Energy and indoor environmental quality monitoring of a lecture building: preliminary results from the KTH Live-In Lab Testbed AH

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SCOPE This work investigates the monitoring system of the KTH Live-In Lab testbed AH, a lecture building testbed in KTH University Campus in Stockholm, Sweden equipped with a modern monitoring and control system. The paper maps and analyzes IEQ parameters and the energy use in the building and scrutinizes its monitoring and control system.
Primary research questions are to understand the reliability of the generated data to provide an accurate and detailed picture of the energy used and of the indoor climate conditions, whether the building is operating under acceptable indoor conditions and whether significant discrepancies with respect to the energy performance certification can be observed.

EXPERIMENTAL SETUP

The Testbed AH is a university building constructed in 2016 used for lecturing; it consists of seven floor areas, 363 study places, six exercise rooms, and 11 group rooms and break out areas for a total of over 3500 m².

The building is extensively monitored with ambient sensors for temperature, Relative Humidity (RH) and CO_2. Dedicated energy meters log space heating,, hot water and electricity. Additional sensors have coolingbeen embedded in the building envelope to investigate, for instance, temperature and relative humidity distribution within the walls.

Indoor room conditions are controlled with balanced ventilation with heat recovery and radiators. Space heating is mainly provided by radiators; the building cooling demand is met via the ventilation system. Two air handling units are used to meet the ventilation needs in the building. Heating coils are used to heat up incoming air from the heat recovery system to temperatures to the target setpoints. Heating and cooling are provided by the district heating and cooling network.

The building had a preliminary monitoring period of one year between October 2018 and September 2019; data collected in that period was used for the energy performance certification. The overall energy demand and the primary energy use were respectively 156 600 kWh/year and 205 000 kWh/year, corresponding to 60 kWh/m²a; this earned the building a B-class certification.

INDOOR THERMAL CONDITIONS RESULTS

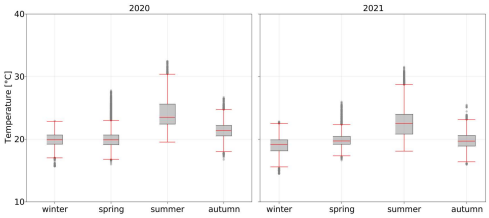
The figure shows the distribution of indoor temperatures in the lecture rooms during the monitored period. The mean temperatures in winter in 2021 is 19°C, slightly lower than the average temperature in 2020, 19.9°C. Lower (25%) and upper quartile (75%) temperatures are 19.2°C and 20.7°C for 2020 and 18.1°C and 19.9°C for 2021; temperatures within the whisker (four interquartiles ranges) are between 15.6 °C and 22.5°C.

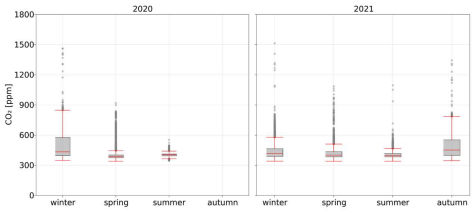
The mean temperature in summer 2021 is 22.8 °C, 1.4 °C lower than in 2020. Lower (25%) and upper quartile (75%) temperatures are 22.4°C and 25.6°C for 2020 and 20.8°C and 24.0°C for 2021; temperatures within the whisker are between 18.1°C and 28.7°C in 2021, showing a spread only 0.2°C smaller than in 2020. Data from mid-season suggest overall similar indoor temperature conditions. In spring and autumn 2021 the mean temperatures are respectively 20.0°C and 19.9°C, with an interquartile range of 1.3°C and 1.7°C respectively. In spring 2020 the mean temperature is 0.2°C higher than in 2021, 20.2°C.

INDOOR AIR QUALITY RESULTS

The box plots show the CO2 concentration in the building lecture rooms for 2020 and 2021 between 8 and 20, i.e., the target use of the building. The box plot is delimited by upper (75%) and lower quartile (25%); the whiskers are delimited by minimum and maximum CO2 values within four interquantile ranges. The dots are the measurements outside the whisker. For all seasons, the hourly CO2 concentration is alwsays below the control set point of 900 ppm. The total number of hourly measurements above 900 ppm is 250, occurring in 52 distinct days over 21 distinct months. Spring seasons present the highest number of outliers, despite being mostly below the control set point. Winter 2020 and Autumn 2021 present the largest inter-quartile ranges of about 160 ppm in both cases.

No reliable measurements were saved in the system during Autumn 2020 due a problem in the SCADA system.

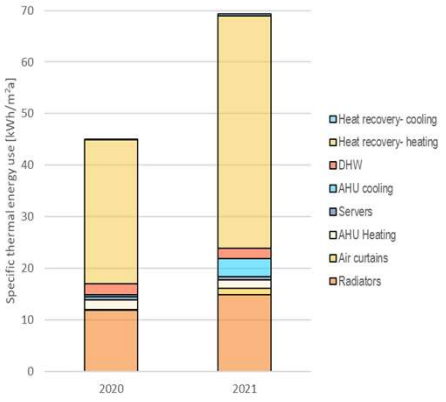




ENERGY RESULTS

The figure illustrates the thermal energy flows in the building for the years 2020 and 2021 before normalization. The heat recovered in the air handling units is instrumental to decrease the energy used and is in both years more than two times the energy delivered by radiators.

Space heating energy represents 40% of the overall energy used, i.e., energy for heating, cooling and electricity for auxiliaries. The energy used for the heating coils is limited due to the high efficiency of the heat recovery system in the AHUs. The contribution of air curtains is mainly for comfort and is marginal. Cooling energy differs significantly in 2020 and 2021 and accounts respectively for 3% and 9% of the total bought energy. Domestic hot water production is not negligible, accounting 5% of the overall energy used in the building



The table compares the normalized specific energy use of the EPC with 2020 and 2021. Energy flows have been normalized using heating and cooling degree days for Stockholm Bromma weather station.
The total energy use is lower in 2020 compared to 2021; this is attributed to distant teaching policies implemented during the Covid pandemics that limited the use of the spaces.

	Space heating [kWh/m²y]	Space cooling [kWh/m²y]	DHW [kWh/m²y]	Auxiliary energy [kWh/m²y]	Total [kWh/m²y]
EPC	23.79	7.15	2.00	17.18	50.12
2020	17.44	1.14	2.18	16.65	37.41
2021	18.20	4.51	2.02	20.35	45.07

CONCLUSIONS

The data collected during the monitoring campaign suggests that indoor air quality is good, with CO2 concentration in the monitored rooms below optimal thresholds.
Energy use in both 2020 and 2021 is below the energy performance certification; the reduction is particularly significant for 2020. Energy used for space heating is more than 20% lower in the monitored years compared to the reference year. The decreased use of the spaces due to Covid restrictions, which is highlighted by CO2 concentration in the two summers, **has clearly influenced** the demand for cooling, which is lower in both years compared to the reference year. Under comparable occupancy conditions, in 2021 the demand for space cooling was 3 kWh/m²a higher, motivated by unnecessarily low indoor temperatures. Hot water stable over the three years, while auxiliary electricity in 2021 is the highest.
The data collection system showed weaknesses; too little data was collected by the monitoring system due to an issue that made the evaluation of the indoor environmental conditions for autumn 2020 impracticable; this issue also partially affected the energy metering.
This work has illustrated the preliminary results of the monitoring campaign of the Live-In Lab Testbed AH. Future work will include a more detailed analysis and the extension to all monitored rooms in the building.

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