Brains4Buildings – Open Knowledge Platform: Practical Insights from Data

Key words: Massive Online Open Courses, Learning communities, Data-driven building operation

MARTÍN MOSTEIRO ROMERO
Department of Architectural Engineering and Technology, TU Delft, Netherlands
m.a.mosteiroromero@tudelft.nl

LAURE ITARD
Department of Architectural Engineering and Technology, TU Delft, Netherlands

New data science technologies used in building management systems (BMS) bring not only many technical challenges but also raise very significant educational challenges for professionals who work in the field of energy management systems in the energy transition. As part of the Brains4Buildings project, we have developed an Open Knowledge Platform that aims to support professionals and researchers who want to know more about the use of BMS data to optimize the operation of HVAC systems. This paper introduces the platform, its key features and content, and serves as an open invitation to wider community to make use of it.

The increasing availability of data from building management systems (BMS), distributed sensors and other internet-of-things (IoT) technologies in the built environment presents an opportunity to improve building energy and climate performance. Data-driven methods can help optimize system operation, support occupant comfort and well-being and enable renewable integration in buildings, among others. Despite these opportunities, such methods are underdeveloped and hardly implemented in real buildings, as it requires the development of Machine Learning and Artificial Intelligence models and algorithms to analyse and use large amounts of data in real time, and implementation is a cumbersome and time-consuming exercise [1]. In addition to these technical challenges, the application of new data science technologies in the built environment also raises significant educational challenges, as professionals in the field of energy management systems need to learn about these methods and how they apply this in real buildings.

In the *Brains4Buildings* project, we have not only developed technical solutions to the challenges presented by the use of data in the built environment, but also to share the results of our research with professionals and the general public through our Learning Community. As part of this endeavour, we have created the *Brains4Buildings Open Knowledge Platform* [2], an online community for self-paced learning on various topics relating to data science and the built environment, along with examples from practice and hands-on exercises. The platform is the result of both the *TransAct* and *Brains4Buildings* projects and includes contributions from researchers and professionals in both projects.

This Open Knowledge Platform aims to support HVAC engineers who want to know more about the use of Building Energy Management System Data (BEMS) to optimize the operation of HVAC systems. It also aims at supporting data scientists who want to learn more on HVAC systems and want to understand BEMS data. The content provided includes the outcomes of various research projects and is therefore also of interest to researchers who are getting involved in this field. Some sections provide deep dives into specific topics, while others might provide quick tips for building professionals or links to external resources where you can learn more about a subject.

Goals and Format

The aim of this Open Knowledge Platform is twofold. On the one hand, we seek to share the state-of-the-art on the use of data science in the built environment as well as the knowledge generated by the Brains4Buildings project with the wider community. The knowledge platform provides content for self-paced learning on various topics relating to data science and the built environment, along with examples from practice and hands-on exercises. On the other hand, we also seek to start a lively community and share as much information as possible. All topics have a discussion forum which makes it possible to share information and provide feedback on the content provided. Tips, suggestions and ideas are welcome, and content in the platform can be changed or added based on feedback to improve information exchange.

Throughout the sections in the learning community, learners gain insight into various topics relating to data science and the built environment. They can also gain practical experience on some of these topics through examples from practice and hands-on exercises. However, this is not a typical online course. Sections are not ordered sequentially, but thematically. If a section is not relevant to a learner's needs, they can skip it entirely. Some sections provide deep dives into specific topics, while others might provide quick tips for building professionals or links to external resources where they can learn more about a subject. As discussed above, each topic includes a discussion section where learners can exchange information, discuss with their peers and provide feedback on the platform.

Content and Organization

After the introduction, the Open Knowledge Platform consists of six main sections (**Figure 1**). The first three sections provide general content for researchers and practitioners in the built environment. These sections largely rely on pre-existent content, providing learners with links to helpful resources to develop a fundamental understanding of the concepts at hand. The latter three sections provide deep dives into different topics researched as part of the Brains4Buildings project. These sections aim to bring learners up to speed on the state-of-the-art on the application of data in the built environment and the results of the Brains4Buildings project.

Sections 2–4: Fundamental knowledge for professionals

Section 2 "HVAC knowledge for data scientists" is aimed at professionals with a background on data science who want to get involved in projects in the built environment. It therefore provides fundamental knowledge on energy demand in buildings, energy

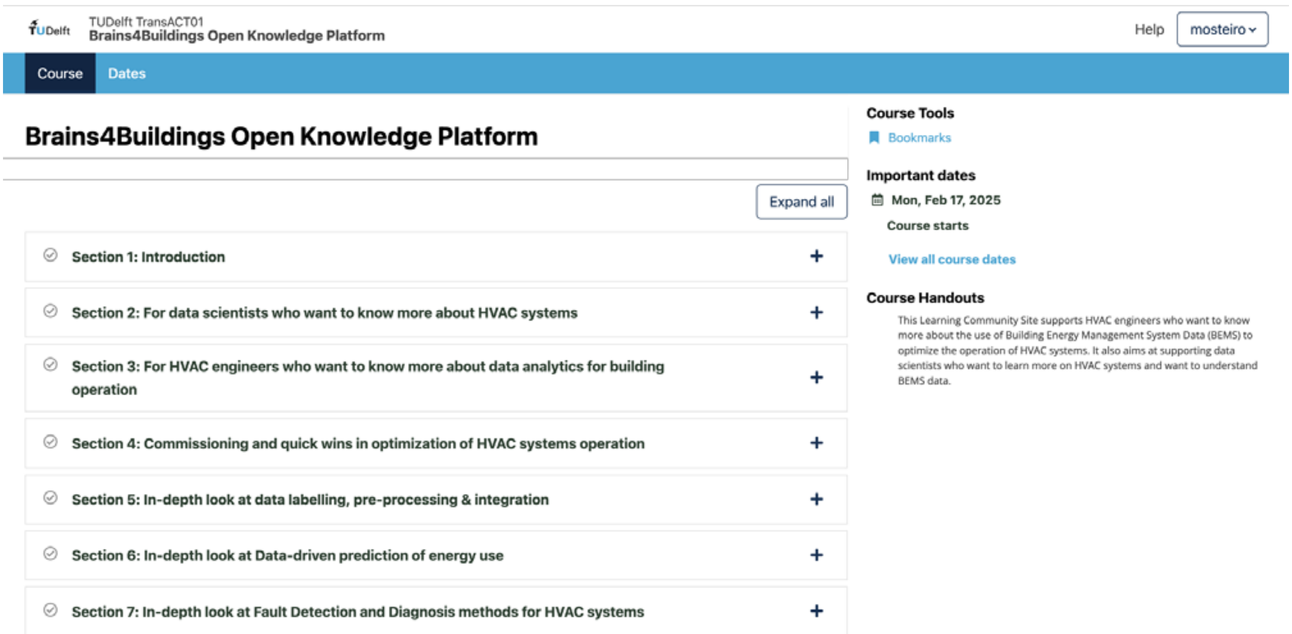

Figure 1. Overview of the Brains4Buildings Open Knowledge Platform from a learner's perspective.

supply systems, HVAC systems, and occupant comfort and health, and how data science can support these goals. The content is largely based on the TU Delft program *Buildings as Sustainable Energy Systems* [3] while incorporating external resources and practical examples. Through videos and practical exercises, learners can gain insight into energy in the built environment.

Section 3 "Data science for HVAC Engineers" is aimed at professionals in the built environment who want to learn more about how they can use data in their projects. The fundamental knowledge on this topic is provided by the Massive Open Online Course (MOOC) *Data Science for Construction, Architecture and Engineering* by Prof. Clayton Miller [4], which is followed by short examples on different applications of data in the built environment.

In Section 4 "Commissioning & Quick Wins", practical advice on how to reduce energy consumption through simple adjustments in building system operation. The content of this section is based on previous work by Halmos Adviseurs [5] and provides practical advice in both English and Dutch for building operators.

Section 5: In-depth look at data labelling, pre-processing and integration

Before any data-driven applications can be carried out, we need to understand what data is available for an application, whether it's sufficient, and whether it is all actually necessary. Most raw data is unusable without pre-processing and interpretation, which often requires a considerable amount of human input. Section 5 summarizes key challenges and best practices in data management in the built environment. This includes content on BMS data labelling and interpretation, data preprocessing techniques, data integration in the built environment, and data management for privacy and security. In addition to real examples on each of these topics taken from the Brains4Buildings project, this section features hands-on exercises using Python (**Figure 2**) so learners can get used to coding and working with data.

Section 6: In-depth look at data-driven prediction of energy

One of the most important applications for data in the built environment is in forecasting energy demand, which can help optimize operation to minimize energy consumption, increase energy flexibility in buildings, and maximize renewable energy

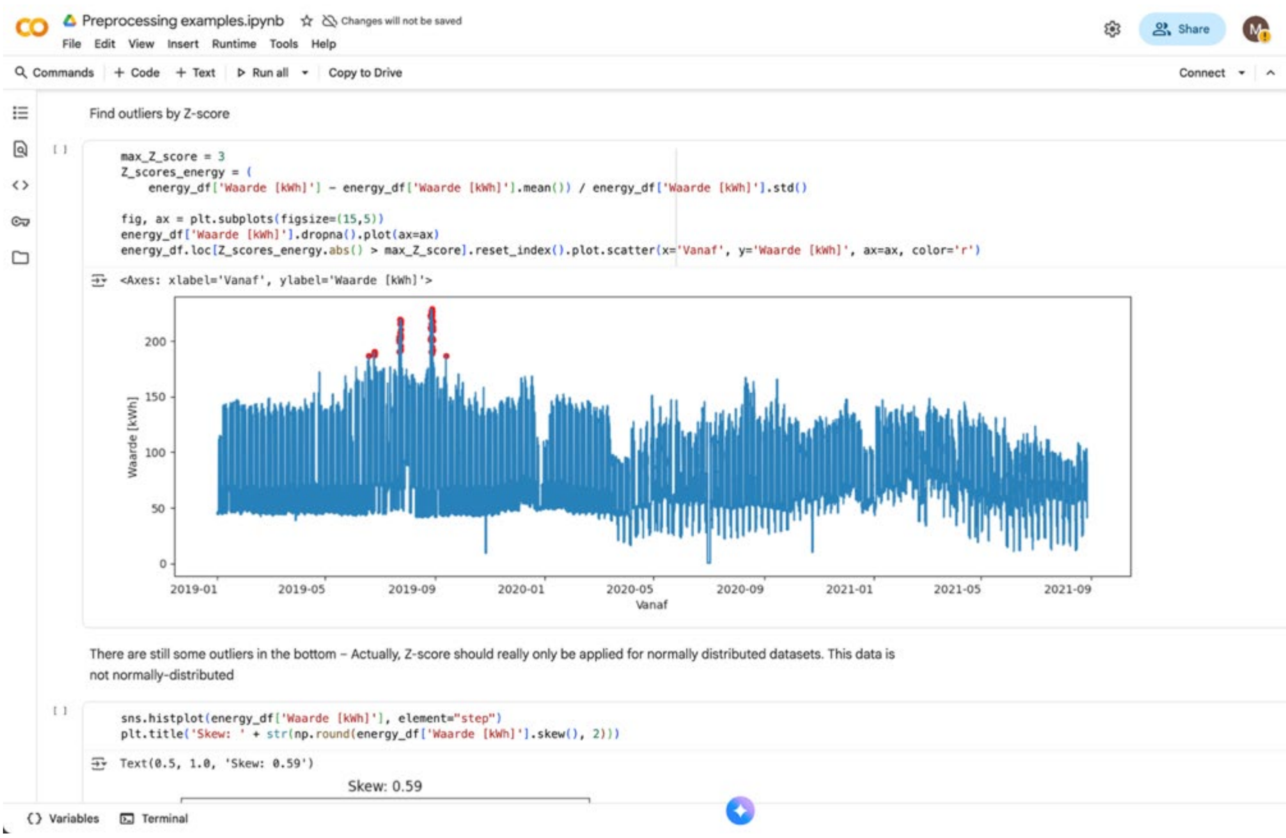

Figure 2. Example of a Google Colab notebook that gives hands-on experience on different data pre-processing techniques.

use. This section provides a general background on building energy modelling methods (white box, grey box and black box) and examples of their application in different projects within Work Package 3 of the Brains4Buildings project. The platform also includes hands-on examples using videos and Colab notebooks to guide learners through a data-driven energy demand forecasting problem using real-world data.

Section 7: In-depth look at Fault Detection and Diagnosis methods

Finally, one of the most promising applications of data science in the built environment in detecting malfunctioning components and controls that might lead to poor building performance. By diagnosing the root cause of an observed deviation in expected performance as early as possible, energy wastage and occupant discomfort can be minimized, and degrading performance can potentially be corrected before a more serious fault occurs. Work Package 1 of the Brains4Buildings project focused on a number of automated fault detection and diagnosis (FDD) applications from the whole building [6, 7] to component scale [8, 9] and incorporating human behaviour in FDD strategies [10, 11]. In Section 7 of the Open Knowledge Platform, the most important FDD methods are presented and categorized, with particular focus on Diagnostic Bayesian Networks (DBN, an example of which is shown in (**Figure 3**) and the 4S3F method developed at TU Delft [12]. Example DBN applications are shown and useful databases for FDD projects are also introduced.

Status and Outlook

The Brains4Buildings Open Knowledge Platform is now openly available on the TU Delft website [2]. The platform has also been incorporated into the Knowledge Hub of the Dutch Green Building Council (DGBC) [13] along with other resources for professionals to pursue decarbonization and energy efficiency in the built environment. Readers are cordially invited to enrol in the platform and join our learning community. Feedback collected in the comments sections will be used in order to continue to improve the learning content in our Open Knowledge Platform.

References

Please see the list of references in the html-version of the article at rehva.eu –> REHVA Journal ■

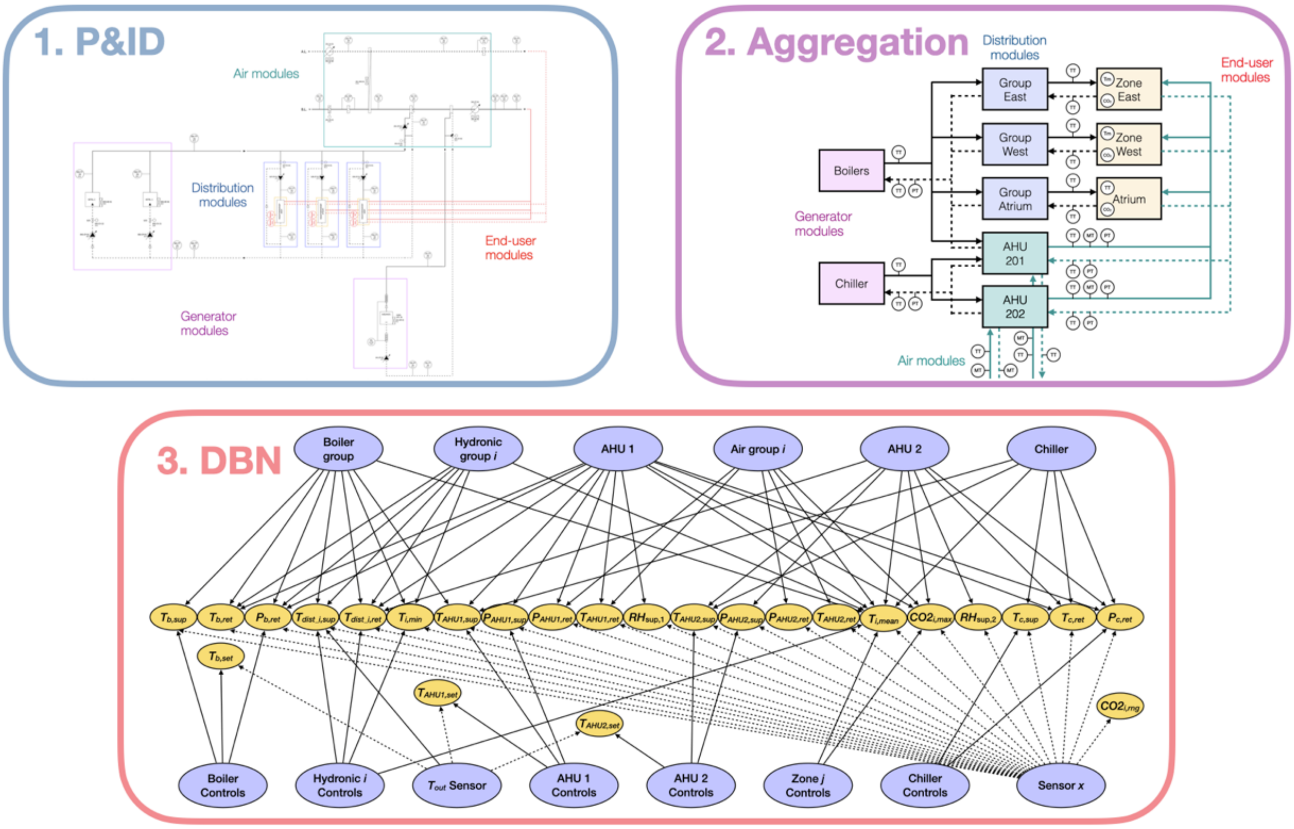

Figure 3. Example of the development of a DBN for whole-building FDD (adapted from [6]).