Lesson Learnt Report

ACT Education Living Laboratory – Lessons Learned Report

Project – LLS2

27 May 2022

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.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program. 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.

i-Hub ACT Education Living Laboratories Lessons Learned Report

The i-Hub ACT Education living laboratory establishes research-quality measurement and verification systems within existing school buildings in order to observe and evaluate technology upgrades within the context of the daily life of these school ecosystems. The technology upgrades trialled in this living laboratory were selected from promising electric heating and cooling strategies that increase the energy flexibility of ACT Education facilities, and deliver increased value for renewable energy, at the site and grid level.

This report explores the lessons learned from establishing this living laboratory and through evaluating technology upgrades. The lessons learned were developed through reflections and observations of the researchers and project team, and through interactions with the various project stakeholders.

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Sub-Project number	LLS2		
Sub-Project commencement date	1st July 2019	Completion date	30th June 2022
Report date	27 May 2022		
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Lessons learnt

Lesson learnt #1	Sub-monitoring of AC split systems to identify performance issues.
Category	Technical

Describe what you learnt about this aspect of the Project.
When examining six air-conditioning units installed within the traditional transportables involved in our testing, one clear fault was diagnosed, and poor energy performance and an inability to achieve set-point temperatures was identified in another unit (which may be due to an AC fault or poor thermal envelope). The performance issues with these units are unlikely to have been identified during typical maintenance inspections, but were identified through detailed comparative analysis of similar units in similar operating modes. The prevalence of AC split systems in the education sector, and the high proportion of AC split system units presenting with functional and efficiency issues in our small sample, suggests the potential for significant energy wastage. The value of detailed sub-metering and ongoing monitoring of energy performance in identifying and rectifying this energy wastage is clear, and should be a point of consideration for schools infrastructure departments.
Please describe what you would do differently next time and how this would help. What are the implications for future Projects?
Unfortunately, the Hiive Technology evaluation trial took place during the height of the COVID-19 pandemic in NSW and ACT. This restricted the research team from travelling to perform site inspections (ideally performed during and before the results are gathered) which makes it very difficult to obtain necessary as-built information and introduces more uncertainty in the results. In an ideal environment, it is advisable to undertake a blower door test to measure the air tightness and employ a thermal camera to examine the building envelope as well as undertake on site calibration of the sensors to ensure they are not impacted by microclimate effects.
If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.
Please include any other information you feel is relevant or helpful in sharing the knowledge you learnt through this stage of the Project. This may be qualitative or quantitative and may include a graph, chart, infographic or table as appropriate.

Lesson learnt #2	Review of quality and performance of envelope and HVAC systems of transportable classrooms can reveal opportunities for significant energy savings and thermal comfort improvements.
Category	Technical

Describe what you learnt about this aspect of the Project.

The technology evaluation study between different types of transportable classrooms showed significant variations on the quality of the envelope (insulation levels and type of glazing) and the performance of HVAC systems. Two transportable classrooms for example on the same location that appeared to be similar had very different HVAC energy use and while one of them had sub-floor insulation, the other's floor was uninsulated. A thorough audit across the whole transportable classrooms' building stock could result in significant opportunities for energy savings and thermal comfort improvements.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

Thorough on-site visits would have assisted in better auditing the facilities but this was not possible due to lockdown covid19 restrictions.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

Digital representations of the school building stock after thorough auditing process could provide opportunities for energy savings and it will make decision making for technology upgrades easier.

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Lesson learnt #3 Establish working relationships with Building Service Officers

Category	Social

Describe what you learnt about this aspect of the Project.

Establishing a living laboratory requires a series of site visits to gain a detailed understanding of how the building operates, gathering of plans, schematics and details the building fabric, installation and maintenance of monitoring sensors, etc. Under normal circumstances this is achievable with the primary barrier being the distance to the site. However, when faced with a global pandemic with restrictions on movements and access to sites, gathering this information becomes a considerable challenge. The research team was based in the Illawarra which was classed under Greater Sydney in terms of COVID-19 restrictions which prevented the team from travelling outside of our region, let alone to the ACT. In addition, ACT education transitioned to an online learning platform with minimal students onsite for large durations.

This highlighted the critical importance of establishing good working relationships with the on the ground staff, especially the Building Services Officers (BSO's). Through collaboration with the BSO's, they were able to assist the team in sourcing critical information about the building including plans, schematics, and materials. The BSO's assisted with the installation and maintenance of the installed monitoring system and conducted live virtual tours for potential technology providers and when troubleshooting issues.

Establishing the living laboratories under the pandemic restrictions resulted in a significant increase in the workload of not only the research team but also the ACT Education staff which is provided through in-kind contributions.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

The research team placed an emphasis on establishing relationships with the BSO's and building managers at an early stage of the project, however, it would be beneficial to include these critical stakeholders earlier in the process including at the concept formation stage. This would not only strengthen these relationships, but also enable the living laboratories to better focus on addressing exiting issues within the building.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

Something that is not widely considered is that optimum operation of HVAC system requires interactions from the designers and installers, but also the maintenance personal, operators, occupants of the building, etc. This is a complex array of stakeholders that require multiple consultations when conducting research or making changes to HVAC systems.

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Lesson learnt #4	Relevant stakeholders required for establishing a living laboratory are greater than expected.
Category	Social

Describe what you learnt about this aspect of the Project.

Establishing a living laboratory requires a detailed understanding of the building and the installation of an extensive monitoring system to measure energy consumption and environmental conditions. However, the non-physical components are equally important, such as establishing legal contracts, understanding what energy contracts are in place, how energy bills are paid, who is the energy retailer, what is the operational schedule of the building, HVAC schedules, etc. All these non-physical elements of a living lab frame how the building is used and what is possible to achieve within the framework of the lab. For example, in the ACT Educational Living Laboratory a collaboration agreement was signed with the Education department, however, there are separate government departments that also need to be liaised with that handle the capital expenditures, manage energy contracts, etc. Each of these departments working together manage the high-level aspects of the buildings with each having varying directives and responsibilities which can cause points of additional discussions.

The buildings also have their own history and have often undergone upgrades and retrofits over their lifetime. This brings an additional layer of complexities with missing information and plans with work sometimes completed by companies that no longer exist. Historical agreements or changing of ownership and contracts may also limit access to information such as energy data. All these also emphasise the importance of moving all possible information into digital records and potentially developing building models that will act as digital representations of the building stock.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

In future projects it is recommended to build a stakeholder map early in the project or during the concept phase. This should examine how various workflows are undertaken. For example, how does the facility pay their energy bills? Who do they pay these to? Who is called when the HVAC isn't working or if someone is uncomfortable? How is new equipment acquired?

These are just a sample of activities and questions that should be asked and mapped to understand the critical personnel for gathering information, establishing and maintaining the living laboratories, and managing the installation, operation, and removal of technology trials. By completing this stakeholder map it will enable a clearer project scope to be defined and highlight potential issues such as missing information, earlier in the project.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

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Lesson learnt #5	Thermal mass within educational buildings in cooler climates
Category	Technical

Describe what you learnt about this aspect of the Project.

The Amaroo School located in Canberra was constructed in 2004 according to passive solar design principles including northerly aspect with solar access onto the thermally massive concrete slab. Raked ceilings with automated clerestory windows were provided for natural ventilation. Such construction is typically considered as exemplary for both thermal comfort and energy efficiency. However, despite the thermal massive envelope providing a more stable internal temperature in the cooler seasons, it required a significant quantity of energy to heat via the gas fired in-slab heating system. Additionally, the internal temperatures did not reach a comfortable level until much later in the day. Furthermore, this stored thermal energy then substantially dissipated through the unoccupied hours of the late afternoon and night requiring additional energy in the early morning to pre-heat the heavyweight building envelope. Although in this instance the energy supply is via a gas boiler, this energy consumption pattern is not conducive for aligning with solar PV generation should the gas boiler be converted to an electric heat pump with the majority of the energy required in the early morning. Furthermore, despite the passive design, the classrooms on the upper floor still experienced overheating issues over the warmer months. Thus, thermal mass is better suited for retaining stable temperatures through the night for 24-hour operations rather than schools which primarily operate during daytime.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

Future projects should consider the role that the thermal mass is providing within the facility and the energy requirement and time required for heating or cooling the occupied spaces to a comfortable level. Given a carbon neutral future, specific attention should be given to how the spaces will be conditioned and how this can align with solar PV generation.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

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Lesson learnt #6 Electrification of gas heating

Category	Technical

Describe what you learnt about this aspect of the Project.

An evaluation was conducted at the Amaroo Living Laboratory with a comparison between a split system air-conditioner and the existing in-slab hydronic heating system. The results illustrated significant differences in energy use and hours of operation between the two systems. It was evident from the measurements that school buildings could benefit from lower thermal mass construction to better align the HVAC energy demand during school operating hours with solar PV energy generation. Nevertheless, in this heavyweight building (Amaroo school), the AC split system was able to quickly increase the indoor air temperature and provide thermal comfort much faster while using less energy than the existing gas-fuelled hydronic heating system. Over the short evaluation period of the study, the electric AC split system was using energy at times of solar PV energy generation and required from 4 to 7 times less energy (75-85% energy savings) based on the measurements taken during this evaluation.

This test evaluated the feasibility and the benefits from using an electric Air Conditioning system as opposed to the existing gas hydronic system. The analysis highlighted that, apart from the obvious greenhouse gas emission reductions, an electric AC split system that can be potentially powered by renewable energy consumes significantly less energy while maintaining the thermal comfort in the classroom of the trial. However, despite split system AC units being a relatively low capital cost cooling solution for the mass market, these systems have no fresh air exchange. They process recirculated air in a dedicated zone. Split systems can create an unsightly and ad hoc retrofit option with substantial maintenance implications and poor BMS integration when compared to integrated and centralised commercial HVAC systems.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

This evaluation demonstrated that the transition away from gas-fuelled HVAC systems in schools towards electric systems is important not only because of the obvious greenhouse gas emissions savings and the unlocking of the full potential of renewable energy supply, but also because it provides significant opportunities to reduce energy costs while maintaining indoor thermal comfort. A whole-of-life approach would beneficial when examining future retrofit options or new builds.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

It would be highly beneficial for future projects to examine alternative electric air conditioning systems that also provide fresh air and the i-HUB living labs have the existing infrastructure for commissioning such comparisons.

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