Geovisualization for Energy Planning

Luigi Santopietro[1(✉)], Giuseppe Faruolo[1], Francesco Scorza[1], Anna Rossi[2], Marco Tancredi[3], Angelo Pepe[3], and Michele Giordano[3]

[1] Laboratory of Urban and Regional Systems Engineering (LISUT), School of Engineering, University of Basilicata, Potenza, Italy
luigi.santopietro@studenti.unibas.it, giuseppe.far88@gmail.com, francesco.scorza@unibas.it
[2] Potenza Municipality, Potenza, Italy
anna.rossi@comune.potenza.it
[3] Lucana Energy Company (SEL), Potenza, Italy
{marco.tancredi,angelo.pepe, michele.giordano}@selspa.it

Abstract. In 2018 across 885 urban areas of the EU-28 only 66% of EU cities have, according to Reckien et al. classification a A1 (autonomously produced plans), A2 (plans produced to comply with national regulations) or A3(plans developed for international climate net- works) mitigation plan, 26% an adaptation plan, and 17% a joint adaptation and mitigation plan, while about 33% lack any form of stand-alone local climate plan [1]. Local climate plans are a new emerging field of application for urban planning and, in this sector appropriate geovisualization techniques could be useful tool in supporting make decisions about actions for local energy and climate plans. Geovisualization can help decision makers or researchers to transfer information to stakeholders and people. In this work we discuss geovisualization approach for energy consumptions and renovation scenarios for private and public buildings delivered in a specific case study: Potenza Municipality. This tool allows to visualize energy consumptions at urban scale thorough a geo- database including individual buildings information with several functions: i.e. to identify urban areas where take action with higher priority. The application to case study of Potenza Municipality is a component of a wider process of developing the Sustainable Energy and Climate Action Plan (SECAP). It shows the potential of geovisualization as a tool to support decisions making and monitoring of actions to be included in the plan.

Keywords: Geovisualization · Visualization · SEAP/SECAP · Local climate plans

1 Introduction

The Covenant of Mayors [2] was launched in 2008 in Europe with the ambition to gather local governments voluntarily committed to achieving and exceeding the EU climate and energy targets. On October 2015, the new Covenant of Mayors for Climate & Energy has been launched. Its goals were defined with cities through a consultation

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process and are ambitious and broad-ranging: signatory cities now pledge to actively support the implementation of the EU 40% GHG-reduction target by 2030 and agree to adopt an integrated approach to climate change mitigation and adaptation and to ensure access to secure, sustainable and affordable energy for all. In the same year 2015, EU submitted the Paris Agreements [3]. This strategy involved energy and climate policy including the so-called 20/20/20 targets [4], namely the reduction of carbon dioxide (CO_2) emissions by 20%, the increase of renewable energy's market share to 20%, and a 20% increase in energy efficiency. In June 2016, the Covenant of Mayors entered a major new phase of its history when choosing to join forces with another city initiative, the Compact of Mayors. The resulting "Global Covenant of Mayors for Climate and Energy" is the largest movement of local governments committed to going beyond their own national climate and energy objectives. Fully in line with the UN Sustainable Development Goals and climate justice principles [5], the Global Covenant of Mayors will tackle three key issues: climate change mitigation, adaptation to the adverse effects of climate change and universal access to secure, clean and affordable energy. When officially joining the Covenant of Mayors, signatories commit to developing a Sustainable Energy and Climate Action Plan (SECAP) within two years. New SECAP opposite to Sustainable Energy Action Plan (SEAP), adds to the reduction of CO_2, adaptation and mitigation to climate change.

In Italy at this moment, the most adopted strategic energy plan at Municipal level is SECAP. These plans, with a bottom-up process, are structured on a numbers of local scale actions, policies and transformations directed to improve the performance of the territorial systems addressing energy efficiency objectives and interested in climate change mitigation/adaptation processes.

The SECAP development process, is based on a very synthetic table of contents and, in the perspectives of the authors, could reveal several weaknesses in the comprehensive structure linking objectives to actions and indicators.

The aim of this work is to experiment an effective way to collect and evaluate energy consumption about public and residential sectors related to the case study of Potenza Municipality as a supporting tool for SECAP development. The issue to reinforce the geovisualization tools connected with SECAP allowed us to test technologies for the visualization of geographic information (spatial, temporal, or attribute, or a combination of all three) in order to create interactive visualizations for geographic analysis, using maps, map-like displays, multimedia, plots and graphs (also in combination) to aid visual thinking and insight/hypotheses generation, and a perspective on cartography [6].

2 Energy Consumption and Case Study of Potenza Municipality

Potenza Municipality in the 2009 became signatory of Covenant of Mayors and drew up its SEAP[7]. At this moment is developing the SECAP with new updated BEI (the previous was referred to SEAP 2009). The core of SECAP is Baseline Emission Inventory (BEI), and in the emission inventories part, it reports data concerning final

energy consumption, local energy production (if applicable), and the emission factors used to calculate CO_2 emissions.

From a methodological point of view, the first inventory year refers to declared baseline year. It represents the year against which the achievements of the emission reductions in your target year are measured. On the bases of BEI data, every four years, Covenant Signatories compile Monitoring Emission Inventory (MEI) to evaluate progresses in terms of emissions reductions. In this way, subsequent inventories may be compared with the BEI and progress to achieve goals, can be monitored.

Collecting or estimate energy consumption is not very easy, only for public sectors, there are (or there should be) open data easily assessable but for residential buildings and other private sectors those data are not available, especially at the single building scale. For the purposes of this study, we collaborate with SEL (Basilicata Region Energy Company) that is responsible of public procurement for local municipalities and public bodies in the sector of energy provisioning. SEL developed a platform (SELBench) to manage energy consumptions and bills in partnership with final users (i.e. local administrations).

To elaborate data concerning BEI (including relevant SECAP sectors) about energy consumption, in this work data comes from:

- SELBench, the SEL database, which collects thermic and electric consumption data by institutions or municipalities in agreement with SEL;
- Statistic benchmark based on mean statistic value about a sample of buildings similar to building interested, the chosen benchmark are processed by Milan Polytechnic, Energy Strategy Group [8]. After selecting the benchmark, the consumption is obtained as:

$$\text{Energy consumption data} = \text{bemchmark}\,[\text{kWh/m}^2 * \text{year}]*\text{area}[\text{m}^2]$$

- Application of archetypes of project TABULA [9] (Typology Approach for BUiLding stock energy Assessment) where every building represents a specific construction age and specific dimension. To obtain the energy performance (expressed in kWh/m^2), it needs four steps:

a. Select the period of construction between seven different periods ranging from 1900 (including buildings built before 1900) to 2005,
b. Select the building size class between four classes: detached houses, terraced houses, multifamily buildings and blocks of flats,
c. Select energy performance between three different building conditions: original state, standard requalification and advanced requalification,
d. Obtained the energy performance, the energy consumption is calculated as:

$$\text{Energy consumption} = \text{energy performance}\,[\text{kWh/m}^2] * \text{area}[\text{m}^2]$$

Collection of data allows us to fill SECAP BEI for the year 2019, as shown in the following Figure (Fig. 1):

Sector		FINAL ENERGY CONSUMPTION [MWh]			
		Electricity	Heat/cold	Fossil fuels Natural gas	Total
BUILDINGS, EQUIPMENT/FACILITIES AND INDUSTRIES					
Municipal buildings, equipment/facilities		3605,938		10526,32786	14132,2659
Tertiary (non municipal) buildings, equipment/facilities		22775,752		53326,36441	76102,1164
Residential buildings		85600		2660	88260
Public lighting		8154,445			8154,445
Industry	Non-ETS	35600		35600	71200
	ETS (not recommended)				0
Subtotal		155736,135	0	102112,6923	257848,827

Fig. 1. Final energy consumption for sectors (adapted from SECAP template)

The results are compared with electric and thermic consumption of SEAP referred to 2009 and PEAC (Energetic and Environmental Municipality Plan) referred to 1997.

Table 1 Final electric consumption for different sectors for years 1997, 2009 and 2019

Final electric consumption [MWH]			
Sector	1997	2009	2019
Municipal buildings	**$4.24 * 10^3$**	**$4.41*10^3$**	**$3.6*10^3$**
Tertiary	**$5.59 *10^4$**	**$2.06*10^5$**	**$2.2*10^4$**
Residential buildings	**$5.43 *10^4$**	**$3.59*10^5$**	**$8,56*10^4$**
Public lighting	**N.a.**	**$1.04*10^4$**	**$8.48*10^3$**
Industry	**$2.70*10^5$**	**$3.31*10^5$**	**$3.5*10^4$**

Some differences come out. From our point of view and on the basis of the analysis of previous plans (SEAP and PEAC), we believe that the proposed estimation gained an advanced level of accuracy.

Table 2. Final thermic consumption for different sectors for years 1997, 2009 and 2018

Final natural gas consumption [MWH]			
Sector	1997	2009	2018
Municipal buildings	**$1.98*10^7$**	**$2,06*10^7$**	**$2.6*10^6$**
Tertiary	**$5.9 *10^7$**	**N.a.**	
Residential buildings	**$2.6 * 10^5$**	**N.a.**	**$2,66* 10^3$**
Industry	**$2.7 *10^6$**	**N.a.**	**$4,63* 10^4$**

Comparing the data in Table 1 and 2 between different years, in this work we focus our studies on some actions about energy efficiency, reduction energy consumption and building renovation of Municipal and Residential buildings. The choice of these two sectors is based on the evidence that they are main contributors to BEI as shown both PEAC and SEAP. Some actions have been undertaking by Potenza Municipality with the PAES from 2009 and haven't completed yet. Two of these actions to achieve 20-20-20 goals [4], are related to municipal and residential building renovation respectively with a CO_2 estimated reduction of 3130 ton/year and 16453 ton/year. The actions will concern substitution of window frames, boilers and installation of RES technologies. In 2020, Potenza Municipality will be a signatory of new COM for Climate and Energy, with a SECAP, so it's a chance to improve reduction of CO_2, reduction of energy consumption and fight against climate change.

3 Geovisualization System for Energy Data

Around 1990 s, were proposed important conceptual frameworks as "Swoopy" framework proposed by DiBiase [10] that offers a continuum in which we see both visual thinking and visual communication, and as such, it provides foundations as to how we think about geovisualization today. In 1994 MacEachren [11], proposed a defining theoretical framework on geovisualization with MacEachren's Cartography. The Cartography framework extends the Swoopy framework, essentially adding the interaction (low vs. high) as a dimension and mapping its relationship to users (public vs. expert), and tasks (communication vs. exploration), in a continuum. MacEachren et al. [12], further developed the Cartography later, slightly adjusting Swoopy's "idealized" research steps exploration, confirmation, synthesis, and presentation by replacing confirmation step with analysis. The updated framework sums up the core functions of geovisualization: with the support from geovisualization software environments, the public (e.g., non-expert users) or specialists (e.g., researchers, decision makers) can discover patterns and form informed questions (exploration), conduct analyses to confirm or reject individual hypotheses (analysis/confirmation), generalize the findings (synthesis), and present/communicate these findings. In this way, we propose geovisualization as fundamental tool for the decisional making of the SECAP actions. The framework developed, is based on two output tools that display collected information about energy consumption for every building using:

1. CityEngine Software (A framework)
2. ArcGIS Earth (B framework)

The choice about technologies is based on comparison between commercial and free software available, related to them has expressed a technical judgment with the aim of the work.

3.1 Geovisualization Framework A

Esri CityEngine is a three-dimensional (3D) modeling software application developed by Esri R&D Center Zurich and is specialized in the generation of 3D urban environments. It improves the shape generation via the rule-based system and data sets similar as the Geographic Information System (GIS). The choice of this software is based on the fully implementation with GIS software and the next possibility of export 3D models to the web, VR experiences, or a geodatabase but it requires expert users or specialist. Starting from footprints of public, residential and industrial buildings, with the rule "*Building_From_Footprints*" have been obtained 3D models related to energy consumption (Fig. 2). In particular, for thermic consumption have been obtained 3D models of energy consumption for every scenario (actual conditions, standard requalification and advanced requalification).

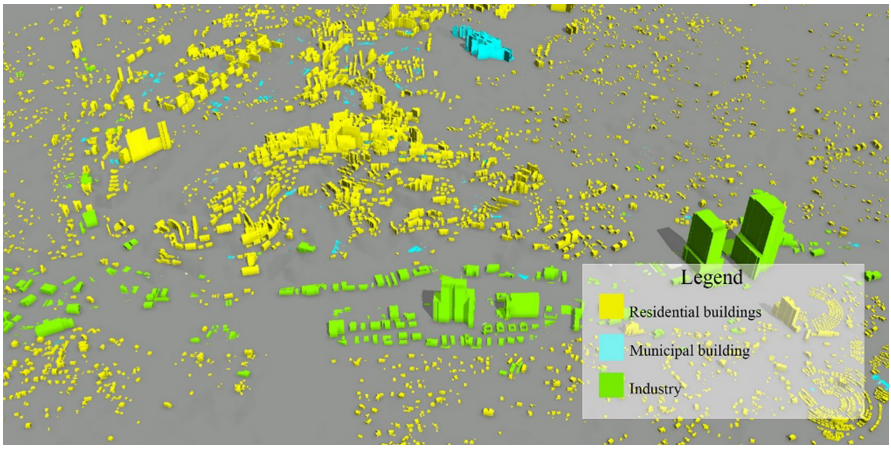

Fig. 2. 3D models of electric energy consumption buildings

3.2 Geovisualization Framework B

ArcGIS Earth, is a free software developed by ESRI to understand spatial information, with World Map. This program, is friendly-user and accessible from all users and not only from specialists as the previous CityEngine. 3D models representing the energy consumption for every scenario are imported as KML files into ArcGIS Earth and the results are shown in Figs. 3 and 4. This representation of 3D models, opposite to previous into CityEngine is more intuitive and understandable for not expert people. This feature could be useful to involve citizen to became active part into decision – making and empowerment them to reduction energy consumption.

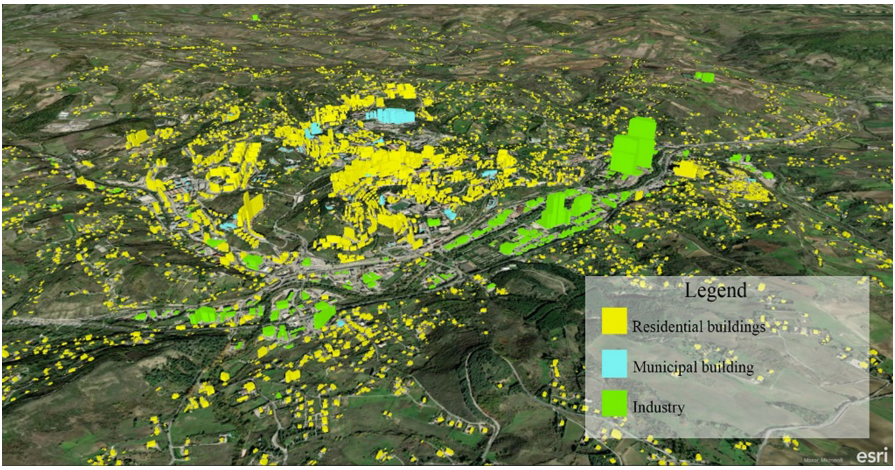

Fig. 3. 3D models of electric consumption in ArcGIS earth

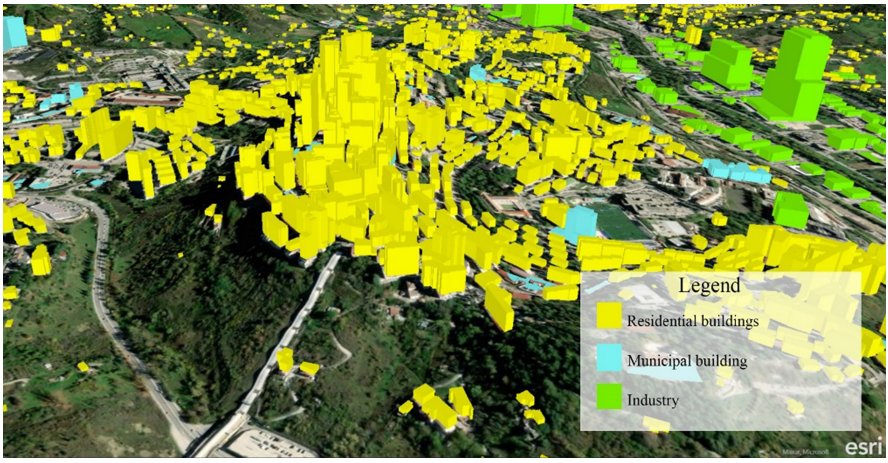

Fig. 4. Particular of 3D models of electric consumption in ArcGIS earth

4 Conclusion

As seen, geovisualization fits as support in decision-making or comparing different energy requalification scenario and a tool to share information/decisions to stakeholders or citizen. Those applications of advanced geovisualization tools are very rare in the SECAP and COM development, while they could represents the effective application of a collaborative approach oriented to include stakeholders and decision makers, but also citizens, in a collaborative elaboration process [13–17]. This assumption goes in the direction to establish a common awareness facing those challenging issues of energy efficiency and climate change mitigation/adaptation.

In order to improve energy efficiency, urban transformations could be monitored and checked any possible overlay between different instruments able to produce impacts and consequences to territory, in a uniform framework [18–21].

We are in the domain of new rational planning for sustainable development, and such tools integrates the existing toolbox for planners and decision makers [22, 23].

As future developments, the choice of open geovisualization tools (available on the internet) can be used to analyze and compare deeper the data organized into GIS, i.e. comparing energy consumption between different archetype or age of construction. Individual citizens, decision makers, investors and operators will easily find spatial explicit opportunities to realize energy renovations in urban context. Other developments are related to:

- improve the visualization of the data, in particular when attributes to display are not closely related to 2D objects (i.e. energy consumption of public lighting).
- compare the 3D visualization obtained in this work, choosing other visualization opportunities as viewshed analyses suggested by Danese et al. [24–26], in order to improve the awareness of citizen to reduce energy consumption and support the detection of highly energy-consuming buildings.

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