DELIVERABLE T1.4.1

D.T1.4.1 – Methodology to collect energy information and their visualization using 3D building models **10/2018**

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A.T1.4 Transnational methodology to collect energy information and their visualization using 3D models

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1. Introduction and aims

The deliverable T1.4.1 belongs to the activities related to the development of a methodology to collect energy information and visualization it using 3D models (A.T1.4). In particular the document reports, beside similar project activities and visualization tools, the pipeline realized to allow end-users to access and visualize energy data in the 3DEMS module of OnePlace. This is based on ICT and geospatial tools able to give access to heterogeneous information in the field of building energy management and efficiency. The document is restricted to project partners (PP), reviewers and JS.

2. State of the art

The deployment of ICT and geospatial solutions in the field of building energy management and efficiency allow to increase capacities of municipalities and energy agencies for improving the energy efficiency of public infrastructures by means of geospatial data and as well as to widespread geoinformatics in the energy sector. Among geospatial tools and solutions, GIS and 3D city models offer many benefits for capture, process, store and visualize energy-related data in urban environments, track consumptions and demands, assess rehabilitation conditions, etc. Many studies have been conducted to assess the potential for renewable energy production, measure energy consumption or improve the energy efficiency at urban scale. Biljecki et al. (2015) identified more than a hundred different applications for 3D city models, where among others indicated the urban energy sector and as a need energy demand estimation of households in order to assess the benefit of energy-efficient retrofitting. Previtali et al. (2014) noted the utility of 3D building models to visualize thermal retrofit of buildings and evaluate energy efficiency. Thermal assessment coupled with 3D building models (D.T1.3.3) may indeed determine thermal bridges and heat losses. Based on the building typology and the additional energy-related data, Carrión (2010) describes a method to calculate energy consumption characteristic and thus it enables generalizing buildings into determined heating classes and as well quickly locate the particular buildings with the deviation to the estimated value. Nouvel et al. (2013) investigated the uncertainties in heating demand calculation with respect to geometric and thermal uncertainties. As geometric category, the building height, volume and window to façade ratios have been identified whereas the air change rate (i.e. a measure of the air volume added to or removed from a space divided by the volume of that space) was used as thermal category. Based on the outcomes, the energy saving potentials per particular buildings were mapped and, in the further steps, the refurbishment priorities were defined.
Many of studies have focused on assessing building roofs 3D geometries, derived using photogrammetry (Nex et al., 2013) or LiDAR data (Zheng et al., 2014; Martian et al., 2015) to install solar collectors or photovoltaic (PV) cells so to produce green energy (Amado and Poggi, 2014; Chaturvedi et al., 2017). If 3D building models are not reconstructed in detail, shading influences of nearby houses or roof components are not taken into consideration and so determined suitable roof areas for solar production might not meet the intended purpose (Strzalka et al., 2012; Alam et al., 2013).

3. Projects and best practices

Modelling in 3D urban energy systems requires the use, harmonization and integration of heterogeneous input data sources in order to (i) understand and visualize how energy flows, (ii) better manage and analyse energy data, (iii) optimize the available energy sources and (iv) implement necessary energy efficient measures. Urban 3D data were already used for research, development and application-oriented projects related to energy efficiency, energy audit, heat losses computation, PV estimation, etc. (Nex et al., 2013; Agugiaro, 2015; Biljecki et al. 2015; Wate and Coors, 2015; Hong et al., 2017). In the following sections, two outstanding cases are reported where geospatial technologies and ICT tools are effectively used to assist cities in understanding urban energy flows and potentials.

The Energy Atlas – Berlin, Germany

The Energy Atlas of Berlin (http://energyatlas.energie.tu-berlin.de/en/) presents an integrated approach for strategic energy planning and use of renewable sources in urban areas (Krüger and Kolbe, 2012 – Fig.1). It enables a representation of the actual state of building stock and their relevant energy data, and it supports the decision process by visualizing the effects of planned measures. The Energy Atlas is build based on the CityGML semantic 3D city model of Berlin. The 3D geometries provide itself a fundamental set of semantic information, such as building address, height, volumes and purpose. In order to increase their usefulness for energy management purposes, various methods and information from existing energy-related databases were incorporated into the 3D city model of Berlin:

- solar potential estimated for ca 500,000 Berlin's roof from the Solar Atlas Berlin. The dataset includes also additional information, such as: roof pitch, solar irradiation as well as average efficiency and price of solar cells (https://www.businesslocationcenter.de/wab/maps/solaratlas);
- data and modeling approach for various utility network (i.e. gas, water, electricity, etc.) developed in the SIMKAS-3D project (Simkas3D, 2010);
- a methodology to perform assessment of the energetic rehabilitation of buildings and heating energy consumption (Carrión, 2010; Carrión et al., 2010).

With these energy-related data and models, the developed application can map energy consumptions, assess heating and electricity demands, present the energetic building characteristics and energy savings potential, design an optimal electricity network as well as present the possibilities of geothermal and solar energy potentials. Given the complexity of the city, the Berlin's Energy Atlas (supported also by a large budget) acts as fundamental best practice and guidance tool in the scope of efficient energy planning and use of renewable energy sources.

The Energy and Climate Atlas - Helsinki, Finland

The Helsinki Climate and Energy Atlas was realized using Helsinki semantic 3D city model (Fig. 1). The energy atlas of the city (https://kartta.hel.fi/3d/atlas) is part of the mySMARTLife project (https://mysmartlife.eu), in which Helsinki has compiled energy-related data on its building stock and made it freely available for public use. The designed application covers all energy-related topics, starting from fundamental building information, such as energy-efficiency upgrades, performance classifications or the energy sources used for heating, ending on sophisticated analyses and simulations in the scope of energy efficiency. The content of the Atlas has been organized in three thematic categories:

- basic building information: it includes use, height, number of floors, building materials, year of construction, etc.
- building energy and repair information: it includes heating mode, source of energy, airflow rate, energy certificates, energy efficiency index and category, etc.
- building consumption data: it includes consumption data for district heating, building electricity and water requests and consumptions, etc.

Solar irradiation estimation and PV potential for the entire city are also available and visualized on the semantic building models. The atlas shows suitable roof locations for solar panels and solar panel potential. The developed Energy and Climate Atlas serves as a modern city's toolkit to reach assumed climate goals, encourage a public community to act, for example, by harnessing solar energy and as well aids enterprises to recognize the proper places for investment in clean technology solutions. It is an important tool for city of Helsinki in order to reduce greenhouse gas emissions by 80% and become carbon neutral by 2035 (http://www.stadinilmasto.fi/en/).

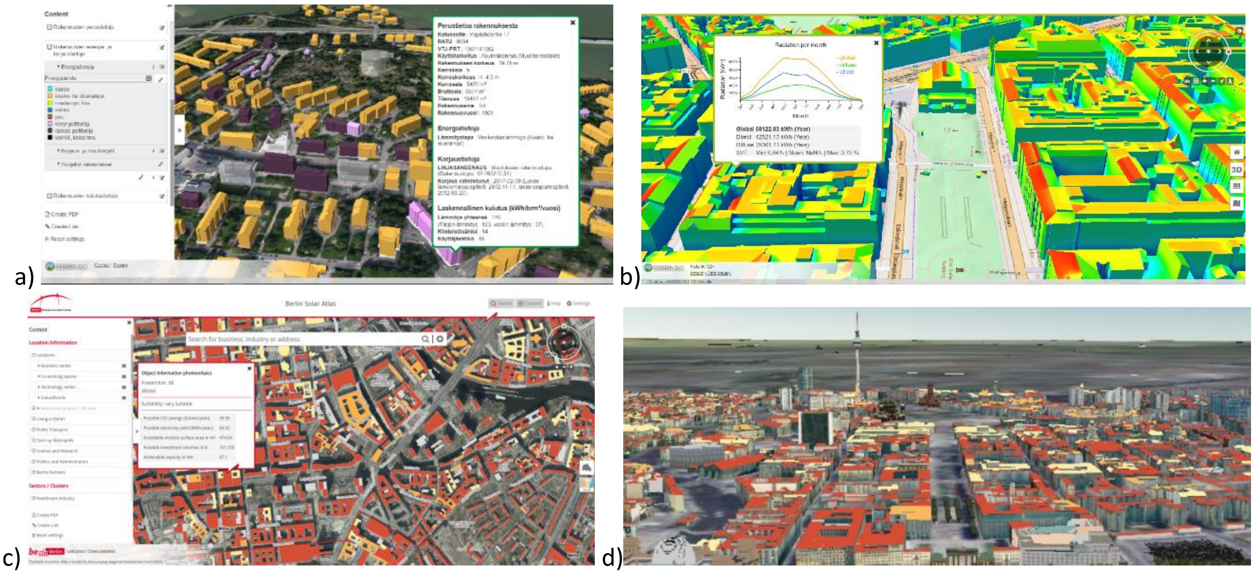

Figure 1: 3D building models of Helsinki visualized based on their energy source (a) and with their solar irradiation analyses (b). 3D buildings in Berlin showing energy-related information (c) and PV potential (d).

4. Methodology

Considering the goals of the project, the collected and harmonized heterogeneous data about buildings and energy (spatial and non-spatial data) in the pilot areas (PA), a methodology was developed in order to:

- Consider the available (geo)data collected in the geodatabases (geoDB - D.T1.1.3), in terms of extensions, resolution, type of information, etc.;
- Consider the created 3D building models (D.T1.2.3), PV solar maps (D.T1.3.2) and thermal data (D.T1.3.3);
- Link 3D geometries with heterogenous non-spatial attributes available in the geoDB (Table 1);
- Project the solar maps onto the 3D roofs.

As none of the pilot areas of the project have 3D city/building models available and new data acquisitions were not feasible, 3D building geometries were generated with the available geospatial data (maps and very low-resolution point clouds). The link of geometries and attributes works using the geolocation of the building whereas the solar maps (at various resolutions) are georeferenced raster data.

Field	**Units**	**Description**
Official name	-	From official documents and geoDB
Year of construction	-	From official documents and geoDB
Address		From official documents and geoDB
Building type	-	**Type of building:** residential, agricultural, civil, medical, educational, government, industrial, military, religious, transport.
Typology (number of floors)	-	From official documents and geoDB

Surface and Volume	m2 / m3	From official documents and geoDB
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	-	A certificate provided by experts
Energy consumption (heating)	GJ/year	From sensors / insitu measurements
Electricity consumption	kWh/year	From sensors / insitu measurements
The specific CO2 emissions	tons/year	From sensors / insitu measurements
The total CO2 emissions	tons/year	From sensors / insitu measurements
Technology used to harvest a renewable energy source	-	**Type of the technology:** photovoltaics (PV), solar collectors, biofuel boilers, heat pumps
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	From sensors / insitu measurements

Table 1: Possible attributes collected for the public buildings in the pilot areas and accessible in OnePlace.

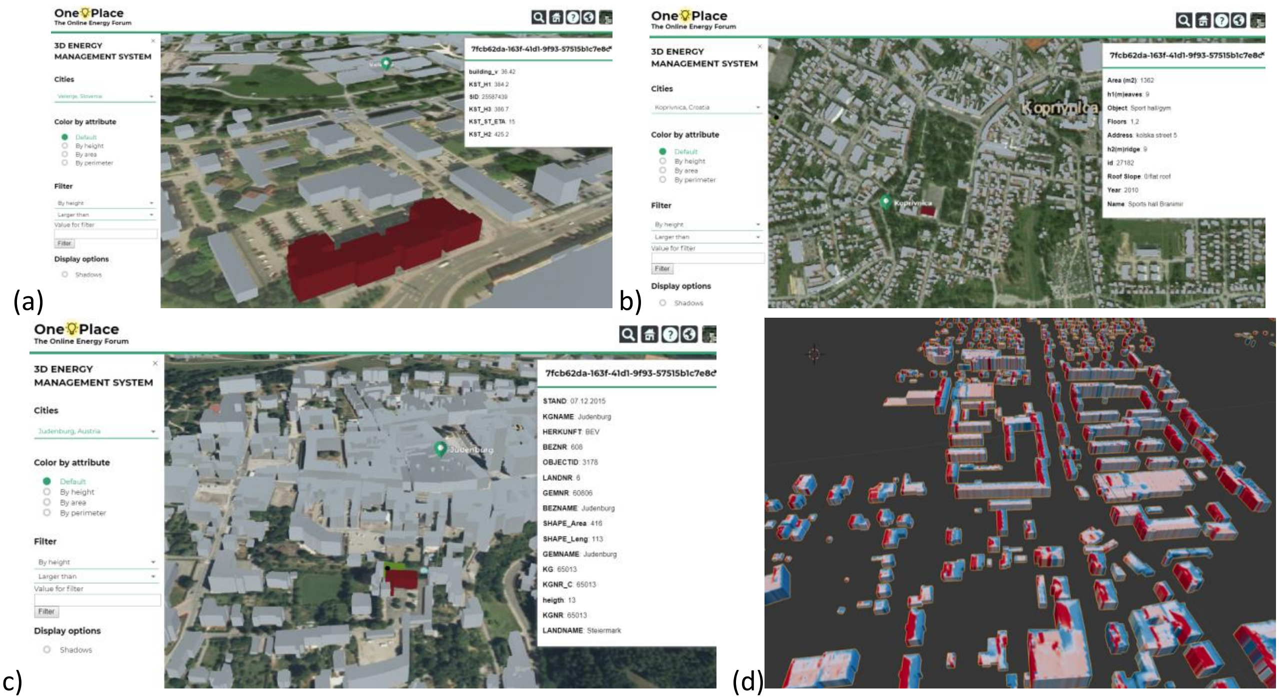

Figure 2: Some initial results of the 3DEMS module of OnePlace (a-b-c) and the projected PV maps on top of the building models (d). The pop-up window with the building data displays the information collected in the geoDB. Such information need to be harmonized as cadastral, topographic and energy-related information varies from country to country.

5. Conclusions

The document reported the realized approach to collect the heterogeneous energy-related information and visualization it within the project online platform (webGIS) by means of 3D building models. Starting from the collected, generated and linked data in WPT1, the 3DEMS webGIS of the OnePlace platform (WPT2) will allow users to interactively navigate a map or 3D building models of a pilot location, select a building of interest and retrieve energy and other cadastral/building information, including non-spatial data (Table 1). Query functions over the same area will be also possible in order to visualize aggregation results and allow better analyses, simulations, etc. For example, the energy-related data available at building level could be used e.g. to help the realization, implementation and monitoring of Sustainable Energy Action Plan (SEAP) at city level and the transition towards low-carbon smart cities.

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