## Map4Data: a mobile App to refine geodata for the SUNSHINE "Building Efficiency Pre-certification Service"

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## Abstract

In 2012 the Municipality of Ferrara, Italy, signed up to the Covenant of Mayors (CoM), the mainstream European movement involving local authorities to reduce greenhouse gas emissions (GHG) by 2020 by increasing energy efficiency and through the use of renewable energy sources.

The GHG target reduction defined in Ferrara is 25%, with two thirds of the saved emissions from buildings; one of the actions of the CoM Sustainable Energy Action Plan (SEAP) is related to the SUNSHINE project (Smart UrbaN ServIces for Higher eNergy Efficiency, www.sunshineproject.eu) for the implementation of the "Buildings energy pre-certification" service, using open geodata already available from authoritative sources.

The local municipal GI department has been deeply involved in the modeling and creation of a public repository of detailed geodata on building energy performance, based on the draft CityGML Energy ADE defined by the SIG3D association (http://en.wiki.energy.sig3d.org/index.php/Main_Page).

The "Building Energy Pre-certification" service is an automatic process to rapidly estimate the the energy performance of buildings at large-scale, using geographical, physical and thermal properties of buildings, together with other parameters related to the context (e.g. climate zone, urban pattern, …), also using typologies and outcomes defined by the TABULA project (http://episcope.eu/building-typology/).

To efficiently run the service, a dedicated mobile application (Map4Data) was implemented to allow professional users to check "on-the-field" the correctness and completeness of buildings' geodata properties (e.g. age of construction, uses, heights, floors, …) and let them add or modify such properties, if missing or needed, via OGC WFS-T interface .

The App is currently used in three pilot cities involved in SUNSHINE project (Ferrara, Lamia, Trento) and is going to be extended and reused in other projects.

## Keywords

Energy, building, Covenant of Mayors, mobile, OGC, INSPIRE

## 1 Introduction

One of the main objectives of the SUNSHINE project is the estimation of energy performance of residential buildings, at urban scale.
Buildings represent about 40% of the whole final energy consumption (European Union, 2010): in 2009 European households were responsible for 68% of the total energy used in buildings, mainly for space heating and domestic hot water (BPIE, 2011).
In this context, buildings have to be viewed as a dynamic (the use of the building can change overtime) source of information (including their internal equipment) as a whole.
Buildings are indeed one of the main CO2 emission sources to be considered by Municipalities and other Public Authorities aiming to reduce the overall amount of energy needed at urban level.
The European-wide approach of the SUNSHINE project is related to the following two main European policies:

- Energy Performance of Buildings Directive (EPBD): the Directive 2010/31/EU (recast) is a key regulatory instrument, which is meant to boost the energy performance of the building sector.
- The Covenant of Mayors: it was launched by the European Commission, after the adoption of the EU Climate and Energy Package in 2008, to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies.

The key document of the Covenant of Mayors is represented by the Sustainable Energy Action Plan (SEAP) where the signatory defines its commitment to reduce CO2 emissions by 2020.
Signatories are committed to submit an 'Implementation Report' every second year following the submission of the SEAP 'for evaluation, monitoring and verification purposes' (European Commission, 2010, p.48).

### 1.1 Sunshine and Energy Maps: State of the Art

One of the purposes of SUNSHINE project is to provide methods to implement automatically large-scale assessment of building energy behaviour based on geodata available from public registers (e.g. topographic maps, cadastre, building permits, energy certificates, etc.) together with buildings' properties derived from other sources (other archives available in other local or national organisation, or information collected through crowdsourcing technologies).
One output is represented by "energy maps".
Energy maps (or "energy density maps") are normally GIS-based and often prepared at the neighborhood, local authority or sub-regional scale .
As described in (CHPA, 2014), an energy map might be used in a variety of ways and applications:

- to create or improve district heating networks
- to define energy strategies
- to identify energy solutions and prioritize projects
- to select carbon compliance/allowable solutions

- to improve the communication and the energy awareness

The current availability of relevant technologies and standards has encouraged the development of many research projects in the area of building energy performance estimation based on publicly available data with the aim of creating energy map (Giovannini et al., 2014).
The main challenge in this task is related to effectively providing data for the whole city area. For example, building certificates, adopted by many of EU countries to describe building efficiency, can provide a very detailed insight on building energy properties, but on the other hand, these certifications are not mandatory for all the residential buildings and their availability is thus very sparse.
So, given the fact that publicly available data generally do not include all the information needed for the energy performance calculation, one of the most common approaches to energy map creation is to estimate the missing information in a reliable way, using the basic input data that is typically available, such as building geometry, building use, construction year, climatic zone, etc. A solid example of this approach is described in (Nouvel et al. 2013), where the City Geography Markup Language (CityGML) standard is used to semantically describe the set of objects that compose the urban environment, a building typology database is exploited to statistically estimate the energy performance properties of buildings and, finally, an Application Domain Extensions (ADE) to the CityGML model is defined to store the estimated information for each building (Kaden and Kolbe, 2013).
A radically different approach is described in (Hay et al, 2010), where thermal images acquired by airborne thermal cameras are used to measure the heating lost by buildings via their roofs and windows and from that the energy performance of the buildings is estimated.
Both approaches have merits and deficiencies. In the former case, input data are publicly available, requiring no additional cost; however, having to rely on typologi-cal databases to estimate the most of the energy parameters yields a result that is typically not very statistically reliable at the building scale and is usually confined to residential buildings (where performance typologies are easier to define). Moreover, the overall software architecture is typically desktop based, so the access to the results is often limited to a small number of users with advanced GIS skills. Another limit is related to the dissemination and exploitation activities of the computed results: for performance reasons, the visualization is commonly provided via a conversion to KML standard, where the link between the building performance data and its geometry is color-coded in each building-style parameter and the other information stored in the starting CityGML file is lost.
The approach presented in this paper belongs to the typological kind, but makes an effort to reduce the common drawbacks that have been delineated. As described in more details in the following sections, our approach is in effect hybrid, leveraging on the outcomes of project TABULA-EPISCOPE (Ballarini et al., 2012) but limiting the use of building parameters estimated typologically.

## 2 The Sunshine "Building Energy Performance estimation"

The "Building efficiency pre-certification service" is an automatic process to rapidly estimate the the energy performance of buildings at large-scale, using geographical, physical and thermal properties of buildings, together with other parameters related to the context (e.g. climate zone, urban pattern, …), also using typologies and outcomes defined by the TABULA project (http://episcope.eu/building-typology/).
The following section lists the specifications of the prototype with respect to hardware performance parameters, host parameters and installed software.

The service is intended to rapidly estimate energy performances of buildings at urban scale, using geographical, physical and thermal properties of building geodata (attributes) together with other parameters related to the geographical context (e.g. climate zone, urban pattern, …).
The Building efficiency pre-certification service is divided into the following software modules, described below:

- *ETL procedures*: backend automatic procedures for transforming data provided by partners, load them in the PostGIS database and generate the CityGML representation.
- *Editing App*: mobile application (client) for checking the quality and the completeness of data provided (on the field).
- *Visualization and editing services*: backend services used by the mobile application for visualizing and correcting data.
- *Processing service*: web service for calculating the estimated energy performance value, at building level, at large scale (district/urban area).

### 2.1 Software components

In the cases of Ferrara, Trento and Lamia (three of the SUNSHINE pilot cities) geodata represented buildings have been based on open data available from authoritative sources.
In the case of Ferrara, for example, the footprints of buildings have been taken from the regional topographic database, available as open data with CC-BY license:
http://geoportale.regione.emilia-romagna.it/it/catalogo/dati-cartografici/cartografia-di-base/database-topografico-regionale/immobili/edificato/unita-volumetrica-dbtr2013-uvl_gpg

Nevertheless, some of the required attributes were missing or needed to be checked on-site (about 5,000 buildings in the historical centre): an on-the-field campaign is organized, involving few people from the local Department of Architecture of the University of Ferrara, for twenty workdays.
The staff of the Department of Architecture used smartphones and tablets to edit attributes via WFS-T service, and updates data on PostGIS database.

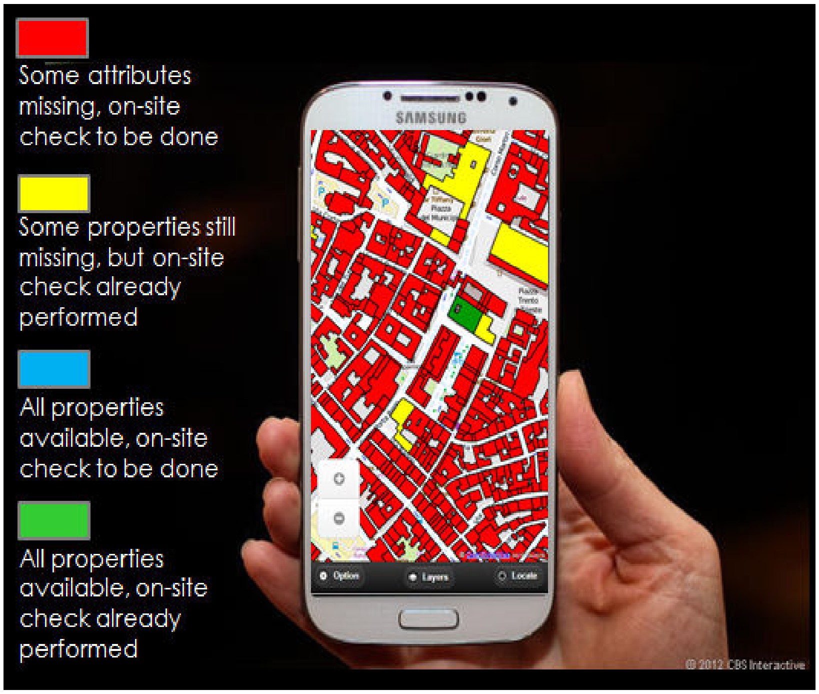


**Figure 1 - Map4Data - WFS-T and data quality checks on buildings' properties**

In aproximately 50 workhours more than 1000 buildings have been controlled:

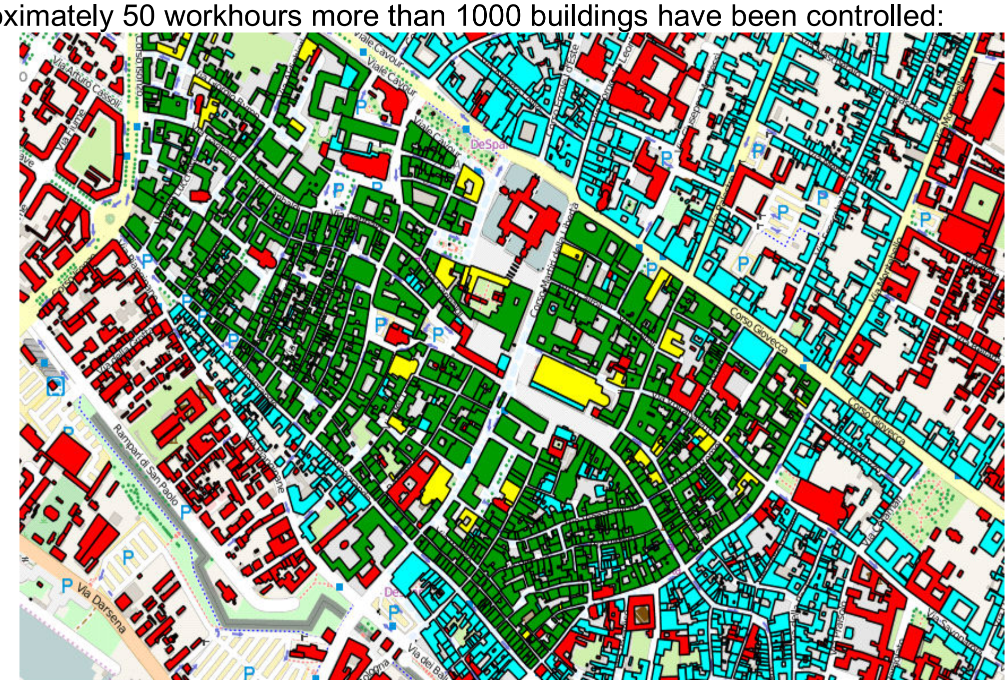

**Figure 2 - Map4Data - Status of quality check of buildings' properties in Ferrara**

### 2.1.1 Map4Data

The "Map4Data" is a mobile application implemented for SUNSHINE partners to allow

them to check “on-the-field” the correctness and completeness of buildings’ geodata properties (e.g. age of construction, uses, …) and let them add or modify such properties, if missing or needed.
The app has been implemented using PhoneGap open source framework , in order to be installed on Android o.s. (4.1 or higher) devices.
Once the app has been installed on a tablet or smartphone, any logged-in user may:

- Visualize a thematic map of buildings and check which buildings have some missing properties; indeed, the thematic map shows buildings with a “traffic light” color code: “red” is used for buildings that have some missing information and have not yet been checked by any user, “yellow” is used for buildings that have been checked by the user but still have some missing information, “green” is used for buildings that have no missing information;
- Click on a polygon representing a building and get its details (attributes);
- Edit attributes, adding missing values or correcting wrong ones;
- Save edits.

This mechanism allows to perform fast visual checks on site, to control thematic completeness and correctness of data, and provide further (missing) information, or correct inaccurate ones.
The data visualized and edited are provided by view and editing backend services, available through GeoServer platform, installed on the SUNSHINE platform.
The “Editing service” is a standard OGC WFS-T service to perform transactional operations and let the user edit the attributes of buildings’ geodata.

#### 2.1.2 Processing service

This component represents the “core” component of the whole “Building Efficiency Pre-certification Service”.
The processing service is the component responsible for the automatic calculation of the pre-certification for each building.
The processing service is a standard OGC WPS service to perform complex operations and calculations such as polygon overlay. The WPS standard also defines how a client can request the execution of a process, and how the output of the process is handled. It defines an interface that facilitates the publishing of geospatial processes, their discovery and their binding to other processes.
WPS extends the web mapping server capabilities to provide geospatial analysis; in the case of the “Building Efficiency pre-Certification Service” the WPS module has been designed to run on GeoServer platform and it will be completed and deployed in the final release.
The WPS module will perform a chain of operations on buildings’ geodata and calculate the value of the estimated energy performance class.

### 2.2 Energy map validation and visualisation

Validation of the model is carried out comparing the estimated energy performance with real energy certifications or (where available) with annual energy consumption real data.
The SUNSHINE Workflow provides an estimation based on the whole building geometry

while energy certifications are apartment-based;

The apartment position (ground floor/middle floor/last floor) influences the heat loss. For this reason, the energy performance estimation workflow is refined as follows and performed for the three above mentioned conditions.

Different software used to calculate the energy performance index produce similar, but not identical, results. The differences between these results are variable and can arrive to 20% in the worst case.

Real data of some building are listed in Table 1 shows, where hypothetic floor number was calculated by comparing the reference area and shape one.

Some considerations on the validation process:

- For old buildings, TABULA overestimates the set of U_VALUES;
- The real energy certificates do not include information on the refurbishment level of the envelope.
- The Delta U Bridge for recent buildings is, in general, overestimated: around 10% independently by the construction year.

The following figure represents the comparison of real and estimated data on the whole dataset composed by two cities, by year of construction.

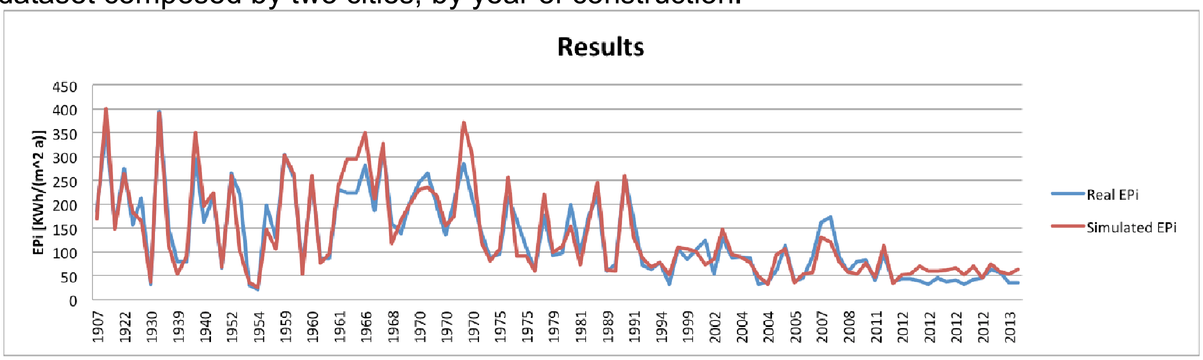


**Figure 3 - Validation graph**

The percentage gap between two values is much greater in the recent buildings, be-cause uncertainties in glazing area are more relevant than U-values.

The following diagram represents the normal distribution of absolute errors. As it is possible to see, the average error between estimated and real data is near the 21% but, taking into account the previous considerations on the validation process, it is easy to understand that the error factor can be effectively decreased.

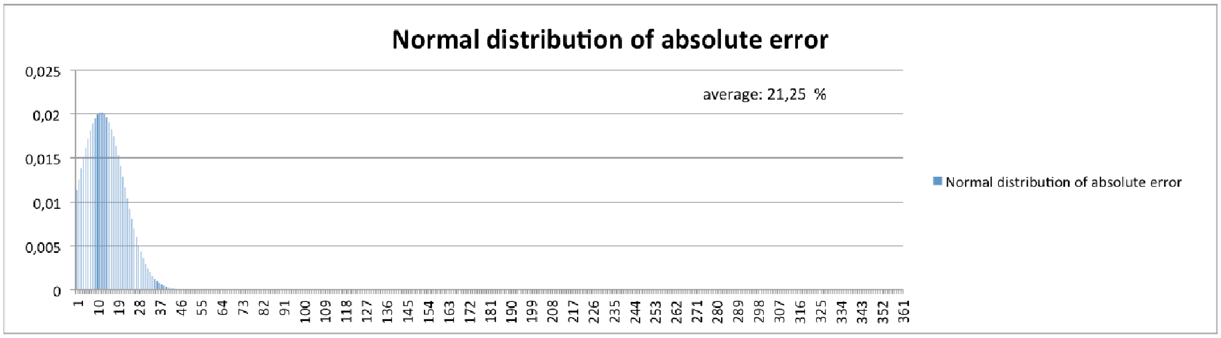


**Figure 4 - Errors distribution against real and estimated data**

Energy maps are generated merging geometry LOD-1 information from the CityGML of the displayed city with the output of the energy performance estimation procedure. More specifically, the color of each extruded KML polygon will be de-pendent on the estimated building energy class. The reference between each building in the KML file and the corresponding building in the 3D CityDB is ensured by storing the unique GML UUID of the building in the KML polygon name property. By the use of a web service it will then be possible to retrieve the energy-related parameters corresponding to the selected object.
The following figure shows, the energy map visualizer composed by two interconnected parts:

1. An HTML5 canvas based on CesiumJS that displays the WebGL virtual globe with KML energy maps, based on CityGML LOD-1 geometries, are loaded;
2. A classical HTML tab, displaying the detailed energy data corresponding to the se-lected building. Comparisons between building energy efficiency characteristics can easily be performed using the “radar” diagram placed in the bottom-left part of the page. The diagram allows the comparison of the most important building proprieties between the current and the previously selected building.

For each building, the web client allows the possibility to refine the main algorithm input data, increasing the energy performance index estimation accuracy and providing some information for the apartment-level estimation.


**Figure 5 - Sunshine 3D client and Energy map (Ferrara)**

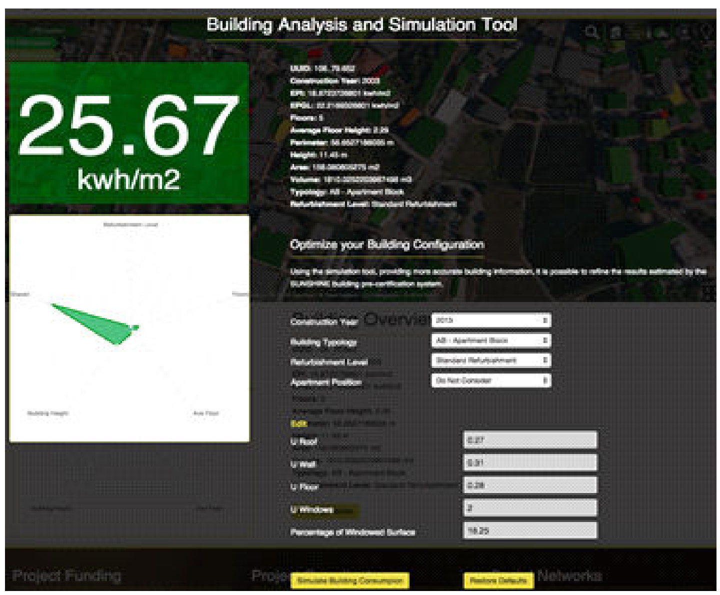


**Figure 6 - Building analysis and simulation tool**

## 3 Conclusions

In this paper we have presented some of the preliminary results of the SUNSHINE project. The use of TABULA building typology database with real build-ing geometry information allows, for a large-scale, application of the building energy performance assessment and the underlying service-oriented system architecture supports a distributed access to the related services.

The objective of high quality estimation of the energy performance of buildings has been greatly facilitated by the approach of on-site data quality checks.
Indeed, as many authors already highlighted, open geodata may suffer from the lack of completeness and/or correctness and often need to be enriched.
The app Map4Data presented allows to perform fast on-site data quality checks, with standard and interoperable OGC services, and using harmonised data (based on INSPIRE data model).
Moreover, the use of the emerging WebGL technology ensures the largest available audience in terms of devices, avoiding the development of device-dependent custom clients for 3D city map visualization.
On the side of data structure and visualization, improvements will be focused on increasing the quality of the geometry displayed, making it possible to render buildings based on CityGML LoD-2 level of detail and on the development of more detailed building size type estimation procedures.

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