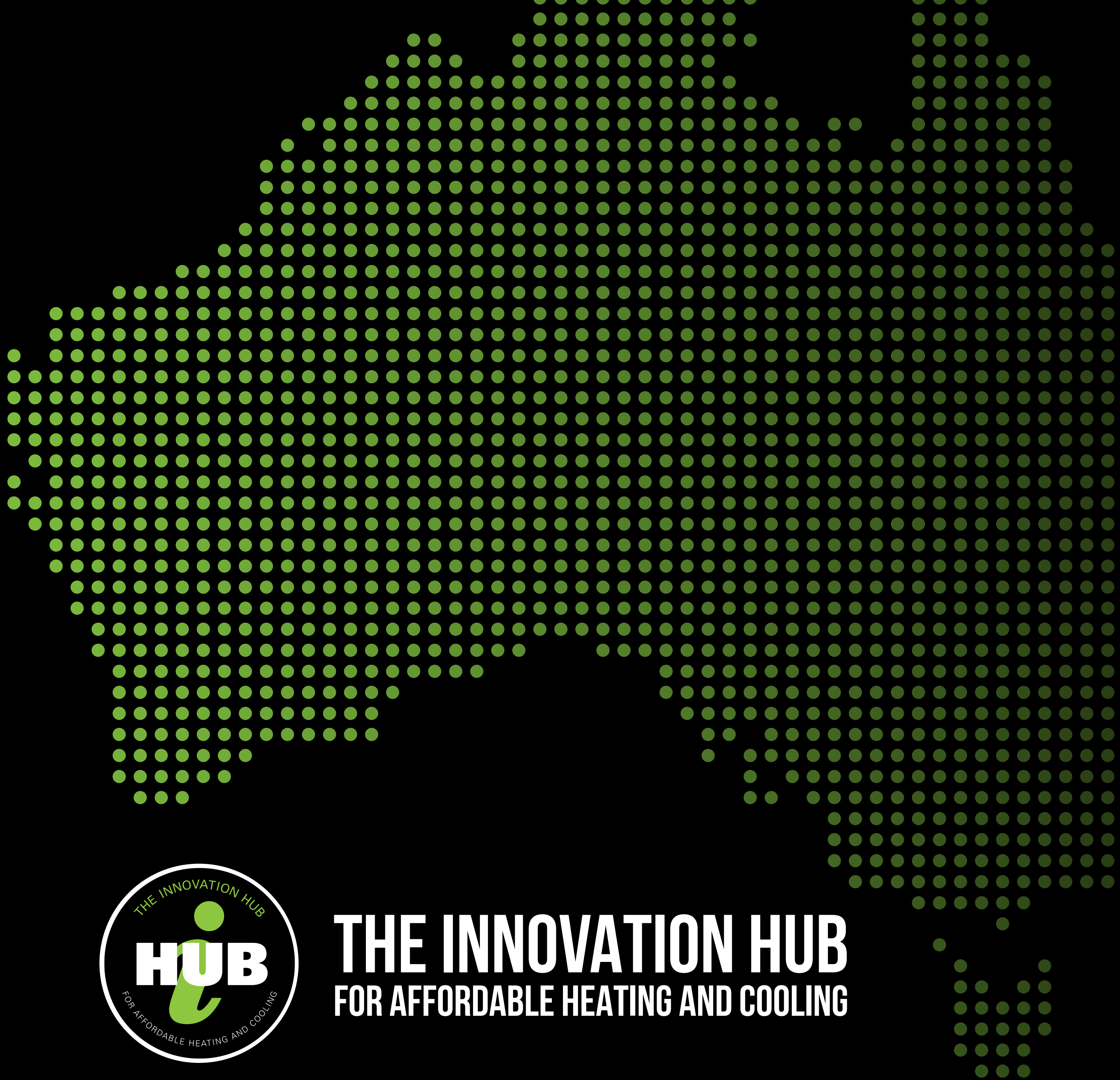

THE INNOVATION HUB
FOR AFFORDABLE HEATING AND COOLING

RENEWABLE ENERGY AND ENABLING TECHNOLOGIES AND SERVICES ROADMAP FOR SCHOOLS

27 MAY 2022

UNIVERSITY
OF WOLLONGONG
AUSTRALIA

I-HUB EDUCATIONAL SECTOR RENEWABLE ENERGY AND ENABLING TECHNOLOGIES AND SERVICES ROADMAP FOR SCHOOLS

The Renewable Energy and Enabling Technology and Services Roadmap for Educational (school) facilities provides high-level strategic principles for the schools sector to assist with policy and planning decisions to support decarbonisation through energy contracts, building design, operation and refurbishment, and renewable energy investments.

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INTRODUCTION

Climate change is already resulting in hotter temperatures, more dangerous fire weather, more droughts and floods, higher sea levels, and drier winter and spring months to southern and eastern Australia (Mackey et al., 2022).

The IPPC report is clear on what is required to stabilise the climate: strong, rapid, and sustained reductions in greenhouse gas emissions, reaching net zero by 2050 at the latest. (IPCC, 2022)

All jurisdictions in Australia have committed to net zero emissions targets; there is a national target for net zero emission by 2050, with an interim target of a 26-28% reduction on 2005 levels by 2030, with most targeting Net Zero Emissions by 2050, as shown in Figure 1. Most state and territory governments have targets aligned with the national ambition, though ACT is aiming for net zero by 2045. Many states also have renewable energy targets for 2030, and some states (ACT and Victoria) are developing electrification strategies.

Governments have typically committed to lead by example. In the buildings sector this means improving the energy efficiency of buildings directly under government control. At the national level this is achieved through minimum energy performance standards outlined in the Energy Efficiency in Government Operations policy. At the state level, school buildings represent a major portion of the buildings sector.

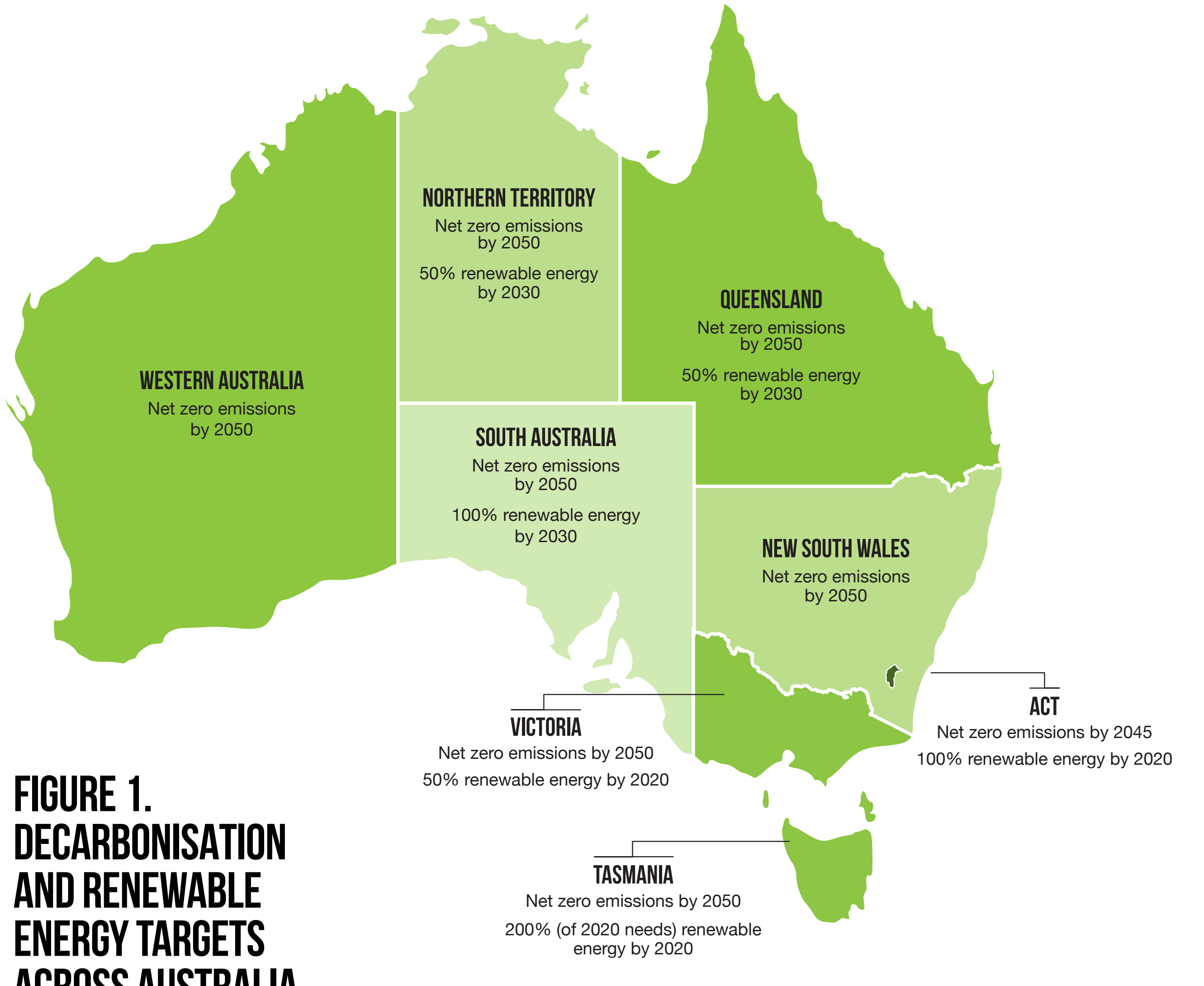


FIGURE 1. DECARBONISATION AND RENEWABLE ENERGY TARGETS ACROSS AUSTRALIA

ENERGY USE IN SCHOOLS

School energy use is situated in a complex space, where the considerations of the appropriate thermal conditions, the provision of appropriate ventilation and the opportunity for building fabric and HVAC system improvements must be managed in a future-focussed and holistic manner within the constraints of capital and operating budgets and climate change policies.

School buildings in Australia are at a confluence of community trends, policy trajectories and societal upheavals that require a transformational change in the management of energy and assets. The pressing need to rapidly reduce greenhouse emissions in the face of increasing global temperatures and recent local climate-related natural disasters are driving decarbonisation policies, including electrification of gas. Recent energy performance improvements in air conditioning systems, and the increased capacity of onsite renewable generation offer promising technological solutions. At the same time, changing community expectations regarding indoor environment quality, particularly provision of cooling and adequate ventilation, are placing upwards pressure on school energy consumption.

The vast majority of energy use in schools is for Heating, Ventilation and Air- Conditioning (HVAC). Data is scarce for Australian schools and energy use will vary greatly by climatic location, however in the UK and US studies estimate 65% - 70% of energy use in schools is for HVAC. Therefore, decarbonisation of schools is largely dependent on the provision of low carbon heating, cooling and ventilation.

Whilst heating has long been standard in most schools, widespread mechanical cooling is newer, with many jurisdictions currently expanding the provision of mechanical cooling in schools. A summary of these programs is presented in Table 1.

This Renewable Energy and Enabling Technology and Services Roadmap for Educational facilities provides **a summary of challenges and opportunities facing school, recommendations for a number of high-level strategic principles to guide the transition, and an introduction to key technologies** for the schools sector to assist with policy and planning decisions to support decarbonisation.

TABLE 1. CURRENT MAJOR STATE UPGRADE PROGRAMS FOR SOLAR PV AND MECHANICAL COOLING IN AUSTRALIAN SCHOOLS.

SOLAR PV
NSW
Schools Renewable Energy Co-contribution Program. Funding for 50 - 95% (dependant on SES) of capital cost for up to 100kW system, and incentive payment for 7 years following installation. **Schools Renewable Energy Infrastructure Pilot Project:** $20 million pilot for large scale solar and batteries in 25 schools. **Solar My School:** Project implementation support provided by Local Government staff. 160 schools to date, with service offered by 16 LGAs only in NSW.
VIC
Greener Government School Buildings: $8.8 million, 171 schools (42 in pilot), system size -40 kW
QLD
Advancing Clean Energy Schools: $97 million, 800 state schools, ~70kW systems
WA
Schools Clean Energy Technology Fund: $44.6 million, 91 schools **Solar Schools Program:** $5 million, 30 schools **Virtual Power Plant Trial:** $8.8 million, 16 schools
SA
Solar Schools: $10 million, 40 schools
TAS
Renewable Energy Schools Program: $5 million, 100 schools
ACT
All ACT public schools have rooftop solar, average of 27kW per school $850,000 since 2018 to expand solar in schools
NT
Rooftop Solar in Schools Program: $5 million, 25 schools

MECHANICAL COOLING
NSW
Cooler classrooms project: $500 million over 5 years for schools inisotherm 30 (600 schools) or by application (300 schools). specification includes direct O supply fans with CO, monitoring and control.
VIC
Cooling policy: Air conditioning provided to schools in NatHERS CZ 20 and 27 (~4% of schools).
QLD
Cooler Cleaner Schools Program: $477 million over 4 years to air condition state schools (over 650 state schools). Air-conditioning to every classroom, library staffroom by mid-2022.
WA
Cooling provided to all WA schools
SA
Most schools appear to have some cooling (363 of 509 at 2019), no publicly notified roll-out.
TAS
Unclear, no publicly notified roll-out or planned implementation.
ACT
Air-conditioning being installed in some schools, but no publicly notified rollout or planned implementation.
NT
Most schools appear to have cooling, no publicly notified roll-out or planned implementation.

CHALLENGE AND OPPORTUNITY: SCHOOLS IN THE ENERGY TRANSITION

Decarbonisation to limit warming below 1.5 °C will require rapid and far-reaching transitions. For the schools sector to lead by example, targeted, hands-on and strategic planning is essential to ensure trends and actions impacting energy use in schools now are aligned with decarbonisation trajectories.

DECARBONISATION

Commitments to reduce greenhouse gas emissions from various levels of governments are already being translated into practical implications for school infrastructure, such as increased installation of renewable generation, a push to reduce energy consumption, and a move to electrification. However, there has not been a clearly defined pathway, with specific strategies, goals and targets, for how schools buildings will achieve decarbonisation.

The i-Hub work (iHub, 2021a) has highlighted a gap in knowledge regarding the energy use and energy performance of Australian school buildings. This lack of performance data presents a challenge to the development of appropriate energy policies to improve the sector's energy performance and pathway towards electrification.

Understanding, benchmarking and tracking the energy performance of schools is crucial. This benchmarking will ensure that progress to decarbonisation is managed holistically, balancing the conflicting challenges to also improve the internal learning environment, and support risk management responses to COVID-19 and air pollution events. This is important at the level of individual schools through energy auditing and utility tracking, and at a portfolio level, for example using NABERS for Schools (see box below)

NABERS FOR SCHOOLS

NABERS (the National Australian Built Environment Rating System) is a well-established building performance rating in many commercial building sectors. The tool uses actual consumption data to benchmark and rate the energy and water performance of individual buildings, with reference to other comparable buildings. NABERS is currently expanding to schools, and may become a valuable tool in prioritising decarbonisation investments across school portfolios.

In the commercial office sector the scheme has been in operation in some form since 1998, operating nationwide since 2009, and has been mandatory since 2011 for building owners when offering more than 2000 m2 of space for sale or lease. This threshold was reduced to 1000 m^2 in 2017.

NABERS has been transformational in the office sector. The average star rating has increased from 3.5 stars in 2010 to 4.8 stars in 2020/21, which corresponds to an average reduction in carbon intensity in rated buildings of 44%. Almost 2000 buildings were rated through NABERS in FY 2020/21. On average, office buildings that have multiple ratings show continuous reductions in energy intensity for each subsequent rating.

A significant driver of NABERS uptake prior to the introduction of CBD were minimum NABERS requirements for government owned or leased buildings, introduced in NSW in 2003, and federally in 2006. This requirement for energy efficiency in government operations offers an inspirational model for the role that government can take in leading by example in schools.

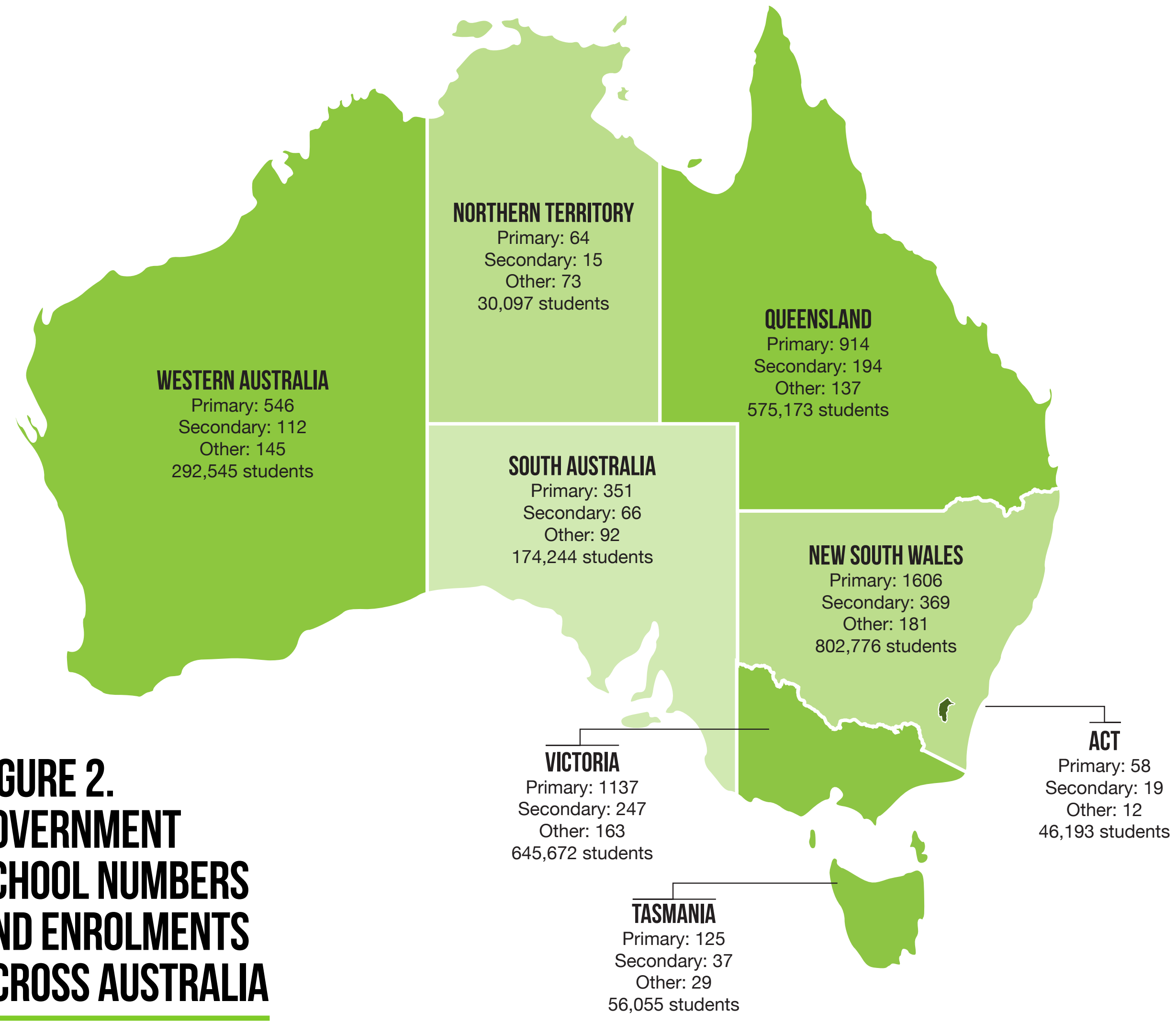


FIGURE 2. GOVERNMENT SCHOOL NUMBERS AND ENROLMENTS ACROSS AUSTRALIA

THE GREENER PATHWAY: RETROFIT

School buildings across Australia represent a large investment, both in financial terms, but more importantly, in terms of the energy used in their construction. There are more than 6,500 government schools across Australia. The embodied carbon of these buildings needs to be valued. Whilst it is undoubtedly more straightforward to construct a new school to be highly energy efficient, it can take many years to 'repay' the embodied carbon of a knock-down and rebuild construction through more efficient operation.

It is clear that large scale retrofit of existing school buildings will be necessary to achieve net zero targets. Recognising the time pressure of decarbonisation, and the lifecycles of schools buildings, focussing on efficiency of new building will be insufficient. Deep retrofits of existing building have been shown to substantially reduce energy consumption, and generally have economically attractive returns through reduced utility costs.

SOLAR FOR SCHOOLS

School energy use profiles are well matched with solar generation profiles, especially for summer cooling loads, meaning that most of the energy generated can be used onsite by schools without the need for local energy storage. This is an important measure in the economics of solar. Schools are also typically low density spaces, which have large roof areas to accommodate substantial arrays.

In recognition of this substantial opportunity, all jurisdictions have invested in solar PV for schools (see Table 1), however the size of the installed systems was often modest. Recent reductions in systems costs make solar financially attractive, and many states are now engaged in programs to expand array size.

ELECTRIFICATION

Transitioning energy supply from direct combustion of fossil fuels to electricity is crucial for decarbonisation. The electricity network in Australia is already becoming greener. Between 2014 and 2021, the National Greenhouse Account Factors show the emissions intensity of the electricity network has decreased by approximately 12%. This is driven by the increasing penetration of renewable energy generation, which is now clearly forecast to increase dramatically within the next several years (AEMO, 2021).

Therefore, decarbonisation of heating first requires the electrification of these energy sources. In the schools sector, this translates to the replacement of gas boilers, furnaces and hot water systems with heat pump technology. As well as decarbonisation, these technologies offer substantial energy efficiency improvements.

THERMAL COMFORT

Increasing deployment of mechanical cooling in Australian homes is translating into increased community expectations for active control of both thermal comfort and ventilation in schools. This is supported by emerging research into the relationship between Indoor Environment Quality (IEQ) and learning performance, which highlights the importance of comfortable learning environments. Historically, schools have typically relied on gas heating during the winter, and ceiling fans combined with natural ventilation to maintain summer comfort.

To improve student thermal comfort (and indirectly, learning performance), many schools have retrofitted reverse-cycle heat pumps to their existing school buildings. Typically this has been done on an ad-hoc basis at the school level, however some jurisdiction have begun roll-out programs in certain regions. This increasing penetration of mechanical cooling has the potential to massively increase energy use in schools, if it is not combined with prudent management and the complementary upgrading of building insulation and air-tightness.

VENTILATION

COVID-19 has highlighted the risk of split-system air-conditioners not adequately supplying outside air in classrooms. Conversely, the impacts of bushfire smoke on air-quality during the recent Black Summer in Australia (2020) highlighted a need for filtration or limited outside air during severe air pollution events.

Adequate fresh air is also related to learning performance. For example, Kocka et al. summarised previous work as: "for every 1 litre per second per person (l/s/p) increase in the ventilation rate up to 15 l/s/p, academic performance increases by 1%".

However, increasing the fresh air into a heated or cooled space, or adding filtration, will both tend to increase HVAC energy consumption. Heat recovery ventilation is a commonly used technology that can mitigate this, and carbon dioxide monitoring can be used as a proxy for control/indication of fresh air supply.

MANAGING RETROFIT ROLL-OUT: BUILDING-CENTRIC, TECHNOLOGY-CENTRIC AND ASSET MANAGEMENT APPROACHES

There are almost 7,000 government schools across Australia, and deep-retrofits (i.e. reducing energy usage by over 50%) will likely be necessary to reach net zero emissions in the sector.

There are a number of common approaches to retrofitting buildings at scale. Each jurisdiction will employ somewhat different governance and implementation strategies, with climate-appropriate priorities, and often a mix of approaches will be most suitable. Some of the advantages and disadvantages of common approaches are as follows.

A **technology-centric approach** looks to *identify priority technologies* that can be implemented on a large number of buildings, using relatively similar design and installation practices, and centralised procurement - the roll-out of solar PV in schools, for example. Typically, a relatively simplistic cost-benefit tool will be used to determine technologies that meet jurisdictional financial performance metrics, and then appropriate locations will be identified, with the number of installations driven by the overall project budget.

The technology-centric approach has many **advantages**, primarily simplicity of management and lower transaction costs. However, the approach has the **disadvantage** that benefits of integrating the technology with other complementary upgrades are missed, and energy savings are typically modest. This approach often targets the 'low-hanging fruit', and will typically leave necessary, but more difficult and expensive, upgrade work for future programs.

A **building-centric approach** looks to *identify priority buildings* for upgrading, based on energy use, lifecycle asset planning, comfort complaints or other similar indicators. Once a building is identified, a detailed energy audit is undertaken, an appropriate target identified, a holistic retrofit package designed, and the business case assembled. The **advantage** of this approach is that it allows for deep energy savings to be achieved by ensuring all appropriate, cost-effective and complementary retrofits are implemented. **Disadvantages** are typically higher transaction and management costs. This is often related to the need to rectify previously unidentified faults with buildings or systems that come to light during upgrade works.

In NSW, the largest state, taking a building-centric approach would require approximately 75 schools to become net zero each year to reach the entire existing stock by 2050.

Understanding **asset lifecycle plans** is crucial for all approaches, however, an **asset management approach** typically centres on the *lifecycle of major assets* in the retrofit decision processes. In the schools sector this would typically be gas boilers, or significant building refurbishments (e.g. roof replacements). Using this approach, an energy assessment should be undertaken and a *retrofit strategy developed as a major piece of equipment approaches end-of-life*. This approach minimises the waste of residual value in assets, however, it does require accurate asset management systems to be in place.

A proposed hybrid pathway for schools energy transformation is as follows:

1. *Identify priority technologies* using a **technology-centric** approach.
2. *Identify a diversity of pilot sites* (5 to 10) that suit the priority technologies using **asset life-cycle** data. Coordinate sites across jurisdictions to share the burden.
3. Use a **building-centric approach** to carefully determine the best value-for-money retrofit packages, using a whole-of-life assessment framework.
4. Undertake robust evaluation of the effectiveness of the individual and packaged retrofits to establish an approved suite of retrofit packages and validated whole-of-life assessment tool.
5. Rollout retrofit packages, targeting priority schools and system end-of life upgrades.

GUIDING PRINCIPLES FOR DECARBONISATION IN SCHOOLS

BENCHMARK AND EVALUATE

The first step in any energy efficiency process is to understand the challenge. That is, what is the current energy performance of school buildings, how far is it from the target?

There is currently limited data in the public domain regarding the total energy use, energy use intensity, energy end-use breakdown and renewable energy supply in schools across Australia. This limits the ability to prioritise poorly performing schools, identify portfolio level solutions, and optimise the transition pathway. As well as energy data, information on the building stock, and heating and cooling systems is limited. Upgrading existing meters to smart interval meters would substantially improve understanding in many states.

This benchmarking could take many forms, including work at the portfolio level to identify schools with higher energy use intensity, higher summer energy use, or likely energy wastage, or at the school level with support for principals to collect data to support decision making. However, in the absence of simple, reliable and regular benchmarking it will be challenging to manage the energy transition.

CONTROLS, INTERNET OF THINGS AND AI

Low cost sensors, networks and advanced machine learning algorithms have created many opportunities in energy management. It is now relatively simple to retrofit monitoring systems or additional control sensors to existing buildings, and to process the collected data for meaningful insights.

These approached can be used, for example, to ensure IEQ is acceptable through monitoring of carbon dioxide levels, enhance controls based on additional sensor inputs, such as occupant feedback monitoring, and automate fault detection and diagnostics in complex systems.

In schools, these new technologies may have a role in integrating legacy and retrofit systems, and in the ongoing evaluation of the energy performance of buildings and systems.

SMART GOALS WITH CLEAR RESPONSIBILITY

An important principle for translating state level decarbonisation targets into meaningful action at school level is to ensure clear goals are in place. Whilst there are many schemes in operation in many jurisdictions that are working towards decarbonisation in schools, there does not appear to be clear pathways for the energy transformation of schools buildings. The **SMART** goals mnemonic is useful to ensure goals are effective: **S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**ime-bound.

In the context of decarbonisation of schools, the actual goals will vary based on the climate, energy mix, building stock and priorities of jurisdictions. However, establishing a clear and appropriate pathway to guide the transition is crucial.

APPLY THE ENERGY HIERARCHY

The energy hierarchy is a simple tool to prioritise energy upgrade options and assist progress to decarbonisation.

Priority is given to upgrades that reduce the need for energy (for example, shading, draught-proofing or insulation). Once energy demand is minimised, the need is met with the most efficient possible option (for example, installing a high-efficiency reverse cycle air-conditioner rather than a direct electric heating). Finally, the much reduced energy demand can be supplied from renewable sources.

A slightly updated energy hierarchy, which acknowledges the significant cost reduction for renewable generation, and the need for electrification is proposed below. As well as prioritising no and low energy solutions, by first minimising the heating and cooling demands of a space, HVAC systems can be right-sized (or avoided altogether), offering significant cost savings.

A **site-centric** approach would use this hierarchy to develop an integrated, future-focused plan for individual schools, considering energy efficiency and electrification in conjunction with renewable generation.

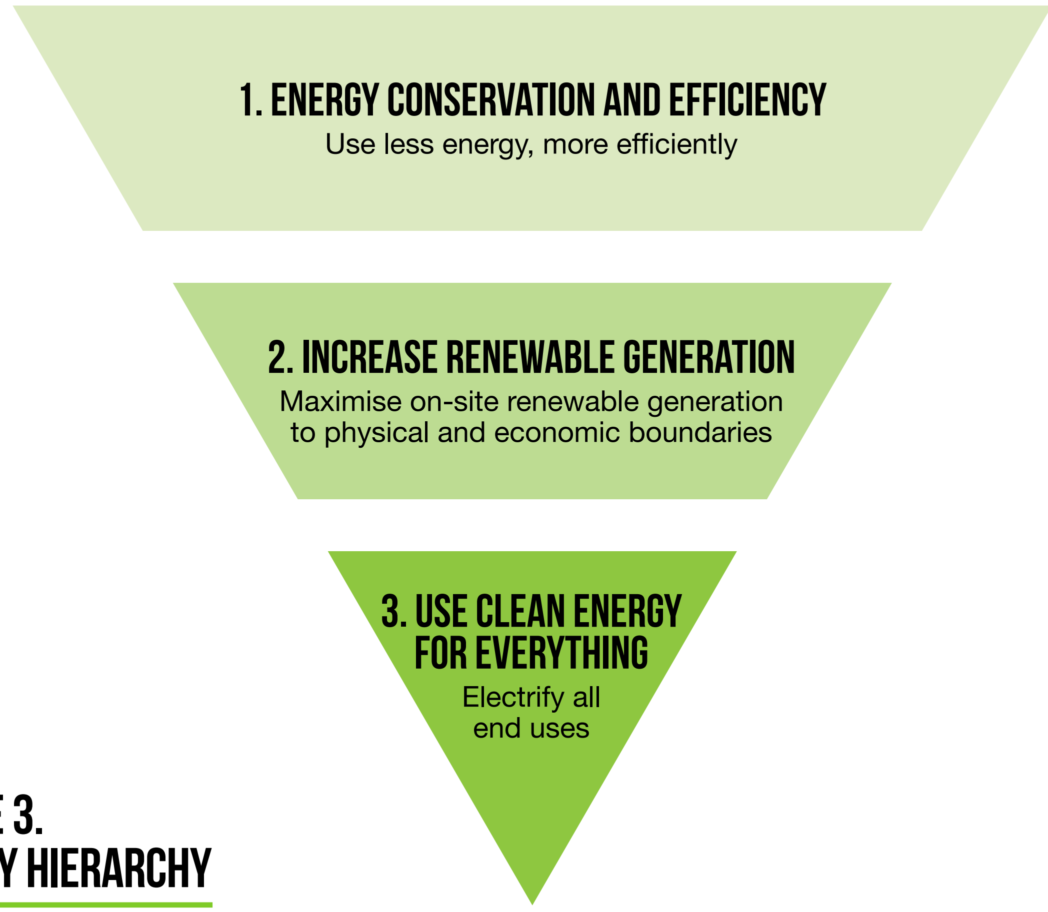


FIGURE 3. ENERGY HIERARCHY

PRIORITISE UPGRADE TO BEST PRACTICE FOR END-OF-LIFE REPLACEMENTS

When major systems approach end-of-life, the economics of upgrades are most favourable. It is therefore essential that appropriate planning is in place to ensure that best practice alternatives are installed when major systems fail. When the upgrade involves a significant change (e.g. from a gas boiler to a heat pump, or major ducting upgrades) this planning can be substantial, time consuming and slow – often involving engaging with multiple new suppliers and trades. Therefore, much of the planning and procurement work needs to be completed as the equipment approaches the predicted end-of-life.

A continuous and proactive approach to planning is necessary, using lifecycle asset management and preventative maintenance approaches. Using asset management and preventative maintenance regimes have been shown to have very positive financial returns (i.e. 545% according to JLL (n.d.)) and there exists a substantial risk that inadequate planning for equipment end of life can result in emergency repairs or replacements that lock-in inappropriate technology for decades.

HEAT PUMPS

Heat pumps are a key technology in the decarbonisation of schools, offering an efficient alternative to replace gas boilers. Large capacity hot water heat pumps operate on the same principle as reverse cycle air-conditioners, and have benefitted from the same technological improvements.

Heat pumps offer substantial efficiency advantages over gas boilers, with typical efficiencies of 400%, compared with ~95% for a gas boiler. Modern heat pumps are more reliable, and able to achieve higher temperatures, than previous generations. Electrifying this (often substantial) energy demand may require infrastructure capacity upgrades, for example to the substation or main switchboard. Expanding PV arrays and adding battery storage may avoid the need for this work.

IMPLEMENT WHOLE-OF-LIFE ASSESSMENTS

Assessing and selecting the optimal upgrade for an existing building typically involves a trade-off between upfront capital costs, and anticipated ongoing cost and benefits. Lifecycle cost assessments allows for the consideration of upfront and ongoing costs and easy to quantify monetary benefits; however, the harder to quantify monetary benefits, and the many non-monetary benefits (or co-benefits) are often overlooked. Using a whole of life assessment framework provides a practical method to account for all of the costs, benefits and risks of a selected technology or service, over the full lifetime of its utilisation. Non-monetary considerations (for example, poor thermal comfort) often drive upgrade decisions, and it is important that the impact of different upgrade options is considered explicitly in the assessment process. An example of a whole-of-life assessment framework for HVAC upgrades in schools is provided by iHub (2021b).

ENSURE COMPLEMENTARY UPGRADES ARE BUNDLED

Many upgrades are naturally complementary, and are either cheaper as a bundle, or enhance the performance when installed as a system. Taking a 'building as a system' approach, whereby the building fabric, heating, cooling, ventilation, control systems and occupants are considered as a single system, can help to ensure that complementary upgrades are not overlooked. A common example of complementary upgrades is to ensure electricians install ceiling fans alongside AC units, or ensuring insulation, draught-proofing and ceiling fans are installed whenever a previously unconditioned space is conditioned.

PICK ALL THE FRUIT AT THE SAME TIME

Simply addressing the low hanging fruit will not achieve the necessary emissions reductions. Holistic retrofits are necessary to achieve deep cuts to emissions and meet decarbonisation targets A major issue with technology-centric (roll-out) approach is that necessary, but more difficult or expensive, upgrades are delayed. When retrofits are bundled together, the more economically attractive technologies can subsidise the more difficult or costly upgrades. In the worst cases, a roll-out program can apply less appropriate and more costly retrofits on schools that are not well integrated with other existing systems or future plans or needs of the whole school system.

REQUIRE MINIMUM ENVELOPE STANDARDS BEFORE ACTIVE COOLING

Providing mechanical heating or cooling without upgrading the building envelope makes reduction of greenhouse emissions more difficult. Any new space that is to be heated or cooled should, wherever practicable, also have ceiling insulation, draught proofing and ceiling fans.

These upgrade are essential to minimise the increase in energy consumption in schools associated with increased mechanical cooling. Ceiling insulation and draught proofing are two of the most cost-effective retrofits available, when applied to mechanically conditioned spaces. They are important to minimise unwanted heat gain or loss, and slow the leakage of conditioned air to the ambient environment. Recent Australian research suggests using ceiling fans in combination with mechanical cooling can reduce the energy used for cooling by 76% (Malik et al., 2022).

NO NEW GAS

New schools should not have a gas connection. A major challenge in the energy transformation facing schools is electrification of gas heating systems. This is a challenging and costly upgrade that can involve the need to upgrade electricity substations and HVAC distribution systems. New schools with gas connections are likely to require similar upgrading in the near future, and a future-focussed pathway would immediately stop constructing schools with gas connections.

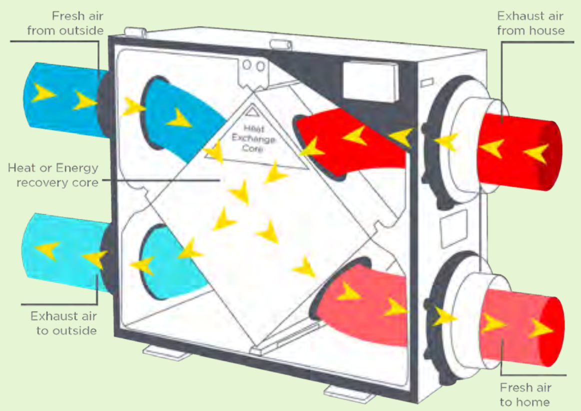
CONTROL VENTILATION

Adequate ventilation is important for healthy buildings, but it must be controlled to avoid energy penalties. Monitoring of carbon dioxide concentration is an effective method to ensure that appropriate ventilation is provided to spaces to ensure indoor environmental quality is satisfactory, without unnecessary energy wastage. However during hot or cold periods, providing minimum ventilation requirements will significantly increase energy usage.

Heat recovery ventilation is a promising technology that uses conditioned exhaust air to pre-heat or cool fresh air. These systems can be retrofitted to spaces with split-system air-conditioning, and will guarantee supply of fresh air with reduced energy requirement for heating of cooling. They are particularly appropriate in locations with more extreme climates. Filtration is another important consideration to improve the resilience of HVAC Systems to outdoor air-pollution events and reduce viral transmission risks.

ENERGY RECOVERY VENTILATION

Energy recovery ventilation (ERV) systems use stale exhaust air to pre-condition incoming fresh air. ERVs transfer both heat and humidity (latent heat), while heat recovery ventilators (HRV) only transfer heat. ERVs use a heat exchange to transfer energy between the air-streams without mixing. For example, during the heating season warm exhaust air would pass the cold fresh air, transferring around 80% of the heat, depending on system efficiency.



ERVs can substantially reduce the energy requirement to maintain comfortable conditions, with estimates of savings up to 50% of heating energy, though this is highly climate dependent.

ERVs do have associated energy costs for the fan energy, however they recover substantial more energy than is consumed. – Typically HRVs recovery around 80% of energy in the exhaust stream. Further, the necessary capacity of the mechanical conditioning system is reduced when combined with an ERV.

Image: www.efficiencyns.ca/tools-resources/guide/ventilation-for-new-homes/

MAXIMISE SOLAR

Schools are very well suited for large solar installations. The energy hierarchy has traditionally recommended installing renewable generation as the final step in an upgrade, however in recent years the cost of solar has fallen dramatically. The alignment between generation and usage in schools, the typical building typologies, and the simplicity of installation make schools ideal sites for the rapid expansion of PV generation. From historic data, it appears most school PV systems are substantially undersized. It is recommended that future roll-out programs install the largest solar PV systems that can be accommodated on the site, within physical and electrical constraints. A staged roll-out of larger systems is preferable to a wide roll-out of smaller systems.

LIMITED APPROPRIATE SCENARIOS FOR ENERGY STORAGE FOR SCHOOLS

Battery storage has limited applications in schools. Battery storage will be a key technology in enabling the energy transition. On its own, battery storage does not reduce greenhouse emissions, however it can help to facilitate greater utilisation of renewable energy, by storing energy generated by renewable for use during periods of low generation (i.e. overnight). Given the close alignment of schools energy use and PV generation profiles, there is limited need for on-site battery storage. However it may be appropriate in situations where:

- Winter heating dominates schools energy use, with a large need for early morning heating before adequate solar PV is available. This could also be met with thermal energy storage.
- Electrification leads to the need for a major upgrade of both substation and main switchboards. Energy storage may provide a cost effective and appropriate alternative solution.

SUMMARY

Society is facing a transformation change. Mitigating the worst effects of climate change will require rapid, deep and sustained reductions in greenhouse gas emissions. Buildings have a key role to play in this transition, and dealing with our existing building is essential. Governments are well placed to lead the way with inspiring examples of deep decarbonisations of portfolios of existing buildings, including schools, hospitals and office spaces.

There are many opportunities to radically improve the energy performance of schools. If done in an integrated way, this can also address the growing concern over indoor environment quality in learning spaces. However, in order to achieve this transition, clear, evidence-backed and urgent pathways must be identified.

The current roadmap offers those administering this transition a number of simple principles to guide the development of these plans, namely:

1. Benchmark and evaluate;
2. Develop SMART goals with clear responsibility;
3. Apply the Energy Hierarchy;
4. Prioritise upgrade to best practice for end-of-life replacements;
5. Implement whole-of-life assessments;
6. Ensure complementary upgrades are bundled;
7. Pick all the fruit at the same time;
8. Require minimum envelope standards before active cooling;
9. No new gas; and
10. Control ventilation
11. Maximise solar.

Each jurisdiction will have different specific challenges, opportunities and pathways, however to address this urgent challenge in the most cost-effective way requires urgent planning.

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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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