The Innovation Hub

for Affordable Heating and Cooling

Final Sub-Project Knowledge Sharing report

Hivve Transportable Classrooms: Impact of Heat Recovery Ventilation on Energy Use and Indoor Air Quality

Project – LLS3

27 May 2022

The University of Wollongong

About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

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The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.**

Final Sub-Project Knowledge Sharing Report

This report is produced at the completion of each IDS sub-project and captures the breadth of activities and information produced in the sub-project including studio logistics. It makes use of cross referencing the individual reports produced in each sub-project rather than repeating information wholesale.

Lead organisation	University of Wollongong		
Sub-Project number	LLS3		
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Report date	27th May 2022		
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1. Sub-Project Overview, Objectives and Importance to Market/Industry

1.1. i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

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1.2. Education Living Laboratories

A 'Living laboratory' is a user-centred open-innovation, ecosystem within collaborative partnerships. Living Laboratories benefit both technology providers and technology users, addressing barriers to the uptake of innovation, such as lack of familiarity, risk aversion and distrust in supplier claims. The i-Hub Living Laboratories are flexible spaces where product suppliers can bring their technology for independent validation. The living laboratories detailed here are Hiwe transportable classrooms used in primary education. Each living lab is detailed below:

Majura (Canberra): Majura Primary School has two identical Hiwe Transportable buildings with each building consisting of two mirrored classrooms, a staff office and a breakout room. Hiwe transportable classrooms have many features designed to improve the thermal comfort and sustainability of these buildings. Features of a Hiwe transportable include:

- Higher performance thermal envelope relative to minimum standards, notably including double glazing.
- An energy efficient split system Air-conditioning unit.
- Rooftop PV generation, with the option of integrated battery storage.
- A monitoring and controls systems to manage energy use and indoor environment.

St Felix (Sydney): St Felix Catholic Primary school has two identical Hiwe Transportable buildings with these classrooms being 100% off-grid. Each transportable building consists of two mirrored classrooms separated by a partition wall with the structures facing each other. The transportables are powered by 18 kW of solar PV and are equipped with 54 kWh of battery storage. Features of a Hiwe transportable include:

- Higher performance thermal envelope relative to minimum standards, notably including double glazing.
- An energy efficient split system Air-conditioning unit.
- Rooftop PV generation, with integrated battery storage.
- A monitoring and controls systems to manage energy use and indoor environment.

1.3. Living Laboratory Objectives

The objective of this project is to evaluate the overall energy, thermal, and indoor air quality performance of the Hiwe transportable classroom package equipped with Heat Recovery Ventilators (HRVs). HRVs utilise the energy in conditioned exhaust air to precondition incoming fresh air, allowing increased ventilation while mitigating the increased heating or cooling demand. The objectives specifically are:

I. Can the installation of a HRV unit provide equivalent or improved ventilation to classroom occupants when compared to existing COVID-19 ventilation policies in schools (i.e. windows open, AC operational).
II. Can the installation of a HRV unit provide a measurable saving in energy consumption while maintaining comfort conditions and improved ventilation in comparison to current COVID-19 ventilation policies in schools?

2. Challenges Experienced and How These Were Overcome

Despite best planning efforts, this living laboratory project experienced several challenges during the establishment and operation phase, not least being the challenges arising from a global pandemic. A selection of these challenges and the strategies implemented to overcome these are summarised below:

1. Supply chain issues (largely related to the high demand for HRVs in response to COVID-19) resulted in extended delays in installation. Final installation occurred on 21st April for St Felix, and 24th April for Majura. These delays have resulted in i) a considerably shorter evaluation period than originally planned, and ii) an evaluation period that has occurred during the shoulder season, with modest heating and cooling requirements.
2. Unknown classroom occupancy levels affect the internal heat gains and CO_2 generated within each classroom. This variable makes a direct comparison difficult with assumptions made for occupancy levels to be the same across each classroom in lieu of data.
3. The occupied sealed envelope tests were only conducted in rooms which contain an installed HRV, to remain compliant with the recommendations of the ACT and NSW education sectors and provide sufficient ventilation. This testing limitation provided an unknown variable of windows being open or closed for the control rooms which can significantly affect the air-conditioning usage and CO_2 levels. The teacher in this classroom was advised to close windows and doors when heating or cooling is in operation, with HRV providing sufficient ventilation of fresh air in accordance with NSW and ACT education sector recommendations.
4. Issues were identified in the monitoring set-up at St Felix which preclude pre-and post- evaluation at this site using 2022 data, and changes in use between 2021 and 2022 made it impossible to compare using pervious years' data. One of these issues is the HVAC monitoring system was on the same circuit as the rest of electricity usage monitoring, making the HVAC portion of the electricity consumption impossible to determine. This was corrected during the installation of the HRV.

3. Summary of Lessons Learnt and Evaluation of the Sub-Project Impact

The living laboratories project consisted of three major phases: establishment of the living lab, baseline data analysis, and technology trial. A brief introduction to the first two stages for LLS3 and a summary of the lessons learnt and impact from each of these phases is presented below.

3.1. Establishing a Living Laboratory

The living labs were setup to evaluate the energy required to achieve and maintain thermal comfort, and the related CO2 concentrations under typical operating conditions. This was achieved by considering the impact of the HRV in comparison to historical energy requirements for the period in which Covid-safe policies have been in effect, as well as in comparison to similar Hivve classrooms for an equivalent testing period. The monitoring equipment includes electrical energy metering, indoor and outdoor temperature sensors, indoor humidity sensors and CO_2 sensors for the test rooms and control rooms. There is a control room adjacent to the HRV room at each school that share a common wall or a partition wall and this room is used for the side by side comparison of the study.

The HRV classrooms are equipped with two alternative HRV operation modes for trial, demand controlled operation based on CO2 monitoring (threshold at 800 ppm) was implemented in Majura, and scheduled operation (8am – 4pm) implemented at St Felix.

The teachers in the HRV equipped classrooms were advised to close windows and doors when heating or cooling is in operation, with HRV providing sufficient ventilation of fresh air in accordance with NSW and ACT education sector recommendations. They were encouraged to use the AC to maintain comfort conditions as usual.

3.2. Baseline Data Analysis

The data was sourced from HIVVE monitoring equipment for indoor temperature (°C), outdoor temperature (°C), indoor humidity (%), electrical energy consumption (kWh) and CO_2 (ppm) at 5-minute intervals. The data ranges from the 24th of April 2022 to the 21st of May 2022 for St Felix with environmental data from February 2020, and from 1st of February 2022 to 13th of May 2022 for Majura.

A pre and post analysis of HRV installation and side by side analysis was undertaken, particularly CO_2 events where concentration above 1000 ppm was of significant focus. Additionally, the energy difference in side by side analysis of HRV + AC equipped rooms and AC only rooms was undertaken to identify energy recovery benefits of the HRV.

3.3. Summary of lessons learned

The HRV systems were effective at controlling CO2 levels within the test classrooms to levels below 1000 ppm for nearly the entire test period. The control rooms in comparison saw a significant increase in time spent over 1000 ppm during school hours as the exterior temperature decreased near the end of testing despite operating under COVID-19 ventilation protocols.

Both scheduled and demand controlled operation of the HRV aligned well with periods of solar generation, allowing for onsite renewables to provide the required energy. Furthermore, operating in demand response mode utilised less energy while delivering appropriate air quality and aligns better with off-grid transportables such as St Felix.

3.4. Summary of Sub-Project Outcomes

Each sub-project was evaluated against a series of outcomes and KPIs. A summary of how the outcomes and KPI's associated with the HIVVE Transportable Classrooms Living Laboratory sub-project have been achieved is provided below.

The HRV's where successful in improving ventilation to the classrooms compared to existing COVID-19 policies in the test classrooms. The number of events with mean CO_2 concentration above 1000 ppm significantly decreased after installation while the control rooms increased in events throughout the testing period. Additionally, the improvements to air quality did not significantly impact energy consumption by the air-conditioning units (AC). The energy consumption of AC by the control room at Majura increased by a mean of 3.3 kWh/day while the AC consumption in the test room reduced by a mean of 0.8 kWh/day.

Between the two control operations discussed in 3.1 there was minimal difference to indoor air quality provided. The scheduled operation used a mean of 4.8 kWh per day while the demand response had a mean of 1.3 kWh and appears to be the more energy efficient operation mode. Within the short testing period there where notable improvements to air quality and reduced AC energy consumption however, the challenges detailed in this report made it difficult to attribute these improvements to the HRV alone. A continuation of this technology evaluation has been in-principle agreed between UOW and the ACT education directorate. Additional data should allow for quantifying the impact of HRV units on energy use and thermal comfort, and the impact on energy availability of the solar battery system.

4. CONCLUSIONS

The implementation of HRVs within the school environment appears to be highly beneficial through lowering of mean CO_2 concentration and maintaining thermal comfort without a significant burden on energy use. The energy requirements of the HRV off set the energy consumption of air-conditioning (AC) having a mean energy usage of HRV + AC less than the adjacent control rooms with AC only. In the pre installation period, the Majura test classroom recorded at least 1 hour with a mean CO_2 above 1000 ppm on 77% of the days; there were no days meeting this threshold after the installation of the HRV unit. Compared to the adjacent control room at Majura there was an increase of 12% in days with 1 hour above 1000 ppm mean CO_2 post HRV installation period.

In both scheduled and demand controlled operation the HRV operates during solar PV generation period, providing lower CO2 levels within the rooms without the need for grid energy. With the cost of grid energy rising considerably in 2022, utilising onsite renewables and decreasing energy consumption is highly desirable.

The evaluation was significantly impacted by COVID-19 related supply chain issues. Procurement of the HRV units commenced in early 2022 with installation planned for summer 2021/22 school holidays, however there were substantial delays in receiving the HRV units by the supplier, and installation was not completed until the autumn school holidays (April 2022). This has resulted in i) a very short period for evaluation, limiting the ability to account and correct for differences in operation during side-by-side comparisons and ii) the evaluation occurring during a mild shoulder season, with only modest requirements for heating or cooling. This has presented significant challenges in evaluating the energy implications of HRV systems. A continuation of this technology evaluation, encompassing winter 2022 and summer 2022/23 has been in-principle agreed between UOW and the ACT education directorate, and this additional data will be invaluable in quantifying the impact of HRV units on energy use and thermal comfort, and the impact on energy availability of the combined solar PV-battery system.

For further information, the complete description of the evaluation with the results obtained is available in the following link: LLS3 Hiwe Transportable Classrooms: Impact of Heat Recovery Ventilation on Energy Use and Indoor Air Quality