Net zero retrofit and the indoor environment – the Glasgow Tenements case study.

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ABSTRACT

In 2019, the UK became the first country to declare Climate Emergency. Since then, policies have focused on achieving legally binding net-zero targets. With the worst-performing building environment in Europe, the UK has targeted the housing sector. While these policies are important to the environment, some of the changes we made to existing homes are not fully understood. This work presents indoor environmental monitoring (temperature, relative humidity and carbon dioxide) of a tenement in Glasgow retrofitted to the enerPHit standard.

The environmental analysis suggests that the temperature (67% of the time), relative humidity (75% of the time) and CO2 (100% of the time) were within the recommended parameters. Overheating as defined by the Passive House Institute (>25°C in more than 10% of the time) was only observed in 1 of the 7 monitored dwellings. The same dwelling also had a higher occurrence of relative humidity below 40%RH. This project showcases the potential to preserve Glasgow's magnificent stone heritage while creating flats requiring less heating than newly constructed equivalents, thanks to natural, low embodied materials.

While retrofit measures can help to reduce the energy consumption significantly - to 25.9 kWh/m2/year in this case (~90% lower than that of a similar), it is important to understand the indoor environmental conditions, as these can lead to increased performance gaps. Moreover, with the increased number of hospitalisation due to poor housing conditions, particularly mould, in the UK, indoor environment conditions have become a pressing matter.

X THE PLACE OF USEFUL LEARNING

University of Strathclyde Engineering

NET ZERO RETROFIT AND THE INDOOR ENVIRONMENT – THE GLASGOW TENEMENTS CASE STUDY.

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OVERALL AIMS OF THE MONITORING

The project aims to collect information about:

01

ENERGY USE

The energy use is monitored through manual readings (all flats). Detailed energy monitoring for the heating system during the heating season will take place from September '23 to March '25 (2 flats).

02

ENVIRONMENTAL CONDITIONS

The indoor environmental conditions monitored are temperature, relative humidity and carbon dioxide as a ventilation proxy.

03

MOISTURE RISK IN THE CONSTRUCTION

Interstitial condensation monitors were located in the building fabric during the construction.

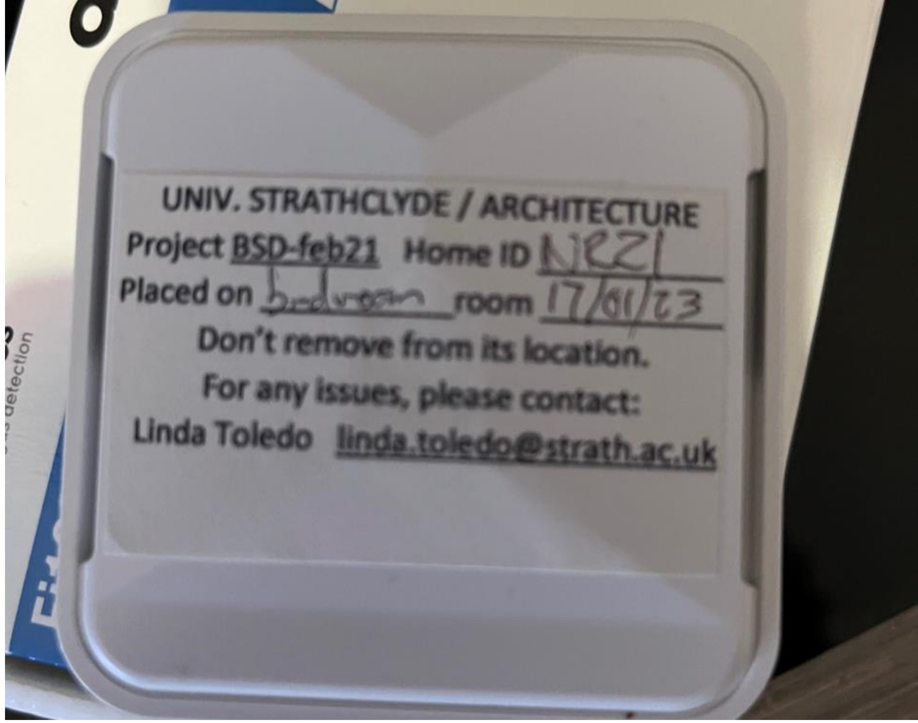
These are interim results. The monitoring period is between February to July 2023.

WHAT WE MEASURED?

The project looks at the relationship of the occupants to energy and the indoor environment. We used a survey to collect the occupant's perception of the indoor environment, the use of the windows and the ventilation system and recorded the energy use.

We also used indoor environment monitors (AICO Ei1025, shown in the images) to measure the **temperature relative humidity and carbon dioxide** at **15-minute intervals in the bedroom, kitchen and living room.**

Detailed sub-monitoring of the mechanical ventilation with heat recovery (MVHR) and waste water heat recovery (WWHR) has been postponed due to delays in access, missing components during construction to the 2023-2024 heating season.



APPROACH TO INSTALLATION & ETHICAL CONSIDERATIONS

The indoor environmental quality was monitored using the AICO Ei1025 (temperature [-10°C to 40°C], relative humidity [15%RH to 95%RH] and carbon dioxide). The system requires a gateway (Ei1000G SmartLINK) connection that uses a GMS network to transmit the data. Each of the flats has its individual system and unique code for data analysis.

The monitors were located in the bedroom, kitchen and living room of each flat and the data was collected at 15-minute intervals. The placement of the sensors was made following the recommendations of international standards (BS EN ISO 16000-1:2006 and ASTM Volume 11.07 Air Quality - D7297-14) and avoiding discomfort to the occupants.

The use of the AICO system allows the collection of the data remotely and visualisation through their HomeLINK dashboard. The data was then downloaded for statistical analysis and further processing for data visualisation in SPSS and Excel.

Ethical approval was approved through the University of Glasgow’s ethical review and consent for each of the occupants was obtained before the any research and installation of monitors could start. While the project was in contact with participants, the monitoring did not seek to collect personal information of the participants, but rather about the building and its use. Hence, there were procedures in place for qualitative data collection (i.e., use of the windows and engagement ventilation system) avoiding the collection of personal information.

APPROACH TO QUALITATIVE DATA COLLECTION

A survey was developed in seven sections. The first section was used to collect information about the household characteristics. The following sections looked at ventilation and occupants' engagement with the building systems. The second and third sections looked at the occupants' understanding and knowledge of the ventilation characteristics of the building and the window and door opening pattern. The final part of this theme in section four was the engagement with the ventilation system (MVHR).

Section 5 of the survey collected data about the advice that the occupants were given when moving to the property, to understand further the level of engagement with the building systems, and also to know if the occupants had any prior knowledge about the building systems.

The following section, looked at a recent addition to the Scottish building regulations, the CO2 monitor in the bedroom, to understand the occupants' knowledge and engagement with the monitor readings.

Finally, the last section looked at the occupants' perception of the indoor environment, including indoor air quality, thermal comfort, natural light and noise levels inside of the flats.

MONITORING CHALLENGES

The project had several challenges that have delayed the start of the project, hence at this point, we have only collected data related between **February to August 2023.**

01

OCCUPANTS' ENGAGEMENT

Not all the occupants' were initially engaged with the project. Despite the use of participant information forms, further vistos were made to explain the project, show the use of the sensors and what was required from the participants.

02

RESEARCHER UNAVAILABILITY DUE TO COVID & TRAVEL

Dr Moreno-Rangel, who was conducting the installation of the sensors, contracted COVID-19 after an international conference. This happened as the monitors were due to be installed and site visits needed to be rescheduled.

03

ACCESS ISSUES

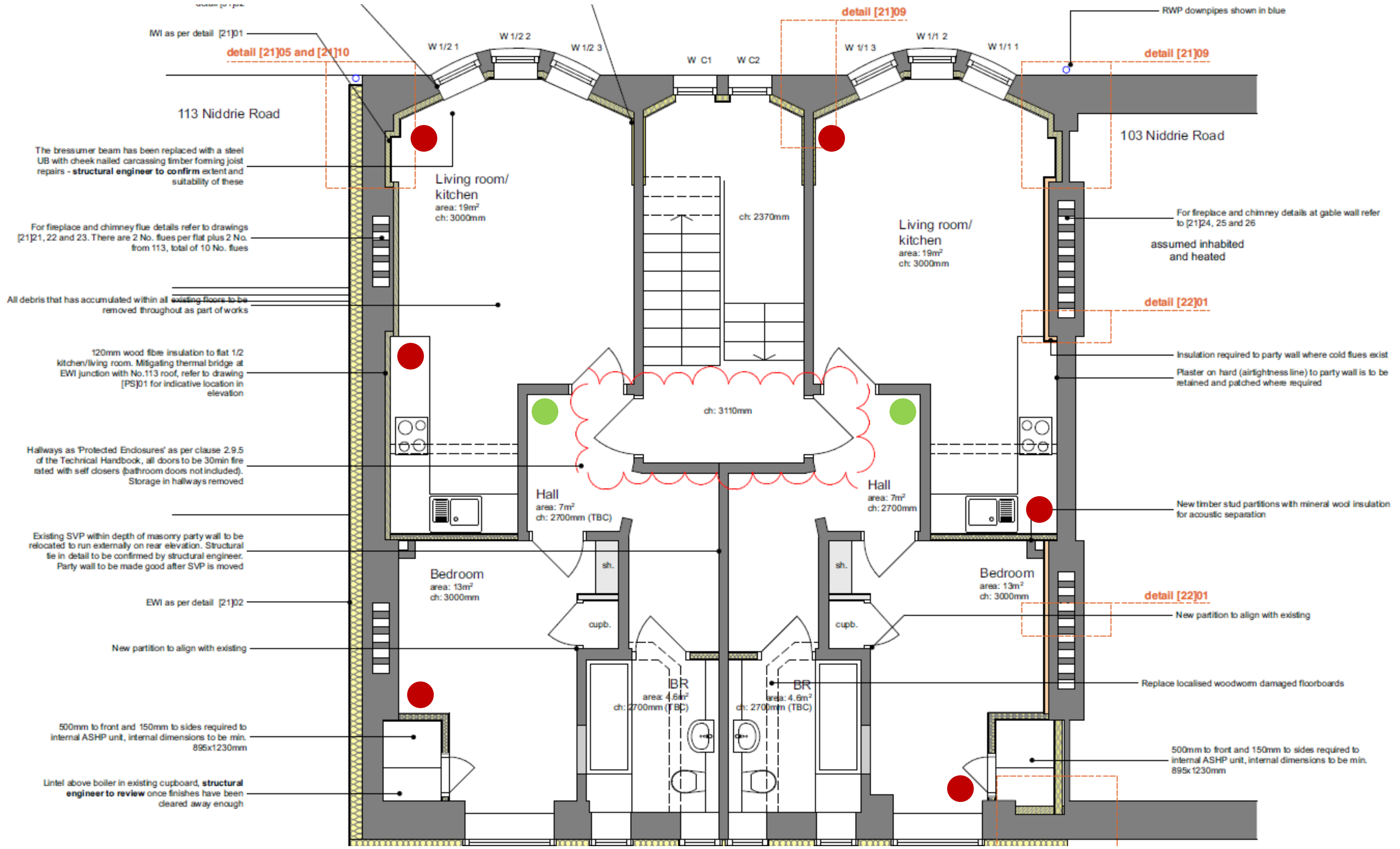
Communication with the occupants was challenging. Some of the occupants had changed their contact details and further on-site visits were required to make contact with the occupants.
Some of the occupants had difficulties planning ahead and this delayed the installation of the sensors.

04

INSTRUMENTS NOT INSTALLTED

Not all the instruments and sensors were installed during the construction. This caused not being able to collect all the data and further visits from researchers, engineers and contractors to install some sensors.

BUILDING LAYOUT AND SENSORS' LOCATION

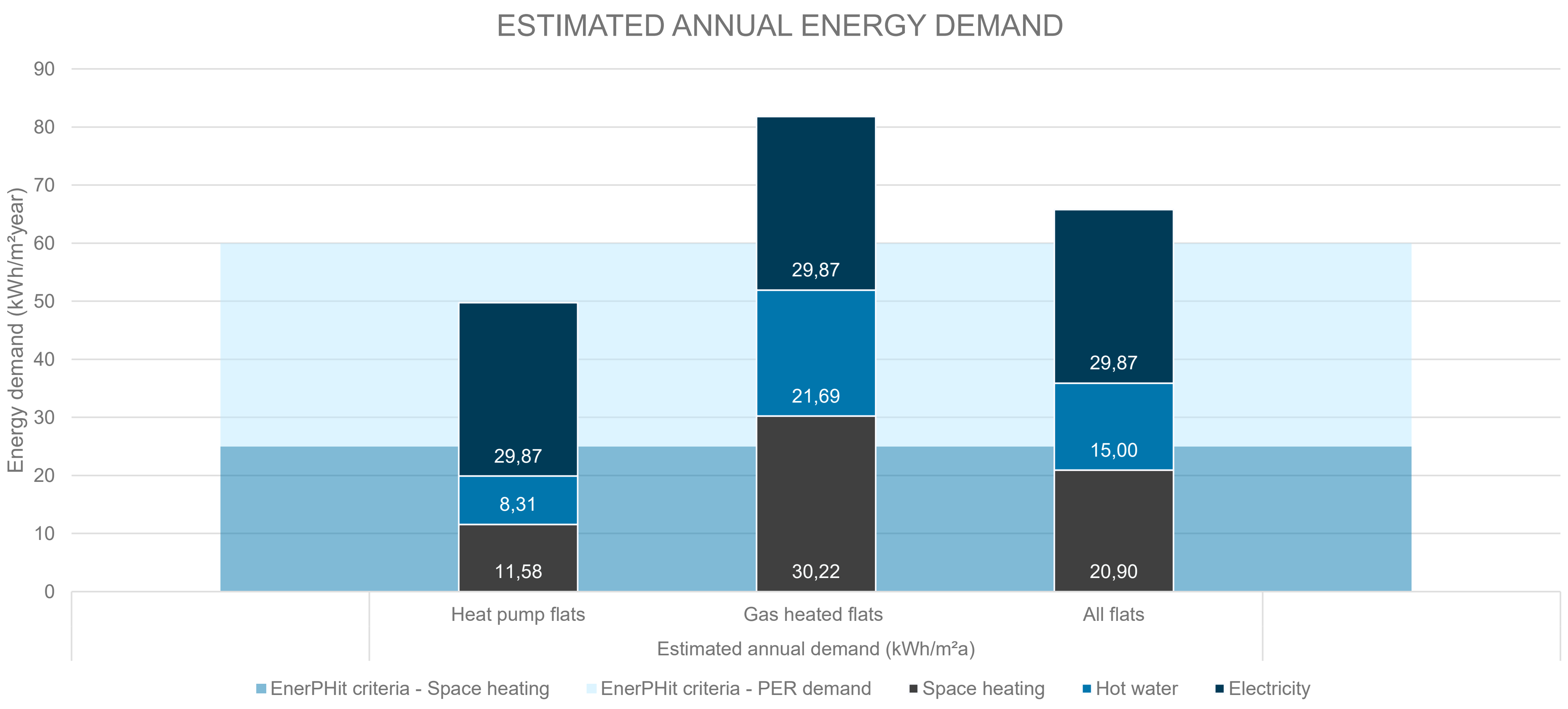


Location of sensors:

Ei1025

Ei1000G

ENERGY DEMAND

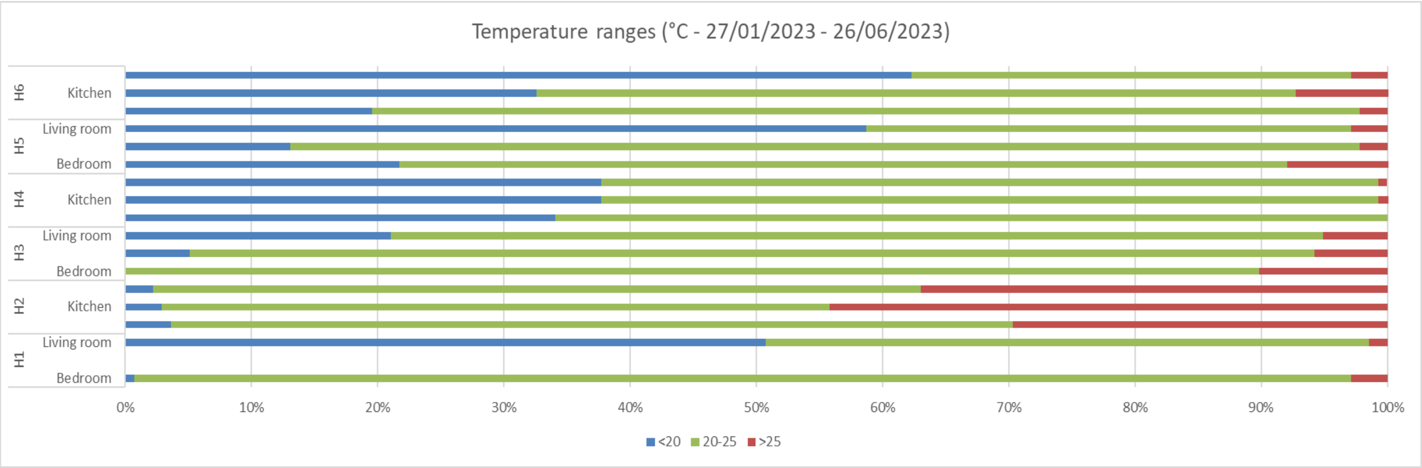


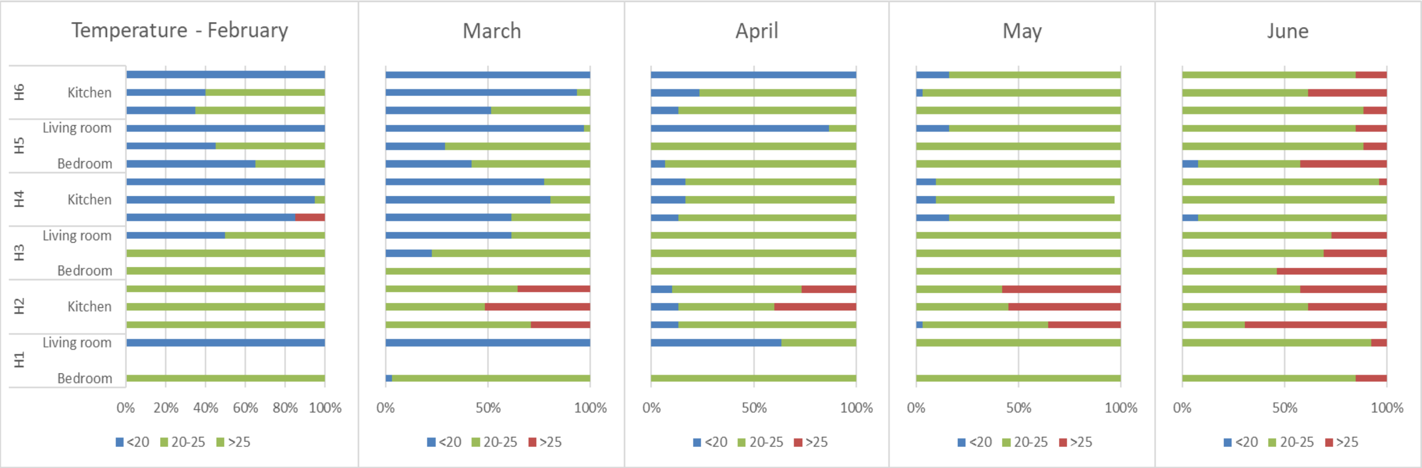
TEMPERATURE

Indoor temperature ranges indicate high satisfaction with the levels of thermal comfort, with low levels of overheating. Most of the overheating temperatures (>25°C, based on the Passivhaus definition) occurred in the month of June when there were heat waves.

The indoor temperatures were lower in the upper flats compared to the lower flats. However, there were some problems with temperatures during the 2022 heating season in the H2 flat. The occupant of this flat (originally from a warm country) reported enjoying warm temperatures and that it was easy to heat the flat to a desired temperature.

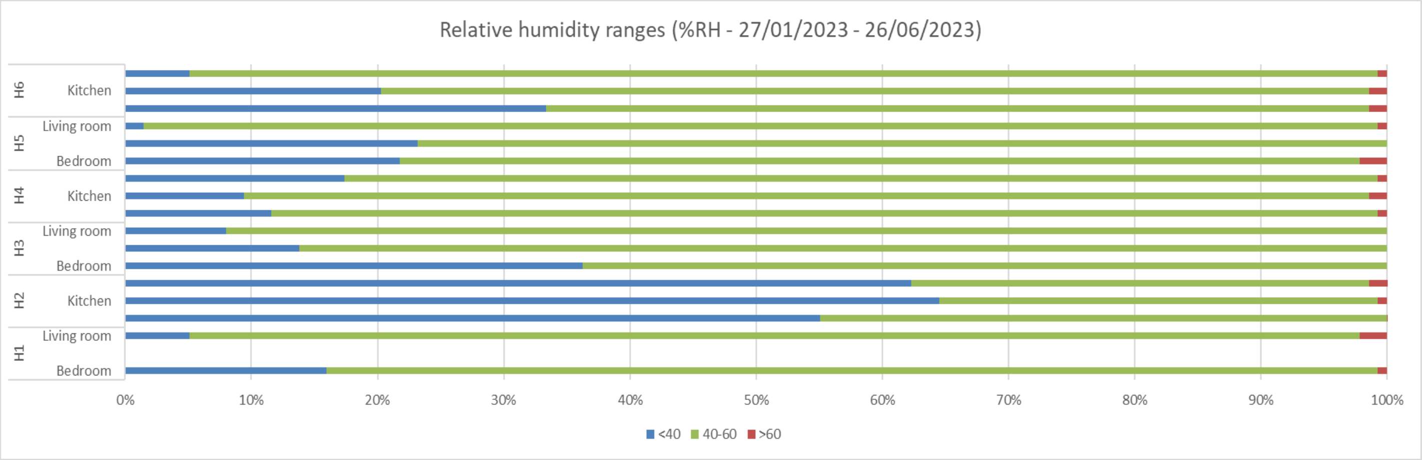
Typical daily temperature levels were [Mean (min-max)]:
Bedroom: 21.8°C (18.0 – 26.4°C)
Kitchen: 21.8°C (15.2 – 50.8°C)
Living room: 20.7°C (17.0 – 25.9°C)



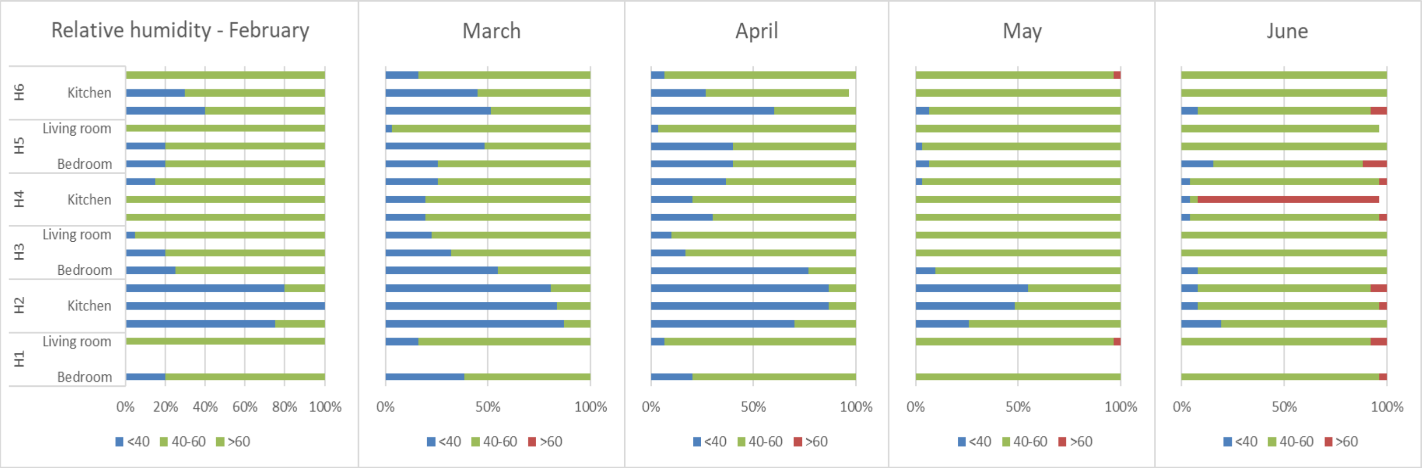


RELATIVE HUMIDITY

Indoor relative humidity ranges indicate high overall satisfaction with the levels. However, levels below 40%RH were observed more than desired, particularly in H2. Levels below 40%RH are associated with dry skin, itchy skin and dry eyes. Nonetheless, the H2 occupants stated to feel comfortable as they found it close to the levels that they were used to.



The indoor relative humidity levels were lower in the lower flats compared to the upper flats. A potential explanation is that the temperature levels could mask the real humidity levels (warmer air can hold a higher moisture level), as the changes in temperature could explain this, as the lower flats were warmer than the upper ones.

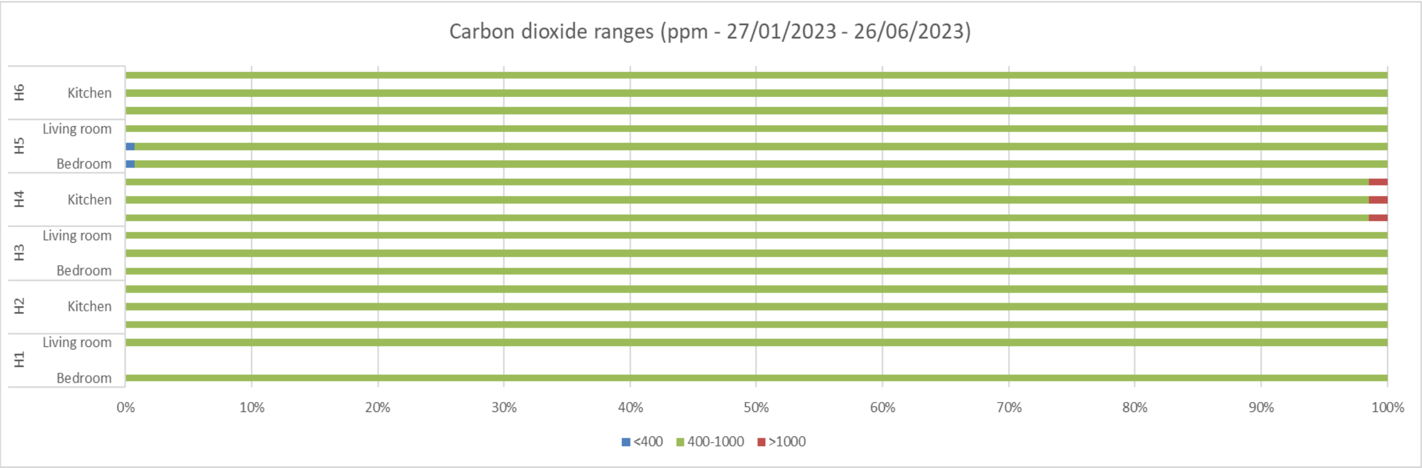


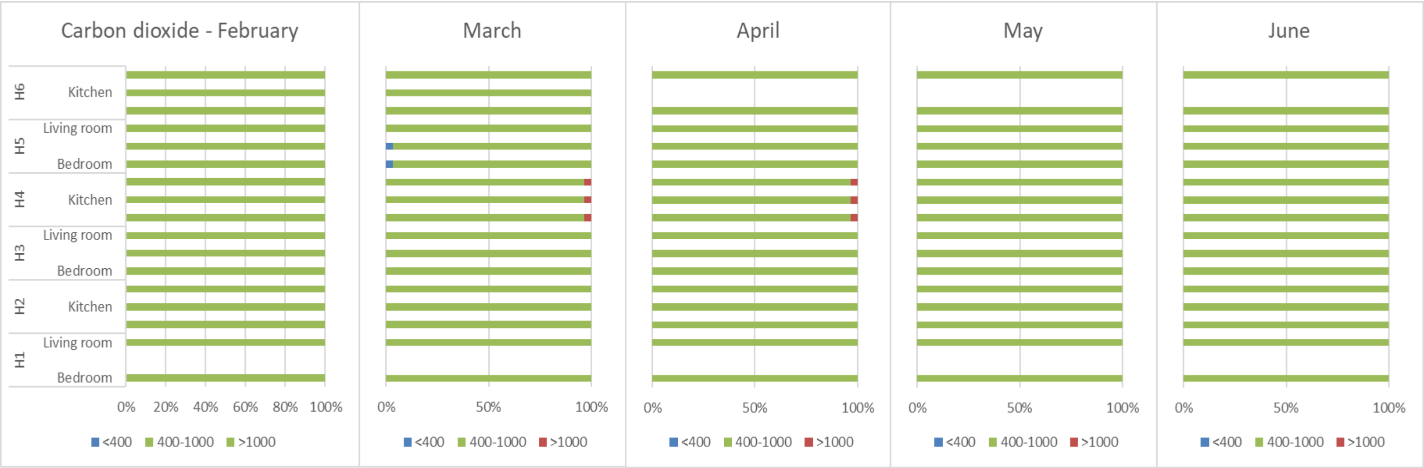
Typical daily relative humidity levels were [Mean (min-max)]:
Bedroom: 43.61%RH (29.4 – 62.5%RH)
Kitchen: 44.4%RH (25.4 – 50.8%RH)
Living room: 46.5%RH (33.1 – 61.4%RH)

CARBON DIOXIDE

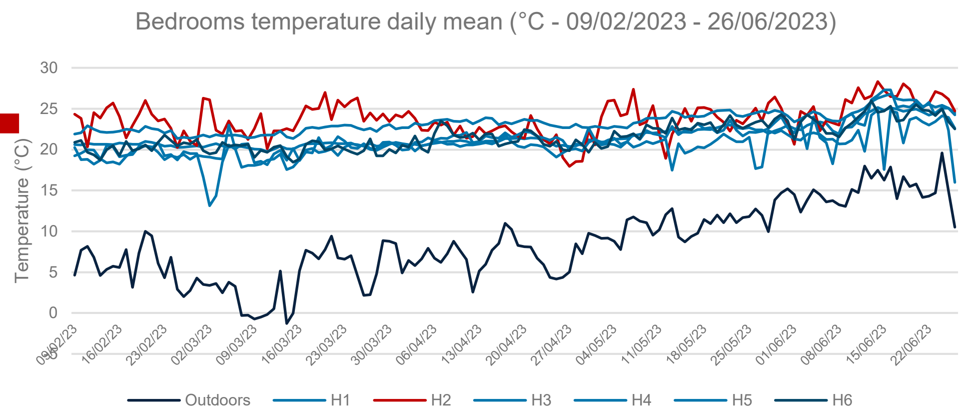
Indoor carbon dioxide ranges indicate high satisfaction with the levels of indoor air quality and ventilation. The flats were below the 1,000 ppm recommended levels for most of the time.

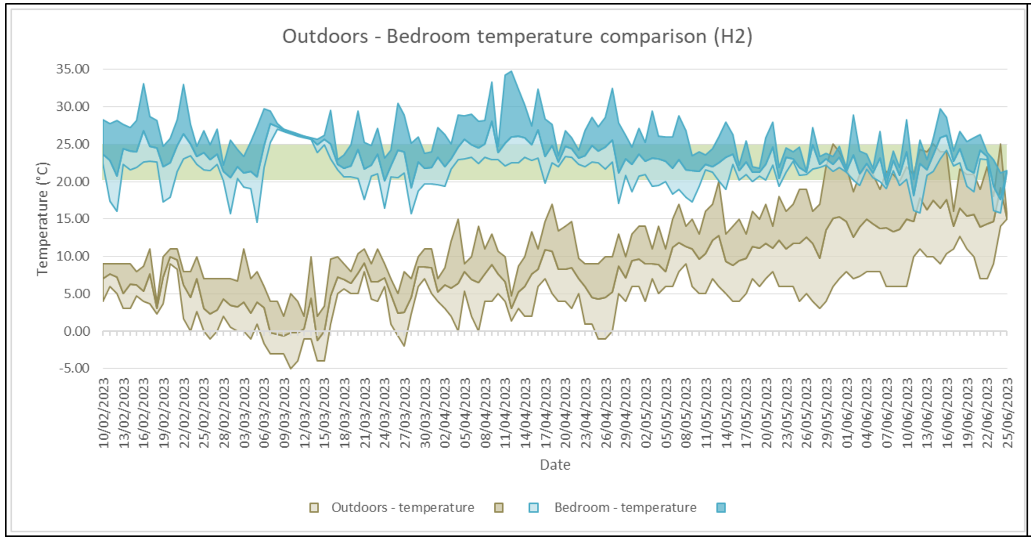
Typical daily CO_2 levels were [Mean (min-max)]:
Bedroom: 527 ppm (418 - 1,013 ppm)
Kitchen: 515 ppm (356 - 899 ppm)
Living room: 506 ppm (419 - 992 ppm)

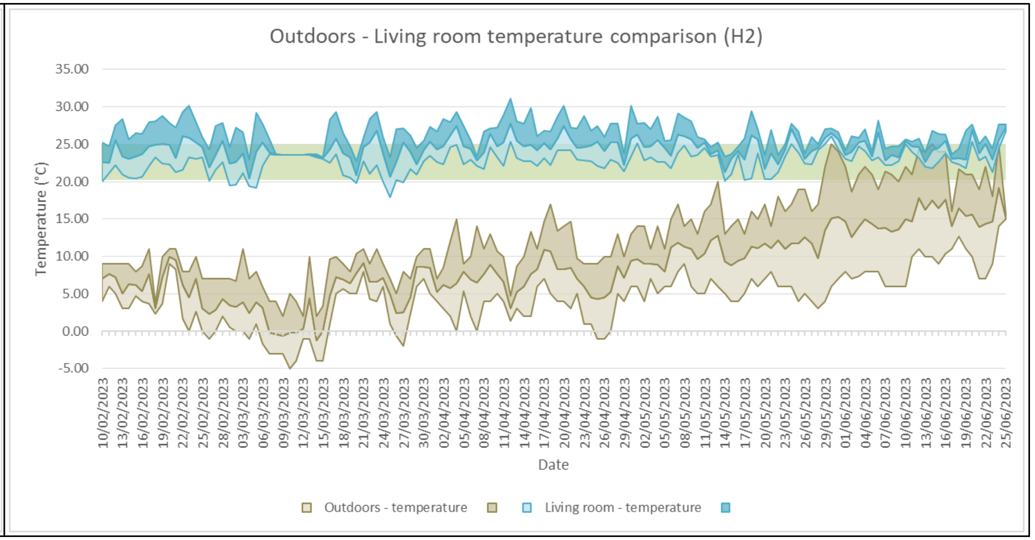




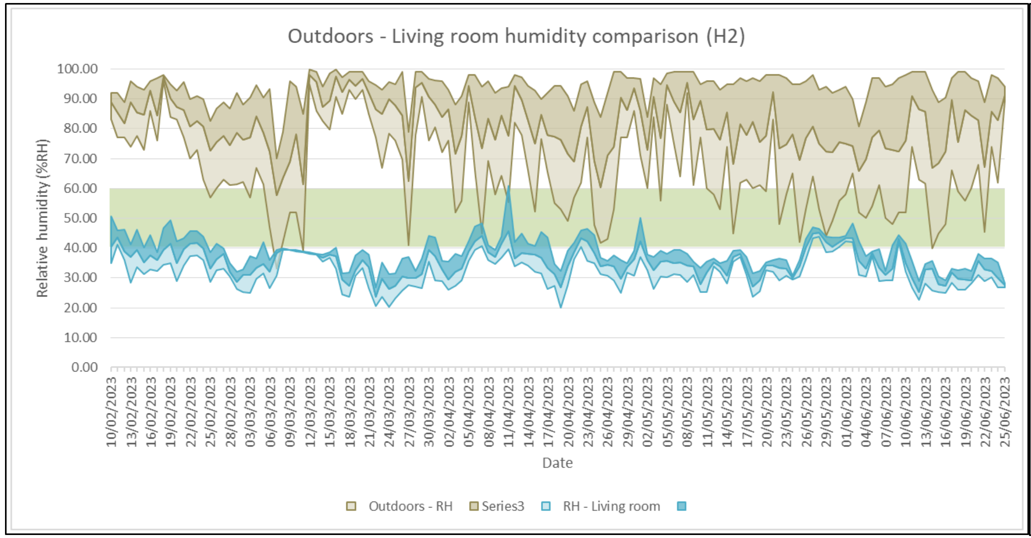
H2 DETAIL - TEMPERATURE

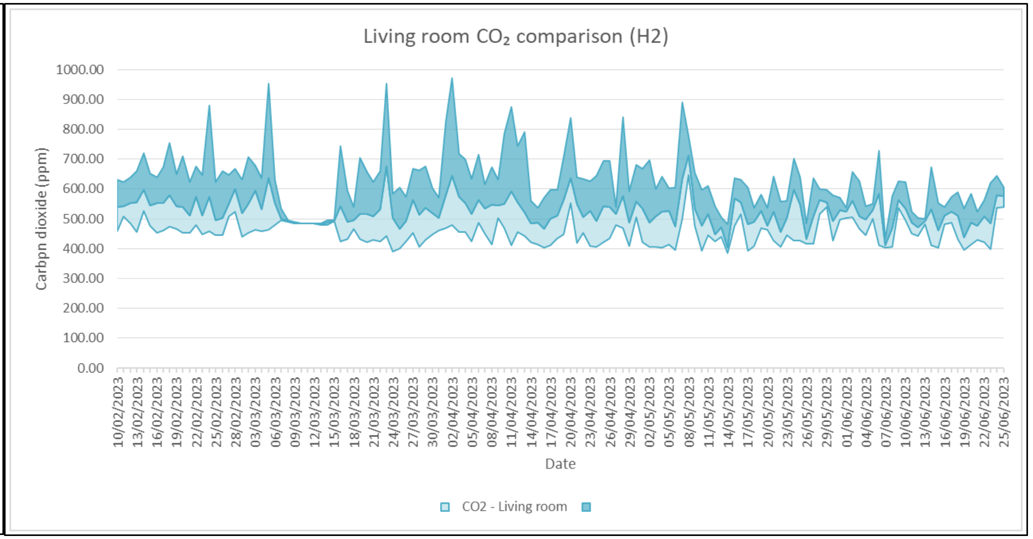






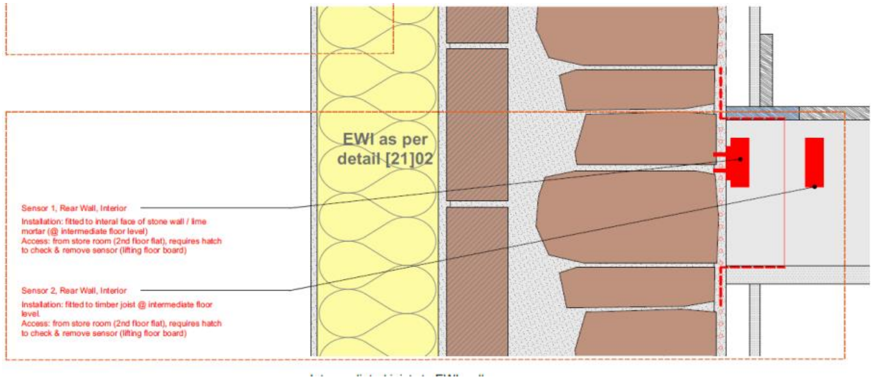
H2 DETAIL - RELATIVE HUMIDITY & CO2

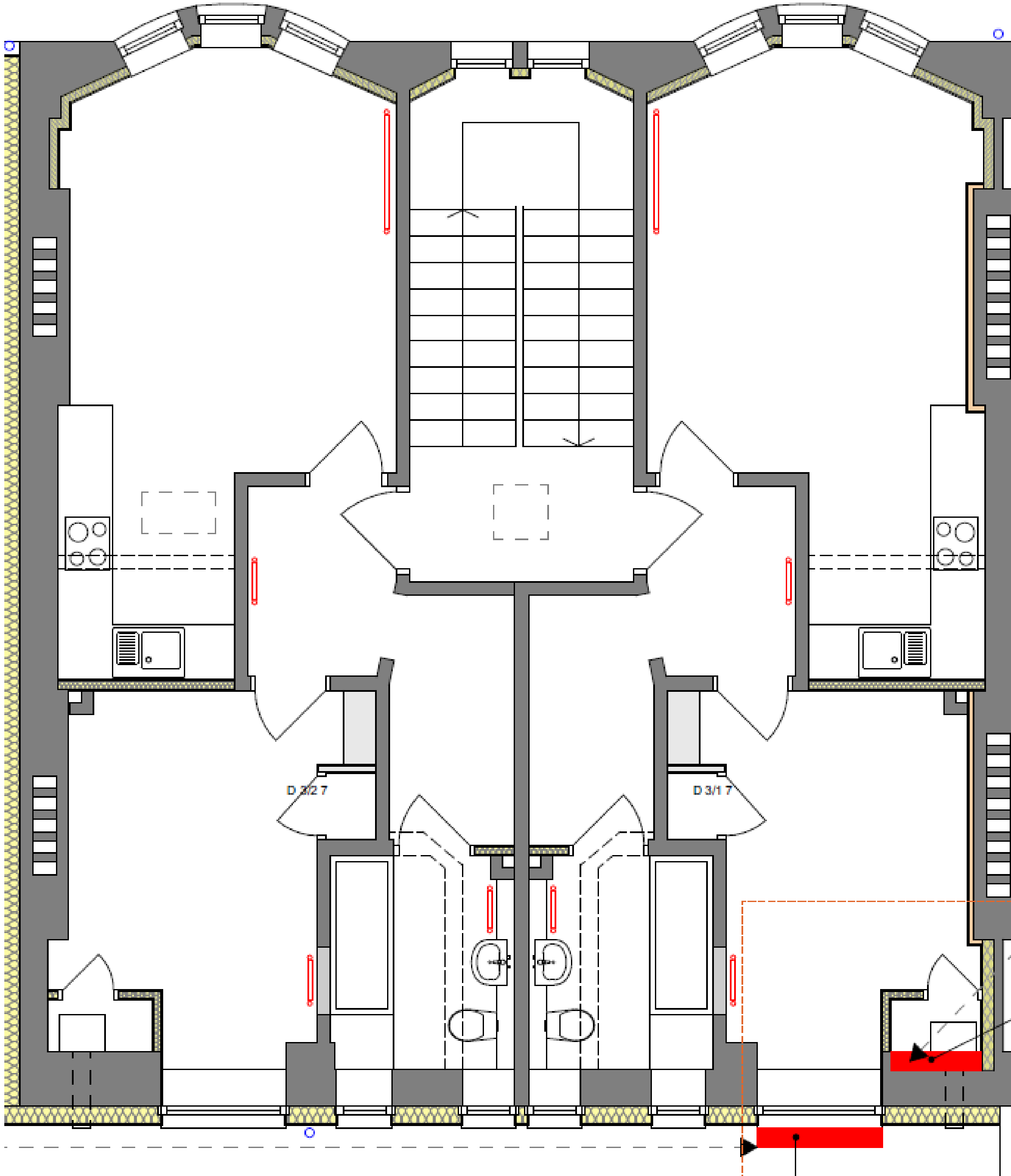




INTERSTITIAL CONDENSATION MONITORING

John Gilbert ARCHITECTS





KEY LESSONS

01

HEAT PUMP UPTAKE

The occupants reported problems with the use and maintenance of the heat pumps. There were skills problems when fixing issues of the system.

02

EnerPHit AND OCCUPANT SATISFACTION

Occupants were highly satisfied with the indoor environment and energy bills from their flats. One occupant stated: “I wish every home were like this one.”

03

EnerPHit AND RETROFIT

EnerPHit is a viable standard to adopt for retrofitting. It can save around 90% of the energy used for heating.

04

ENERGY USE AND INDOOR ENVIRONMENT

Occupant satisfaction and physical measurements of the indoor environment indicate good levels of comfort for the occupants.

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