The Innovation Hub

for Affordable Heating and Cooling

Final Sub-Project Knowledge Sharing report

Living Labs Educational Sector – Knowledge Sharing Report

Project – LLS1

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 Living Lab 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	LLS1		
Sub-Project commencement date	1st July 2019	Completion Date	30th June 2022
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. Living Laboratories Schools Sector-wide

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.

Unlike other Living Labs, a Sector Wide Living Laboratory does not establish singular or multiple environments for detailed energy and indoor environmental quality (IEQ) monitoring, but rather assesses the existing historical data for a given sector, to evaluate how different technologies and energy sources impact the sector as a whole. Additionally, guidelines and frameworks are required to assist education personnel in assessing existing assets and building stock, to upgrade and replace outdated and end-of-life technologies, in an attempt to decarbonise the school sector and support the achievement of energy and emissions reduction targets set by relevant governing bodies.

Education directorates from several Australian states and territories provided historical data from a multitude of primary schools across eastern Australia, including varying degrees of information and data granularity to gain further insights on the schooling sector, examining the effects of rurality, socio-economics, climatic regionality, energy sourcing and technology usage, and how these factors impact operational carbon and energy demand.

Table 1 outlines the relevant data provided to assist in this sector wide assessment:

Table 1: Summary of data collected (where n is the number of schools relevant for the given parameter)

State	n	Period	Temporality	Gas data	n_{Gas}	PV identified	PV Generation data available	n_{Solar}
New South Wales (NSW)	1561	Jul 18-Jun 19	Monthly	Y	548	Y	Y	1139
Victoria (VIC)	1074	2019	15 min	Y	514	Y	N	515
Queensland (QLD)	896	2014-2020	Annual	$	23	N	N	Unknown
Tasmania (TAS)	121	Jul 19- Jun 20	Monthly	Y	1	Y	Y	64
Australian Capital Territory (ACT)	49	2015-2021	15 min	Y	48	Y	Y	17*

1.3. Living Laboratory Objectives

The i-Hub living laboratories activity stream has the objective to quantify (i.e. analyse measurable data) and qualify (i.e. develop insights into reasons, motivations and opinions) the potential for practical and cost-effective innovative technologies in educational settings to achieve a 30%+ reduction in energy demand/consumption and greenhouse gas emissions relative to business-as-usual (BAU) baselines. Importantly, Australia's school stock used an estimated 8.8PJ of energy in 2020. The provision of, or demand for, thermally comfortable teaching environments through passive or active systems is a large driver for rising energy consumption in Australian schools.

Through evaluating the impact of renewable energy technologies and electrification across the existing schooling stock, stakeholders will be provided with a Roadmap outlining the processes, strategies and technologies which may enable schools to provide thermally comfortable environments for staff and students, while reducing energy demand and abating operational carbon to meet the various emissions reduction targets specified by the relevant governing bodies.

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 including the closing of schools and prohibiting of interstate travel. A selection of these challenges and the strategies implemented to overcome these are summarised below:

1. **Data correlation:** All participating states and territories have a method of recording and storing data, with these methods being inconsistent from one another. While some states thoroughly record energy usage data in conjunction with interrelated data (e.g. solar generation, gross floor area, student enrolments, CO_2 usage, energy sourcing, metered readings, etc.), others may only record subsets of these factors. The inconsistency of the related details impacts the degree of assessability of the correlating data, and while pertinent findings can be obtained, they are limited when compared to their more detailed state (or territory) counterpart datasets. To account for this, all state and territory data is compared where possible to yield the most holistic sector wide comparison, with other comparisons being made on subsections of the overall dataset where more detailed data or additional datasets are available.

2. **Data management systems:** All participating states and territories have a method of recording and storing data, with these methods being inconsistent from one another. While some states were found to have a concise method of managing relevant data in a singular database (e.g. .csv file, .xslm, etc.), other states were found to have separate files for relevant schools, years, regions etc. making it difficult to compile data into a singular database.

   Sorting and cleaning of the data was necessary, with scripting being utilised to simplify this process, though it was necessary to develop a script for each individual state (with some states requiring multiple scripts) due to the uniqueness of the data storage practices.

3. **Data granularity:** All participating states and territories have a method of recording and storing data, with these methods being inconsistent from one another. Granularity of datasets factored into the detail of the assessment provided for the related schooling region, with monthly granularity revealing how energy demand shifts with changing seasons, while 15-minute granularity revealing more about typical daily energy demands, energy usage (and generation) profiles, and also indicating if energy usage is ongoing during weekends or holidays in school districts. While data for similar granularities may be compared, there is no method available to accurately refine granularity without physical metering upgrades at the school.

4. **Acquisition of data from varying state bodies:** Sourcing of energy data was required at a state or territory level, with information not being readily available to the public. Before data could be acquired, the correct people or departments needed to be identified, with these roles and departments constantly changing. Numerous data requests needed to be lodged, with response times and varying with each state, department, and personnel, with the quality and quantity of offered data differing. Even with persistence, these methods were not always successful, with some states/territories being unable to provide data for varying reasons.

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

The sector wide living laboratory project consisted of five major phases: developing a living lab framework, establishing a knowledge sharing task group and sourcing of relevant data, collation/ evaluation of data, developing a whole of life assessment, and the development of an enabling technologies roadmap. A summary of the impact from each of these phases and the subsequent lessons learned is presented below.

2.1. REETSEF for School-base Living Labs

Prior to determining the boundaries of the living laboratories, a Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF) for the Education Sector was first created which defined the KPIs and methods of evaluation to be used to assess the impact of technology upgrades. This REETSEF examined previous living laboratories and green proving grounds which highlighted that a range of societal, electricity network, and facility owner/manager KPI's were required to assess the effectiveness of potential technologies.

Following this, an audit was performed on select schools (LLS2 ACT Education),a baseline evaluation of the school using the REETSEF, and a living laboratory operations manual produced specifically for the schools audited, which details the type and position of all installed sensors. This process also highlighted some of the potential areas for improvement, such as electrification of gas heating systems. While this operations manual specifically relates to relevant schools in the ACT, the theory and installation practices may still be relevant for schools in other states and territories. Links to these two reports can be found below.

Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF)

Living Lab Operations Manual: ACT Education

2.2. Knowledge Sharing Task Group and Data Sourcing

Prior to any assessment of the education sector being possible, sourcing of data was necessary from which a baseline assessment could be derived. The ACT Schools Living Lab (LLS2) provided existing contacts within the ACT Education Directorate, giving a means to source historical school data for one Australian Territory, however, the correct personnel and departments at other state and territory education directorates needed to be identified, to correctly address any data requests. This undertaking was further complicated by the advent of Covid-19, as additional stress was being placed on the varying educational directorates in transitioning to online learning Australia wide.

Eventually, responses were received from all states and territories, with 5 directorates able to provide the necessary data (NSW, VIC, ACT, QLD, TAS) in varying formats, while three others were unable to contribute data for varying reasons. Data was intermittently received from different directorates from February 2019 up until March 2022. This process identified the complexity in sourcing data from varying educational departments and highlighted the need for improved data sourcing and retention on the behalf of some of the education directorates. These aspects are further detailed in the lessons learned report (*LLS1: Education Sector Wide Lessons Learned Report*) and the enabling technologies Roadmap (*Renewable Energy and Enabling Technologies and Services Roadmap for Schools*).

Additionally, the process of identifying relevant personnel and departments within each education directorate assisted in the recruitment of members for the knowledge sharing task group, to provide invaluable feedback on the outcomes of the sector wide analysis, insights into major obstacles being faced within each directorate, and contact information for additional relevant personnel within the directorate or other government agencies. Interestingly, such a group did not exist prior to this project despite the similarities in the challenges encountered in the sector across the various states and jurisdictions.

2.3. Collation and Evaluation of Baseline Data

When the data was provided by each of the participating education directorates, the presentation and layout of this data differed, with some participants providing data in multiple formats. Before any data could be analysed, it was first necessary to collate the data, transforming it into a usable format which was uniform across all data sets. Some process's checked for missing data points; others eliminated errors while also identifying anomalous datapoints/datasets. This process is critical in the analysis of the sector wide data, as it validates the dataset, and ensures that further analysis can proceed uninterrupted. It also highlights limitations in the dataset, imposing what may or may not be investigated based on the provisional data.

This processing period was also used to incorporate other relevant data within the final dataset, including socio-economic data collected from the Australian Bureau of Statistics (Socio-Economic Indexes for Australia (SEIFA), 2016), remoteness indexation from the Australian Bureau of Statistics (Postcode 2017 to Remoteness Area 2016), climatic regionality from the National Construction Code and NatHERS, and Heating/Cooling degree hours from the National Construction Code.

The processing of data identified the inconsistencies between education directorate datasets, and highlighted improvements which may be incorporated by each education department to better utilise their available data.

Post-processed data required aggregation to realistically compare schools across the sector, due to the discrepancies in gross floor area (GFA) and enrolment numbers. A regression of both GFA and enrolment against energy usage reveals an R^2 value of 0.59 and 0.6 respectively, meaning both transformations are similarly correlated, and both area-based and enrolment-based normalisation methods are equally useful in comparing schooling stock.

Of the 3,701 schools analysed in this sector wide assessment (encompassing approximately 82% of the population), the mean energy consumption across all schools was found to be 38 kWh/m^2/year, or 542 kWh/student/year (depending on normalisation). The installation of Solar PV was found to reduce net-energy usage by approximately 16%, with electrification of schools being found to reduce energy usage by 27% when compared against schools utilising gas per m^2 (mean of 45.3 kWh/m^2/yr vs 33.1 kWh/m^2/yr)

Energy consumption discrepancies across differing jurisdictions was substantial, with ACT having the greatest median energy demand per school (367MWh/school/year), though this is due to the ACT containing fewer schools within its jurisdiction with a substantially larger average size when compared to other states and territories. Considering normalised energy consumption (per m^2 or per enrolment) the relative differences between jurisdictions was reduced, although schools in the

ACT were still the largest consumers with a median of 873 kWh/student/yr (225% greater), and 77.2 kWh/m^2/yr (250% greater).

However, this information does not definitively imply that the ACT is contributing to a greater extent. When examining emissions intensity factors (based on NGER factors) ACT and VIC are comparable, contributing approximately equivalent CO_2 values per student and per m^2. Correlations were also witnessed between energy demands and remoteness indices, climatic regionality and socio-economics, though results depend on the method of normalisation, highlighting the need for thorough examination and presentation of the data.

This sector wide evaluation highlighted the importance of capturing necessary quantifiable data, while also indicating how the use of natural gas and electrification can impact the energy demands and carbon emissions of the schooling stock. For greater detail as to how this analysis was undertaken and the results achieved, please refer to the following associated knowledge outputs.

LLS1 Education Sector Wide – Baseline data analysis

Energy consumption in Australian primary schools: influences and metrics (journal manuscript under review)

LLS1 Education Sector Wide – Baseline addendum report: Living Labs Educational Sector Energy Baseline and Key Performance

2.4. Whole of Life Assessment

Many of the key performance indicators identified in the REETSEF are designed to support the assessment of technology improvements at the network and societal level, with consideration of benefits to the individual school limited to reduced energy consumption and utility costs. A whole of life assessment is designed to provide an easy-to-use guide for sector stakeholders to implement a whole of life design and assessment approach to compare costs and benefits of alternative HVAC technologies.

The purpose of whole of life is to improve the functional performance of the asset for the whole of life with a focus on durability, maintainability, sustainability and investment efficiency. Whole of life planning should assist in school learning spaces being built to a higher quality, resulting in improved education benefits.

The education sector whole of life assessment guide was developed with these principles in mind, considering operational, non-monetary/monetary, and technological suitability concerns when assessing the upgrade or replacement of HVAC technologies within schools. Frameworks were developed to assist personnel in this decision-making process, offering assessment criteria (e.g. site/context, IEQ, fit-for-purpose, sustainability, monetary, etc.) to guide asset and procurement managers through the whole of life assessment process. A links to the whole of life assessment guide can be found below.

Whole of life assessment guide for HVAC technology replacement decisions: Sector Wide

2.5. Enabling Technologies Roadmap

The analysis of the sector wide energy baseline was presented to relevant stakeholders via a knowledge sharing task group, where major findings were discussed, with varying education directorates outlining the difficulties they have faced in achieving emissions and energy reduction strategies, in addition to improving thermal comfort and classroom IEQ. These difficulties (in addition

to the sector wide findings) were translated into the enabling technologies Roadmap, outlining key recommendations and guiding principles to meet decarbonisation and energy reduction targets specified by relevant governing bodies. Some of these key strategies and recommendations include (but are not limited to):

- Benchmarking and evaluation of schools and individual buildings
- Prioritisation of upgrades to best practice for end-of-life replacements
- Ensure complementary upgrades are bundled or completed sequentially
- Establishing minimum envelope standards before inclusion of active systems
- Low-hanging fruit solutions should be avoided

The Roadmap provides a high-level strategic overview for the school sector, to assist with policy and planning decisions associated with decarbonisation, energy reduction, and improved IEQ within the Australian education sector. The Roadmap itself does not outline specific solutions nor the directions which should be taken within each individual school, but rather affords recommendations as to how these reduction targets can be addressed.

Renewable Energy and Enabling Technologies and Services Roadmap for Schools

2.6. 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 Education Sector Wide Living Laboratory sub-project have been achieved is provided below.

- *Development and approval of a 'Renewable Energy and Enabling Technology and Services Evaluation Framework' (REETSEF) that will be applied to Education (Schools) Living Lab operations and product validation protocols. (i.e. Living Lab operation Guidelines)*: The REETSEF has been developed and disseminated through the knowledge sharing task group, with the framework having guided in the installation and monitoring practices for several living labs streams (LLS2 and LLS3).

- *Establishment of a Renewable Energy Knowledge Sharing Task-group for Schools, that enables the two-way flow of information between the project and the sector:* A knowledge sharing task group has been established, encompassing education directorates from several states and territories, while also incorporating members of additional governmental bodies and private enterprise. Knowledge has been disseminated through this task-group, with feedback also being provided from the task-group via knowledge sharing workshops.

- *Sector wide baseline data that enables quantification of technology impact at a building level and extrapolation of sector wide impact, to be distributed to stakeholders through the Knowledge Sharing Task-Group:* Data collation and assessment has occurred for a sector wide assessment of all primary schools across eastern Australia (covering 5 states and territories, encompassing 82% of the Australian population). This assessment evaluates the impact of renewable energy and fossil fuels on the energy demand and carbon emissions of relevant schools, while also assessing the impacts of climatic regionality, remoteness indexation and socioeconomics on energy demands. This knowledge has been disseminated via the knowledge sharing task group, through academic publication, and through publication via the i-Hub website. In addition, findings and the collected dataset are shared with the

NABERS team for the development of the NABERS Schools tool. Initial discussions on the topic have started with the NABERS team expressing an interest to expand the study to other states and include also data from high schools.

- *Enhanced industry understanding of the value of, and processes involved, in whole of life assessments and KPIs, including improving the value proposition for energy efficiency/renewable energy, with an interim report to be distributed to the sector:* A whole of life assessment guide has been developed to assist asset and procurement managers within the education sector to further assess the longevity and ongoing life of current HVAC assets, and offer strategies to better assist in assessing future HVAC technologies. This guide has been distributed to the knowledge sharing task group, and through publication on the i-Hub website.

- *Demonstration of potential for a 30%+ reduction in energy demand/consumption and greenhouse gas emissions, and a 25% increase in the value of renewable energy for Educational (school) facilities, relative to existing baseline metrics:* The baseline assessment has highlighted that the inclusion of Solar PV alone (on average) can reduce the net-energy usage by approximately 16%, while through the analysis of the data collected in this study it was shown that there are significant energy usage differences between schools of the same climate (on a per student basis). This demonstrates a significant potential for energy savings (e.g. in ACT there are schools that use ~45-50 kWh/m^2 student and schools that use >120 kWh/m^2 student, i.e. this shows that a 65-70% potential for energy savings exist on a per student basis). The inclusion of active and passive solutions is believed to further reduce energy demand requirements. Additionally, CO_2 emissions were found to be substantially reduced in states where the reliance on fossil fuels was diminished (i.e. Tasmania), indicating the further impact of electrification and renewable energy sourcing.

- *A Renewable Energy and Enabling Technology and Services Roadmap for Educational (school) facilities that can be utilised by the schools sector in their policy and procedure processes and decisions regarding energy contracts, building design and operation, and renewable energy investments, including an analysis of the potential for increased value of renewable energy and reduction in energy demand/consumption, against baseline metrics.* A renewable energy and enabling technologies Roadmap has been developed, incorporating the findings from the sector wide baseline energy assessment, and feedback from the knowledge sharing task group. This Roadmap outlines recommendations for the education sector regarding strategies and technologies to best tackle decarbonisation, to meet emissions and energy reduction targets into the future. This Roadmap has been distributed to the knowledge sharing task group, and through publication on the i-Hub website.

4. CONCLUSIONS

Australia's school stock consumes a considerable amount of energy, estimated at 8.8 PJ in 2020, with a substantial proportion of this attributed to HVAC systems, to maintain classroom thermal comfort conditions. Further demand for thermally comfortable learning environments for both teachers and students may see these demands increase in coming years. The typical operating times for schools closely align with average daily solar profiles, highlighting the potential advantages to incorporating solar PV and passive designs principles within our schooling stock, while upgrading or replacing outdated or end-of-life assets.

The education sector wide living laboratory sought to quantify and qualify the potential for innovative technologies and the integration of technologies in school settings to add value to renewable energy, improving schools' capacity to decarbonise and adjust to future energy demands while simultaneously contributing to occupant wellbeing, comfort and health, with an increase of 25% towards the value of renewable energy for schools relative to business-as-usual (BAU).

Several guides and frameworks have been established to assist schools in the upgrade or replacement of existing outdated and end-of-life assets and building stock, to maximise their impact on achieving energy and emissions reduction targets. A whole-of-life assessment guide provides a framework to assess individual assets, while the enabling technologies roadmap recommends a diverse range of technological and strategical opportunities to reduce energy demand and emissions, while providing more thermally comfortable learning environments.

The baseline analysis assesses the schooling sector as a whole (across eastern Australia) indicating the impacts of electrification and renewable installations across a diverse range of climatic and socioeconomic jurisdictions. This baseline reveals that installation of solar PV and schoolwide electrification reduces the overall energy demand of the schooling stock. When combined with other active and passive strategies, substantial energy savings will be evident across the Australian education sector.

Following i-Hub, the University of Wollongong is discussing a collaboration with NABERS, to integrate the sector wide energy analysis within the NABERS Accelerate for Schools, to assist in developing a NABERS rating scheme within the education sector. This will utilise the findings of the education sector baseline and further assist the education sector in developing a more efficient schooling stock. Additionally, the knowledge sharing task group is anticipated to continue, with idea sharing and knowledge dissemination to continue as education directorates work towards a more energy efficient future.