Digitisation and analysis of energy data at municipal scale: an application to the municipality of Mendrisio

Marco Belliardi[1*], Nerio Cereghetti[1], Albedo Bettini[1], Katia Dalle Fusine[2], Francesco Vismara[2], Michela Sormani[3], Mario Briccola[4], Gabriele Martinenghi[4], Martin Muntaner[4], Paolo Camponovo[5], Filippo De Gottardi[6], Moreno Pusterla[6], Gabriele Gianolli[6]

[1] University of Applied Sciences and Arts of Southern Switzerland (SUPSI), CH-6850 Mendrisio, Switzerland
[2] TiGIS Sagl, CH-6850 Mendrisio, Switzerland
[3] Enermi Sagl, CH-6928 Manno, Switzerland
[4] Municipality of Mendrisio - Technical office, Mendrisio, Switzerland
[5] Municipality of Mendrisio - Data Processing Centre, Mendrisio, Switzerland
[6] Municipality of Mendrisio - Industrial companies (AIM), Mendrisio, Switzerland

* marco.belliardi@supsi.ch

Abstract. The concept of Smart Cities has gained significant attention in recent years due to the increasing need for efficient energy management in urban areas. This paper describes a digital platform for the management of energy databases that aims to synchronize, update, and analyze different energy installations and uses in the municipality of Mendrisio [1]according to the Smart City concept. The platform interweaves and compares various energy databases to ensure better efficiency in the use of thermal and electrical energy, as well as optimize the consumption and production of renewable energies. The geodigital platform created is capable of conducting energy assessments for the development of new district heating projects in the municipality and the creation of local energy communities. This paper presents the design and functionalities of the proposed digital platform, highlighting its potential for improving energy management in Smart Cities and facilitating the transition to more sustainable energy practices. The results of this study, financed by Swiss Energy together with Canton Ticino and AIM (Aziende Industriali Mendrisio), contribute to the growing body of research on digital technologies for energy management in urban areas and provide insights for policymakers and urban planners seeking innovative solutions for sustainable energy development.

1. Introduction

The need for sustainable and efficient energy management has become increasingly urgent in recent years [1], [2] and [3]. Municipal, cantonal, and federal governments have been actively investing in the development of energy databases and resources to help them better understand and manage their energy consumption and production. However, it is not enough to simply gather data, it is so essential to analyze and optimize the information collected in a way that ensures efficient and sustainable use of energy resources. To achieve this goal, it is crucial to adopt innovative technologies and tools, such as digital

[1] Mendrisio is a municipality in the Canton of Ticino (Switzerland) with a total surface of about 32 km^2 and about 15'000 inhabitants.

platforms, that enable local energy planning to make informed decisions [4] and [5]. In particular, thermal and electrical needs must increasingly rely on sustainable and renewable energy sources, and digital technologies can provide invaluable insights and facilitate the transition to more sustainable energy practices. This paper aims to present a digital platform for the management of energy databases that follows the Smart City concept. The platform seeks to synchronize, update, and analyze various energy installations and uses in the city to ensure better efficiency in energy use, as well as optimize the consumption and production of renewable energy. The geodigital platform created allows to conduct energy assessments for the development of new district heating projects, as well as the creation of local energy communities.

2. Method

Every energy database in Switzerland has its own critical points and advantages, and it is essential to compare them to reduce the risk of errors or missing information. It is therefore fundamental to compare different energy databases to minimize errors and missing information. It is planned to select and collect appropriate energy databases, to communicate with data managers and to create an online GIS (Geographic Information System) portal called GEOME for easy data access and analysis. The project, still ongoing and in development, has the scope to identify suitable areas for new district heating systems and new RCP[2] projects (energy communities, RCP in Swiss Italian [6]). The following sections provide more detailed information about each of these stages of the project.

2.1. Analysis and collection of the available databases

To ensure reliable and up-to-date energy data, a list of available databases and their data availability was compiled. The authors relied on their experience in similar works ([7], [8], [9], [10]) and their knowledge of available databases in Switzerland. Municipal, cantonal and federal databases were ordered for inclusion in the list. The databases were evaluated based on the quality and reliability of the data they contained. The following table shows the databases used in this study and the information they contain:

Table 1: List of databases included in GEOME portal

Database name	**Level**	**Information Contained and Used**	**Accuracy**
Federal Register of Buildings and Dwellings (RBD)	National	• Building category and surface • Building interval/age • Thermal generator and source	+
Minergie database	National	• Building category and surface • Certification year • Thermal generator and source	++
Solar roof layer	National	• Roof surface and solar aptitude • Electric energy production	++
Control of heating systems (ConComDat)	Cantonal	• Building category • Burner year, source (fuel) and power	++
Cantonal incentives for heat pumps	Cantonal	• Subsidy year • Thermal source	++
Cantonal database for geothermal BHE[3] and wells	Cantonal	• Thermal source • Permission year	-
Municipal building permits	Municipal	• Thermal source • Permission year	+
Installations of the municipal energy company	Municipal	• Thermal source and year permission • Power (photovoltaic, heat pump, gas burner)	+
Electricity consumption of the municipal energy company	Municipal	• Year electric consumption (for big users also hourly consumption)	++
Gas consumption	Municipal	• Year gas consumption	++
Gas network	Municipal	• Length and track	++

[2] RCP: Raggruppamento ai fini del consumo proprio

[3] BHE: Borehole Heat Exchanger

All the databases used in this study provided information associated with buildings (EGID) and their entrances (EDID)[4]. In cases where such information was not available in databases, the address or the municipal fund was used to identify the building. Cross-referencing the different datasets was essential to ensure accurate and reliable analysis. Therefore, having access to information about the physical location of buildings was critical in allowing the databases to be effectively compared and analyzed. To ensure accuracy and reliability of the data used in the analysis, the authors made efforts to correct any missing or incorrect data in the databases. In cases where information was missing or incorrect, such as missing house numbers or incorrect street spellings, the authors attempted to correct the data manually.

As shown in the Table 1, some databases were considered not completely reliable in terms of the information they contained. For example, census errors, changes in energy sources not reported, and census being conducted in different years were some of the challenges encountered. Therefore, the authors prioritized the use of data acquired from more reliable sources, such as the Minergie database, combustion control database, and cantonal incentives database. This allowed for a more streamlined flow of information and ensured that the analysis was based on the most accurate and reliable data available.

2.2. Creation of the GIS portal GEOME

Data information collected from the various databases were organized into a georeferencing program GEOME for the city of Mendrisio. The program allows project partners to interact with the data in real-time, providing a more efficient way to query and analyze the information. This approach was taken to ensure that all project partners had access to the same information, allowing for better collaboration and decision-making. Using the georeferencing program developed for the project, it is possible to query each building in the municipal area of Mendrisio and obtain information based on the most reliable data sources available. As mentioned earlier, some databases were prioritized due to their reliability and accuracy, and the program takes this into account when presenting information about each building. However, the program also allows for querying of other databases, and users with administrative rights can suggest changes or correct data that may be inaccurate. By allowing users to suggest changes and corrections, the program can be continuously updated to ensure that it reflects the most accurate and reliable information available.

An example of the georeferencing program in action can be seen with the SUPSI building in Mendrisio. As a Minergie-certified building, the program offers information about this certification when the building is queried.

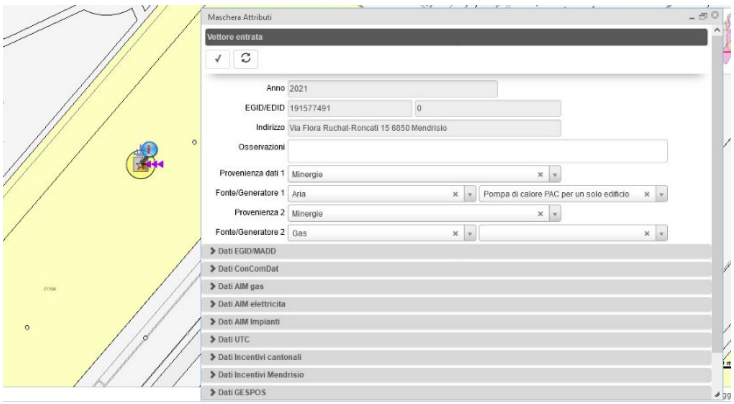

Figure 1. Example of querying a building with databases (priority Minergie data)

Additionally, the program uses various icons to represent different types of information, such as heat generators, photovoltaic systems, and energy sources. This visual representation of the data makes it easier for users to quickly identify relevant information and make informed decisions based on this information. The use of icons also helps to streamline the data presentation process, making it more accessible and user-friendly.

[4] For more information about EDID and EGID see https://www.bfs.admin.ch/bfs/it/home/registri/registro-persone/armonizzazione-registri/egid-ewid.html

2.3. Energy data analysis

In order to identify suitable areas for new district heating plants, the energy thermal needs of each building were analysed and assessed. This involved examining the current heating systems in use and the potential for introducing renewable energy sources such as heat pumps, solar thermal systems, or biomass boilers. The results of this analysis were used to identify priority areas for the development of new district heating plants. In parallel with the analysis of suitable areas for district heating plants, the project also focused on the creation of new energy communities (RCPs).

2.3.1. District Heating

For the evaluation of new district heating plants, the thermal densities on the territory are calculated using GEOME. The program allows for the variation of areas between 100 hectares and 50 hectares to identify the densest areas. The thermal needs are evaluated on a theoretical level, taking into consideration the heat indices described in [9] and [10]. Additionally, there is the option to manually modify the thermal needs of building, based on more reliable information obtained from the databases. GEOME also allows the drawing of hypothetical district heating networks on the identified dense areas. Buildings within a radius of a user defined meters, which is definable by the user, can be associated with the district heating network. Once the buildings are associated, it is possible to remove them from the network if they do not meet certain criteria set by the user, such as exclusion of heat pumps or installations after a certain year. Finally, GEOME calculates the total thermal demand for the network by dividing it by the calculated length of the network. This is indicator is normally considered significant if it exceeds around 2 MWh/m [11]. The intention is to evaluate and deepen the analysis in different districts of Mendrisio, such as Rancate, Meride, Arzo, Besazio, etc.

2.3.2. Energy communities (RCPs)

In the case of evaluating new RCP installations in the municipality of Mendrisio, the GEOME software is used to calculate electricity densities over an area of 50 or 100 hectares. These densities are based on data monitored by the local energy company. The software also allows the possibility of coupling these densities with the presence or absence of large consumers, defined as those with an annual consumption greater than 100 MWh. This information can be useful in identifying potential sites for new RCP installations. In addition to electricity densities and large consumers, the presence of already installed photovoltaic systems or suitable roofs can also be taken into account in identifying potential areas for new RCPs. This information is obtained by de different databased integrated and also visualizing the "solar roof" layer [12].

3. Results

While the project is currently ongoing and definitive results are not yet available, some preliminary analyses have been conducted focusing on the potential for district heating and RCPs. In this chapter, the initial findings of the project are presented.

3.1. District heating results

Fig. 2 displays a visual representation of the calculation of thermal demand densities within the entire Mendrisio municipal area. The different shades of dark colors in the figure are used to represent varying levels of thermal densities, where darker shades indicate higher thermal densities.

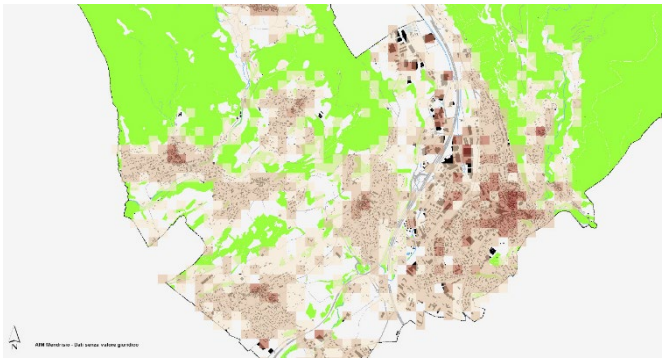

Figure 2. Mapping of the heat thermal density of the Mendrisio area

Figure 3 shows calculation for Meride (a district of Mendrisio) in term of thermal density and a proposed district heating with the network drawing by associating buildings within a radius of 10 meters.

Figure 3. Thermal density mapping (left) and district heating network with buildings (right) of Meride

For the preliminary calculation, all buildings were considered without excluding certain buildings with singularities (i.e., new heating system, heat pumps, etc.).
The following table presents a summary of the key information obtained from the GEOME portal, providing an overview of the various outputs, as well as the number of buildings, length of heating network, and the total heat demand associated with related density rate.

Table 2. Results of the district heating evaluation in a Mendrisio neighborhood (Meride)

	Information	**Values**
Network	Total length	632 [m]
	Tracks parts	214 + 130 + 53 etc. [m]
Buildings	Buffer on the track	10 [m]
	Energy	2 [GWh/year]
	Numbers of buildings	46 -
	Heating system	all
Calculation	Linear energy density	3.2 [MWh/m]

3.2. Energy communities' results

The part related to the evaluation of new energy communication projects (RCPs) is not yet finalized, but various density maps and thinking have been created. These maps allow visualization of energy consumption on 50-meter rasters while filtering out small consumers, large consumers on the free market, and large consumers not on the free market. These density maps can identify areas and buildings with higher energy consumption, and therefore areas with greater potential for implementing RCPs. Figure 6 shows an example of such a map, specifically the density of small consumers in the area. The darker colors on the map indicate higher densities of small consumers. The sun icon shows the presence of a photovoltaic system.

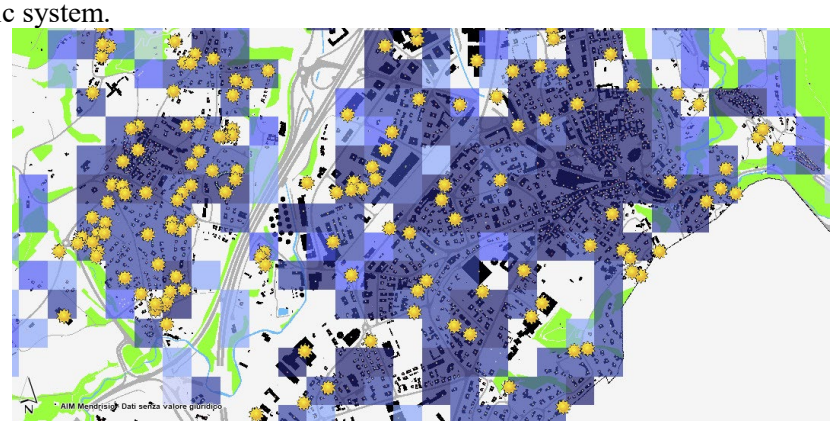

Figure 4. Mapping of electricity densities (small consumers) and PV systems in the Mendrisio area

The authors have refrained from providing more specific information on the density intervals and the presence of large consumers in order to protect the privacy of the individuals or entities involved.

4. Conclusions and discussion

Despite the fact that the project is ongoing and no final official results have been reached, the initial analyses have demonstrated promising potential on the method and previous results. The aim is to provide the municipality of Mendrisio and its electricity company (AIM) with a quick-to-use digital tool that allows them to find opportunities to improve energy efficiency and promote the use of renewable energy sources, supporting the objectives of sustainability and energy planning in the area. By georeferencing and mapping energy sources and installations, by taking information from different energy data bases, the project enables the identification of areas suitable for the creation of new district heating networks and new self-consumption communities, thereby promoting the use of renewable energy sources and reducing costs for citizens and businesses. By using data-driven solutions and innovative technology, the project has demonstrated the importance of taking a proactive approach towards reducing energy consumptions and promoting renewable energy sources. It is hoped that the findings and recommendations of this project will be used to guide future energy planning initiatives in the region, and inspire other communities to adopt similar strategies for achieving greater energy efficiency and sustainability.

The collaboration of the different partners has allowed for the pooling of resources, knowledge, and expertise, enabling the project to make substantial progress towards its goals. The project has been able to take advantage of the diverse perspectives and experiences of the different partners to create a comprehensive and innovative platform that is designed to improve energy efficiency in the municipality.

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