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PREDIS-MHI Thermal Data: Thermal readings from a section of a sub-metered tertiary multi-use building

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Abstract

The French Construction and Housing Code had set an obligation for tertiary buildings to reduce their final energy consumption by 40% in 2030, 50% in 2040, and 60% in 2050. According to ADEME, tertiary buildings in France account for almost a third of the energy consumed in the built environment. As such, buildings in this category could be an important lever to meet these goals necessitated by the energy transition. The availability of high-quality datasets from this sector will be a crucial enabler in meeting these goals by developing and testing new energy management approaches in the buildings. In this paper, we present the thermal energy datasets available and published online for the PREDIS-MHI zone of the GreEn-ER building, a tertiary building with more than a thousand sensors used for research, teaching, and administrative activities in Grenoble.

Keywords: Open Energy Data; Sub-metered tertiary building; Data Use case

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Figure 2: Closer view of the PREDIS-MHI Platform

To maintain thermal comfort in the PREDIS-MHI platform, a combination of ventilation, heating, and cooling systems is implemented. Ventilation is provided by fresh air delivered through a central Air Handling Unit (AHU), located on the building's rooftop and supplemented with a local water battery for air preconditioning as shown in Figure 3. For temperature control, there are two primary sources:

- Air Preconditioning: At the AHU level, a coil system preconditions the air, serving both heating and cooling purposes. This preconditioned air is then distributed throughout the lab.
- Room-Specific Temperature Adjustment: Each room is fitted with a terminal coil with a local water battery, that allows for the adjustment of air temperature to meet the specific needs of that room.

Additionally, a reversible hydronic ceiling system is installed in each room. This system connects to the district heating network for heating in the winter and to local chillers for cooling in the summer, ensuring a comfortable environment year-round. A machine-readable description of this system is available as part of the dataset.

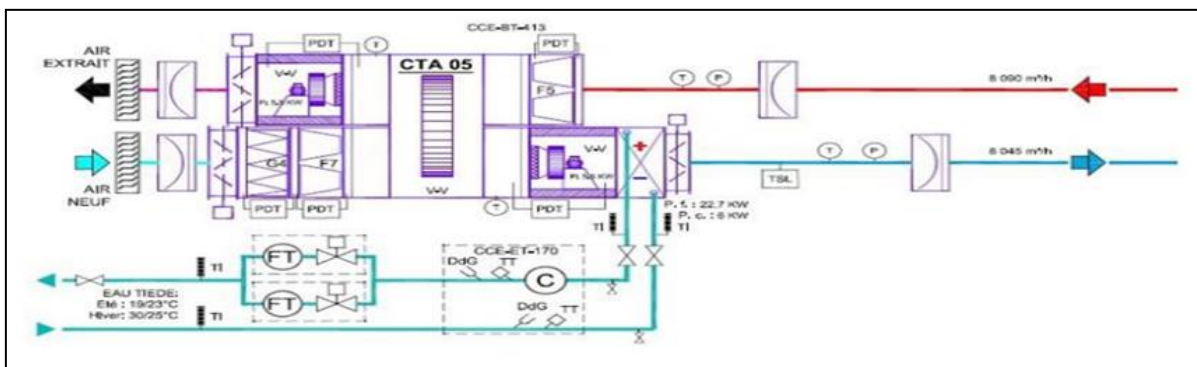


Figure 3: The Air Handling Unit

PREDIS-MHI Data

Description of The Data

The dataset covered the energy use in 6 offices, one classroom, and an exposition room. Figure 4 shows the arrangement of the dataset with room-level data including temperature, CO₂, and airflow rates. There is also specific data from the Air handling unit as well as general data in the root folder of the dataset.

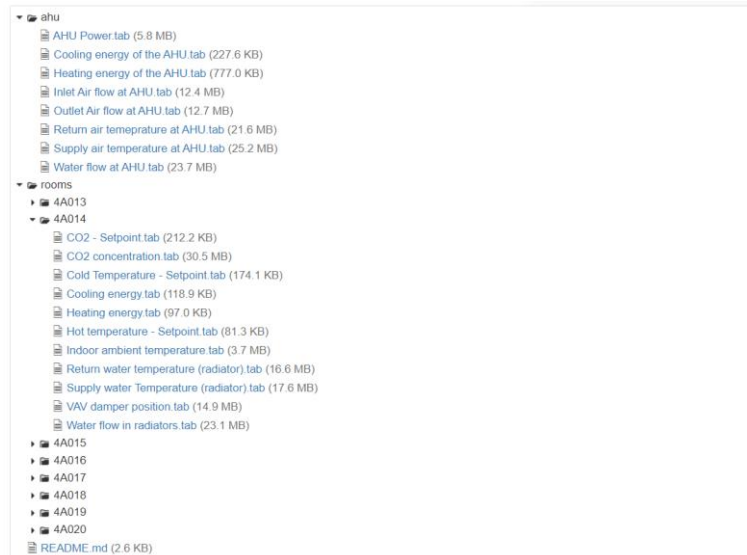


Figure 4: Folder structure of the PREDIS-MHI dataset on [recherche.data.gouv](https://recherche.data.gouv.fr/)

Dataset Construction

The GreEn-ER building is equipped with numerous sensors/actuators which measure the values of variables in real time. These sensors have been positioned at precise positions, mainly in the rooms. In addition to the measured value in real-time by these sensors, certain virtual meters are also created through a rule-based algorithm. The creation of these virtual meters is possible due to the building management software, known as EcoStruxure [4].

The data storage process comprises multiple steps. The data is measured by installed sensors in real-time and is stored in the memory of the concerned programmable logic controller (PLC). The PLC has a data retention of 15 days; therefore, every new registered value pushes out the oldest registered value from the memory. To avoid the loss of this data, the values from these PLCs is copied on the SQL database. This SQL database does not have a retention policy. No pre-treatment of data is realised at this stage. This data can be visualised by using the EcoStruxure web interface. Only a limited part of this data is related to the demo zone of GreEn-ER building, therefore, the data of demo zone is at disposal for research and teaching. If necessary, a pre-treatment of data is realised at this stage. This data is retrievable from the timeseries database on MHI server (known as influxDB) and can be visualized publicly using the Grafana web interface tool. Figure 5 illustrates a simplified version of the registration and visualisation process of GreEn-ER data.

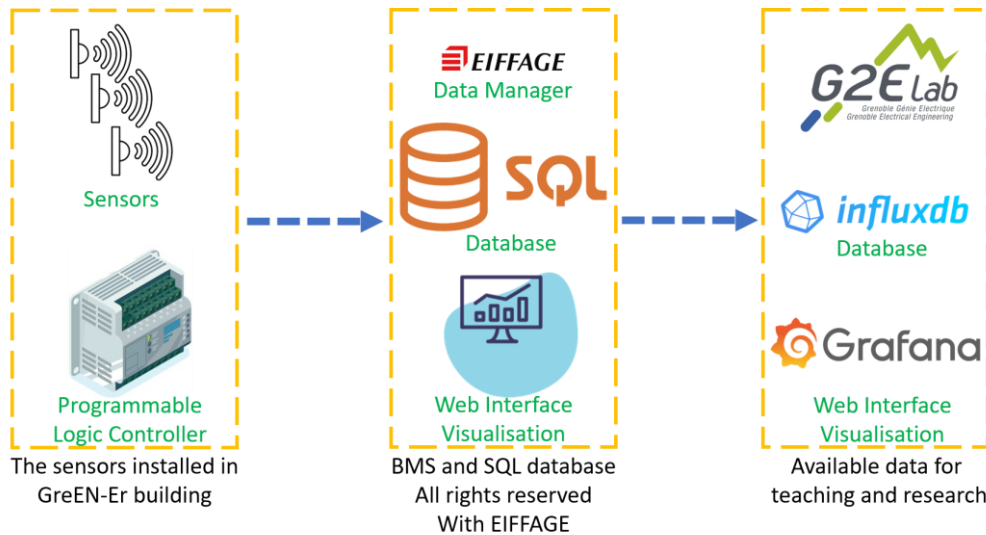


Figure 5: Simplified schematic diagram of GreEn-ER data registration and visualisation process

Use of The Data

A practical application of PREDIS-MHI data use involves developing a thermal model through the Dimosim simulation tool. This model serves as a foundation for testing and evaluating advanced algorithms for managing energy systems. Dimosim is a bottom-up dynamic simulation platform, developed by the CSTB [5]. This tool is based on an object-oriented structure. The models of buildings and energy components are based on a physical description.

To run the Dimosim model, several information was needed. First, a detailed weather data file in .epw format is required to provide weather conditions. This is sourced from the weather station on the building [6]. Additionally, the simulation needs to specify the duration of each timestep. A Geojson file describing the building is also crucial. This file includes details about the building's shape and design, in addition to the data of the physical characteristics in the simulated zone. Other information such as thermal energy consumption and energy system specifications are also needed.

The building's technical documentation is used to extract the essential data for the Geojson file, including the building's footprint and the thermal properties of its walls and windows. In addition, a meteorological file is created using data from the building's meteorological station. Furthermore, it's important to estimate both the total energy used to heat and cool the lab and the individual energy used by each office. For this purpose, a large dataset was collected from the lab's database, recording energy and temperature sensor measurements from June 2015 until 2022. For each room within the PREDIS-MHI zone, a virtual global energy meter is designated to approximate the aggregate thermal energy supplied by various energy systems. To enhance accuracy in this simulation, the analysis did not rely on readings from these virtual meters. Instead, calculations of the actual energy distributed to each room were conducted using data from real energy meters. Each office is conditioned using two methods: radiant ceilings and ventilation. The radiant ceilings are equipped with cumulative energy meters, which can calculate the ceiling's thermal energy consumption over time. In the case of ventilation, the energy output of the ventilation air flow is determined by two types of sensors. The first type is a cumulative energy meter at the air handling unit (AHU) level, which allows the estimation of the total energy produced and distributed by the

AHU. The second type includes zonal airflow meters. This data is analyzed to determine the proportion of air delivered to the offices as a percentage of the total air delivered from the AHU. The energy delivered to each office is then estimated by multiplying this calculated airflow percentage by the total energy delivered by the AHU.

The collected raw data comprised DataFrame files, which documented the measurements from each sensor at consistent time intervals. A data processing script was crafted to transform and graphically represent the data, enabling the visualization of both overall and specific heating and cooling energy consumption, in addition to the airflow data. The external conditions data are also captured and treated to create the meteo file associated with the model. Indoor temperature and airflow data within the rooms were recorded every 10 minutes, although some datasets contained missing values, which were filled using the data from the preceding time step. Additionally, external weather conditions, including temperature and both direct and diffused solar radiation, were tracked with the same 10-minute resolution. For energy consumption metrics, cumulative energy meters were used, which log data each time a 1 kWh threshold is exceeded, rather than at fixed intervals. To align with the hourly time step of the Dimosim simulation, all collected data was standardized to a one-hour resolution by interpolation. The 3D representation of the model in Figure 6 shows three thermal zones-Greener 0, Greener 1, and Greener 2-which serve as boundary conditions for the simulated PREDIS-MHI area, referred to as G2ELab.

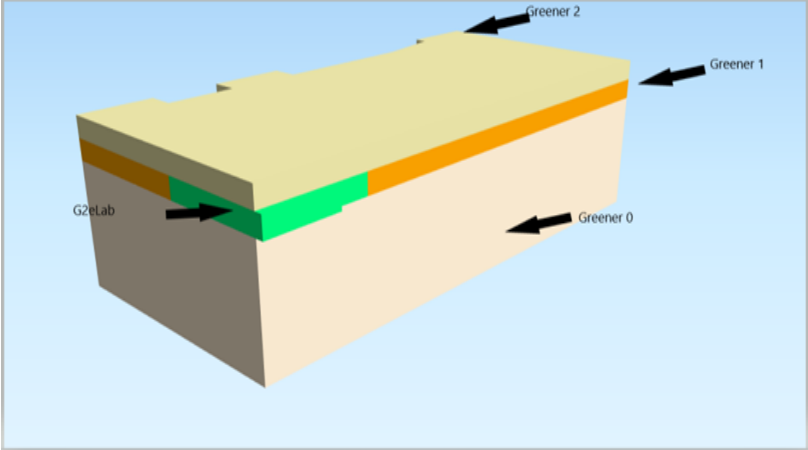


Figure 6: 3d Q-GIS view of the model used in Dimosim simulation.

Visualization of Data

As stated in the previous part, the raw data collected was a set of DataFrame files containing the values recorded by each sensor for a standard time step. In order to use and visualize the information given by the sensors, a data treatment script was developed. This script generates graphs of both overall and specific heating and cooling consumption, showcasing energy trends throughout a selected year. It also incorporates indoor temperature and airflow information into the analysis. Data of various measures are consolidated into a single DataFrame, with values standardized to a one-hour interval through interpolation. For temperature datasets containing missing values, these gaps are filled using data from the previous time step. A graphical user interface within the script allows users to select specific datasets for visualization, presenting annual trends of data. Graphs illustrate the operational patterns of the ventilation system, which is inactive overnight as shown in Figure 2, where the air change rate (ACR) value, indicating the

volume of fresh air introduced into the space per hour, exhibits elevated levels from 6 AM to 6 PM during the daytime and significantly decreases during the night-time. Similarly, temperature variations within the rooms align with predetermined economy and comfort thresholds for night and day periods, respectively.

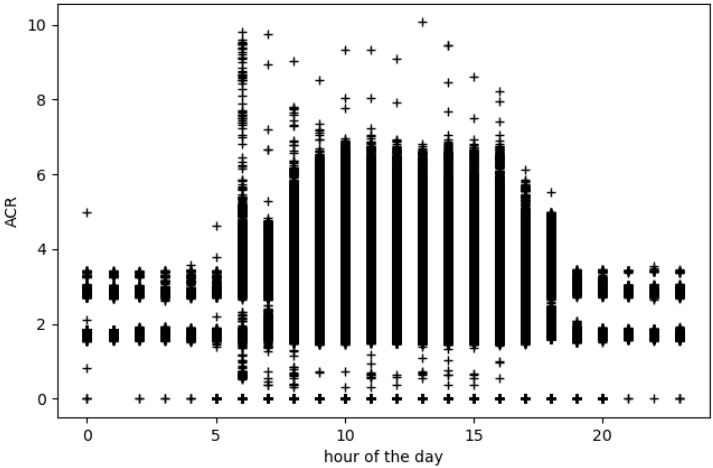


Figure 7: The evolution of air change rate in the rooms according to the day hour.

The energy consumption graphs indicate heating from January to April and October to December, with cooling occurring from July to September (see Figure 8).

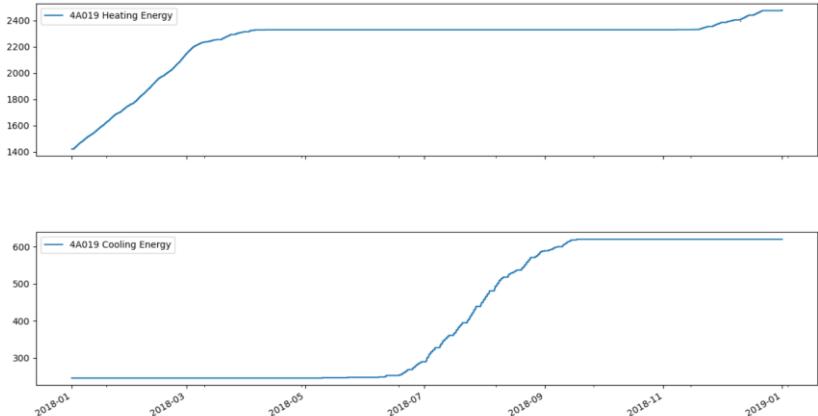


Figure 8: Example of heating and cooling energy in the room 4A019 of PREDIS-MHI zone.

Value of the PREDIS-MHI Thermal Dataset

The dataset has been in use not only for teaching at ENSE3 and research in G2ELab, rather it is also used for other purposes. The building took part in the energy flexibility competition during the academic year 2021-2022, launched by RTE (the French transmission operator) and a private entity, known as A4MT (short for action for market transformation). The energy savings obtained by modifying the thermal setpoints is calculated thanks to this data.

In addition to this, the G2ELab is part of an ongoing experiment in its living lab. This experiment is part of a research work carried out in the framework of a European project, known as COLLECTiEF [7]. The purpose of this project is to play on the energy flexibility capacity of the HVAC system while considering the human comfort. The analysis of data is ongoing, whereas the initial results are

published regarding the indoor thermal comfort analysis [8]. Based on these studies, it is envisaged that an automated and robust machine learning based mechanism will be applied to achieve optimum energy flexibility without compromising human comfort in the building.

Conclusions

This article has introduced the PREDIS-MHI Thermal a thermal energy dataset from a thermally and electrically separated section of the GreEn-ER building in Grenoble. In addition to this, the lifecycle was used to describe the process for the available energy datasets from the GreEn-ER building, a mixed-use education building in France.

As future work, we intend to publish the rest of the datasets from the GreEn-ER building. These include the thermal data from the rest of the building, the electrical data from the PREDIS-MHI platform which contains a solar PV array and EV charging points as well as the weather data from the building's weather station.

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