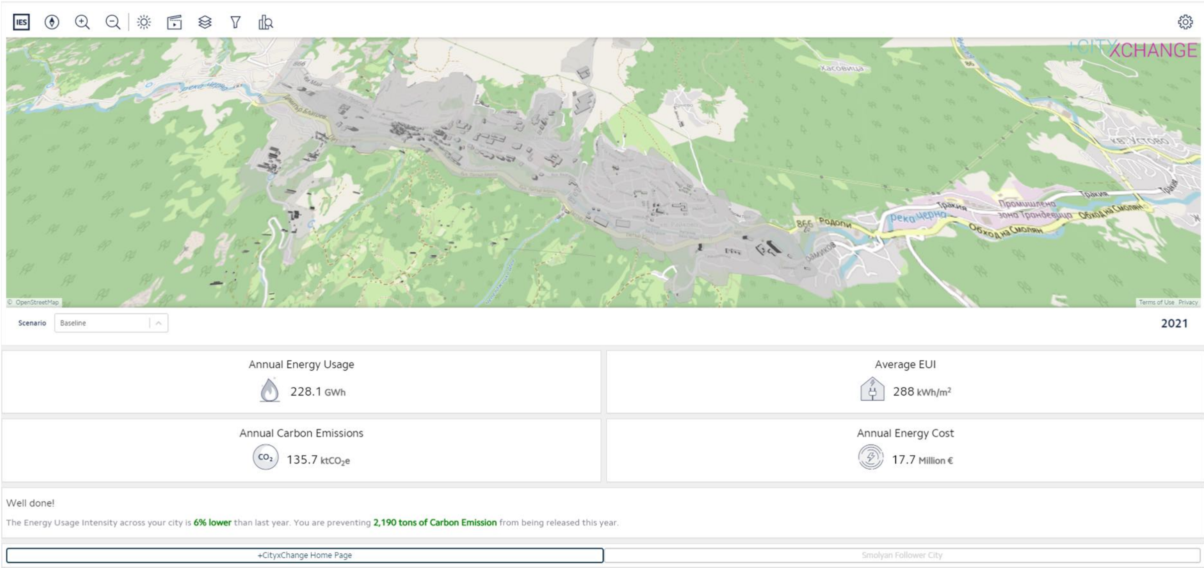
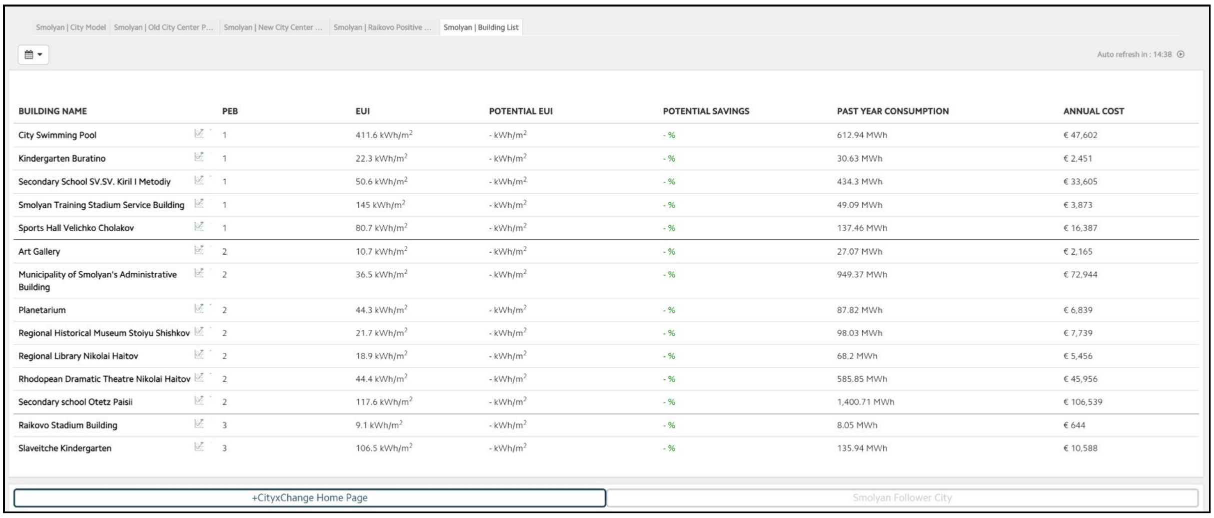


Figure 71 Smolyan DST Dashboard view



BUILDING NAME	PEB	EUI	POTENTIAL EUI	POTENTIAL SAVINGS	PAST YEAR CONSUMPTION	ANNUAL COST
City Swimming Pool	1	411.6 kWh/m²	- kWh/m²	- %	612.94 MWh	€ 47,602
Kindergarten Buratino	1	22.3 kWh/m²	- kWh/m²	- %	30.63 MWh	€ 2,451
Secondary School SV.SV. Kiril I Metodiy	1	50.6 kWh/m²	- kWh/m²	- %	434.3 MWh	€ 33,605
Smolyan Training Stadium Service Building	1	145 kWh/m²	- kWh/m²	- %	49.09 MWh	€ 3,873
Sports Hall Velichko Cholakov	1	80.7 kWh/m²	- kWh/m²	- %	137.46 MWh	€ 16,387
Art Gallery	2	10.7 kWh/m²	- kWh/m²	- %	27.07 MWh	€ 2,165
Municipality of Smolyan's Administrative Building	2	36.5 kWh/m²	- kWh/m²	- %	949.37 MWh	€ 72,944
Planetarium	2	44.3 kWh/m²	- kWh/m²	- %	87.82 MWh	€ 6,839
Regional Historical Museum Stoiyu Shishkov	2	21.7 kWh/m²	- kWh/m²	- %	98.03 MWh	€ 7,739
Regional Library Nikolai Haitov	2	18.9 kWh/m²	- kWh/m²	- %	68.2 MWh	€ 5,456
Rhodopean Dramatic Theatre Nikolai Haitov	2	44.4 kWh/m²	- kWh/m²	- %	585.85 MWh	€ 45,956
Secondary school Otetz Paisii	2	117.6 kWh/m²	- kWh/m²	- %	1,400.71 MWh	€ 106,539
Raikovo Stadium Building	3	9.1 kWh/m²	- kWh/m²	- %	8.05 MWh	€ 644
Slaveitche Kindergarten	3	106.5 kWh/m²	- kWh/m²	- %	135.94 MWh	€ 10,588

Figure 72 Smolyan Potential PEB Building List view

8. DST Baseline for Võru

8.1 Introduction to the City, Demo Area and PEB

Voru (14 km2) is a small city situated in the South-Eastern part of Estonia and has a population of 12 367. Details for the DD, DA and potential PEBs will be found in D6.3: Technical feasibility study of the potential PEB replications in each FC.

The figure below is a map of the Demonstration District, Area and Sites.

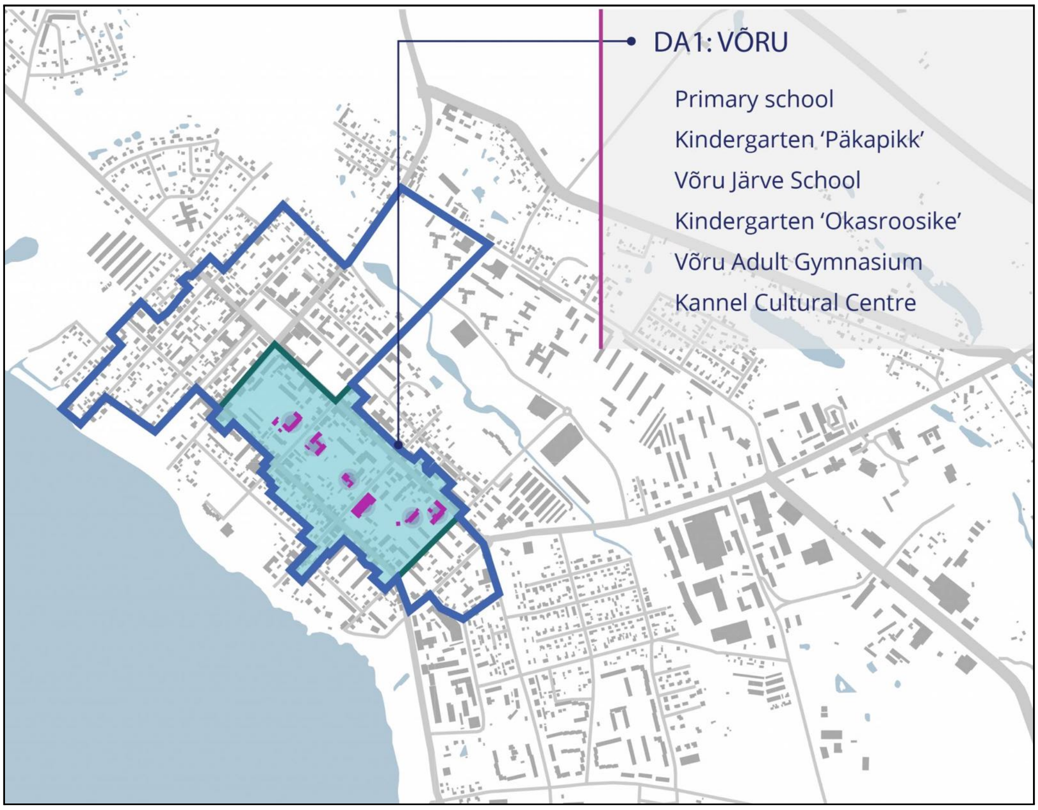


Figure 73 Voru Demo District, Areas and Sites

The figure below shows the total area imported into the DST (area inside the red line), the Demonstration District *(buildings in dark green)*, and the potential PEB buildings *(dark brown)*. The model includes 1,966 buildings, 520 of which are within the demo area.

Figure 74 The Voru Area Modelled

The 3D map images above are taken from the Dashboard view for the Voru City model using the data imported from OSM and obtained from Voru Municipality.

8.1.1 Voru Potential PEB

The Voru PEB consists of eight buildings, one of which was under construction at the time of the analysis. Each of the buildings were modelled based on the building data checklist completed by the city.

At the time of modelling, the buildings proposed to be in the PEB are as follows and shown in the model below:

- Kesklinna kool primary school
- Võru Historical Bank House
- Health Centre (currently being built)
- "Päkapikk" kindergarten
- Järve School
- Culture Center "Kannel"
- "Okasroosike" kindergarten
- Adult Education Centre (Jüri 42)

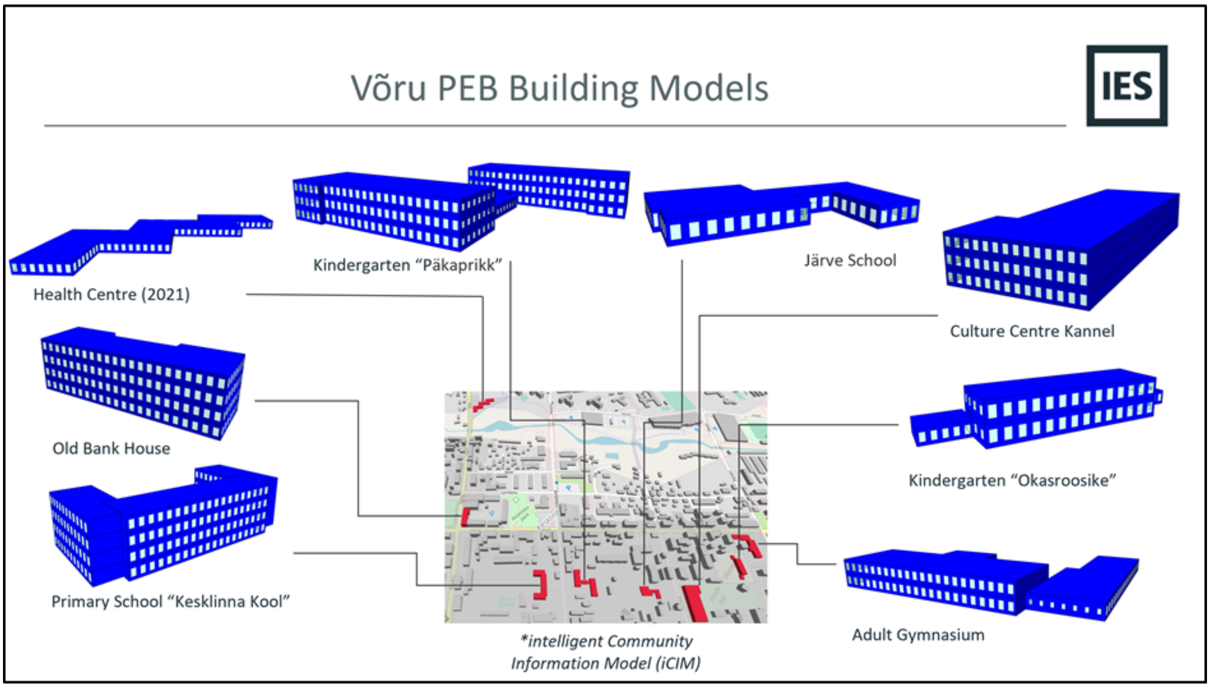


Figure 75 Voru Potential PEB Buildings

8.2 Data Collection for Baseline Model

In terms of data collection for Voru, the Data Checklist was filled in as requested with all of the necessary attributes for the city and demo area modelling.

For the City/Demo District model, the import from OSM was used for buildings and their geometries. This was then enriched with applicable data from the data checklist. The data which was not in the checklist was that of roof types, so Google Maps was instead used to check the most common types and these were used in the modelling.

For the potential PEB buildings in the Demonstration Area, all of the data requested in the checklist was obtained except for:

- Constructions and U-values of most of the buildings. Assumed values were used in agreement with Voru
- Building plans, & building sections (dwg/PDF) for 2 buildings: Culture Centre Kannel, Voru Adult Gymnasium.
- Energy consumption data for the Health Centre as it is not yet built
- BMS data due to the buildings either not having this application, or it was not possible to download the information in the time requested.

For the supply side of electricity in the PEB, a map was received from Voru confirming that the PEB buildings are all connected to the same electricity substation.

The IWEC weather file from the closest weather station, located in the city of Saint Petersburg,, was used for energy simulations and for the calculation of heating degree days

Socio-economic data was collected for Voru at the city level in the following categories:

- Property values
- Life expectancy
- Premature deaths
- Crime
- Disposable income
- Employment
- Air quality

For energy supply costs, a flat unit rate of 0.113 €/kWh and 0.048 €/kWh have been considered for electricity and natural gas respectively. Both biomass and waste heat have been assigned a cost of 0.06 €/kWh.

8.3 Baseline Model Results

Once the buildings within the PEB and the demo area had been modelled, the baseline was simulated for the year 2021.

8.3.1 City Modelling Results

For the Demo District, the simulated buildings recorded a Total Annual Energy Usage of 155.6 GWh, equating to an Average Energy Usage Intensity of 415 kWh/m^2. The associated Annual Carbon Emissions from the buildings was 86.89 ktCO_2e.

The figure below shows the baseline model of Voru, with buildings within the demo area highlighted based on their total energy demand. The DST allows for the visualisation of a range of attributes and simulation results, including the total carbon emissions as shown in the subsequent figure.

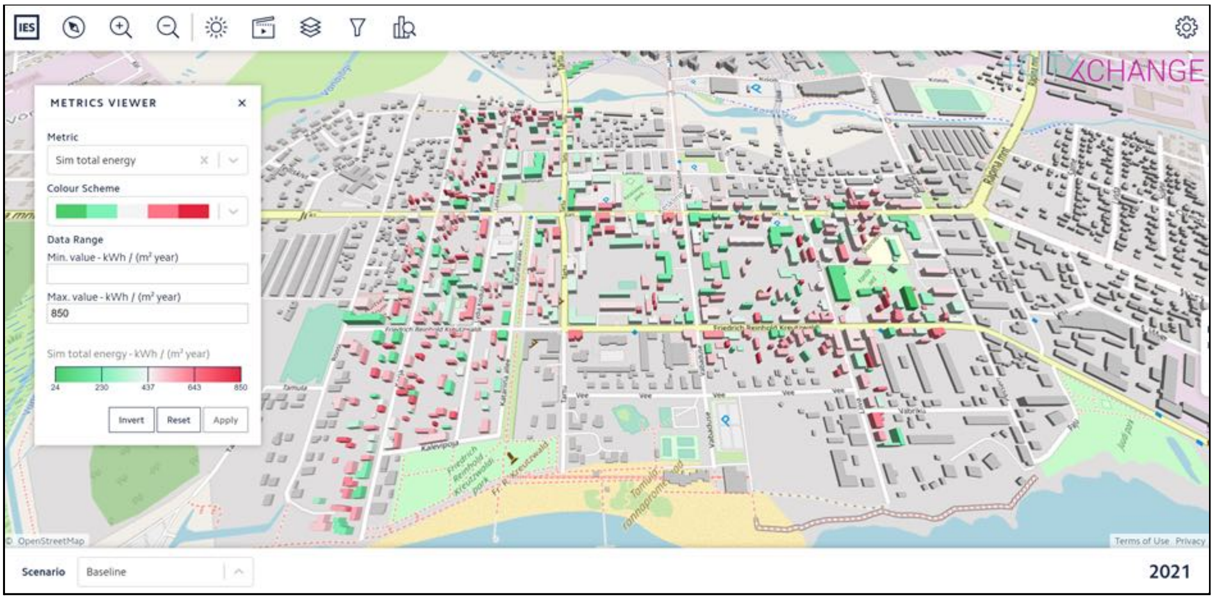


Figure 76 Voru Demo District Baseline Model Building Energy Demand

Figure 77 Voru Demo District Baseline Model Building Carbon Emissions

8.3.2 Potential PEB Energy Demand and Supply Baseline

The simulation results for the PEB buildings were validated against the annual energy consumption figures provided. As the Health Centre was under construction at the time, the results were validated against the expected energy rating of the building. The accuracy of the simulations is shown below:

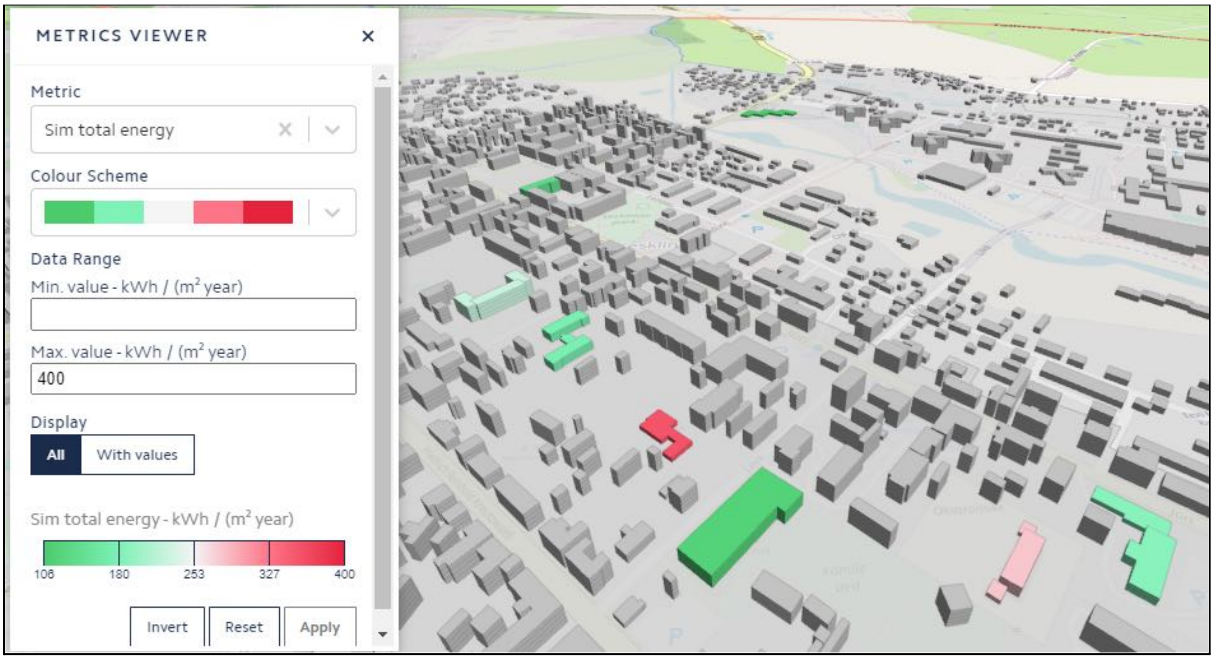


Figure 78 Voru PEB Buildings Energy Demand Baseline Model

PEB Building	**Energy use (energy bills) [kWh/m²/year]**	**Energy use (simulated) [kWh/m²/year]**	**% difference**
Culture Centre Kannel	110.7	120.4	8.8
Health Centre for Family Doctors		106.1	
Kindergarten Okasroosike	273.3	279.1	2.1
Kindergarten Pakapikk	157.7	175.8	11.5
Primary School Kesklinna Kool	240.3	227.0	-5.5
Voru Adult Gymnasium	182.0	187.1	2.8
Voru Jarve School	349.1	355.0	1.7
Old Bank House	128.5	138.9	8.1
Total	**172.6**	**171.6**	**-0.6**

Figure 79 Potential PEB Voru Buildings Energy Demand Baseline Results compared to actual Energy Consumption

The data from the eight PEB buildings was imported into the IES iVN to create the energy supply baseline model.The figure below shows the 2D view of the baseline iVN model, where each of the PEB buildings is connected to the same electricity node, representative of their common substation.

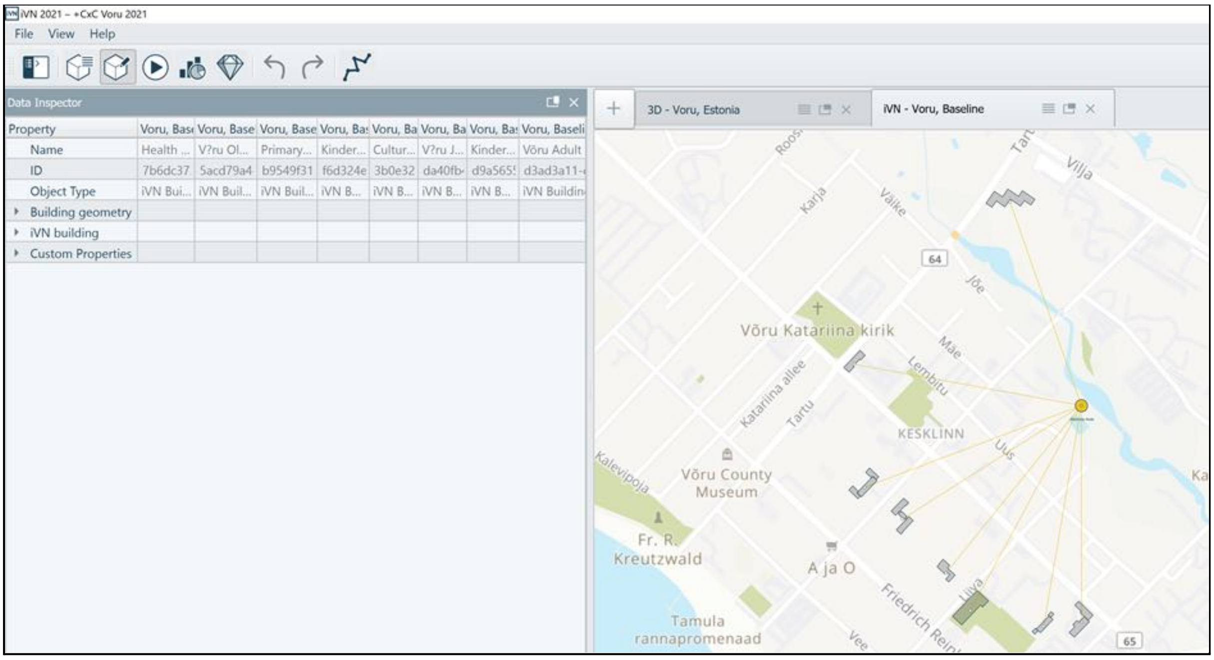


Figure 80 Voru Electricity Supply Potential PEB Baseline

8.3.3 Socio Economic Baseline

The data collected was imported into the DST and can be visualised at boundary level as shown below.

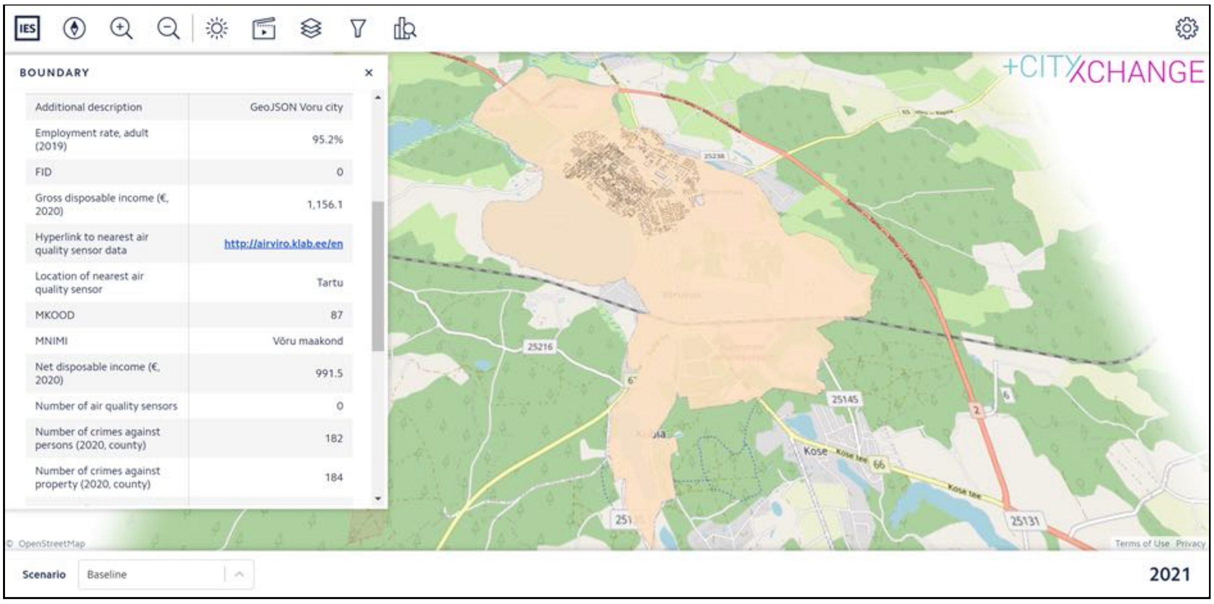


Figure 81 Voru Socio Economic Baseline Results

8.4 Reporting and Decision Support (Dashboard Views)

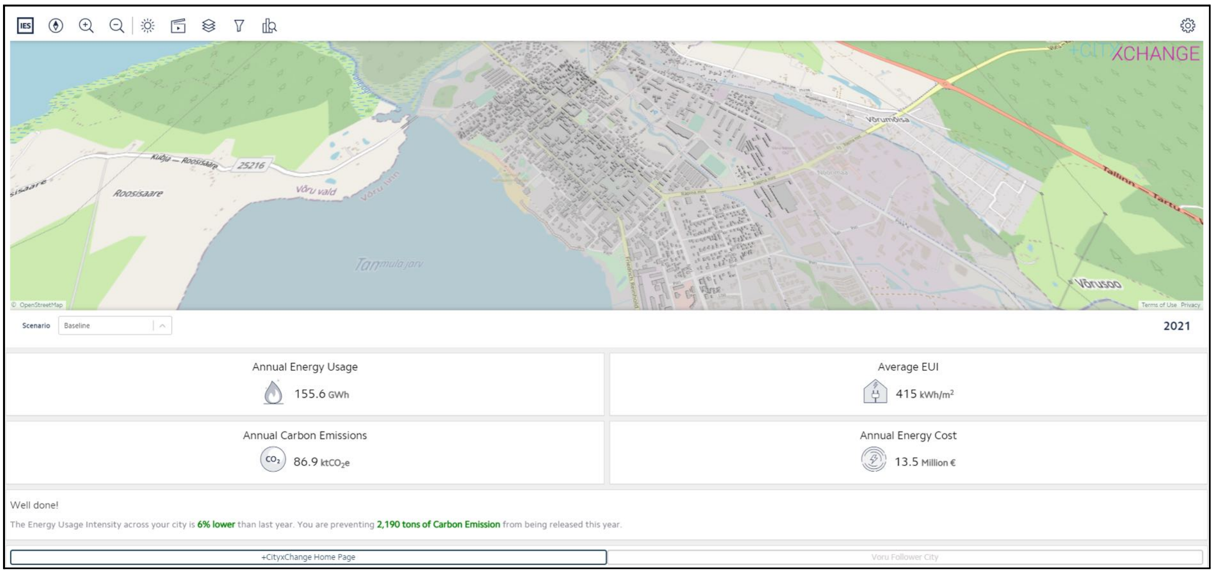


Figure 82 Voru DST Dashboard view

Voru | City Model Voru | Voru Positive Energy ... Voru | Building List

Auto refresh in : 07:36

BUILDING NAME	PEB	EUI	POTENTIAL EUI	POTENTIAL SAVINGS	PAST YEAR CONSUMPTION	ANNUAL COST
Culture Centre Kannel	1	120.4 kWh/m^2	- kWh/m^2	- %	625.79 MWh	€ 43,722
Health Centre for Family Doctors	1	106.1 kWh/m^2	- kWh/m^2	- %	171.72 MWh	€ 19,404
Kindergarten Okasroosike	1	279.1 kWh/m^2	- kWh/m^2	- %	243 MWh	€ 15,738
Kindergarten Pakapikk	1	175.8 kWh/m^2	- kWh/m^2	- %	465.66 MWh	€ 30,287
Primary School Kesklinna kool	1	227 kWh/m^2	- kWh/m^2	- %	869.67 MWh	€ 58,144
Voru Adult Gymnasium	1	187.1 kWh/m^2	- kWh/m^2	- %	325.79 MWh	€ 20,878
Voru Jarve School	1	355 kWh/m^2	- kWh/m^2	- %	197.84 MWh	€ 13,113
Voru Old Bank House	1	138.9 kWh/m^2	- kWh/m^2	- %	316.35 MWh	€ 23,161
-	2	- kWh/m^2	- kWh/m^2	- %	- MWh	€ -
-	2	- kWh/m^2	- kWh/m^2	- %	- MWh	€ -

+CityxChange Home Page | Voru Follower City

Figure 83 Voru PEB Building List view

9. Future Modelling to Support the PEB Designs and Bold City Visions

Activities that have been occurring in T6.4 Feasibility Studies have identified numerous interventions that each Follower City would like to implement in order to create its PEBs and further the path to Net Zero across the city by producing a Bold City Vision..

The DST is an ideal tool to help visualise the impact of each intervention and now that the baseline models for each City have been completed, training needs to occur with relevant people in each City for them to be able to take control of using the tool for themselves (see Section 3.3 for details on Training).

The figure below shows a summary of the interventions proposed by each city as part of T6.4, alongside what will be possible for the modelling in the DST after training.

Summary of Smart City Interventions (SCIs) proposed in T6.4

User needs no support - applicable to all buildings modelled

User needs IES support - applicable to all buildings modelled

Should be done by expert - only applicable to PEB buildings

Category of Intervention	Type of intervention	Applicable City	Ease of modelling in DST after training	Approach/Comment
Reducing energy consumption and Improving energy efficiency	Renovatiion of buidling envelope to improve energy efficiency	Alba Iulia, Sestao, Smolyan, Voru		User is able to select from a wide range of insulation level, infiltration levels and u-values of windows
	Addition of new HVAC systems	Alba Iulia, Pisek, Sestao, Smolyan, Voru		User is able to select from wide range of heating and cooling system types, efficiencies, and fuel types
	Optimisation of HVAC systems	Alba Iulia		Requires us of IESVE software to be done by expert user
	Update internal building lighting to LEDs	Alba Iulia, Pisek, Sestao, Voru		User is able to select from wide range of lighting improvements
	Update extenal building lighting to LEDs	Sestao		External lighting was not included in the baseline models and would need IES expert to update and re-simulate for this.
	Update lighting to include sensors/smart lighting)	Pisek, Voru		User would need to assume % improvement in lighting energy consumption
	Upgraded internal equipment that uses energy	Alba Iulia, Pisek, Voru		User would need to assume % improvement in energy consumption of internal equipment
	Green purchasing policy for new internal equipment	Pisek		User would need to assume % improvement in energy consumption due to policy implementation
Increasing energy production and use from RES	Increasing power production and use from PVs	Alba Iulia, Pisek, Sestao, Smolyan, Voru		Modelling in iVN software required and likely to need support to ensure correct setup of PVs
	Addition of energy storgae from PVs	Alba Iulia, Pisek, Smolyan, Voru		Modelling in iVN software required and likely to need support to ensure correct setup of storage
	Optimisation of RES	Smolyan		Optimisation is currently a manual process and requires support to ensure correct setup
Integrated energy solutions	Smart Metering	Alba Iulia, Sestao, Smolyan		User would need to assume % improvement in energy consumption from smart metering
	Smart Automation	Alba Iulia, Pisek, Smolyan, Voru		User would need to assume % improvement in energy consumption from smart automation
	Smart Grid	Pisek, Sestao		Optimisation for the grid is currently a manual process and requires support to ensure correct setup
	E-Charging stations	Alba Iulia, Sestao, Smolyan		E-charging simaultion is available but will need support for cirrect setup and operation
Education and learning	Improved ways to engage with citizens regarding energy improvements and	Alba Iulia, Pisek, Sestao, Smolyan, Voru		User would need to assume % improvement in energy consumption from education activities

Figure 84 Summary of interventions in D6.3 with possible modelling in the DST

The figure shows that whilst it is possible to model and simulate all interventions being considered using the DST, some will require less effort and support than others. The options highlighted in green will be easy for the user to model by themselves, whereas those in amber will require some guidance and those in red will require an IES consultant or expert IES user to complete. Overall, it is positive that nearly all interventions can be modelled with little outside resources required.

10. Conclusion

This document's purpose was to demonstrate the Integrated Modelling and Decision Support Tool developed for the +CityxChange project and launched for the Follower Cities. This has been achieved through ongoing engagement with the Follower Cities and launch/demonstration events in April/May 2021. The document represents the content of the demonstration given as well as explaining how the DST (as detailed in D1.4: Creation of the +CityxChange Integrated Design and Decision Support Tool; and partly in D4.1 and D5.2) was developed.

The main area of demonstration has been concerned with creating the baseline for the current energy and socio economic situation in the Follower Cities Demonstration Districts, Areas and potential PEB buildings. From this baseline, future potential scenarios can now be modelled to begin to guide the cities on the potential of achieving their PEBs and the most suitable approaches to creating a Bold City Vision.

To achieve an effective baseline, data was first gathered concerning the Follower Cities and their Demonstration District and potential PEBs. This data was imported into the DST and mapped to the building types and construction categories contained within it. Fuel types, carbon emissions of fuel and tariffs were also set and the baseline for energy demand in the cities was conducted.

For the buildings in the PEB area, a more detailed energy baseline was formed by accessing certain parameters within IESVE software to increase the accuracy of the models prior to simulation. The result was then compared to the monthly energy bills provided to ensure the models accurately reflected the real life building operation and performance. Where actual energy data was available, it was possible to achieve the following results in terms of accuracy of the simulations:

Follower City PEB	**% difference of simulation vs actual energy consumption**
Alba Iulia PEB 1	N/A due to no energy consumption data
Alba Iulia PEB 2	3.8%
Pisek PEB A	12.9% (large amount of assumed data used in modelling due to lack of data)
Pisek PEB B	8.9% (large amount of assumed data used in modelling due to lack of data)
Sestao PEB 1	N/A due to no energy consumption data
Sestao PEB 2	N/A due to no energy consumption data
Smolyan PEB 1	-1.0%

Smolyan PEB 2	0.3%
Smolyan PEB 2	2.4%
Voru PEB	0.6%

Figure 85 Accuracy of DST simulations compared to actual energy consumption

In terms of the energy supply baseline, where possible this was completed using a map of the electricity network within the PEB which showed the location of substations which was then replicated in the DST. The location of sub stations was needed for PEB design so that sharing of energy/energy trading between buildings can be achieved. As long as the buildings are connected to the same substation, then electricity could be shared and its use optimised.

For the socio economic baseline, where possible, census data was available from each city at the lowest boundary level and added to the DST. The aim was to be able to model the socio economic impacts of PEB creation, and to achieve this we must have socio economic data as or close to a PEB level. It should be noted however, that as the lowest level of data available was much larger than the PEB boundaries, an analysis of the socio economic impacts of PEB creation will be difficult to achieve.

Although the data to baseline mobility was not available, it was confirmed by all cities that EV charging points are not currently installed in the Demonstration Districts which meant this aspect is baselined at zero.

Following all baselines being completed, proposed energy interventions were produced as part of Task 6.4, and these were reviewed to check how the DST could potentially model these (see Section 9).

In order to allow different users to view results and analyse potential future plans, online dashboards were set up and access can be given according to the user's needs. It needs to be agreed with each Follower City what content should be made public to ensure maximum non-technical stakeholders can be reached, pending the training sessions and further use.

Training material is available for the Follower Cities in the form of the Online PEB Design Workflow tool (details in D1.4), which guides the user step by step through the process of creating a baseline and modelling the best ways to achieve a PEB for their area of interest. It also links to relevant videos and help guides that are available for IES software.

The next steps regarding the Follower City DSTs have been identified as follows:

- Further engagement and training to the relevant Follower City staff by IES RD planned (Section 3.3) and conducted via support for IES RD and the Online PEB Design Workflow Tool. This will enable relevant people in the Follower Cities to run future energy simulations for themselves and to analyse the results.

- T6.2 BCVs - now the baselines are set, the DST for each Follower City can be used to help the city create its Bold City Vision. The DST can be used to replicate PEBs across the areas modelled and also show decarbonisation over time. As well as this, the impact of different measure on socio economic indicators can be modelled.

References

Purshouse, N., De.Donatis, L., Neu, O., Kerrigan, R., D1.4 Demonstration of the +CityxChange Integrated Modelling Platform. +CityxChange Project Deliverable (confidential). 2021.

Purshouse, N., De.Donatis, L., Neu, O., Kerrigan, R., D4.1 Limerick DST (Integrated Modelling and Decision Support Tool) including training manuals/videos. +CityxChange Project Deliverable. 2020. https://cityxchange.eu/knowledge-base/d4-1-limerick-dst-integrated-modelling-and-decision-support-tool-including-training-manuals-videos/

Purshouse, N., De.Donatis, L., Neu, O., Kerrigan, R., D5.2 Trondheim DST including training manuals/videos +CityxChange Project Deliverable. 2021. https://cityxchange.eu/knowledge-base/d5-2-trondheim-dst-including-training-manuals-videos/

D6.3: Technical feasibility study of the potential PEB replications in each FC. +CityxChange Project Deliverable. 2022, forthcoming.

Annex: Building checklists (example)

Building Data Checklist	Required?	Example
General building information		
Construction year	Yes	*e.g. 2002*
Condition (Bad, Fair, Good)	Yes	*e.g. Good*
Ownership (Owner occupied)	Yes	*e.g. Tenancy*
Building hours of use (Morning & Evening)	Yes	*e.g. 9am - 5pm Mon-Fri*
Building type	Yes	*e.g. Office*
Building address	Yes	*e.g. Office, Block 1, Street Name*
Fuel utilised	Yes	*e.g. Gas for heating and DHW*
Construction type (e.g. Concrete frame, wooden frame, etc)	Yes	*e.g. Wooden frame construction*
HVAC type (e.g. heating/ cooling / natural ventilation, etc)	Yes	*e.g. Radiators for heating & Natural ventillation for both cooling and IAQ*
EPC (Energy Performance Certification) level (please if this is a national certification, provide document explaining how this works)	Yes (if available)	*e.g. B3 (eventually attach pdf with EPC description)*
Site photographs	if possible	*e.g. jpeg files*
Is the building listed (protected)? E.g. historical building..	if applicable	*e.g. yes/no and comment with details (eventually provide national regulations on what can/cannot be done)*
AMR data and energy costs information		
Fossil Fuel Yearly (kWh)	Yes	*e.g. 2250 kWh gas*
Electricity Yearly (kWh)	Yes	*e.g. 1862 kWh electricity*
Electricity bills	Yes	*Total energy costs for electricity, or break down of month energy bills in kWh / cost e.g. Jan - 100kWh, €60 feb - 120kWh, €70 etc...*
Fossil fuel bills	Yes	*Total energy costs for fossil fuel, or break down of month energy bills in kWh / cost e.g. Jan - 100kWh, €60 feb - 120kWh, €70 etc...*
RECs, RHI, other energy costs/incentives?	Yes	*e.g.government incentives; if yes, specify*
Construction / Building envelope (with U-values)		
External wall	Yes	*U-Values / constructiondetails e.g. Timber cladding with 200mm wood fibre insultation board, 90mm crosslam timber, 60x60mm counter battens, 60mm service zone and clay plaster lining board . U-Value of 0.3W/m2K*
Internal partition	Yes	*U-Values / construction, to same detail as above*
Internal ceiling/floor	Yes	*U-Values / construction, to same detail as above*
Ground floor/ roof	Yes	*U-Values / construction, to same detail as above*
Window %, type and frame	Yes	*e.g. Double glazed window, gas filled, with 10% frame. WWR 20% W, 10% E, 0% N, 25% S.*

Infiltration rate - Property air tightness (poor, basic, good)	Yes	*e.g. poor (if available, specify n50 value or blower door test results)*
Infiltration rate - Any External Vents Present?	if applicable	*e.g Yes or No, and number/ position*
Existing improvements		
Detail on existing improvements since construction (examples below) - Roof insulation, - Cavity wall - Over cladded wall - Condensation Boiler - Double glazing, - Underfloor heating, - High Efficiency Chiller - High Efficiency Air Conditioning Distribution - etc...	Yes	*Please list improvements and give as much detail as possible.. e.g. Refurbished in 2016 with - 50m cavity insulation, - triple glazed windows (U=0.4W/m2K), - External walls reclad with aluminium panels (U=0.27W/m2K) - high efficiency boiler (95%) (U-Values of any building fabric upgrades would be helpful, along with efficiency of systems, or datasheets)*
Documentation on energy saving measures that have been implemented from the initial design.	if available	*e.g.expected/obtained savings & datasheets documentation of the above*
Building layout drawings and models		
Footprint area	Yes	*e.g. 578 m2*
Floor area (GIFA / Net)	Yes	*e.g. 1987 m2*
Floor plans	Yes	*pdf, dwg, dxf files*
Zone - Descriptions/end use (i.e. meeting room, labs, etc...)	Yes	*e.g. toilet*
Zones - HVAC/Lighting/Equipment drawings	Yes	*e.g. ME drawings*
Building orientation	Yes	*e.g. degrees from North (clockwise - take front façade as reference)*
3d Model (BIM, IES-VE, Revit, SketchUp, Rhino etc.)	if available (highly desirable)	*e.g. any available model (current or past)*
Schedules per Zone/Room		
Number of people + hours of occupancy	Yes	*Please state the number of people per room if known, but at minimum, the number of people occupying the building. E.g. 20 people, occupy building from 9am-5pm mon-fri, taking an hour for lunch at 1pm.*
Lighting Gains best-guess schedules	Yes	*Please estimate the lighting gains in W/m2 based on lighting type. E.g. Room 1, 2 and 3 each have 20 flourescent light bulbs with power of 12W/m2. Room 4 and 5 have 15,,, etc. Types of lighting / specifications would be helpful to estimate gains and lux levels.*
Equipment Gains best-guess schedules	Yes	*Please list the types of equipment used in each room, and the power consumption in known (or a best guess on what this might be) e.g. Room 1 has five desktop computers consuming 85W when on (same hours as occupancy), along with 15 laptops consuming 45W when in use. Desktop computers and Laptops typically in sleep mode from 1pm-2pm, consuming 2W and 4W, respectively. All machines are turned off outside of office opening hours*

Individual Zone/room set points heating & cooling	Yes	*Please specify the use of each room, along with the setpoint temperatures of each. E.g. Open plan room (room 5) has heating set point of 20°C and cooling of 23°C. Kitchen has heating set point of 19°C and cooling of 23°C, etc*
Lighting Systems per area		
Current lamp type	Yes	*e.g. fluorescent bulbs*
Number used in different areas	Yes	*e.g. 4 bulbs in room 1, 8 in room 2..*
Wattage of each lamp type	Yes	*e.g. 15 W bulbs*
Document any automation control on the light system (i.e. schedule control, daylight sensor, motion sensor control etc.)	Yes	*e.g. motion control in toilets, no control in office area*
Equipment Systems per area		
Count of and name plate data from plug-in devices	Yes	*e.g. 5 laptops per office room, one printer*
In-use power of equipment	Yes	*e.g. 60 W per laptop, 80 W printer/scanner*
Renewables		
Photovoltaics (PV) - area, inclination, orientation	if applicable	*e.g. 200 m2 PVs, 30 degrees inclination South-East*
PV - Manufacturer's data	if applicable	*e.g. datasheet of manufacturer*
PV - electricity production	if available	*e.g. electricity production in the most recent available year (monthly/yearly)*
Solar Panels - Area, inclination, orientation	if applicable	*e.g. 200 m2 solar panels, 30 degrees inclination South-West*
Solar Panels - Manufacturer's data	if applicable	*e.g. datasheet of manufacturer*
CHP - Fuel Type	if applicable	*e.g. gas*
CHP - Heat output (rated output)	if applicable	*e.g. 1000 kW*
CHP - Thermal efficiency (rated output)	if applicable	*e.g. 0.5*
CHP - Power Efficiency (rated output)	if applicable	*e.g. 0.28*
CHP - Fraction of rated heat output at minimum output	if applicable	*e.g. 0.5*
CHP - Thermal efficiency (minimum output)	if applicable	*e.g. 0.57*
CHP - Power efficiency (minimum output)	if applicable	*e.g. 0.2*
Thermal energy storage type, capacity	if applicable	*e.g. ice thermal storage, 200 MW*
Document any other renewable energy source	if applicable	*e.g. wind turbines, tidal power*
HVAC - Heating		
Heating type, fuel, and system age	Yes	*e.g. radiators & heat pumps*
Seasonal efficiency (sCOP)	Yes	*e.g. 2.7*
HVAC - Cooling		
Cooling type and system age	Yes	*e.g. air conditioning*
Seasonal efficiency (SEER)	Yes	*e.g. 13*
HVAC - Others		
Document the hot water system, if available	Yes	*e.g. describe the system and attach datasheet if available*
Hot water system: energy source	Yes	*e.g. electricity*
Hot water system: delivery efficiency	Yes	*e.g. 0.95*
System storage type, volume, loop length, pump power, time switch, flow rate	if possible	*e.g. 1000 L storage, 20m, 0.2 kW ..*
HVAC – AHU/FCU		

Design airflow rates or ac/h per room	Yes	*e.g. office 3 ach/h (or l/s), toilets 15 ac/h, kitchen 25 ac/h*
Heat recovery effectiveness (if any)	Yes	*e.g. 0.38*
Fan types and sizes	if possible	*e.g. centrifugal fans, 70mm*
Air supply temperature (document proportional control strategy)	if possible	*e.g. 25 °C - specify if different room by room and during heating/cooling period*
Document if room condition (temperature and humidity) is maintained in each area	if possible	*e.g. one specific area constantly above set point temperature*
Document any demand control ventilation strategy implemented	if possible	*e.g. modulate fresh air damper according to room sensor CO2 concentration*
Coil characteristics and controls	if possible	*e.g. cooling coil output T controlled by indoor room T*
Document specification of the AHUs/FCUs	if possible	*e.g. datasheet of AHUs / FCUs*
BMS / sensors data		
Is there any BMS system installed? If so, please specify	if applicable	*e.g. lighting control*
Is there remote access to BMS network?	if applicable	*e.g. yes, through secured VPN*
Is there any smart sensor in the building (e.g. measuring temperature, CO2..)	if applicable	*e.g. yes, temperature sensor in bedrooms and kitchen*
Where are the data measured from the sensors stored?	if applicable	*e.g. online database*