

## BAC in Action: Connected heat pumps in the ZEB Laboratory building

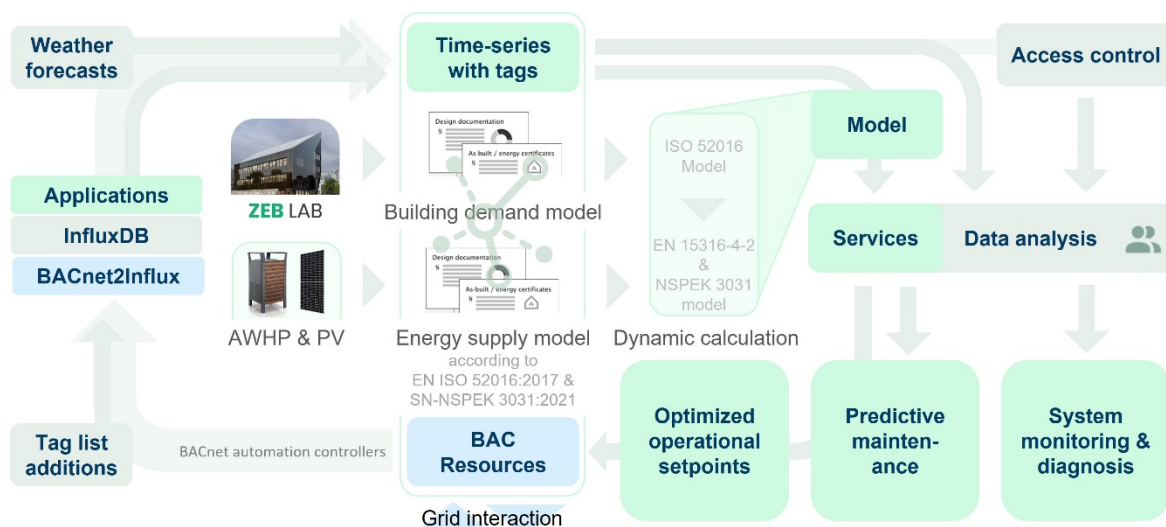


Figure 1: The project is the first to use data processing pipelines from the new ZEB Laboratory to develop applications.

### Summary of project

Commercial buildings generate large amounts of data over various protocols that can be ingested into databases for operational use of the data downstream. Analyzing the information from daily operations can help create new and innovative services. In the ZEB Laboratory office building located in Trondheim, Norway, connected heat pumps are central to the energy concept and offer potential to optimize the use of on-site generated electricity and heat storage. In this project we combine monitoring data from the heat pump units, the plant and room level automation controllers with design and as-built information to:

- Analyze the heat pump operation by extracting time-series from a database and writing back model outputs or metrics for visualizations.
- Model the heat pump COP and emitted power based on the exergetic approach in EN 15316-4-2.
- Model the heating demand using an RC-model informed from as-built documentation (xml file).

“We identified a need to perform these calculations under realistic climate and use, in a way that maintain continuity with operation phase data collection.”

*Kristian S. Skeie, Researcher SINTEF*

The hardware abstraction and three tier architecture:

- A building automation controller is used to make data available over BACnet/IP messaging protocol integrating heat pump units (Modbus), electricity meters (Modbus RTU) and heating meters (MBUS).
- Data ingestion is performed by a program BACnet2Influx that acts as a gateway and writes streams of time-series data and tags to InfluxDB.
- InfluxDB is utilized to combine data from multiple sources and query data on minute-resolution.

#### Performance monitoring

A data processing pipeline was made in Python (Pandas) using the InfluxDB client library. Outliers and operating conditions were identified based on minute data (system modes, defrost cycles, functioning of fans and circulation pumps). The HPs are fixed output (on/off); thus, the length of operating cycles is of particular interest and mean performance metrics are calculated, handling periods under defrost, start-up and end of a cycle, or short and long cycles separately. Metrics are written back to the Influx for visualization.

#### Predictive maintenance concept

We started the development of a concept for predictive maintenance of heat pump systems using the system as a pilot. The goal is to establish a degradation model for the

heat pump and find the maintenance schedule that minimizes the LCC. It will then be possible for us to forecast the cumulative costs due to performance reductions. Based on that information, it is possible to simulate maintenance activities and impact on LCC to find the optimal maintenance schedule. The first part of the concept involved setting up pre-processing steps and providing feedback to improve the system's operations.

#### *Optimise heat pump operation*

The simplified model of the heat pump plant, building and PV system follows national guidelines or European norms and is informed by as-built information; thus, data is not needed to train the model but is used for calibration. In addition, to be valuable in benchmarking actual operation, the modelling framework demonstrated potential in forecasting energy production and energy need for the next day, as well as performing effectively in particle-swarm optimization. These capabilities will be utilized to optimize setpoints and operating strategies in the future.

### Learnings and results

The development of data processing flows, models and analytics were streamlined using the time-series platform. The analysis identified several opportunities to improve operations. Challenges encountered included the lack of separate heating meters for each unit, missing values, and different sampling time of devices. To ensure the reliability and efficiency of data analysis in the context of IoT data, it is important to build a consistent and repeatable data pipeline and to properly manage metadata information.

Influx tags were derived from BACnet codes and a manual tag list (Excel), but an automatic method to check the quality still needs to be implemented, like Bricks schema. The COP was incorrectly labelled, and the unit scaling of some meters was wrong, leading to productivity loss. Unless data is properly defined, it is hard to interpret, hindering the development of interoperable IoT services.

The hourly model regularly executed on actual weather provided a benchmark of design performance pre-requisites and demonstrated potential in forecasting applications. Work will proceed on the integration layer aiming for a computation-friendly architecture that can be applied to other buildings.

### FACTS ABOUT THE PROJECT

**IoT Category:** Optimize heat pump operation, performance monitoring and predictive maintenance concept.

**Goal:** Use design and as-built documentation to reduce the effort to perform performance calculations based on realistic climate and use, maintaining continuity with operation phase data.

**Beneficiary:** building owner & end user

**Analysis method:** ISO standard-based energy calculations, data analysis and visualization.

**Modelling requirements:** Python scripts

**Data required:** physical information from design and as-built documentation, operation data for model calibration and performance comparison, or weather forecasts, and prices for optimization.

**Data interface:** InfluxDB queries (1-min, hourly)

**Transmission protocol:** BACnet, UDP, TCP.

**Quality-of-Service:** 1 minute & hourly scheduling

**Project participants:** SINTEF

**Technology availability:** Optimize heat pump operation TRL4. and Predictive maintenance TRL2.

**Time schedule:** 2022

### Contact information

**Kristian Stenerud Skeie**, SINTEF Community, Trondheim, Norway

✉ kristian.skeie@sintef.no

☎ +47 47632566

**John Clauß**, SINTEF Community, Trondheim, Norway

✉ john.clauss@sintef.no

☎ +47 94284156

**Cansu Birgen**, SINTEF Energy, Trondheim, Norway

✉ cansu.birgen@sintef.no

☎ +47 93477784