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BOOSTEE-CE

DELIVERABLE T2.1.5

Development of the fourth module - 3D EMS & webGIS viewer

Version 1
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D.T2.1.5: Development of the fourth module – 3D EMS & webGIS viewer

A.T2.1 Development of the Online Energy Platform – OnePlace

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1. Introduction

The deliverable T2.1.5 belongs to the activities related to the development of OnePlace platform (A.T2.1) and is correlated with activity A.T2.2 development of advanced 3D Energy Management System (EMS). In particular, the document reports the pipeline realized to allow end-users to access and visualize energy data in the 3D EMS module of OnePlace. The 3D EMS module is based on ICT and geospatial tools able to give access to heterogeneous information in the field of building energy management and efficiency.

2. Development of the fourth module – 3D EMS & webGIS viewer

The OnePlace platform aims to support the local authorities in undertaking actions to improve the energy performance of public buildings. Public buildings are infrastructures where the greatest progress can be made towards energy efficiency transformation in urban environments but to boost this process different energy planning domains (i.e. estimation of energy consumption, solar potential estimation, etc.) have to be tackled. This requires a holistic approach and the combination of extensive and complex, spatial (cadastral footprints, LiDAR, 3D building models, etc.) and non-spatial (i.e. cadastral information, energy demand, technical data, etc.) information on public buildings, which may be found in many different offices and encoded in different databases. **The 3D energy management tool (3DEMS)** serves as seedbed for implementation of energy efficient measures in the project's pilot areas. The tool shows the practicality use of geospatial data and 3D building models for energy-related needs, improves energy efficiency planning and management, facilitates renewable energy usage and help in defining Sustainable Energy Action Plans (SEAP) at urban level.

3. Pilot areas within 3D EMS & webGIS viewer

For or each pilot's area and their pilot's buildings, geospatial databases with urban and energy data were created in order to combine them with 3D building geometries within the 3D EMS project tool. The 3D EMS is deployed to 8 pilot areas (Fig.1):

- Emilia Romagna region (Italy);
- Judenburg-Lindfeld municipality (Austria);
- Zlin region (Czech Republic);
- Tolna municipality (Hungary);
- Plonsk municipality (Poland);
- Koprivnica municipality (Croatia);
- Velenje municipality (Slovenia);
- Poland / Czech Republic crossborder region.

Figure 1. The BOOSTEE-CE pilot's areas.

4. Development of the geodatabases

The heart of 3D EMS is an energy geographical database and its content. The challenges for a robust and smart design of the 3D Energy Management System (EMS) were:

- the selection of the useful output information that this system should provide (the information that produces an added value to help energy managers and policy makers in daily operations to improve spatial decision making, rather than a detailed list of information that may be found in many different places),
- the smart exploitation of existing information, such as: cadastral information, energy computation, heat loses and etc. instead of production of new data layers,
- define the level of detail that makes the provided or produced information useful,
- discovery solar energy potentials of public buildings roofs,

- define refurbishment priorities and plan actions what will lead to decreased energy consumption.

On this base, the specific data were collected, checked, harmonized and integrated. In performing the harmonization and integration of the collected very heterogeneous data and information, the BOOSTEE-CE project considered the needs of providing energy-related datasets and to a satisfied large group of potential users (local, regional, national authorities as well as the general public) with various requirements and experience as well as many data and information providers with different scope as well as expectations. Due to these facts, the 3D EMS was build based on heterogeneous databases (Table 1) and 3D building models (LOD1 and LOD2) in order to allow local authorities to boost energy-efficient actions in cities. Considering the goals of the project, the **heterogeneous data about energy and buildings** (spatial and non-spatial data) in pilot areas (PA) include:

- building footprints: with/without attribute information (such as number of floors, building height, etc.);
- maps: 2D vector or raster products representing, at a certain scale, city elements such as buildings, roads, parks, communication lines, etc. They can also have energy-related information related e.g. to photovoltaic (PV) potential of building roofs (solar maps);
- point clouds acquired with LiDAR flights or generated with photogrammetric flights, from where buildings heights and roof shapes could be inferred Digital Elevation Model (DEM) / Digital Surface Model (DSM) of the surrounding environment for the PV potential estimation;
- aerial visible images: they are the starting data of the photogrammetric technique from which point clouds, orthoimages, 3D buildings or maps can be produced;
- thermal images acquired with thermal cameras to document the heating loses of e.g. building facades or roofs;
- other information such as construction plans, energy audit certificates, energy bills.

Field	Units	Description
Official name	-	-
Year of construction	-	-
Building type	-	**Type of building:** residential, agricultural, civil, medical, educational, government, industrial, military, religious, transport.
Typology (number of floors)	-	-
Energy source type (heat)	-	**Type of the heat source:** geothermal energy, district heating, cogeneration unit, heat pump, biofuel boilers, solid fuel, electricity, natural gas, oil.
Energy audit	-	-
Energy consumption (heating)	GJ/year	-
Electricity consumption	kWh/year	-
The specific CO2 emissions	tons/year	-
The total CO2 emissions	tons/year	-
Technology used to harvest a renewable energy source	-	**Type of the technology:** photovoltaics (PV), solar collectors, biofuel boilers, heat pumps

Field	Units	Description
Estimated photovoltaic potential of roof	kW	Calculated from the solar potential maps
EE measures already implemented in the building	-	**Type of the measures:** (i) reducing heating demand: improving the insulation, limiting the exposed surface area, reducing ventilation losses, selecting efficient heating system, new roof; (ii) reducing cooling demand, (iii) reducing energy use for lighting, (iv) reducing energy used for heating water, etc.
Recommended EE measures for the building	-	
Estimation of the amount of heating losses	MWh/year	-

Table 2. Data records in project databases linked to the 3D geometries queryable in 3DEMS.

5. Generation of 3D building models in the pilot areas

Generation of 3D Building Models (3D BM) in LOD1 or LOD2 format (Figure 2) rely on the available geodata collected in the pilot areas, harmonized and structured in geospatial databases (see Section 2.4). Starting from these data, two methods have been adopted and upscaled in order to create the 3D building models:

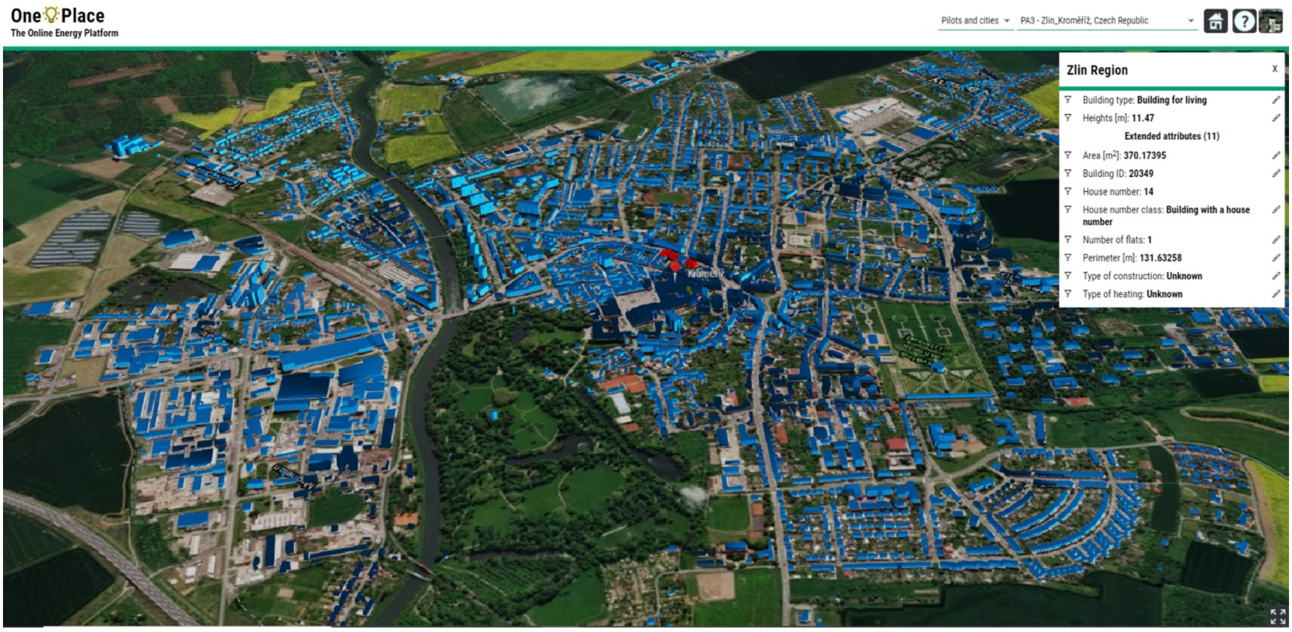
a) building footprint with attribute information: the shp files of the PA's topographic maps contain locations and shapes of buildings. Each building (or group of buildings) is characterize by a polygon (its footprint) enriched with a table of information (generally called attributes). Among this information, we could find evidences of the building height or number of floors. Hence using extruding functions, a LOD1 building model can be generated. These 3D geometric entities keep the attributes and, in a dedicated viewer, can be queried to retrieve information;
b) LiDAR point clouds with building footprints: the 3D point clouds feature a variable density of points, going from few per square meter to some dozen points per square meter. The point clouds describe quite decently the shape of the buildings, particularly for the denser clouds. According to the point density, we have applied two methods:
    a. sparse point cloud (few points/sqm): geometric intersection of the point cloud with the available footprints, derivation of the highest point in the identified part of the cloud and extrusion of the footprint up to such height value to generate LOD1 building models.
    b. dense point cloud: geometric intersection of the point cloud with the available footprints, fitting of geometric primitives / shapes of building roofs to the identified part of the cloud and generation of LOD2 building models. The fitting procedure is performed in an iterative way, testing various roof shapes and identifying the shape leading to the smallest least squares residual.

Figure 2. Different Level of Detail (LoD) in 3D building models (source: TU Delft).

The presented methodology comprises different software modules available either in the open-source domain or as in-house tools of the project partners. The project's target aims to some 300 buildings in total although it was reached more than 10,000 buildings. A LOD2 was foreseen for the specific buildings where the project investment will be applied, for the surrounding are a LOD1 were generated. Both types of models are queryable in the OnePlace platform.

Figure 3. Generated 3D building models for PA1 – Emilia Romagna, Italy (PP7).

Figure 4. Generated 3D building models for PA2 – Judenburg, Austria (PP10).



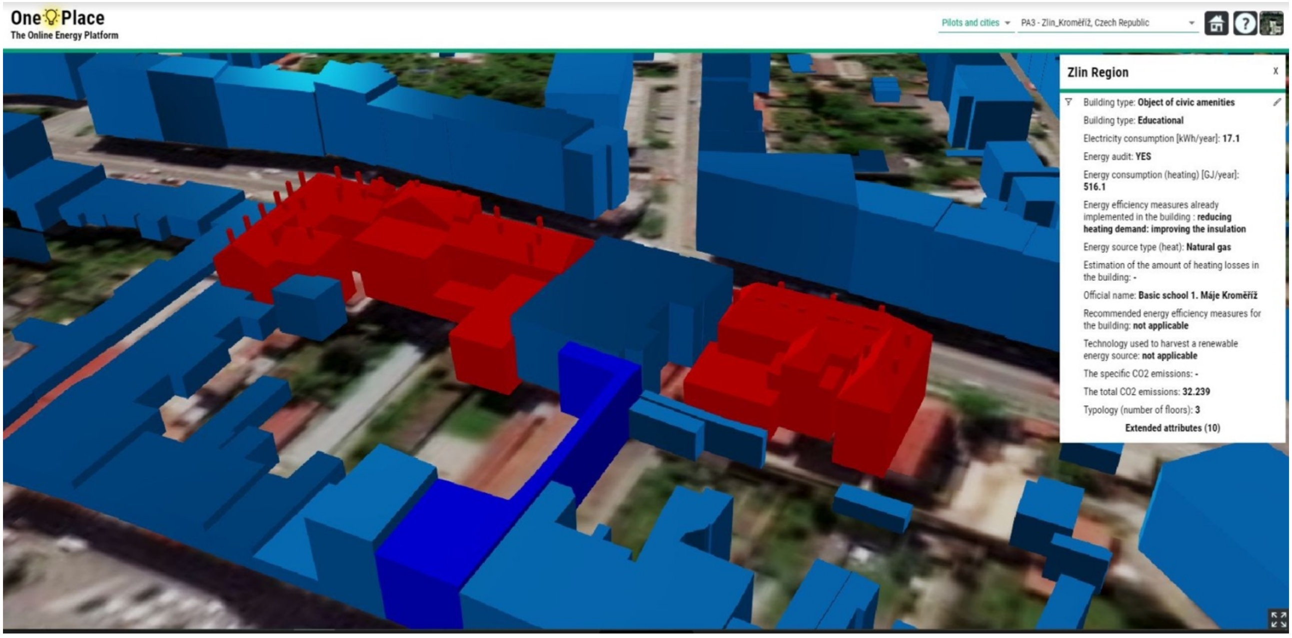


Figure 5. Generated 3D building models for PA3 – Zlin, Czech Republic (PP3), Kromeriz municipality.

Figure 6. Generated 3D building models for PA3 – Zlin, Czech Republic (PP3), Holesov municipality.

Figure 7. Generated 3D building models for PA4 – Tolna, Hungary (PP6).

Figure 8. Generated 3D building models for PA5 – Plonsk, Poland (PP13).

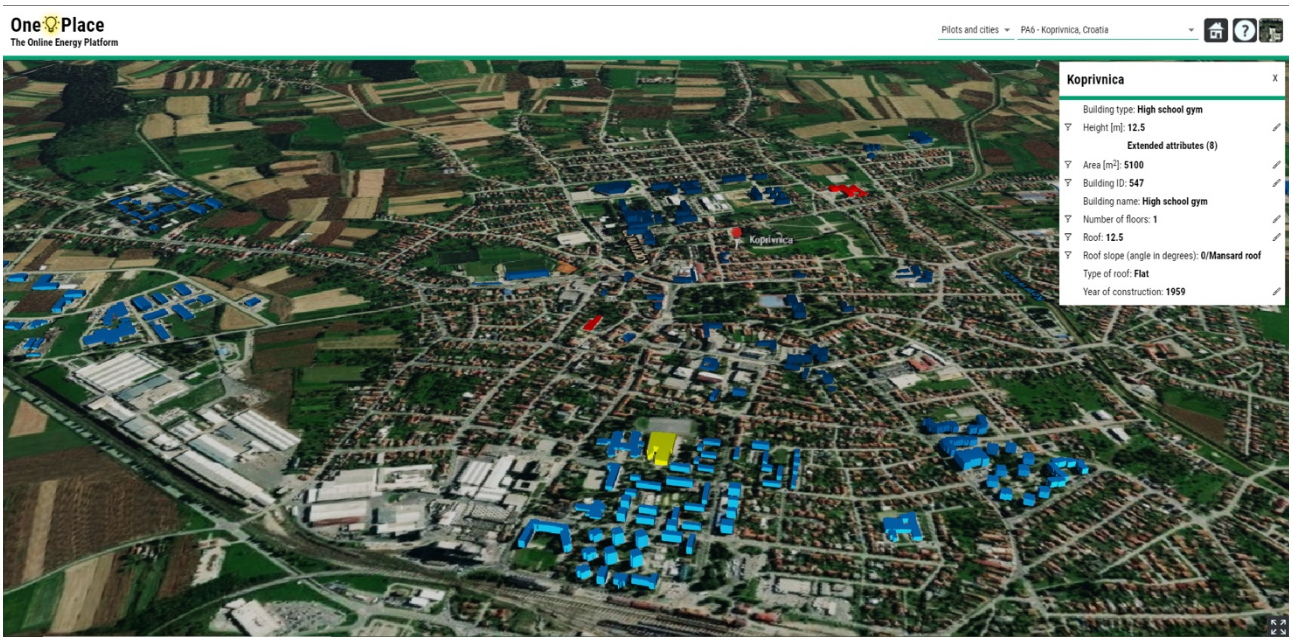


Figure 9. Generated 3D building models for PA6 – Koprivnica, Croatia (PP9).

Figure 10. Generated 3D building models for PA7 – Velenje, Slovenia (PP8).

Figure 11. Generated 3D building models for PA8 – the CZ-PL cross-border region (PP12) – Zacler municipality.

Figure 12. Generated 3D building models for PA8 – the CZ-PL cross-border region (PP12) - Lubawka municipality.

6. Creation of solar maps of building roofs

From the available geospatial data (see chapter 2.4 - in particular the Digital Surface Models – DSM), occlusions and shadowing effects were considered and calculated in order to correctly estimate the incoming solar light (Direct, Diffuse and Global) on each roof within the pilots' areas. In the next figures the produced annual solar maps are presented for the areas with a high-resolution terrain model, trimmed using the available building footprints. In the areas without high-resolution terrain models (Bologna, Tolna and Koprivnica), the available services SolarGIS and PVGis were used, where global terrain model at some hundred meters resolution are included.

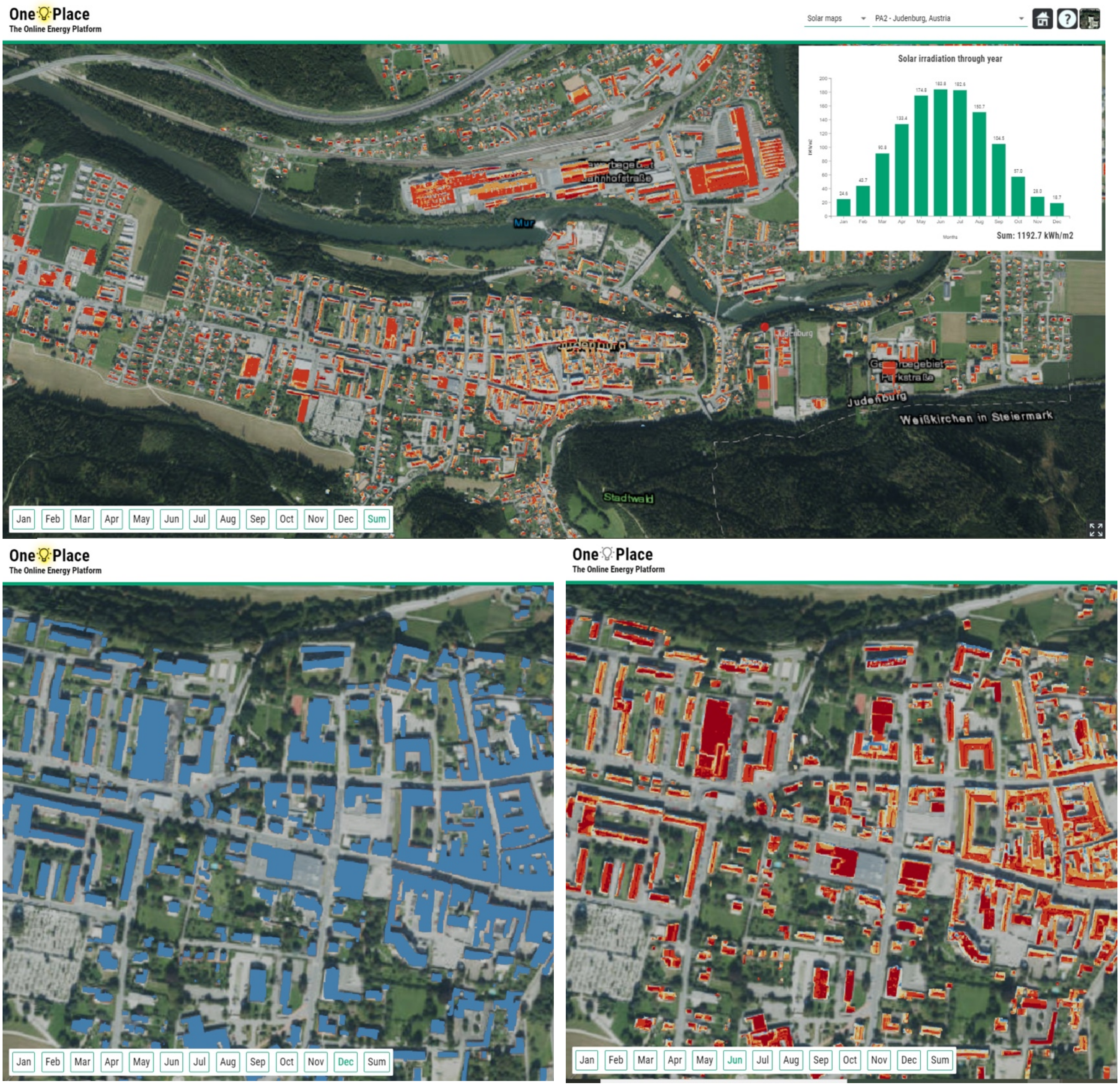


Figure 13. Judenburg-Lindfeld municipality (Austria) – Overall solar irradiation per year (above) and photovoltaic PV maps in December (lower left) and June (lower right).

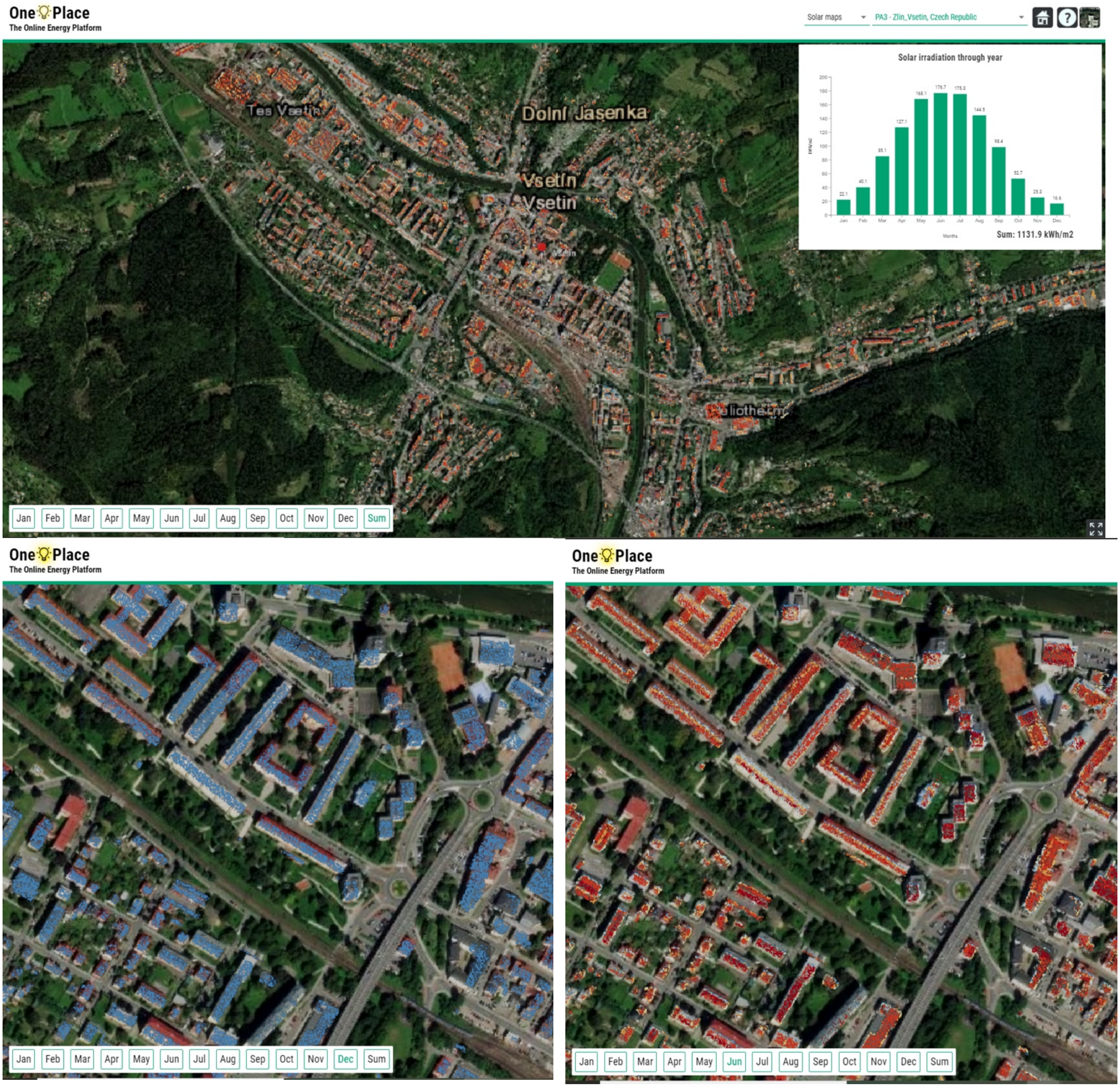


Figure 14. Zlin region – Vsetin (Czech Republic) – Overall solar irradiation per year (above) and photovoltaic PV maps in December (lower left) and June (lower right).

Figure 15. Plonsk municipality (Poland) – Overall solar irradiation per year (above) and photovoltaic PV maps in December (lower left) and June (lower right).

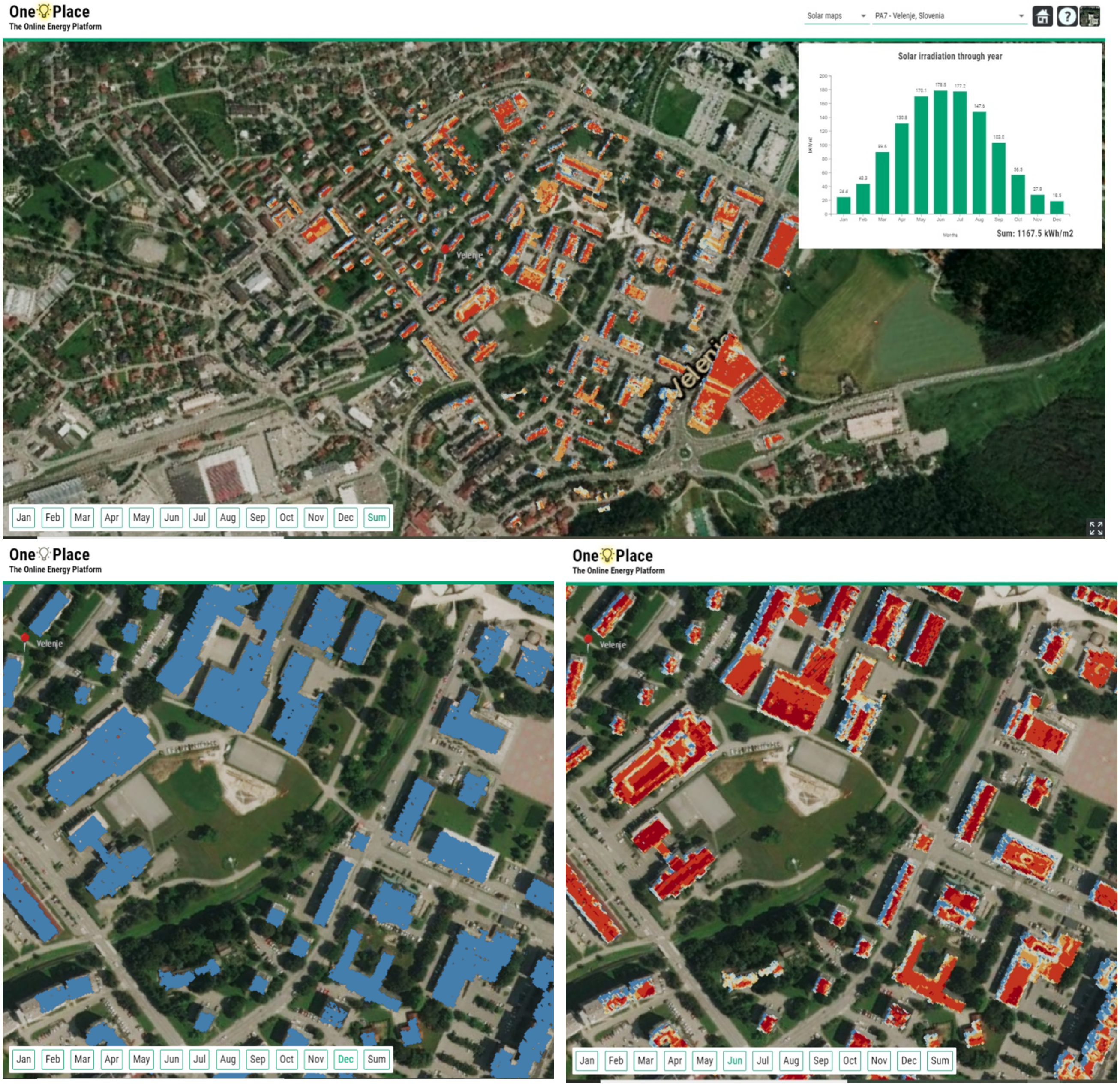


Figure 16. Velenje municipality (Slovenia) - photovoltaic PV maps in December (on the left) and June (on the right).

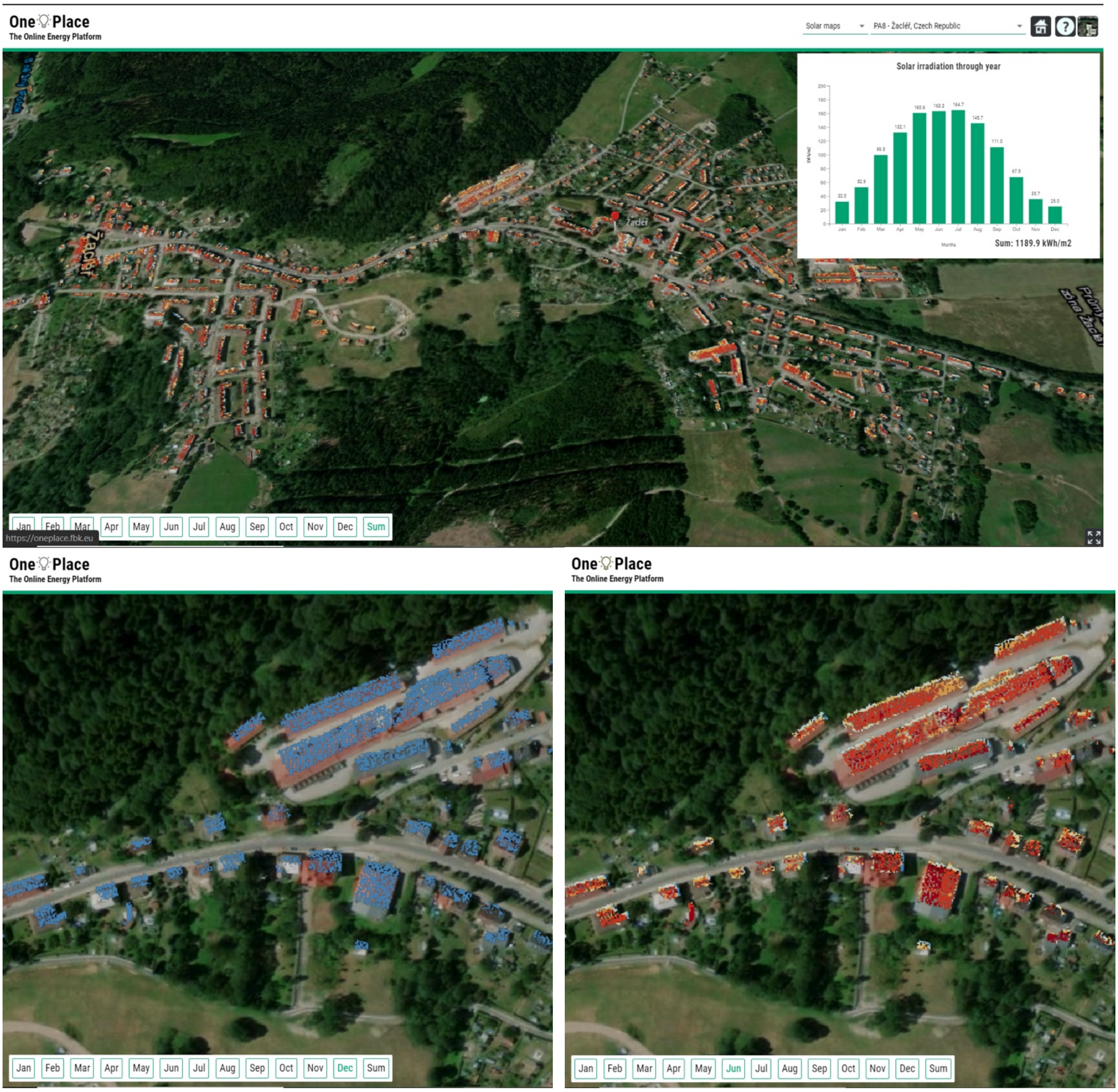


Figure 17. Poland / Czech Republic crossborder region (example of Zacler, CZ) - photovoltaic PV maps in December (on the left) and June (on the right).

7. 3D EMS architecture and web viewer

The 3D EMS module of OnePlace relies on Feature Manipulation Engine (FME) and Cesium[1] tools. FME software is used to transform the shape file with the 3D building information in 3D tiles. The 3D tiles are important in order to extrude the buildings and to extract all the data information of each building. Then the Cesium viewer renders online all 3D data on top of geographic information (maps, orthoimages, etc.). For texturing the buildings with PV maps the georeferencing information of the maps are used in order to project the raster information on top of the 3D geometries.

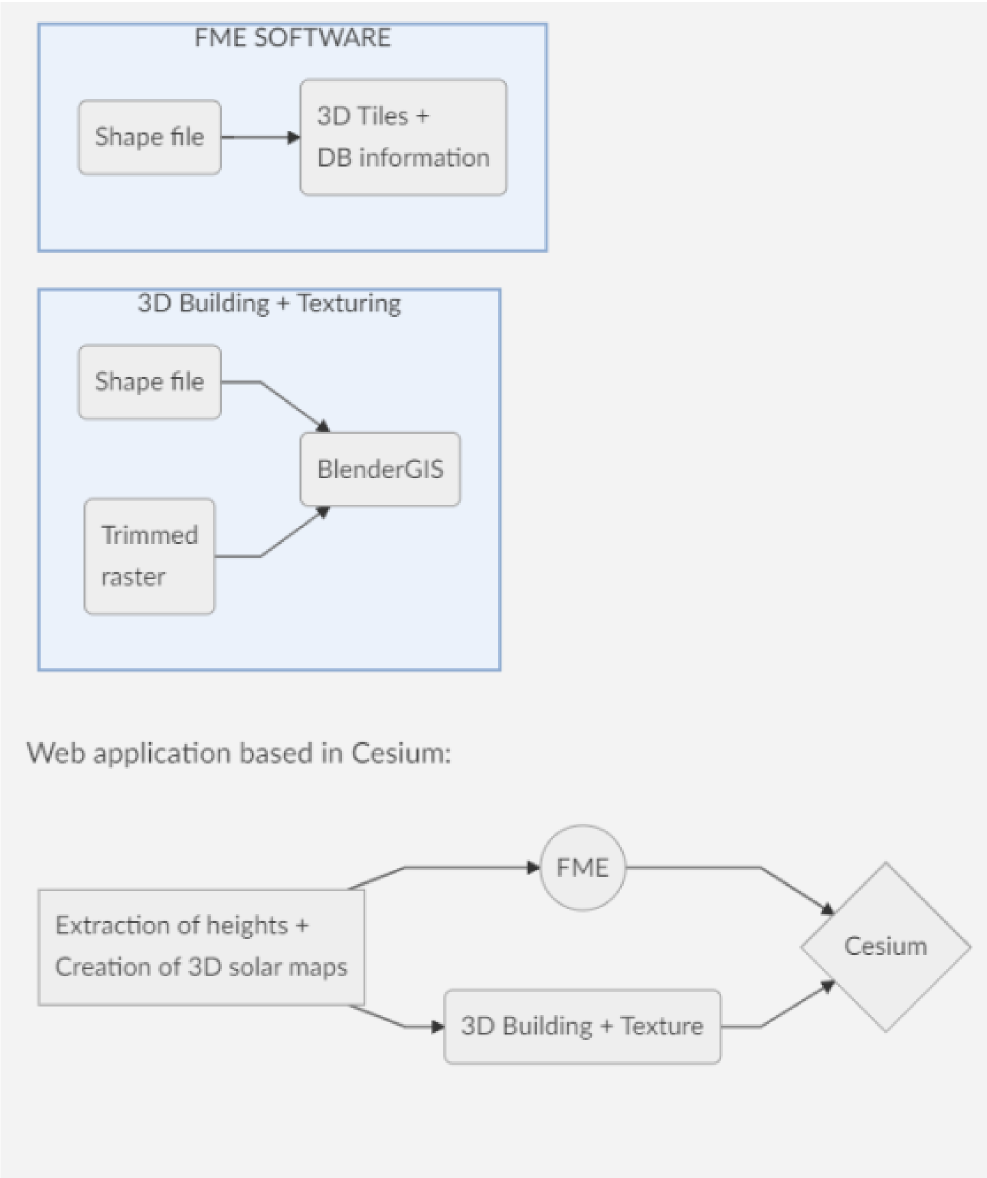


Figure 18. Architecture of the 3D EMSmodule in OnePlace.

[1] https://cesium.com/

8. Query heterogeneous information

The OnePlace module 3D EMS(Fig. 19-20) allows users to access pilot locations in a web viewer that renders a 3D representation of the landscape based on satellite imagery or map information together with 3D geometries of buildings. Such 3D buildings can be "clicked" in order to pop-up and access heterogeneous information, including energy audit certificates. In the following figure (Fig. 21-28), some of the generated queryable 3D city models are shown as screenshots of the developed web platform. The platform allows to visualize more than 7 locations as for the CZ/PL cross-border area we have two municipalities (Zacler and Lubawka) and for the Zlin area were have 5 municipalities.

Figure 19. OnePlace platform.

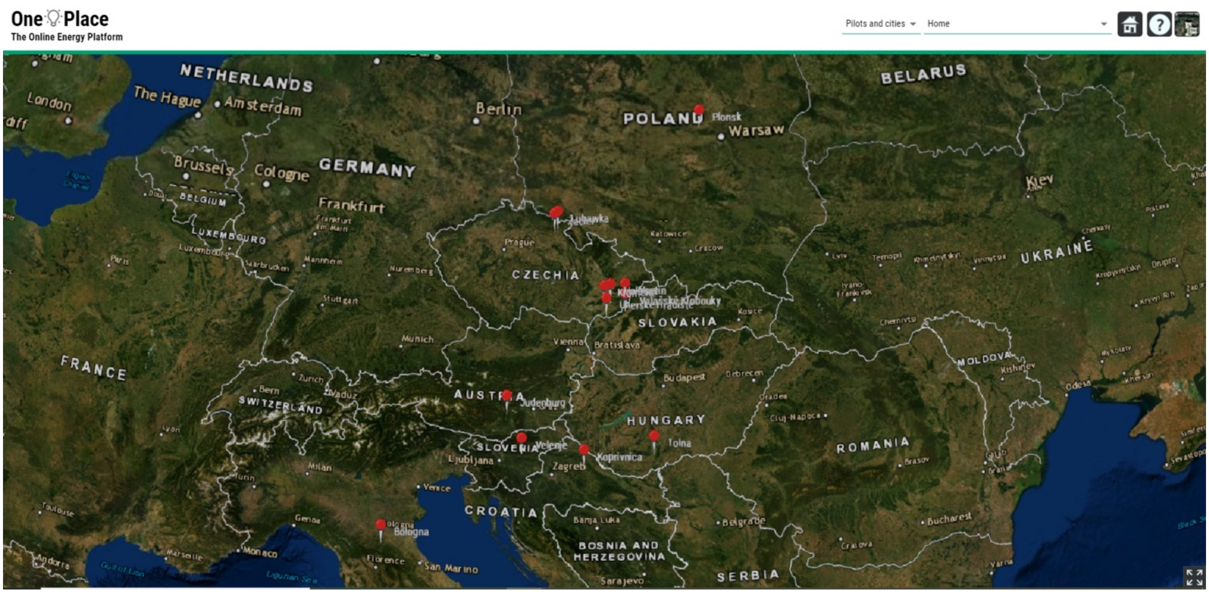


Figure 20. 3D EMS module.

In the next figures some renderings of the 8 PA locations present how 3DMES can be used to display energy-related information on top of 3D city models.

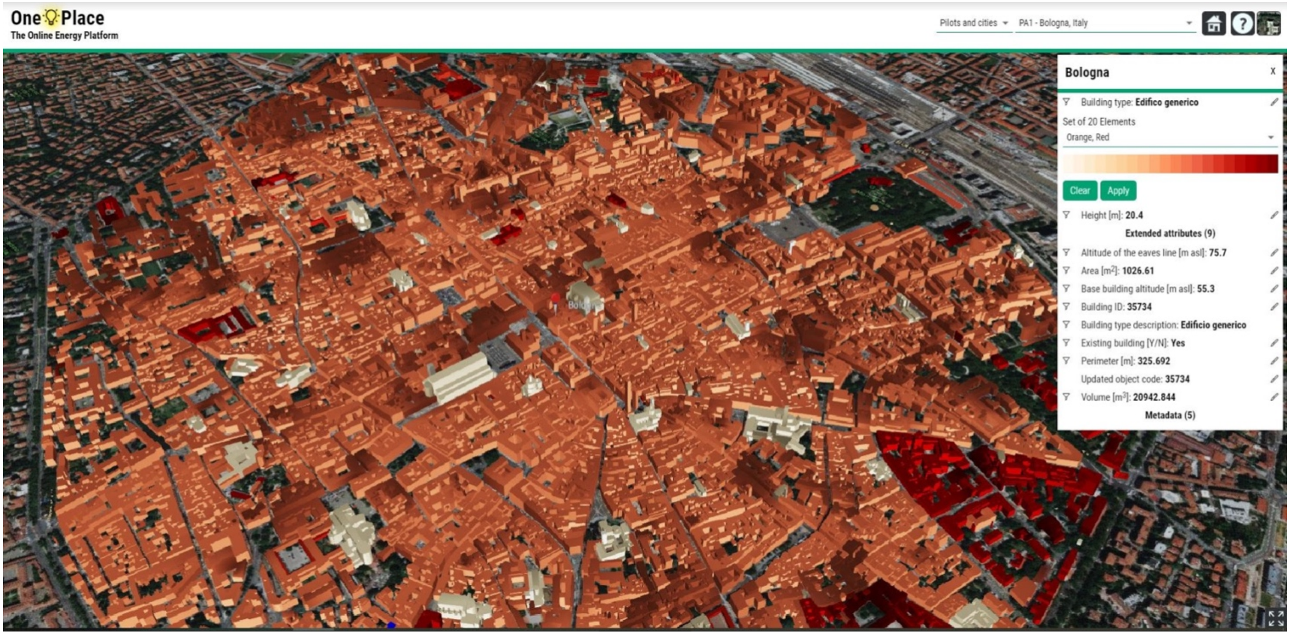


Figure 21. Emilia Romagna region (Italy).

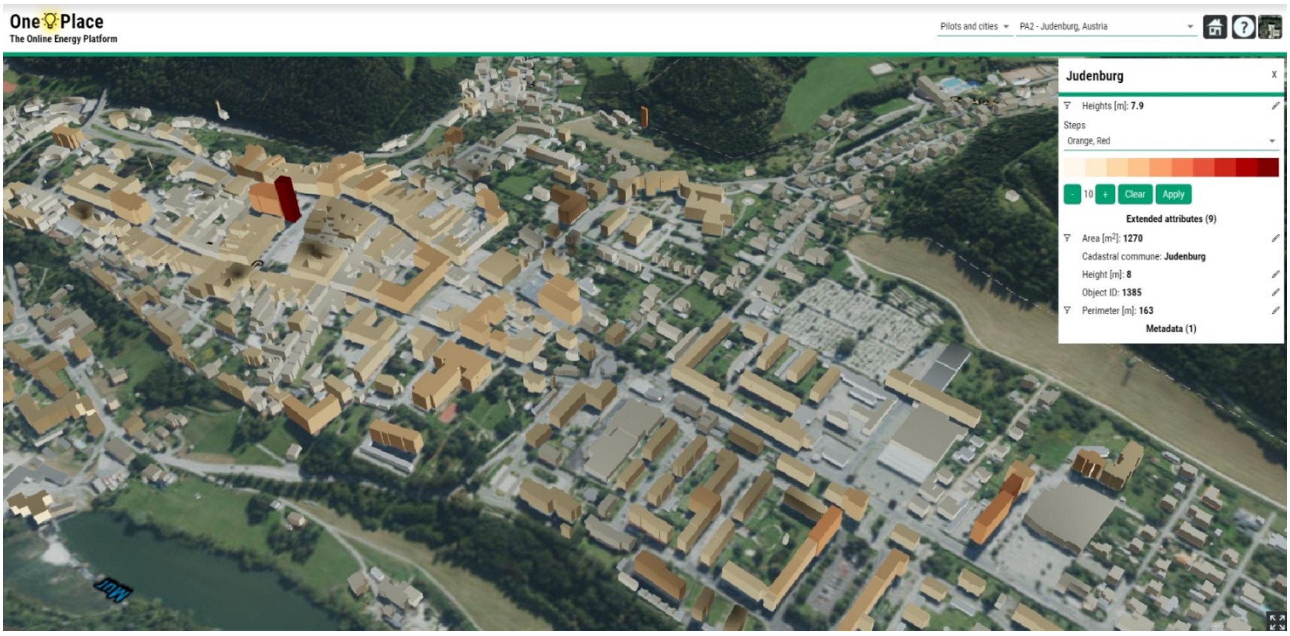


Figure 22. Judenburg-Lindfeld municipality (Austria).

Figure 23. Zlin region (Czech Republic).

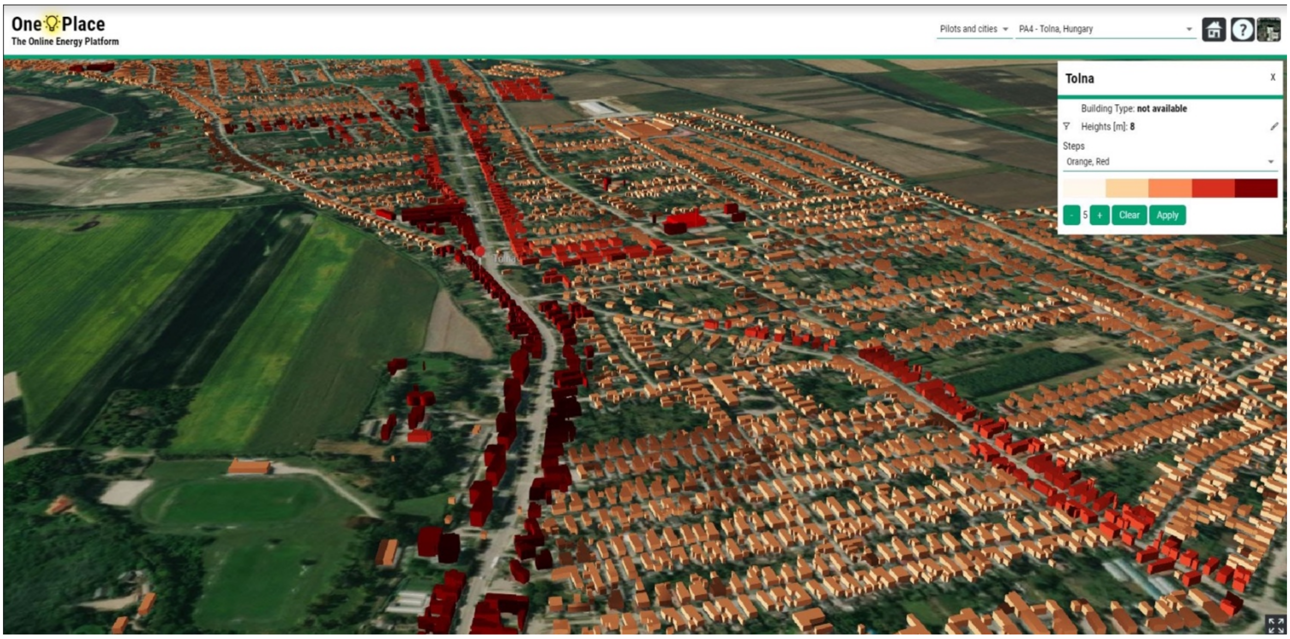


Figure 24. Tolna municipality (Hungary).

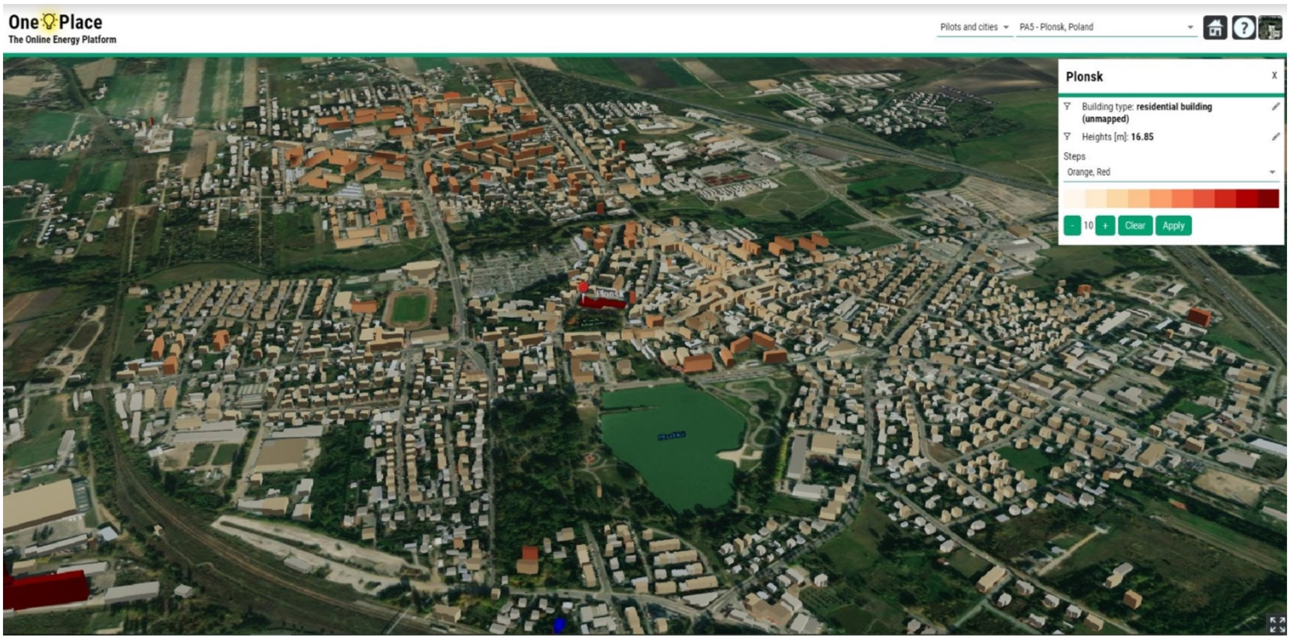


Figure 25. Plonsk municipality (Poland).

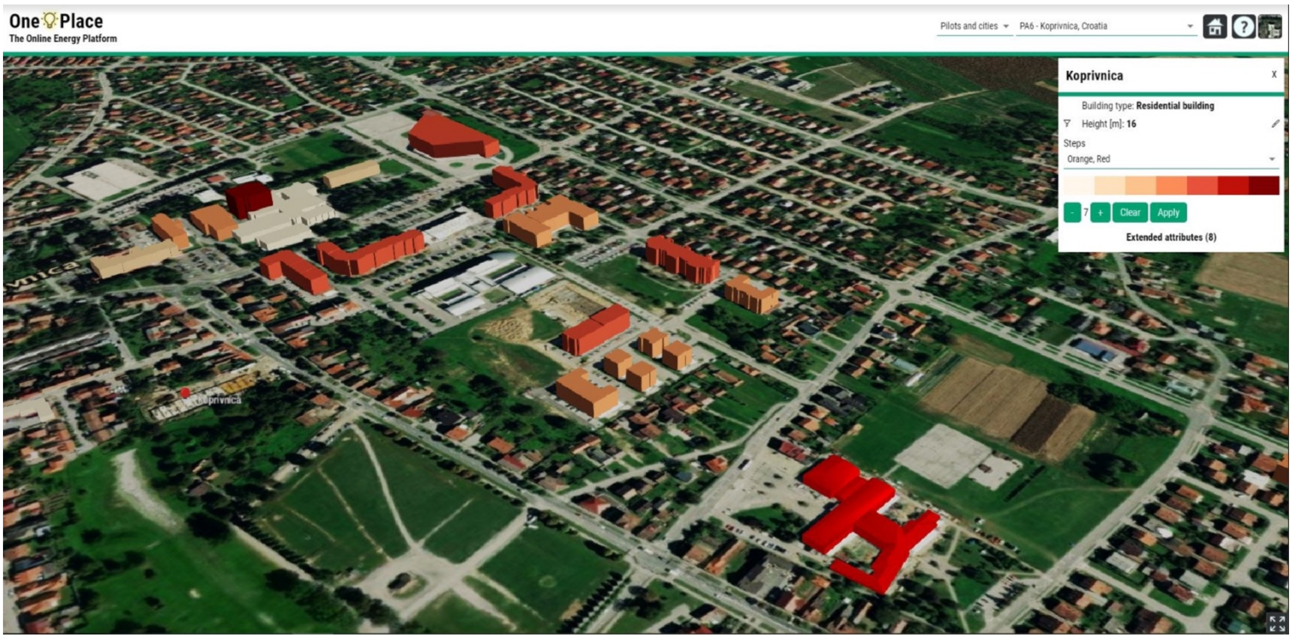


Figure 26. Koprivnica municipality (Croatia).

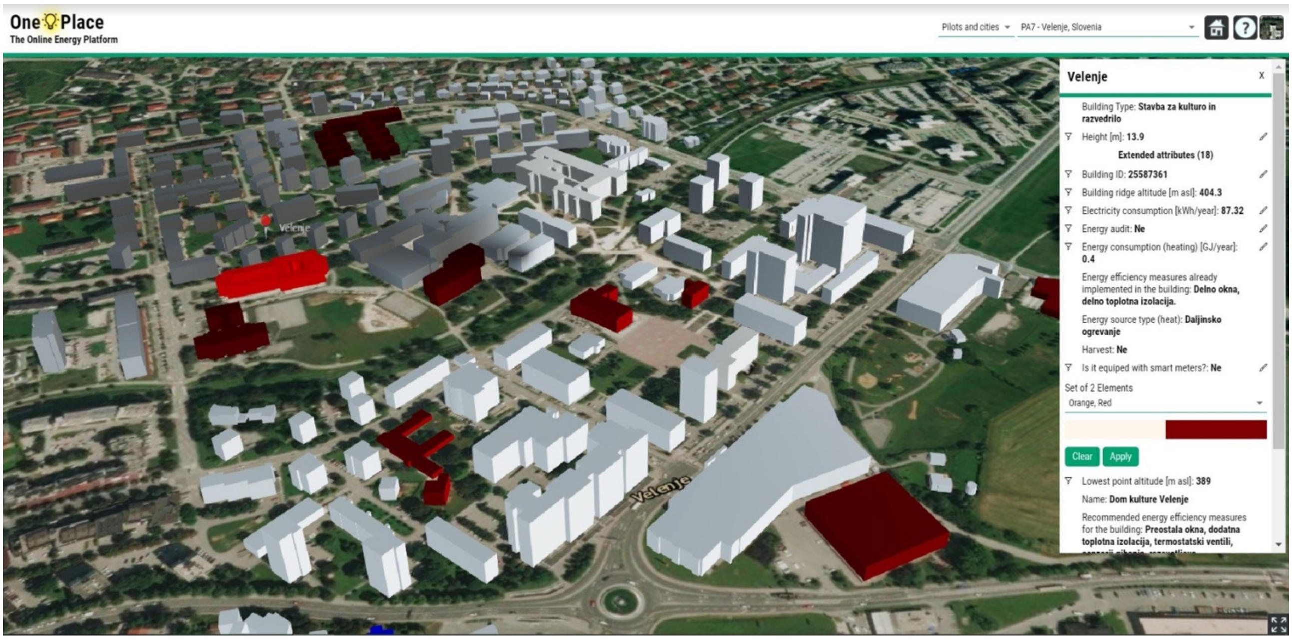


Figure 27. Velenje municipality (Slovenia).

Figure 28. Poland / Czech Republic crossborder region: Zacler (above) and Lubawka (below) municipalies.

9. Conclusions

The document presented to the realized OnePlace platform (oneplace.fbk.eu) and, in particular, the 3D Energy Management System (EMS) module. The document reported the pipeline realized to allow end-users to access and visualize energy data within the 3D EMS module of OnePlace, based on ICT and geospatial tools able to give access to heterogeneous information in the field of building energy management and efficiency. The tool was realized to improve energy efficiency planning and management, facilitate renewable energy usage and help in defining Sustainable Energy Action Plans (SEAP) at urban level. Thanks to its modularity, the tool could be replicated in other locations and urban areas in order to capitalize the BOOSTEE-CE investment and activities.