Renewable Energy and Enabling Technologies Roadmap for Healthcare

Report #LLHC1-4

QUEENSLAND UNIVERSITY OF TECHNOLOGY

THE INNOVATION HUB
HUB
FOR AFFORDABLE HEATING AND COOLING

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.

The i-Hub Initiatives

SMART BUILDING DATA CLEARING HOUSE

LIVING LABORATORIES - GREEN PROVING GROUNDS

INTEGRATED DESIGN STUDIOS

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i-Hub Healthcare Living Laboratories Sector-wide engagement and impact

The Healthcare Living Laboratories Sector Engagement project will quantify healthcare sector energy consumption, identify the potential for renewable energy technologies to reduce sector energy consumption and cost for HVAC in particular, and propose requirements for optimal integration of renewable energy technologies.

Lead organisation

Queensland University of Technology (QUT)

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01

Executive Summary

The objective of the i-Hub Living Laboratories Healthcare Sector, through which this report was developed, was to enable hospitals and residential aged care facilities to transition to a net-zero carbon emissions (NZCE) future.

This Renewable Energy and Enabling Technologies Roadmap for Healthcare is presented in the form of a practical guide to assist organisations to develop a bespoke renewable energy and enabling technologies and services implementation plan for individual healthcare buildings (that may also be part of a portfolio of assets). This plan – focusing on stationary energy use and supply in healthcare facilities - can be one part of a larger NZCE strategy that would also need to tackle emissions from non-energy sources (e.g. supplies, pharmaceuticals, waste).

Healthcare facilities, for the purposes of this report, are defined as hospitals and aged care facilities. The strategies contained in this document could also be adapted to other types of healthcare facilities, such as general practice surgeries, allied health practices, day surgeries, pharmacies, independent living units etc.

The roadmap consists of two parts: establishment of the framework (through which the plan will be actioned), and examination of the energy system options, as shown in Figure 1.1.

The framework was developed following workshops with the Healthcare Sector Knowledge Sharing Taskgroup. It is structured to include questions and checklists to help organisations to establish internal systems that are needed to enable the implementation of specific actions in their facility/facilities.

The technology options section pulls together information from participating stakeholder groups as well as some outcomes from the three i-Hub activity streams: Living Labs, Integrated Design Studios and Data Clearing House. This section is summarised in Figure 1.2.

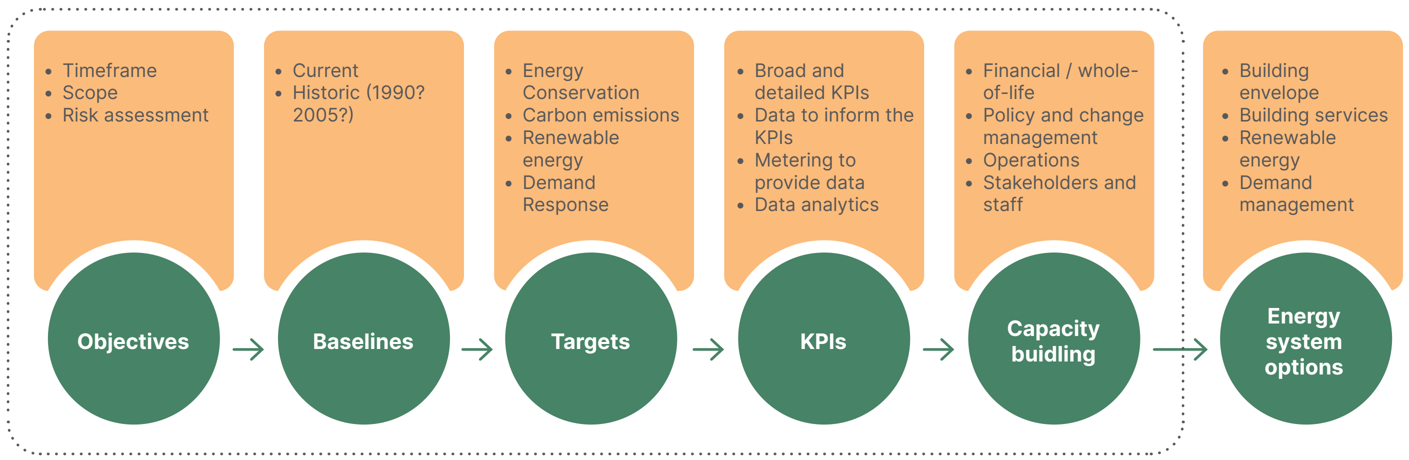


Figure 1.1 **Roadmap structure**

Healthcare Technology Roadmap

	NEW BUILDINGS	EXISTING BUILDINGS	OPERATION & MAINTENANCE	HEALTH CO-BENEFITS	PROCUREMENT
BUILDING ENVELOPE	Design Life / Adaptable Design Passive Design Design for Deconstruction Model for future climates Energy intensity benchmark kW/m^2 Roof solar reflectance Air tightness	Insulation upgrade Glazing upgrade Window shading (ext & int) Energy intensity benchmark kW/m^2 Roof solar reflectance Air tightness	Reed switches (doors & windows) Landscape design and maintenance Energy intensity benchmark kW/m^2 Roof cleanliness Weatherstripping	Reduced Urban Heat Island Effect (UHIE) Resilience (passive survivability) Glare control	Design Brief and Design Guidelines Total Cost of Ownership Asset register Building plan register / storage
HVAC SYSTEMS	HVAC – boiler (elec., heat pump) Variable capacity & airflow Natural & Mixed-Mode Ventilation Zoning & Smart Controls Real time visibility Access for servicing Occupancy schedules (real) Water storage & filtration	HVAC – boiler (elec., heat pump) Locate to minimise UHIE Locate above flood lines Protection (hail, ash, corrosion) Electronics and PCB protection Access for servicing Occupancy schedules (real) Water storage & filtration	Ventilation Mode Outdoor Air Supply % Filters & Air Purifiers Start-up / Shut-down procedures Set points & dead bands Continuous commissioning Predictive maintenance Water compliance	Indoor Air Quality Thermal Comfort Personal Controls	Technology Readiness Level Design Brief Performance guarantee Total Cost of Ownership O&M contract Performance report /data accessibility
LIGHTING SYSTEMS	Optimise natural light Lighting circuits parallel to windows + PE sensors	LEDs Lighting Levels (variable) PE sensors	Lighting Schedules (real) Lamp Replacement Schedule Automated controls + manual override	Visual Comfort Glare control Personal control	Performance brief Total Cost of Ownership
STERILISATION SYSTEMS	AS4187 (new) Electrification potential Impact on site demand (kW) and energy use (kWh)	AS4187 (new) Electrification potential Impact on site demand (kW) and energy use (kWh)	Impact on HVAC system components, sizing and operation	Infection control	Impact on NZE / Renewable Energy Master planning
MONITORING & CONTROL SYSTEMS	Next-Gen BMS	Next-Gen BMS	Digital Twins & Artificial Intelligence Data /Records Management and Analysis Processes	Fast response to occupants Easier reporting	Staff training CEO/Board reporting Third party contracts – data access
DEMAND RESPONSE SYSTEMS	Next-Gen Sensors, controls, connectivity, communication	Next-Gen Sensors, controls, connectivity, communication	Opt in – opt out mechanisms Discretionary loads Income	Supports electricity grid	Internal policy 3rd party aggregator CEO/Board reporting
RENEWABLE ENERGY & STORAGE SYSTEMS	Rooftop PV & inverter capacity Warranty and typical life Chemical & thermal energy storage (batteries, water, thermal mass) Ownership and control mechanism	Rooftop PV & inverter capacity Warranty and typical life Chemical & thermal energy storage (batteries, water, thermal mass) Ownership and control mechanism	PV cleaning schedule Accessibility Area required (size, safety, accessibility) O&M contract or process	Resilience (power outages) Reduced carbon emissions	Onsite availability m^2 Offsite options Acceptability of carbon offsets Total cost of ownership

Figure 1.2 **Roadmap Technology Options**

Table of Contents

List of Figures

List of Tables

02

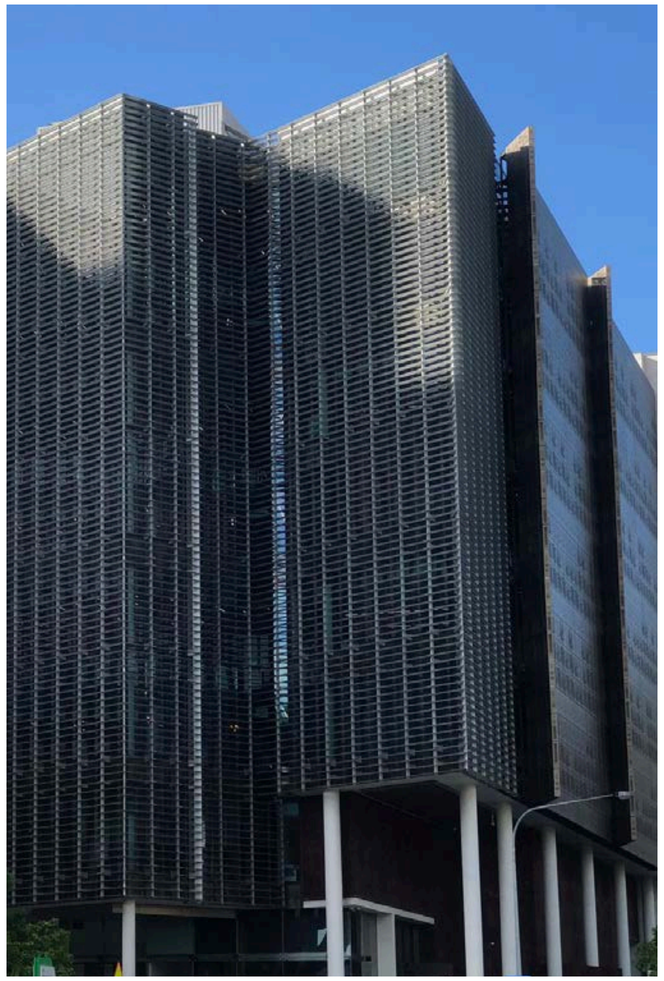
Introduction

A recent publication in the Medical Journal of Australia[1] reported that:

- Australia's healthcare sector is believed to be responsible for 7% of Australia's carbon footprint
- Energy consumption from fossil fuel sources is a considerable part of the sector's carbon emissions, as well as contributing to local air pollution
- Heating, ventilation and air-conditioning (HVAC) are a high contributor to hospital energy demand
- Public hospitals responsible for >50% of public sector energy use in most states and territories
- Net zero carbon emissions goals and renewable energy targets are not uniform
- Although the % of hospital energy use met by renewables is rising (refer to Table 2.1, extracted from the MJA article), it is lagging behind where it needs to be in order to address climate change.

Energy	2016/17	2017/18	2018/19
National baseline renewables	15.7%	17.0%	24.0%
Total hospital energy consumed	4,132,162 MWh	4,213,694 MWh	4,121,911 MWh
Hospital renewable energy produced	13,651 MWh	18,350 MWh	94.415 MWh
Hospital energy % renewable	0.33%	0.44%	2.29%

Table 2.1 **National baseline renewable energy data and public hospital consumption and renewables**



In an effort to address climate change each state and territory has a target year for achieving net-zero carbon emissions (NZCE) and most jurisdictions have interim emissions reduction targets (Table 2.2). Note that the 'targets' may be legislated or aspirational.

State / Territory	Interim emissions reduction target	NZCE target	Renewable energy (electricity) target
ACT	50-60% on 1990 levels by 2025 65-75% on 1990 levels by 2030 90-95% on 1990 levels by 2040	2045	100% by 2030
NSW	50% on 2005 levels by 2030	2050	Nil
NT		2050	50% (elec) by 2030
QLD	30% on 2005 levels by 2030	2050	50% by 2030
SA	50+% on 2005 levels by 2030	2050	100% by 2030 (Actual 62% in 2021)
TAS	NZCE in 6 of last 7 years	2030	100% achieved 2018
VIC	28-33% on 2005 levels by 2025 45-50% on 2005 levels by 2030	2050	50% by 2030
WA	>50% on 2005 levels by mid-2030	2050	Nil

Table 2.2 **NZE and interim emissions reductions targets in Australian states and territories**

1 Burch, H., Anstey, M., McGain, F. 2021. Renewable energy use in Australian public hospitals. Med J Aust 2021:215(4). Doi:10.5694/mja2.51197

As well as contributing to the problem, healthcare services will also be impacted by climate change in multiple ways, as expressed, for example, by Queensland Health (Figure 2.1).

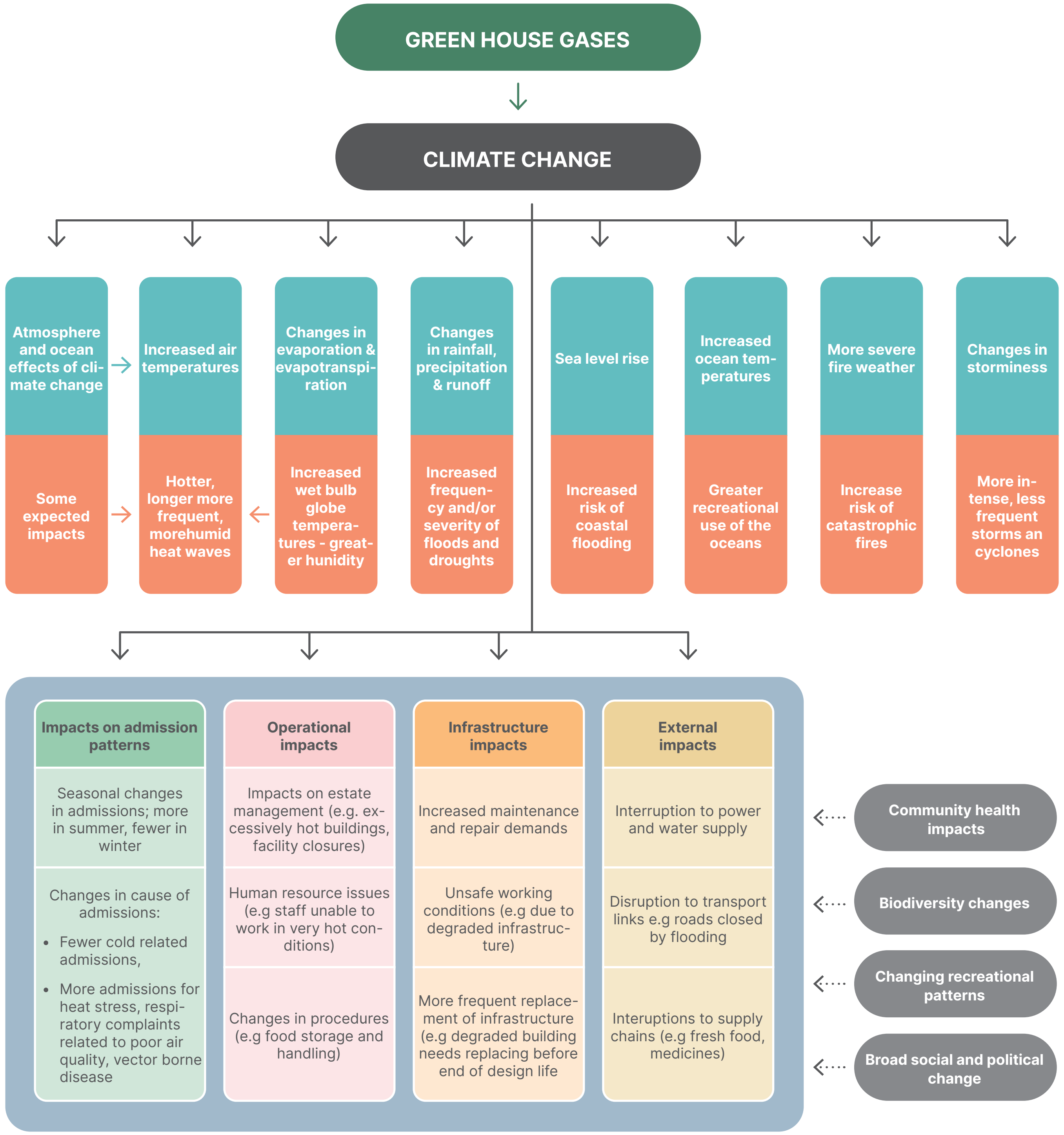


Figure 2.1 **Links between greenhouse gas emissions, climate change and healthcare services**[2]

[2] Queensland Health (2019) Climate change adaption planning guidance Guidelines, Queensland Government

The changing climate is exposing our patients and communities to more frequent and intense extreme weather. Bushfires and associated smoke pollution, floods, heatwaves and drought have had devastating impacts, and they continue to pose unacceptably high risks to public health.

Health professionals are increasingly treating climate-related illnesses, and healthcare services are vulnerable to a range of risks, including an increase in patient demand and threats to infrastructure, workforce and supply chain.

Doctors for the Environment Australia (DEA). 2020.

Moving Australia's Healthcare Sector to 'Net Zero' Emissions by 2040

The objective of the i-Hub Living Laboratories Healthcare Sector, through which this report was developed, was to enable hospitals and residential aged care facilities to transition to a net-zero carbon (NZCE) future[3]. NZCE requires more than setting targets at a jurisdiction level. It requires establishing, at an enterprise level and even at an individual building level, a detailed implementation plan – a plan of action.

This Renewable Energy and Enabling Technologies Roadmap for Healthcare is presented in the form of a practical guide (a 'journey planner' and workbook), to assist organisations to develop a bespoke renewable energy and enabling technologies and services implementation plan for individual healthcare buildings (that may also be part of a portfolio of assets). This plan – focusing on stationary energy use and supply in healthcare facilities, can be one part of a larger NZCE strategy that would also need to tackle emissions from non-energy sources (e.g. supplies, pharmaceuticals, waste).

Healthcare facilities, for the purposes of this report, are defined as hospitals and aged care facilities. The strategies contained in this document could also be adapted to other types of healthcare facilities, such as general practice surgeries, allied health practices, day surgeries, pharmacies, independent living units etc.

[3] Healthcare Sector Renewable Energy and Enabling Technology and Services Framework (REETSEF), i-Hub. April 2020

The development of a building-specific roadmap consists of two main steps:

- Establishing the framework (through which the plan will be actioned), and
- Examining the energy system options

The framework (presented in Section 3) builds on previous i-Hub Living Lab reports and was developed following workshops of the Healthcare Sector Knowledge Sharing Taskgroup. It is structured to include basic information for each subsection, and a checklist or list of questions that need to be considered by the person developing the building specific roadmap. The checklists and questions will help organisations to identify specific actions that can be taken for their facility/facilities.

The stationary energy technical options (presented in Section 4) are based on the technology types and individual technologies evaluated in the i-Hub Living Labs or other i-Hub activities (Integrated Design Studios and Data Clearing House). The focus is on renewable energy and enabling technologies and services, including energy efficiency, demand management and demand response.

The process of developing a building specific roadmap is presented in Figure 2.2. The two steps, combined, should enable organisations to determine, for each facility or for a portfolio, the value of renewable energy for that facility or portfolio. This value – to society, to networks, and to specific facilities – will in many cases be best realised through the combination of efficiency, renewable energy generation and flexible loads in a 'smart' and connected ecosystem (Figure 2.3).

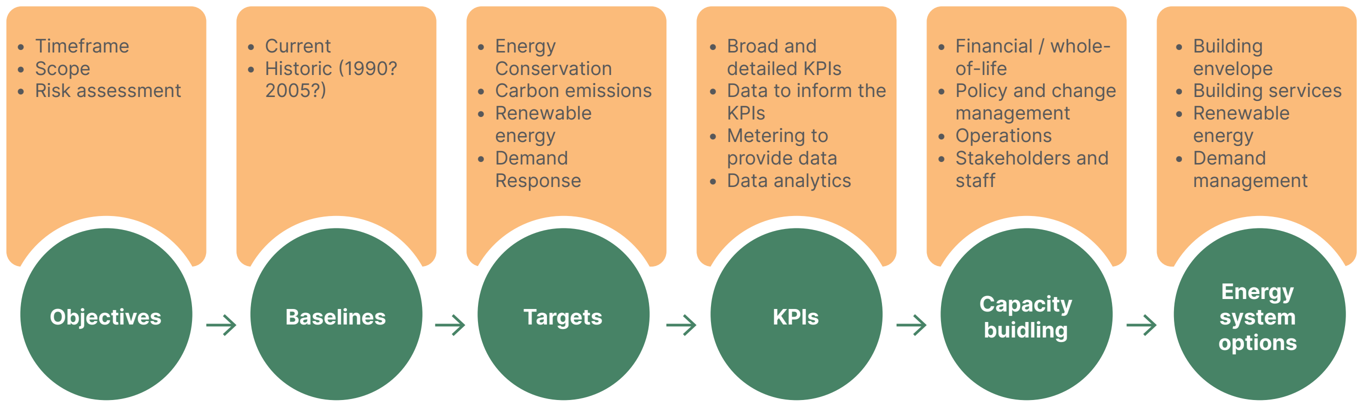


Figure 2.2 **Process of developing a facility specific Roadmap**

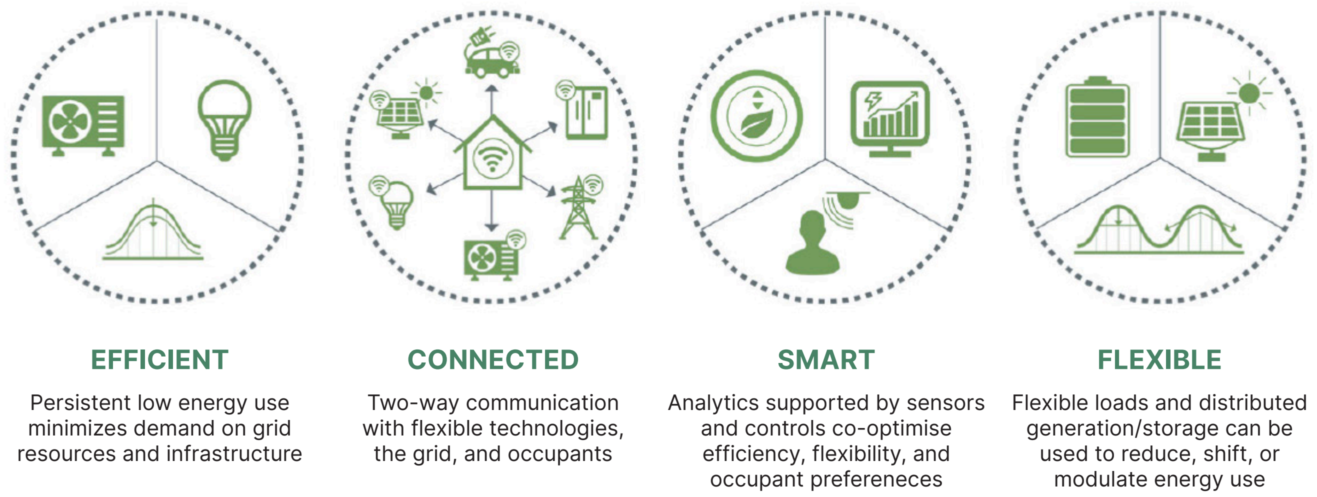


Figure 2.3 **Grid-interactive efficient buildings**[4]

[4] www.energy.gov/eere/buildings/geb April 2019

In addition to the Healthcare Sector Knowledge Sharing Group, this Roadmap is indebted to the Australasian Health Infrastructure Alliance (AHIA). The AHIA comprises the senior asset manager from the public health authority of each Australian state and territory and from New Zealand. It has a commitment to collaborate on the development of best practice and sharing of solutions for common issues in capital and asset management. The AHIA manages the Australasian Health Facility Guidelines that are used for the design of public hospitals throughout Australia. The ESD subgroup of the AHIA (refer to Figure 2.4) was an active participant in the i-Hub Living Lab activities, and its members have provided much information that has informed this Roadmap.

This Roadmap complements the net-zero emissions work and declarations of the following organisations that collectively represent both the asset management and clinical aspects of healthcare facilities:

- Global Green and Healthy Hospitals (GGHH) www.greenhospitals.net
- Health Care Without Harm www.noharm.org
- Climate and Health Alliance (CAHA) www.caha.org.au
- Doctors for the Environment Australia (DEA) www.dea.org.au
- Australian Medical Association (AMA)
- Royal College of Physicians (RACP)
- Royal Australian College of General Practitioners (RACGP)
- Australian College of Emergency Medicine (ACEM)
- Australian College of Rural and Remote Medicine (ACRRM)
- College of Intensive Care Medicine (CICM)
- Australian and New Zealand College of Anaesthesia (ANZCA)
- Royal Australian and New Zealand College of Psychiatrists (RANZCP)

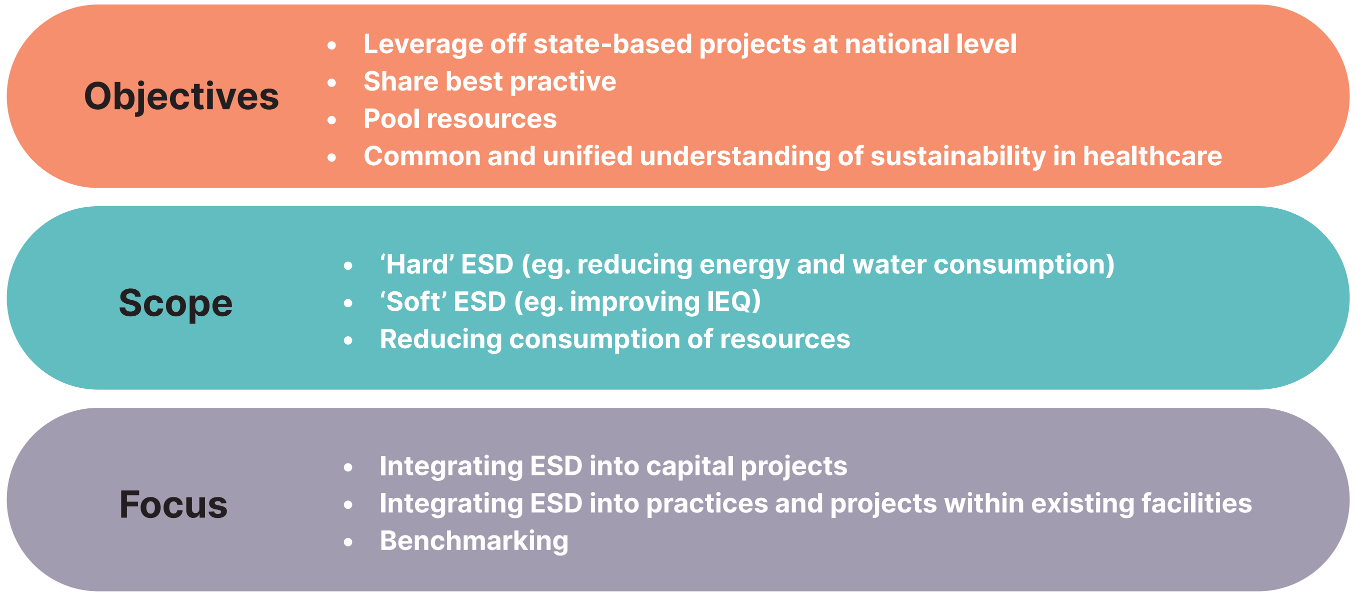


Figure 2.4 **AHIA ESD Subgroup Terms of Reference**

03

Step One: Establish The Framework

Establishing the framework for your action plan is the most important step for success in implementation. This section is intended to guide you through the process. You can use this section like a workbook – recording your answers in the relevant sections, or use the questions as prompts for establishing your own document.

Name of facility:	
Address:	
Type of facility (e.g. hospital, residential aged care, clinic):	

3.1. Establish Objectives, Baselines and Targets

The importance of defining and tracking progress is summed up in the common saying "you can't manage what you don't measure". This section will guide you in articulating the objectives for developing a facility renewable energy roadmap, understanding current energy use, establishing targets, and selecting appropriate key performance indicators to measure progress. The purpose of this section is to enable the development of a more nuanced and detailed approach, beyond a simplistic 'net-zero emissions by [year]'.

3.1.1 What are your objectives?

Answer the questions in Table 3.1 to clearly articulate your objectives for this specific facility.

Questions	Your Response
Why are you doing this roadmap? What (or who) is the main driver?	
What is your timeframe? e.g. long term implications for new facility or major retrofit, or shorter timeframe e.g. maintenance and operation schedule; infrastructure that might need replacement in 10-20 years...	
Is there an immediate risk / urgency? What is driving this urgency? Is it real or perceived?	
Have you done a climate change risk assessment? What opportunities and risks were identified?	
What area / systems / assets are to be included in this roadmap? (whole campus, individual building, portfolio of building assets (in different locations)).	
What internal and external policies, practices, legal or legislation considerations have to be taken into account?	
Can you go beyond these? (i.e. are you bound to minimal performance established by regulations? Are you restricted by government targets?)	

Table 3.1 **Articulate your objectives**

3.1.2 What is your baseline energy use and greenhouse gas emissions?

Answer the questions in Table 3.2 to establish your baseline energy use data. This step will help you understand your current energy use, before setting targets (sections 3.1.3 – 3.1.6), and establishing processes to report on progress towards those targets (Section 3.2). It is particularly important to understand what energy use is included in the baseline and the implications of the selection of a baseline year. For example, if the building is part of a property portfolio, having the same baseline year may be beneficial, for benchmarking purposes. The selected baseline may also need to be normalised (e.g. to account for unusual weather and operations). For tracking progress in meeting your targets, it is equally important to understand what data is needed to determine this baseline; how this data is collected; what further data could be collected to improve knowledge about the facility's energy use; and how this data can be best utilised to inform future actions.

Questions	Your Response
What is your current annual energy use? Consider stationary energy use as well as transport energy use (for fleet vehicles). For greenhouse gas emissions, include Scope 1 (e.g. gas and diesel use) and Scope 2 (electricity) emissions. Your baseline may be reported in annual figures or may be more refined (e.g. monthly).	Year: ...... (indicate reporting unit and timeframe, for each source) ☐ Stationary energy – electricity ______ ☐ Stationary energy – gas ______ ☐ Stationary energy – other (e.g. diesel) _____ ☐ Greenhouse gas emissions (CO2-e) _____ ☐ Renewable energy generation (onsite) _____
What will be your baseline year? (from which targets will be set and progress measured) Is the baseline fixed, or will progress be measured against a movable baseline (annual or periodic e.g. every 5 years)?	Year used for baseline: [year] ..... ☐ Baseline is fixed (yes/no) ☐ Baseline is movable (annual / periodic) ☐ Baseline is historic (e.g. 1990, 2005)
What data is your baseline based on?	☐ Energy bills ☐ Main meters ☐ Sub-meters
What is the data frequency?	
Who is responsible for collecting / presenting / reporting on this data?	
Do you regularly (at least annually) report on your carbon emissions? By what mechanism? (e.g. NGER). To whom? (e.g. Board, Shareholders, Government)	
Do you regularly (at least annually) report on your energy use (e.g. NABERS)? To whom? Is this information used internally to determine actions to improve performance in the next reporting period?	
Is energy demand included in your baseline? Does this facility get billed a demand charge? Do you know what the facility's maximum demand is, per month?	Demand charge: yes / no Maximum demand per month: ____
Do you have a data storage system to store all energy data onsite? Describe your data storage system here (what data is stored and where). (Minimum: NMI[5] information and data) NOTE: Don't rely on third parties. For example, some utilities store data on a 'user dashboard', but this data expires and is lost forever.	
Do you have a data analysis system to enable the data to be used for decision making in operations, maintenance and investment? Describe your data analysis system here.	
Do your data collection, storage and analysis systems meet recognized standards (e.g. International Performance Measurement and Verification Protocol (IPMVP)? Describe here. NOTE: Independent M&V may be required for business activities such as energy performance contracting or savings insurance based offerings. Good M&V protocols also add confidence for internal business decisions regarding energy investments (in buildings, plant, operations etc).	

Table 3.2 **Establishing and understanding your baseline**

[5] NMI = National Meter Identifier – the unique number associated with each electricity meter connected to the network. You should, at a minimum, have a record of each connected meter (the NMI), what circuits are connected to that meter, and a system and process to store the data from each NMI.

3.1.3 What is your carbon reduction target?

Use Table 3.3 to document your carbon reduction target. This requires consideration of the type of target (fixed output, percentage improvement, or both), the scope encompassed by the target, and your organisation's approach to carbon offsets. Note that an annual reduction of 7.6% is required between 2020 and 2030 to meet the 1.5°C Paris Agreement target. Doctors for the Environment Australia (DEA) are calling for an 80% reduction by 2030 and net zero emissions by 2040[6].

Achieving an 80% reduction in healthcare's CO2e emissions by 2030 from 2014/15 levels would be consistent with the emission reductions needed to protect health and sufficient to instigate widespread transformational changes within the sector.

McGain, F, Kayak E, Burch H. A sustainable future in health: ensuring as health professionals our own house is in order and leading by example. Medical Journal of Australia. 2020:213(8):381-.e1.

Questions	Your Response
What is your target year for achieving NZCE? What are your interim targets (measured against the baseline year determined in previous section)[7,8].	☐ NZCE target year ___________ ☐ ___% reduction by [year] _______
If your interim target is less than ~ 80% reduction by 2030, provide justification for this. (The science indicates that a reduction of 7.6% every year is required for the decade 2020 – 2030 in order to meet the 1.5°C Paris Agreement target)[9].	
What energy aspects are in scope? NOTE: It is assumed that the minimum requirement is inclusion of Scope 1 (emissions from energy sources owned and controlled by the facility) and Scope 2 (indirect emissions from energy resources purchased).	☐ Stationary energy (electricity) ☐ Stationary energy (gas) ☐ Stationary energy (diesel / other fuels) ☐ Transport energy (diesel / petrol) – fleet vehicles ☐ Property maintenance energy (e.g. diesel / petrol) ☐ Scope 3 emissions from staff transport ☐ Scope 3 emissions (emissions in goods and services, full supply chain)
Are carbon offsets an acceptable option for your organisation, in meeting carbon targets? The options presented here are based on the IEA Technology Guide[10], and are presented in increasing order (i.e. the least desirable is listed first; the most desirable listed last)	☐ Yes, in any circumstances ☐ Yes, but only if no technology option exists ☐ Yes, if the alternative has a price premium that we are unable to justify ☐ Yes, if it requires too much engineering or procurement effort to implement ☐ No
If you allow for carbon offsets, what procedures will you put in place to account for them? Validate them? Track them over time?	

Table 3.3 **Establishing your carbon reduction target**

3.1.4 What is your energy conservation / energy efficiency target?

In this document, energy conservation refers to reducing the amount of end use energy required to deliver the energy services of a building (e.g. space heating and cooling, lighting, water heating, ventilation etc). Energy efficiency refers to the technical performance of devices (i.e. how efficiently they convert energy sources to provide the required service).

The International Renewable Energy Agency (IRENA) argues that 38% of the carbon reductions needed for the world's energy transition can come from energy conservation and energy efficiency[11]. The GGHH[12] Energy Guidance Document for Members recommends, for existing buildings, an energy conservation / efficiency program that will reduce energy consumption by a minimum of 10% in a single year and will continue to produce ongoing energy savings of 2% per annum, resulting in a further 10% reduction in each five-year period. For new hospitals, GGHH recommends designs achieve building energy performance targets of 320 kWh/m^2 or less.

Questions	Your Response
What are your energy conservation and energy efficiency targets?	☐ Energy conservation target of ___ reduction by [year] ☐ Energy efficiency target of ___ reduction by [year]
Do you have a process whereby passive solutions (e.g. for cooling, for lighting) are considered and evaluated whenever energy services are required? (e.g. evaluating the benefits of additional insulation and shaded for windows, before considering split AC systems)	☐ Yes (explain the policy or process) ☐ No
Do you have a building envelope energy efficiency target for space heating and cooling? (e.g. kW/m^2)	☐ Yes, ____ kW/m^2 ☐ No ☐ Don't know
Do you have a minimum energy efficiency requirement for all space heating and cooling equipment? How was this minimum requirement determined (e.g. NCC2019)? Is this minimum requirement embedded in Design Briefs and Procurement Procedures?	Minimum COP / EER ___________ Basis for this minimum: ___________ ☐ Embedded in Design Briefs ☐ Embedded in procurement processes
Do you have a minimum energy efficiency requirement for lighting?	Minimum lumens/Watt Basis for this minimum: ___________ ☐ Embedded in Design Briefs ☐ Embedded in procurement processes
Do you have a minimum energy efficiency requirement for all pumps and fans?	Minimum requirement ___________ Basis for this minimum: ___________ ☐ Embedded in Design Briefs ☐ Embedded in procurement processes
Do you have a minimum energy efficiency requirement for water heaters?	Minimum requirement ___________ Basis for this minimum: ___________ ☐ Embedded in Design Briefs ☐ Embedded in procurement processes

Table 3.4 **Establishing your energy conservation and energy efficiency target**

3.1.5 What is your demand management / demand response target?

Demand management (DM) in this report refers to the monitoring of site monthly peak demand and the management of loads to limit this peak in order to reduce demand charges from the network. Demand-side management (DSM) is the term used by the utilities to encourage customers to reduce their energy use during peak hours, or to move the time of energy use to off-peak times (called load shifting). Demand response (DR) is the voluntary reduction of a site's electricity consumption from the network, by either load shedding or providing on-site generation. DR can assist with the stability of the electricity network during times of peak demand by allowing the market operator more flexibility to balance the supply and demand on the electricity network. DR is expected to play an important part of the future electricity network as more renewable energy and storage enters the system, with the drive towards a decentralized zero emissions network. Participation in DR markets can generate revenue as compensation for these services and/or reduce your electricity costs. An evaluation of DR options for healthcare facilities can be found in complementary i-Hub report: Net Zero Energy and Resilient Hospitals – considerations of future climate, pandemics, and demand management.

Table 3.5 may help you understand your current and future options in DM and DR.

Questions	Your Response
Do you know your site's demand charge? What is your site's peak demand (monthly)? Do you have a trigger point for demand management? What demand management actions are triggered at this point? E.g. HVAC control, Pump control ...	Demand charge ___$/kW Site peak demand _____ Trigger point ___kW DM Actions:
What is your site's total generator capacity? (refer to KPI Table 3.7 for more detailed generator information that will be required)	
Which DR options are you currently participating in? Such participation may be direct (managed by you) or indirect (managed through a third party aggregator)	☐ Load Shedding (turning off loads) ☐ Using onsite generators to reduce grid load ☐ Using onsite generators to feed to the grid ☐ Through DNSP for demand charge reduction ☐ Through energy retailer for NEM Spot Market response to high price events ☐ Through AEMO registration ☐ Through a third-party aggregator
Which DR participation options have you investigated?	☐ Load Shedding (turning off loads) ☐ Using onsite generators to reduce grid load ☐ Using onsite generators to feed to the grid ☐ Through DNSP for demand charge reduction ☐ Through energy retailer for NEM Spot Market response to high price events ☐ Through AEMO registration ☐ Through a third-party aggregator
How is your current DR participation monitored, reported? How are any financial benefits accounted for?	
What internal processes are required to evaluate DR participation options? (Who? How?)	

Table 3.5 **Establishing your demand management / demand response target**

3.1.6 What is your renewable energy target?

The overall strategy recommended by the GGHH Energy Guidance Document for Members includes (i) renewable sources for at least 5% of total energy demand; (ii) purchase and/or generate renewable energy; and (iii) investigate onsite RE in all new building plans.

Australia's healthcare facilities can aim for much more than that, especially considering the low cost of rooftop PV and high solar radiation. A key limiting factor for rooftop PV however can be the available roof space, especially for multistorey buildings such as major hospitals. There are multiple pathways to achieving 100% renewable energy however. Use Table 3.6 to guide you through the process of establishing and achieving a target.

Questions	Your Response
What is your RE target? This may be in terms of the size of rooftop PV system (in kWp); or in output of such a system (in kWh/year) or as a % of building energy use.	___ kWp ___ kWh/year or ___ kWh/day ___ % of building energy use
What is the timeframe for achieving this target?	[year]
Does this target relate to just one building, or all buildings on a particular campus/site, or to all of your organisation's building assets?	
How will this target be met? This may be through renewables installed on your building and/or the ownership of an offsite solar farm; or through a power purchase agreement (PPA) ; or through the grid.	☐ Onsite renewables [____ kWp or MWp____] ☐ Offsite renewables [___ kWp or ___ MWp] ☐ Power purchase agreement ☐ Through the grid (i.e. state based increases in % of renewables on the grid)
What mechanism do you have to evaluate the relative advantages, disadvantages and tradeoffs between these options? (onsite/offsite renewables; PPA, grid)	
How will progress towards meeting your targets be measured? E.g. do you have the metering in place to record rooftop solar output (kWh) and building total use (kWh)? Do you have systems in place to audit the PPA? To record the annual renewables share of the grid?	
Have you undertaken a feasibility study to determine the roof area that could be available for PV; what size PV system could be accommodated, and if any additional factors needs to be considered (e.g. roof structure capacity to bear the additional load; wiring of the system to the main switch board (MSB); site connection constraints; DNSP connection requirements)	
What mechanism will you use to evaluate the financial feasibility of investing in onsite/offsite renewables and/or entering a PPA?	☐ Benefit:cost analysis ☐ Internal rate of return (IRR) ☐ Return on Investment (ROI) ☐ Simple payback period ☐ Total cost of ownership (TCOO) ☐ Net Present Value (NPV)
Do you have a process in place to evaluate the impact of all future building and energy technology purchase and operation actions on this renewable energy target?	

Table 3.6 **Establishing your renewable energy target**

3.2. Select Key Performance Indicators

The old adage "You can't manage what you don't measure" is especially true with regards to energy. It has been typical in the past for healthcare facilities to report via fairly basic energy use intensity (EUI) indicators such as kWh/bed/year or kWh/m²/year. Such KPIs, while useful for understanding annual trends, have limited usefulness for tracking movement towards NZCE goals. They also don't enable tracking the uptake or utilisation rate of renewable energy, or trends in site peak demand. More nuanced KPIs are presented in the following sections, enabling you to select a suite of KPIs to match your goals.

Once you have selected KPIs suitable for your context, you then need to consider what information source/s you will need to report on each of the KPIs. For example:

- What sensors, meters and submeters are required? Where? What measurement interval will they record (e.g. minute, 5 minute, 30 minute, hourly).
- How will this data be collected and stored?
- How will the data be analysed? What graphs or data analytics do you need for informed decisions?
- Who will be responsible for this task? And how will they be resourced?

3.2.1 Energy KPIs for whole of building / campus

The KPIs in Table 3.7 relate to a whole building or campus. The KPIs are grouped into three main categories:

i. those relating to energy use and impact on the network;

ii. those relating to backup power, renewable energy and energy storage; and

iii. those relating to occupant health

Select the KPIs most appropriate for your context and your goals. You may consider starting with a limited set of KPIs, and plan to add more KPIs over time, to improve the delivery of health services.

[6] Doctors for the Environment Australia. 2020. Moving Australia's Healthcare Sector to 'Net Zero' Emissions by 2040

[7] NHS Carbon Reduction Plan 2020: NHS Carbon Footprint (emissions under NHS direct control), targets net zero by 2040, with an ambition for an interim 80% reduction by 2028-2032. The NHS Carbon Footprint Plus (wider supply chain) aims for net zero by 2045, with an ambition for 80% reduction by 2036-2039.

[8] SA Health (scope 1 and 2 direct emissions) aims for a 50% reduction by 2026 and 80% by 2030, from a 2005 baseline. Note that most of this is assumed to be met through grid decarbonisation in SA. Core scope includes stationary energy (whole of government contract sites and lease sites); transport (fleet cars and emergency services and other); water and waste (from owned facilities only); refrigerants; medical gases; construction (hospitals and carparks); embodied CO2 for major equipment (PCs, passenger cars, ambulances), and food (for patients only). Non-core scope includes other transport (patient, visitor, staff) and other procurement (freight transport, pharmaceuticals, bio medical equipment, business services, paper products).

[9] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C. 2018. https://www.ipcc.ch/sr15/

[10] Refer to IEA Clean Technology Guide which provides guidance on 'reasonableness' regarding the potential application of carbon offsets. It is a useful evolving document for tracking technology solution maturity. www.iea.org/articles/etc-clean-energy-technology-guide

[11] IRENA (2021), World Energy Transitions Outlook – 1.5°C Pathway. www.irena.org/publications

[12] Global Green and Healthy Hospitals (GGHH) www.greenhospitals.net

KPI	Explanatory comments
Energy use intensity EUI ☐ kWh/m²/yr ☐ kWh/bed/yr ☐ kWh/separation/yr ☐ Other …	Total annual energy use (specify if all stationary energy sources or not) divided by a specific metric such as floor area, number of beds, or separations (as per NABERS reporting requirements) WARNING: ensure that your energy use is the total consumption, and not the net consumption (total – renewable energy generation)
Energy reporting ☐ Annual NABERS Healthcare Energy & Water Rating ☐ Other annual reporting […]	An annual rating enables tracking of energy (and water use) over time (self-comparison), and some level of benchmarking with similar facilities.
Carbon intensity ☐ kg CO2-e (per m² or bed or …)	Use the same metric as per EUI (e.g. floor area or beds).
Site energy ☐ Monthly Peak Demand (kW or MW) ☐ Electric Load Factor (ELF) ☐ Load shape ☐ Grid Purchase Ratio (R_{grid})	Peak demand is the highest 30minute peak in electricity demand, per month. Information required includes timing (time of day), seasonality, load shape, and the load factor. ELF is the average electric load divided by peak electric load (day | month | year). Load shape is the load as a function of time (usually graphed) – to determine temporal changes in load (time of day, day of week, month, season). R_{grid} is the ratio of electrical energy purchased from the grid to the total electrical energy used by the system over a period of time.
Demand response ☐ Demand response capacity (kW) ☐ Grid support capability	The total load (kW) available for supporting electricity grid needs. This may be demand response capacity (i.e. ability to reduce loads and/or switch loads to generators), or network support services (e.g. using generators to provide frequency support to the grid) Understand whether these capabilities are automated or manual.
Onsite backup generator/s ☐ Capacity ☐ Availability ☐ Load design ☐ Onsite fuel storage ☐ Fuel supply chain resilience ☐ Fuel carbon intensity	Electrical capacity of backup generators plus their availability. Are generators grid-synchronous or not? What loads are covered by the generators under emergency conditions? Is there spare capacity? What are the network connection conditions for these generators? What fuel storage capacity is on site (in litres, and in generator run time)? How often is this fuel replaced and/or refreshed?
Renewable Energy	
☐ Renewable energy self-consumption rate	1. % of onsite renewable energy consumed by the site (by month, season or year)
☐ Renewable energy fraction – onsite. Also called PV Generation Ratio (RPV,GEN)	2. % of site energy consumption that is powered from onsite renewable sources
☐ Renewable energy fraction – from PPA	3. % of site energy consumption that is powered from offsite renewable energy through a power purchase agreement or similar
☐ Renewable energy fraction – from the grid	4. % of site energy consumption that is renewable energy, as a function of a green grid
☐ Time of day renewables % (renewables generation v load profile)	5. The time of day ratio of renewables generation v energy load can be used to calculate time-of-day carbon intensity (by looking at electricity use on the National Electricity Market)
☐ Load Cover Factor (Y_{load})	6. Load Cover Factor is the relation between the electricity produced on-site and directly used, and the total electrical energy use[13]
☐ Supply Cover Factor (Y_{supply})	7. Supply Cover Factor is the relation between the electricity produced on-site and directly used, and the total renewable electricity produced on-site.
Onsite energy storage ☐ Electric (kWhe) ☐ Thermal (kWhth) ☐ Chemical (e.g. litres diesel) ☐ Chemical (batteries) Capacity; Charge and discharge rate	Record of the stored energy (total), plus charge / discharge rate; and hours/days of supply (at the typical rate relative to each source)
Health indicators ☐ Infection rates ☐ Average length of stay ☐ Staff absences / turnover ☐ Satisfaction ratings (staff, patient/ resident, visitors)	Tracking health indicators can be a good way of determining if the building is supporting occupant health or inhibiting it. Changes to overall infection rates (e.g. patients) can be an indication of building ventilation effectiveness. Post-occupancy evaluations (e.g. comfort surveys) can help determine if building design and operation are meeting the intent (of energy efficient, comfortable and healthy indoor environment)
Patient / Resident Vital Signs ☐ Temperature, heart rate, blood pressure, respiratory rate, blood oxygen saturation, hydration ☐ Medication level (esp. pain) ☐ Anxiety / stress / Cognition	In some healthcare settings, e.g. residential aged care, it may be useful to have in place strategies for clinical notes to be considered in the light of building services. For example, research indicates that visual, thermal and acoustic discomfort or comfort can impact on medication levels for pain control, as well as stress and cognition

Table 3.7 **Whole of Building Energy KPIs**

[13] Load Cover Factor and Supply Cover Factor are KPIs listed in Technical, economic and environmental performance KPIs definition. 2020. EU Tri-HP Project.

3.2.2 Energy KPIs per building service and clinical service

More nuanced KPIs, at a building services level, can help focus attention on where the carbon reduction strategies can be targeted (e.g. where the largest reductions can be achieved, or the easiest, or the most cost effective). Table 3.8 focuses on KPIs that could be used to better understand and manage key services in healthcare facilities: HVAC, hot water, steam, and lighting. Depending on the metering and submetering available, it may also be possible to report these KPIs based on clinical services (e.g. emergency department, operating theatres, wards, outpatients, specialist suites, mortuary, back of house, catering, laundry etc). This level of detailed reporting may provide an opportunity to engage clinical staff in carbon reduction strategies specific to their work area.

KPI	Explanatory comments
EUI per building service (kWh/m²/ day or month) ☐ Space heating ☐ Space cooling ☐ Ventilation ☐ Domestic hot water ☐ Steam / sterilisation ☐ Internal lighting ☐ External lighting	HVAC, hot water, sterilisation and lighting account for the bulk of a facility's energy use. Understanding the specific contribution of each of these separately, will help to identify opportunities for reductions (e.g. when equipment needs replacing) or to present a business case for investment (e.g. in HVAC or lighting controls, or the electrification of heating, or alternative sterilisation strategies)
Energy efficiency of HVAC system	
☐ W/m²	1. Energy demand of the complete HVAC system
☐ COP/SCOP (heating efficiency)	2. Heating efficiency
☐ EER/SEER (cooling efficiency)	3. Cooling efficiency
☐ kWh/m²*CDD	4. Normalised energy use by cooling degree days
☐ Mechanical cooling ratio	5. Ratio of mechanical cooling hours to fee cooling hours
☐ W/gpm	6. Ratio of hydro system (water, refrigerant) power to the flow rate transported
☐ Pump Energy Index (PEI)	7. Ratio of electrical input power of reference pump to input power
☐ Integrated part load value (IPLV)	8. Cooling part-load efficiency of a chiller
☐ Fan energy efficiency	9. Ratio of output power to input power
HVAC settings / assumptions ☐ Heating and cooling set points ☐ Dead bands ☐ Adaptive or fixed comfort model ☐ Assumed met and clo for occupants ☐ Individual control (private rooms) ☐ Occupant control (share spaces) ☐ Central control (BMS/ FM)	Energy efficiency can be enhanced through optimising space temperature control. This means careful consideration of the heating and cooling set points (relative to the climate, the specific zone, and the occupants). Determining the highest acceptable space temperature (before cooling) and the lowest acceptable space temperature (before heating) requires understanding and documenting the different clothing (clo), and metabolic rates (met) of staff, patients or residents, and visitors, as well as the thermal comfort 'rationale' - fixed or adaptive comfort. The 'dead band' is the temperature range between heating and cooling. Healthcare facilities should not automatically use HVAC settings typically used in office environments.[14]
Energy efficiency of Hot water ☐ SCOP	The efficiency of converting an energy source into hot water is measured by Seasonal Coefficient of Performance (SCOP).
Energy efficiency of steam / sterilisation ☐ Electrical maximum demand (kVA) ☐ Heat Load (kW)	Meeting the requirements for AS4187 may present an opportunity for moving away from gas for steam generation. Implementing an all electric CSSD will impacdt on electrical maximum demand (that may require a new transformer and main switch board) as well as heat load (requiring a chiller upgrade). Increase outside air, and new decontamination exhaust and AHU systems may also be required.
Energy efficiency of lighting ☐ Lighting efficiency (lm/W) ☐ Lighting power density (W/m²)	Lighting efficiency can be measured by both its output (lumens per watt) and by its power density (watts per square meter).

Table 3.8 **Building and Clinical Energy KPIs**

[14] Space temperature set point and control bands. HVAC&R Skills Workshop Module 84. AIRAH. August 2015

3.2.3 Indoor Environment KPIs

Table 3.9 presents a range of KPIs that can be used to quantify thermal, visual and acoustic comfort, and indoor air quality. Health and energy are closely aligned, and the purpose of these KPIs is to ensure that health KPIs are not neglected when addressing energy efficiency and carbon reduction targets. Ideally actions, whether implemented by facilities management or clinical staff, need to be selected to provide multiple benefits whenever possible: for energy conservation, energy efficiency, greenhouse gas reductions and improved occupant and patient health and safety.

KPI	Explanatory comments
Thermal comfort ☐ Temperature ☐ Relative Humidity ☐ Control (personal**)**	
Indoor air quality ☐ Air flow rate ☐ Carbon dioxide (CO_2) ☐ Carbon monoxide (CO) ☐ Nitrogen dioxide (NO_2) ☐ Ozone (O_3) ☐ PM2.5 and PM10 ☐ TVOC (Volatile Organic Compounds)	
Acoustic comfort ☐ dB ☐ Speech intelligibility ☐ Sound transmission class (STC)	
Visual comfort ☐ Average daylight factor ☐ Continuous daylight factor ☐ Luminance contrast ☐ Colour Rendition Index (CRI) ☐ Control (personal)	
Post Occupancy Evaluation ☐ Staff ☐ Patients / residents ☐ Visitors	
Occupant clothing insulation (clo) ☐ Staff ☐ Patients / residents	Occupant clothing levels (clo) and metabolic rates (met) are used in establishing HVAC operation parameters. Thermal comfort is impacted by assumptions rather than actual clo and met levels for different occupant cohorts (staff, patients / residents, visitors). This has implications for HVAC set point temperatures and operation (who has control, in which zones).
☐ Records are kept of actions taken to address occupant concerns or building services alarms.	

Table 3.9 **Options for Indoor Environment KPIs**

3.2.4 Resilience KPIs

Climate change is expected to impact Health activities in three main ways: in planning and operations, in health service demand; and in indirect impacts (e.g. power and water supply). Table 3.5 presents a range of resilience KPIs, focusing on the resilience of a building, its energy systems and the energy infrastructure to which it is connected - to be able to provide safe and healthy indoor conditions in the event of protracted hot weather or heat waves. This is an emerging field internationally, and the examples presented here are from the International Energy Agency Annex 80 – Resilient Cooling.

KPI	Explanatory comments
Indoor Environment Quality	
☐ Indoor Overheating Degree (IOD) + Ambient Warmness Degree (AWD) + Overheating Escalation Factor (OEF)	Statistical metrics that indicate the overheating of an indoor space, the heat stress of an outdoor environment, and the proportion of both. IOD corresponds to the weighted unmet hours criteria defined by EN TR 16789-2:2019 and the weighted exceedance hours defined in ASHRAE 55 2020. Can be applied to controlled, hybrid and free-running buildings, and to all kinds of cooling strategies and technologies.
☐ Unmet Hours (hrs/ month)	The number of hours of occupation outside a zonal comfort criterion within a given time of zone occupation. Can be applied to controlled, hybrid and free-running buildings, and to all kinds of cooling strategies and technologies. Recommended to be expressed as hours per month.
☐ Passive Survivability	The ability to maintain safe indoor thermal conditions in the absence of active cooling, e.g. air conditioning. Based on a definition of survivable indoor conditions (which will depend on the climate and type of building and its occupants).
☐ Thermal Autonomy (% of occupied hours)	The ability of a building to provide acceptable thermal comfort, without mechanical heating or cooling.
Energy Metric	
☐ Annual energy demand intensity kWh/(m^2.yr)	Annual cooling load per conditioned floor area Annual heating load per conditioned floor area Annual cooling source energy per conditioned floor area Annual heating source per conditioned floor area
☐ Annual cooling source energy saving intensity kWh/(m^2.yr)	The annual reduction of source energy for cooling, per conditioned floor area, that can be achieved b a specific (resilient) cooling measure, against a conventional cooling solution without this specific (resilient) cooling measure.
HVAC and Grid Metrics	
☐ Seasonal Energy Efficiency Ratio (SEER) ☐ Seasonal Coeff. Of Performance (SCOP)	The seasonal ratio between the useful cooling output of a refrigerator, chiller or air conditioner system, to its power input (for the full cooling period). Applies to a whole system (not just the compressor). Can be applied to active cooling technologies and automated passive technologies (e.g. fans, circuit pumps). SCOP is the same, only applying to heating.
☐ Reduction in peak source power demand intensity (W/m^2)	The annual reduction of source peak power demand, relative to the floor area, that can be achieved by a specific (resilient) cooling measure, against a conventional cooling solution without this specific (resilient) cooling measure. Could be extended by quantifying number of annual hours during which grid power demand exceeds grid power supply.
☐ Recovery time	The time required to recover from a failure (i.e. to meet the designed thermal conditions after a power failure)

Table 3.10 **Resilience KPIs**

3.2.5 Health co-benefits KPIs

Similar to indoor environment KPIs, actions, whether implemented by facilities management or clinical staff, need to be selected to provide multiple benefits whenever possible: for energy conservation, energy efficiency, greenhouse gas reductions and improved occupant and patient health and safety.

Table 3.11 presents KPIs that you might find useful for your particular facility. The reporting of health KPIs as well as energy KPIs can help in presenting a business case for change, financially benefitting clinical and facility management budgets, and assisting both facets of a healthcare business to achieve its carbon reduction targets.

KPI	Explanatory comments
☐ WELL Building Standard V2 ☐ Green Star As Built rating (Indoor Environment Quality) ☐ Other	
☐ Infection rates	
☐ Average length of stay	
☐ Pain medication level	
☐ Staff absences	
☐ Staff turnover	
☐ Staff satisfaction (with the built environment)	
☐ Patient / resident satisfaction (with the built environment)	

Table 3.11 **Health benefit KPIs**

"We don't even have the most basic sub-metering for energy management let alone occupancy sensors and the sensors needed to manage indoor air quality"

Workshop Participant

3.3. Build your capacity to implement actions

This section provides some guidance on how to build your organisation's capacity to implement actions that lead to carbon emission reductions. It encompasses enterprise risk management, finance instruments and skills development.

3.3.1 Enterprise Risk Management

The setting of NZCE targets requires leadership at the Board and Executive Management level, embedding NZCE into strategic planning. Net zero becomes embedded in the Enterprise Risk Management process and all sectors of the organisation are empowered to develop, deploy, monitor and report on the actions required to achieve those targets. It is the senior executive that should assign roles and responsibilities for achieving the targets, giving appropriate authority, staffing and budgets to do so.

Developing a comprehensive risk management plan is part of that process. Table 3.12 and Table 3.13 summarise some of the risks and hazards that relate to healthcare energy systems. This information should be used to incorporate into the organisation's Risk Register (if not there already).

The risks then need to be classified in order to determine how best to manage them (and what department within the organisation could take ownership). Useful risk classification structures include

- PESTLE (Political, Economic, Socio-Cultural, Technological, Legal, Environmental)
- TECOP (Technical, Economic, Commercial, Organisational, Political)

Each risk then needs to be analysed (likelihood, consequences, level of risk), evaluated (ranked) and risk management options assigned (avoid, reduce, transfer, share).

A key part of this process is undertaking stakeholder mapping, documenting all stakeholders and their respective interest in achieving the NZCE goals. As mentioned previously in this report, it is important to include both asset / facilities management staff and clinical staff / practitioners in this mapping and the resultant organisational structures put in place to achieve net zero emissions. Patients / residents and their visitors are additional key stakeholders, as is society in general.

It is likely that the public health department in your state has undertaken significant work in this area already, that you can use to develop your building / campus level Risk Management Plan. An example is Queensland Health's 2019 Climate change adaptation planning guidance Almanac (a compendium of information on climate change risks, impacts and adaptation options for each region in Queensland), and Guidelines (for developing a Climate Change Risk Management Plan).

Major System	Sub-system
Structural System	Materials and structural systems used in the building
Existing service systems	Electrical system
	Fuel storage facility
	HVAC system
Planning systems	Demand planning
	Policy and procedure development
	Capability and service planning
	Energy planning
	Procurement planning

Table 3.12 **Healthcare energy systems impacted by climate change[15]**

[15] Derived from QLD Health Climate change adaptation planning guidance (2019) and AIRAH Resilience Checklist (2021)

Hazard category	Specific hazard example	Impact on energy systems
Heat related	Increase in mean temperature and extreme heat (frequency, duration, magnitude and intensity of heat waves), impacting both daytime and night time temperatures	Building/s overheating – health impact / potential heat stress for occupants Increased cooling load / requirement Increased energy demand (& cost) Heat island effect for HVAC&R equipment (reduced performance and energy efficiency) Increased pressure on site energy capacity Increased risk of HVAC&R failure Reduced network capacity ~ increase in load-shedding / blackouts
Relative Humidity related	Increase in RH	Decrease in effectiveness of some cooling systems (e.g. evaporative coolers, ceiling fans) Decrease in thermal performance of building Higher dew point, and hence mould and mildew on building materials and HVAC&R ducts
Rainfall related	Disruption to utilities e.g. loss of mains power Inundation of facilities (e.g. plant room and essential services) Flooding leading to damage / preventing transport access	Reliance on backup systems (with impacts on building services not on critical or essential services circuits) Damage to HVAC&R equipment Loss of power Limited access for service providers Inability to secure further diesel supplies for generators
Bushfire related	Increase in air particulates	Smoke penetration into building through unsealed areas (infiltration) or HVAC&R systems Accumulation of ash in HVAC&R systems...
Drought related	Increase in dust	Dust penetration in unsealed areas and fouling of filtration systems / cooling towers
Storm / cyclone related	Increase in storm intensity (wind and hail) Increase in cyclone frequency or intensity	Increased damage to HVAC&R assets, utilities and services Increased damage to building structure (esp. roof, guttering, windows) Reduced integrity of roof or ductwork structures (leakage)
Airborne Contaminants		Increased ventilation requirements Increased need for air purification and infection control Airborne contaminants penetration through HVAC&R systems

Table 3.13 **Climate-related hazards and energy associated impacts for healthcare facilities[16]**

[16] Derived from QLD Health Climate change adaptation planning guidance: Almanac (2019) and AIRAH's Resilience Checklist (2021)

3.3.2 Financial mechanisms

The two key financial issues that prevent energy efficiency, renewable energy and other technology upgrades have been identified as:

- Simplistic assessments based on capital costs
- Organisational divisions between capital and operating budgets

> *Assessing and selecting alternative technologies is a multi-objective optimisation problem, with competing constraints. Economically, comparison typically involves a trade-off between upfront capital costs and anticipated ongoing benefits. A Whole of Life Assessment process provides a practical framework to account for all of the costs, benefits and risks of a selected technology or service, over the full lifetime of its utilisation... A Whole of Life assessment should have a future focus, and explicitly consider relevant future plans for the site, building and systems. Common relevant considerations may include plans for net-zero emissions, removal of gas infrastructure, or installation of large renewable generation sources[17].*

The components of a whole-of-life (WOL) assessment are illustrated in Figure 3.1.

A WOL approach is consistent with some health departments already. For example, Queensland Health highlights the need to plan for expected future local climatic conditions (e.g. 2030, 50, 70) and invest in retrofitting and more resilient construction design to prevent or reduce future damage and the potential for disruption. It highlights the importance of considering the sustainability of investment decisions, including WOL costs (e.g. where materials sourced, how they are manufacturered, and where they will be disposed) as well as benefits such as reduced insurance premiums and increased workplace satisfaction and staff retention. The credit rating company Moody's has advised Queensland Treasury that health-related expenditure in the state is likely to increase in future as a result of climate change, putting the state's AAA credit rating at risk (Moody's 2018), therefore possibly leading to tougher financial regulation and cuts in spending.

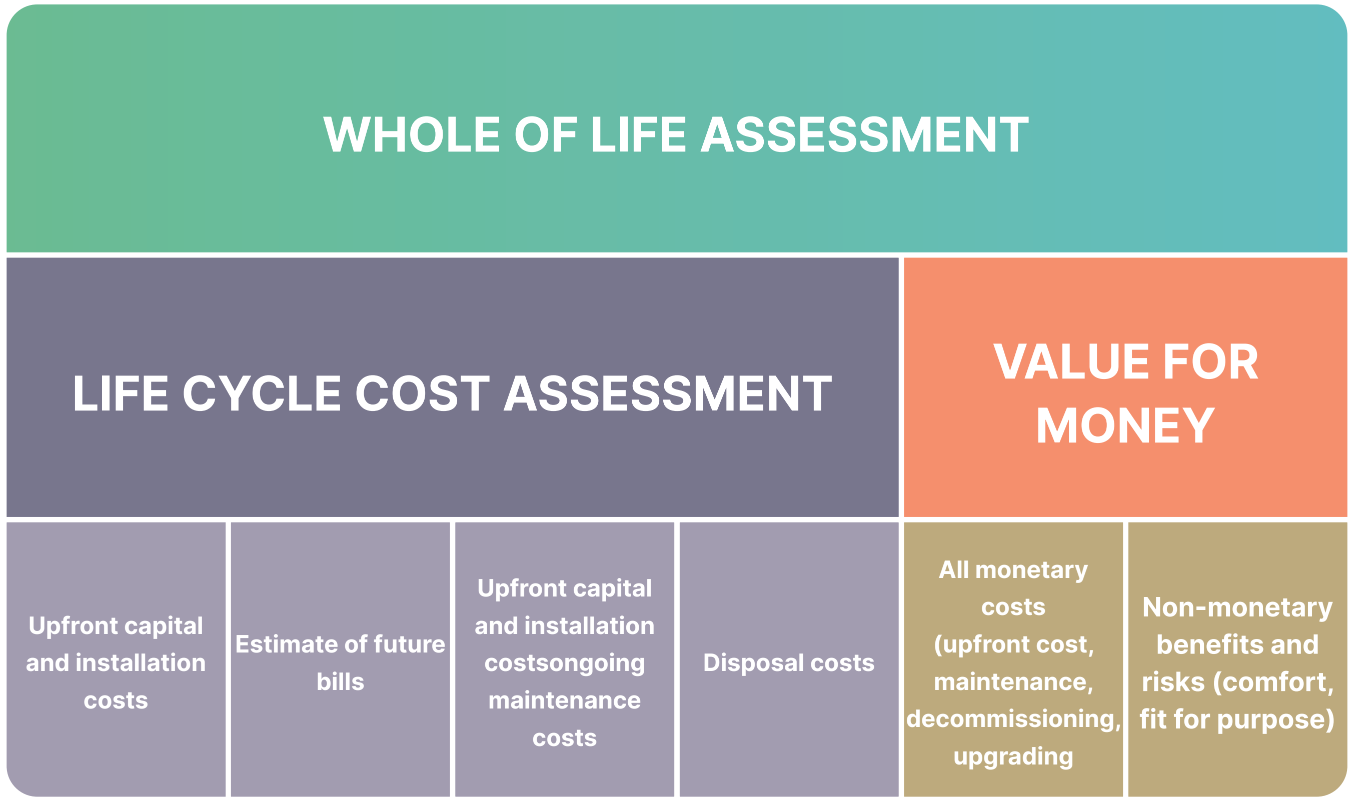


Figure 3.1 **Components of Whole of Life Assessment (WOL)**

[17] University of Wollongong. 2021. Whole of life assessment guide for HVAC technology replacement decisions: Education Sector. i-Hub Living Lab Schools Sector Report.

3.3.3 Skills Development and Networking

The implementation of activities to achieve net-zero emissions goals relies on people, and their individual and collective knowledge and skills. Networking is an important component of this, actioned through attendance at seminars and workshops. Specific knowledge sharing activities, such as i-Hub's Healthcare Knowledge Sharing Group, the AHIA ESD group, and AIRAH's Resilience Special Technical Group, are avenues with an even stronger intent and capability for collaboration.

At an organisational or building level, the formation and empowerment of teams is important. The building of teams, team diversity and executive support for teams are covered in ISO 50001 in regard to building an energy management system. The upskilling of individuals is part of team development. Two not-for-profit organisations that provide education, training and networking opportunities relevant to this Roadmap are briefly discussed below.

The Energy Efficiency Council (EEC) (www.eec.org.au) "collaborates with its members and partners to deliver training and events that support the Council's mission to building a sophisticated market for energy management products and services that delivers:

- Health, comfortable buildings;
- Productive, competitive businesses; and
- An affordable, reliable and sustainable energy system for Australia."

The EEC is also focusing on cross sectional skills (e.g. in finance, communications, design thinking etc) for energy professionals.

AIRAH, the host organisation for the i-Hub, provides extensive education and training for HVAC&R professionals and practitioners. They offer face-to-face, online and in-house programs, courses, seminar and webinars. They also produce technical manual and design application manuals, and regular publications and podcasts. www.airah.org.au

3.3.4 Summary

Complete Table 3.14 with regard to your organisation's capacity to implement NZCE activities. Add additional information to each question (e.g. if you answer 'no' or 'don't know' to any question, write what action you will take to rectify this).

Questions	Your Response
Is NZCE included in your organisation's strategic planning documents and processes?	☐ Yes ☐ No ☐ Don't know
Do the energy and hazard risks appear in the organisation's Risk Management Plan?	☐ Yes ☐ Some ☐ No ☐ Don't know
Does your organisation support Whole-of-Life approaches to design, procurement and operational decisions?	☐ Yes ☐ No ☐ Don't know
Does your organisation support staff participation in networking and collaboration events that focus on knowledge sharing? (support via time allocation, and via permission to share information)	☐ Yes ☐ No ☐ Don't know
Does your organisation support staff skills development? E.g. (financial support, time allocation, recognition)	☐ Yes ☐ No ☐ Don't know

Table 3.14 **Establishing your organisational capacity to implement NZCE activities**

04

Step Two: Examine technical options for achieving NZCE

A facility's energy system comprises the building, its services, the equipment that provides those services, and the energy sources to which the building is connected. The purpose of this section is to provide some guidance of technologies and processes that could assist you in reducing your carbon emissions through each of these avenues. This is not a comprehensive set of options, but provides some examples explored through the i-Hub's projects over the past three years. A Carbon-Catalogue (of NZCE potential) is being prepared as part of the i-Hub's Integrated Design Studio projects. It will shortly be available on the i-Hub website (www.i-Hub.org.au) and complements this report.

Some of the items discussed in the following sections may eventually find their way into the Australasian Health Facility Guidelines, managed by the AHIA.

The UK's National Health Service (NHS) has also just produced a Net Zero Carbon Hospital Standard that will be applied to 40 new facilities in the near future. This Standard may be available shortly on the NHS website. The NHS also has a 'whole of system' approach to upgrading existing buildings to meet NZCE targets. It notes that a significant portion of the investment required overlaps with regulation maintenance and upkeep work[18]. The focus for existing buildings is on:

- Upgrading lighting to LEDs
- Interventions on air conditioning and cooling, building fabric (insulation), space heating, ventilation and hot water
- Optimising the way buildings are used, through use of intelligent and real-time energy monitoring and control, and artificial intelligence
- Making better use of roofs and ground space for on-site renewable energy and heat generation
- Decarbonising heat (removing all coal and oil heating systems as soon as possible, and electrifying steam boilers)
- Purchasing 100% renewable energy (from April 2021)

Sustainable options

Considering sustainable options (e.g. energy efficiency, renewable energy, electric vehicles) could help organisations to reduce emissions, contributing to keeping climate change below dangerous levels and demonstrating community leadership.

Queensland Health, Climate change adaptation planning guidance - GUIDELINES Nov 2019

4.1.1 Building envelope systems

The building envelope is the first line of defence against high energy use. Good passive design will maximise the thermal efficiency of the building, which in turn reduces the space heating and cooling loads that impact on HVAC equipment selection, operation and energy use. The following information will help your organisation to articulate the performance goals for the building, both now and over the service life of the building. This in turn will assist in specifying these goals and expectations in Design Briefs and Procurement Contracts for new build or refurbishment projects.

If you are currently planning a new building or refurbishment, consider completing the questions in Table 4.1.

Questions	Your Response
What is the design life for the proposed building?	☐ 50 years ☐ 30 years ☐ Other ____
Is the building designed for deconstruction?	☐ Yes ☐ No ☐ Don't Know
What energy efficiency regulations are you using as the basis for your design?	☐ NCC2022 ☐ NCC2022 + ___ % ☐ Other ________
Are you benchmarking energy performance of the design, through building simulation?	☐ Yes ☐ Software used ____________ ☐ Company used ____________ ☐ No
Has the energy performance of the building been simulated for future climates? What climate files have been used for the simulation?	☐ No ☐ Yes ☐ TMY2 (current) ☐ 2030 ☐ 2050 ☐ 2070 ☐ 2090

Table 4.1 **Considerations for new buildings or major refurbishments**

The process of designing a new building is also important. A proposed set of Integrated Design Principles for NZCE buildings (Table 4.2) was developed through the i-Hub Integrated Design Studios activities. These principles are based on Rocky Mountain Institute's Factor 10 Engineering Design Principles (principles for dramatic improvement in energy efficiency) and present a more integrated, multi-disciplinary, whole-of-life approach to sustainable building design. This set of principles may be helpful to your organisation in planning new facilities or major retrofits. More information on the Integrated Design process can be found in the IDS section of the i-Hub website www.i-Hub.org.au.

[18] NHS Delivering a 'Net Zero' National Health Service. 2020. www.england.nhs.uk

Design phase	Integrated Design Principles for Net-Zero Emissions Buildings
Before design starts	Establish a clear, shared, ambitious NZE goal and timeframe for achieving that goal. Consider including other related goals, such as resilience, adaptation, grid autonomy. Determine KPIs that reflect the goals, including ambitious energy efficiency.
	Convene a transdisciplinary design team (e.g. engineers, architects, construction contractor, building owner/manager/occupants, ID specialist/facilitator) with diverse skills and experiences.
	Avoid the linear march through traditional design phases (project objectives and aspirations; design concept development; master planning; design development; feasibility evaluation). ID is iterative, with successive stages informing earlier ideas.
	Implement an Integrated Project Delivery contract that rewards teams for meeting KPIs and providing savings, rather than producing documents.
Focus on the right problem	Understand the purpose of the building and the needs of the people who will occupy it. What energy services will be required and what environmental, regulatory, technical and social contexts are likely to exist over this period?
	Push past end-uses (e.g. HVAC), resulting services (e.g. comfort) and ultimate benefits (e.g. health, productivity) to understand the full range of ways to fulfill the purpose/s.
	Take a whole-of-life approach to designs and their consequences (i.e consider current and future occupants and environmental context).
	Establish BAU benchmarks for the KPIs, and whole-system, lifecycle value of savings (e.g. in kWh, kW, CO2e, HVAC kVa, PV kWp etc)
	Use science and the plethora of simulation and modelling tools available to determine the theoretical minimum amount of energy needed to provide the energy services (especially HVAC). Consider how far each practical design constraint (e.g. cost, safety, performance, accessibility) moves away from that theoretical minimum.
Design Integratively	Don't start with a familiar or previous design or conventional assumptions or methods. Start afresh with no preconceptions.
	Question all rules of thumb and assumptions. Require all proposed design options to demonstrate performance against the KPIs.
	Establish a hierarchy of approaches: super energy efficient building envelope (design and materials), building services (technologies and controls), and renewable energy (generation, storage, control). This will produce compounding savings upstream.
	Simplify systems and components, valuing passive solutions over active solutions wherever possible
	Think beyond current benefit:cost evaluations and minimum performance standards. Incorporate whole-of-life, total cost of ownership, and non-monetary value evaluations
	Create enhanced value by ensuring each part, subsystem or system provides multiple benefits.
	Optimise energy systems to meet the diverse annual conditions (use and generation), and implement control strategies to minimise or shift peak demand and optimise self-consumption
	Incorporate technologies (e.g. integrated BMS, EMS) and processes (e.g. post occupancy evaluation) to inform design success and future designs.

Table 4.2 **Design Principles for Net Zero Emissions Buildings**

A number of the integrated design studios examined NZCE options for aged care buildings (and mixed-use buildings incorporating residential aged care). Some of the solutions examined, and indicative energy and/or health benefits, are summarised in Table 4.3. Full reports of each of these studios will be published on the i-Hub website, along with the IDS Carbon Catalogue.

Technology	Indicative demand reduction potential (compared with BAU)	Renewable Energy Potential	Co-Benefits
HoneyComb Blinds	12.5% reduction in cooling energy		Increased occupant thermal and visual comfort Suitable for retrofits
Vertical Green Systems	20-44% reduction in cooling energy	Would increase the % of load met by PV	Increase thermal comfort; health and environment benefits; dementia benefits
Adaptive Design	-	-	Lower embodied energy over life of the building
Secondary Roof (analysis for tropical location)	15.8% decrease in cooling energy ~21% reduction in peak cooling load	Would increase the hosting capacity for PV and increase the % of load being met by PV	Increased thermal comfort (natural ventilation mode)
Parametric design – for optimising materials selection	>10% reduction in cooling demand	Would increase the % of load met by PV	Eliminates trial and error Examines more combinations of options that possible by human analysis only
Parametric design – for natural ventilation and control strategies	A process to enable quantification of reduction in cooling load		33% increase in indoor comfort Potential for optimal performance outcome within the cost parameters required
Massed Timber (Glulam, CLT)			Reduced embodied energy

Table 4.3 **Some building envelope improvement strategies**

Figure 4.1 **Secondary roof proposed by designer Tristan Clark**

4.1.2 Energy services (Electrification of heat services)

"Electrification via heat pumps is a genuinely big deal now and is a fundamental issue being looked at in earnest for HVAC and DHW by all state health departments. And I anticipate that mandated formal electrification policies and strategies are likely to emerge within the next 1-3 years for most if not all state health departments. "

(Workshop participant)

We are hoping to phase out cogen by 2025 in SA as it no longer makes environmental sense in the context of our rapidly decarbonised grid. HVAC strategies and cogen are obviously intimately linked.

(Workshop participant)

The moves by most states and territory governments towards implementing net zero energy goals, and increasing the share of renewable energy, means that building electrification will need to occur at some point. As part of i-Hub Living Lab activities, QUT examined the impact of space heating electrification of one of the buildings on the Queensland Children's Hospital precinct: the 9-storey Centre for Children's Health Research (CCHR) that houses research laboratories, pathology service and offices[19]. For illustrative purposes, the analysis involved electrification of the boiler via a resistive element electric boiler combined with the installation of 109.6 kWp rooftop PV. (Note: this should not be taken to imply that resistive element electric boilers are the recommended technology). Key findings from this simulation study include:

- In the current climate, electrification could reduce annual onsite energy use by 17%, carbon emissions by 4.7% and annual operational energy costs by 4.2%.
- Future climate scenarios show an increase in cooling demand and a decrease in heating demand
- The heating load can be completely covered by the PV system by 2050 (i.e. net zero energy space heating for this building, in this climate zone, by the period 2040-2060).

This simulation demonstrated the feasibility of space heating electrification for this building. The feasibility of heating electrification more broadly is dependent on specific buildings (the building envelope) and location, so future work needs to include modelling of more hospital and aged care facilities in order to plan the transition to a net zero energy future in an orderly fashion.

[19] Details of this simulation can be found in LLHC4 Technical Report: Analysis of Future Energy Use. It will be published on the i-Hub website. Other analysis in that report includes energy forecasts for the Queensland Children's Hospital out to 2090; the effectiveness of pandemic mode ventilation strategies; and the impact of AS4187 Sterilisation on hospital HVAC and energy plant.

4.1.3 HVAC systems, operation, digital twins and AI

The technology selection and sizing of HVAC systems, and the energy use of HVAC, is dependent on both the climatic context (e.g. the heating and cooling degree days) and on the thermal efficiency of the building envelope (i.e. the resultant heating and cooling loads (W/m^2)). Relying on reduced cooling demand due to the building optimisation strategies shown in Table 4.3, the tropical Integrated Design Studios project examined low energy and renewable energy technologies as shown in Table 4.4. Dedicated Outdoor Air Systems (DOAS) were also proposed, as they separate the treatment of latent and sensible heat loads. The capital costs are higher, but the operational costs much lower than more conventional HVAC systems.

Technology	Indicative demand reduction potential (compared with BAU)	Renewable Energy Potential	Co-Benefits
Dedicated Outdoor Air System (DOAS)			
Geothermal (ground source) heat pumps for cooling	~30% reduction in cooling energy (but depends on local context for suitability)	100% renewable energy (if PV used for balance of system components)	
Radiant Hydronic Cooling	80% reduction in yearly operation and maintenance (including energy costs). Suitable if thermal load of the building envelope is $<50W/m^2$		Lowest total cost of ownership (compared to chilled water and variable refrigerant cooling systems)

Table 4.4 **Feasibility evaluation of alternative cooling technologies**

COVID has impacted on HVAC operation and will likely lead to permanent changes.

COVID / pandemics is a fundamental non-negotiable that now needs to be considered in HVAC and building design for all buildings, but especially healthcare facilities (Workshop participant)

Modelling by Stantec, conducted as part of i-Hub Living Lab subprojects[20], indicated that:

- increasing outdoor air to 100% increases HVAC energy consumption
- the effectiveness of increasing outdoor air is unknown, as the droplet recirculation rate depends on the type and configuration of the ventilation system
- local exhaust and filtration systems, and portable air purifiers appear more effective

Digital Twins and Artificial Intelligence (AI) have an important role to play in the operation and maintenance of HVAC systems. Technology evaluations[21] conducted in two healthcare living labs showed:

- a HVAC Plant digital twin revealed that two chillers in an aged care facility were operating 25% below their design performance
- a digital twin of a hospital's chiller primary system showed peak demand reduction of 99kVA and annual energy savings of 188MWh with optimised chiller staging
- A 'rapid feedback' AI technology demonstrated annual energy saving potential of 34 MWh cooling plant

[20] Details of this modelling can be found in LLHC5 Report: Net Zero Emissions and Resilient Hospitals and LLHC4 Technical Report: Analysis of Hospital Future Energy Use

[21] These technology evaluations will be available on the i-Hub website.

Other useful resources for improving HVAC operation include AIRAH's Best Practice Guidelines (e.g. Water conservation in cooling towers) and Resilience Checklist for HVAC&C systems.

The IEA Annex 80 (Resilient Cooling) is currently evaluating a range of passive and active cooling technologies, using resilience KPIs. This work is expected to be completed in June 2023, with the full reports available online.

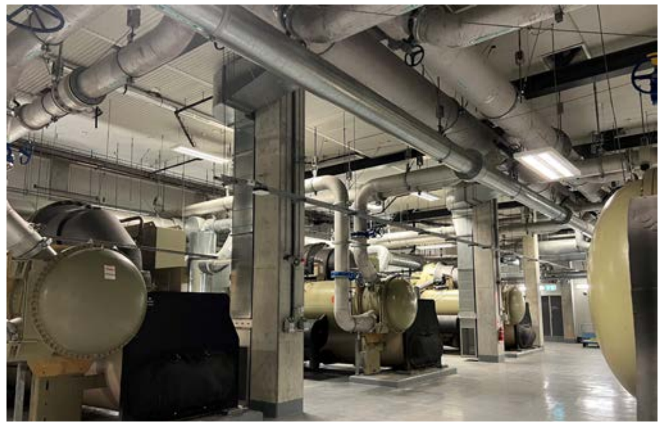


Figure 4.2 **Chiller plant**

4.1.4 Next-gen Building Management Systems (BMS)

The absence of a BMS (as is the case in many aged care facilities and small healthcare facilities) can make it difficult to undertake the monitoring and control of energy systems. The common 'traditional' BMS also has limitations, as shown in Table 4.5. Next-gen BMS have a systems integration approach, using a cloud based platform. This enables the collation and analysis of building data in a much more effective and efficient manner. The benefits of cloud based data have been demonstrated in the i-Hub's Data Clearing House suite of activities. These reports demonstrate the benefits that various clients have had from making building data easily available. They will be available on the i-Hub website.

	Traditional BMS	Next-gen BMS (Smart building System Integration Platform)
Typical services	HVAC + Lighting + Access control + Power monitoring	Could include Digital Twins; Artificial Intelligence; and Grid Efficient Buildings
Purpose	Make sure building systems function on a day-to-day basis Monitor for problems Undertake basic controls (manual & automated)	Monitor and control all powered systems in the building to fully optimise energy use through the entire site
	Disadvantages Highly manual and labour-intensive Silo approach Not comprehensive (doesn't include all building services or the whole energy system) Maintenance is calendar-based and reactive Occupants have no insight or control All complaints go through FM Each building managed independently	**Advantages** Commissioning can be continuous Maintenance can be predictive Multiple buildings can be on the one system, allowing benchmarking

Table 4.5 **Comparison of traditional and next-gen BMS**

4.1.5 Energy generation and storage

Rooftop solar is by far the most prolific renewable energy technology in Australia, with proven reliability and performance, and low implementation costs. Some alternatives were proposed in the Integrated Design Studios, as shown in Table 4.6.

Technology	Indicative demand reduction potential (compared with BAU)	Renewable Energy Potential	Co-Benefits
Hybrid green-solar roof (Green roof integrated photovoltaics)	Likely to reduce building cooling load	Increase PV efficiency and PV output	Reduced heat transfer through the roof
Geothermal (ground source) heat pumps for cooling	~30% reduction in cooling energy (but depends on local context for suitability)	100%	
Battery-Supercapacitor (BSC) hybrid device (graphene capacitor technology) with integrated inverter	Can provide backup power (extent not quantified in this report) Potential to participate in demand response markets (very fast response time, for grid frequency stabilisation)	360kWp could meet NZE (for the particular building examined) Modules of 50kWh	Supercapacitors can respond to high frequency fluctuations, increasing the lifetime of the battery and decreasing the size required for a particular capacity. Claims to be fully recyclable
Solar-Hydrogen Power Generation (Site masterplan approach including maximising rooftop PV + hydrogen electrolyser + low pressure metal hydride storage vessel)	Feasible if buildings achieve significant reduction in EUI (66%) (Case study building was a mixed-use development incorporating aged care)	100% possible if sustainable construction methods significantly reduce demand	Replace diesel generator; avoid diesel exhaust emissions (local air pollution) Less reliance on supply chain (for diesel generators)

Table 4.6 **Feasibility evaluation of alternative cooling technologies**

Healthcare facilities typically have a low-risk appetite for technologies that are perceived to present a risk to energy supply or building operation. Understanding a proposed solution's technology readiness level is a key part of risk management. TRLs (Figure 4.2) measure the growing maturity of a technology, through ideation, research, development and deployment phases. This does not mean that healthcare facilities should only consider solutions at TRL9 though, as risk mitigation strategies can be implemented.

The i-Hub's Living Laboratories were conceived to enable evaluation of technologies at TRL 6-9. The three healthcare living labs (Warrigal Aged Care community in NSW, Fernhill Residential Aged Care in QLD, and QLD Children's Hospital) remain available to test further technologies. Existing technology evaluation reports can be found on the i-Hub website.

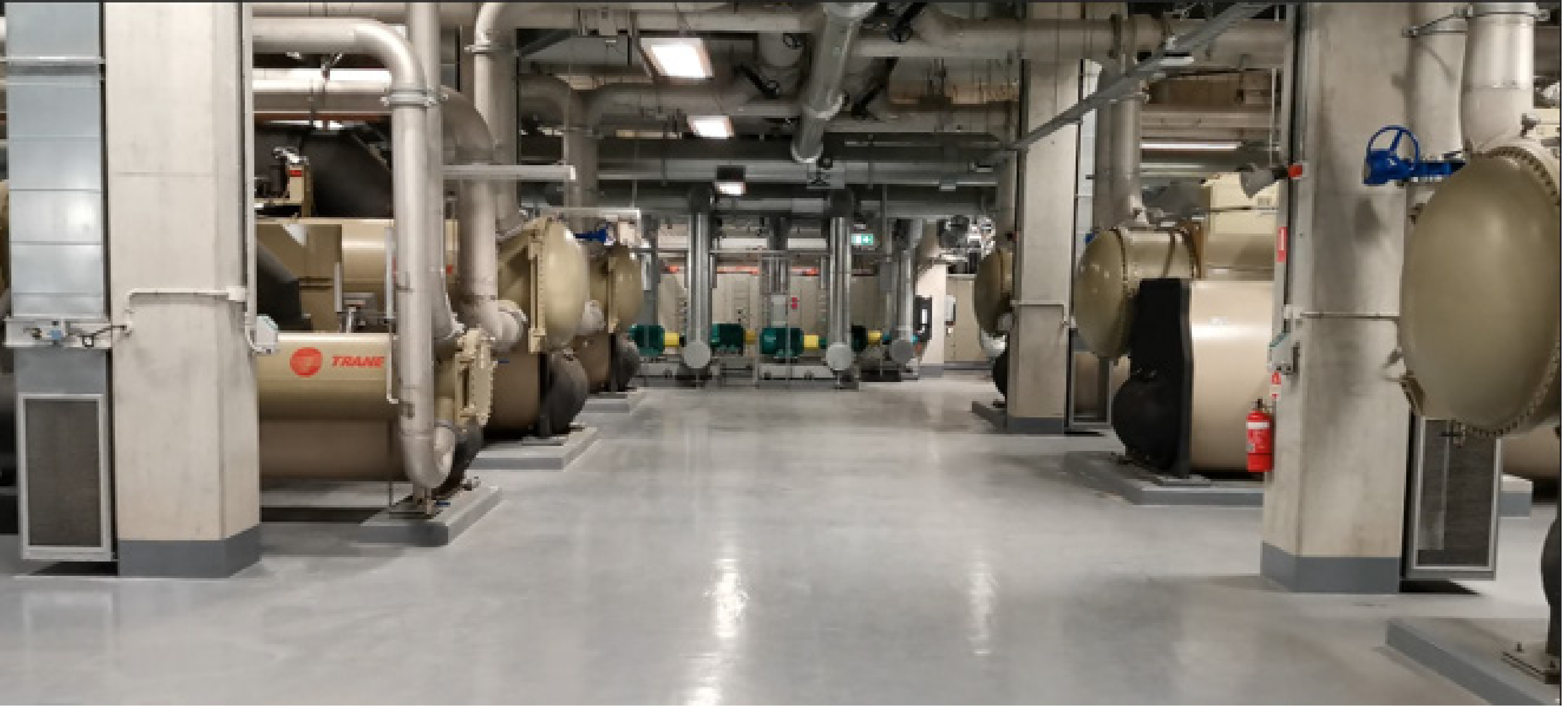


Figure 4.3 **Hospital Energy plant**

TECHNOLOGY READINESS LEVEL (TRL)

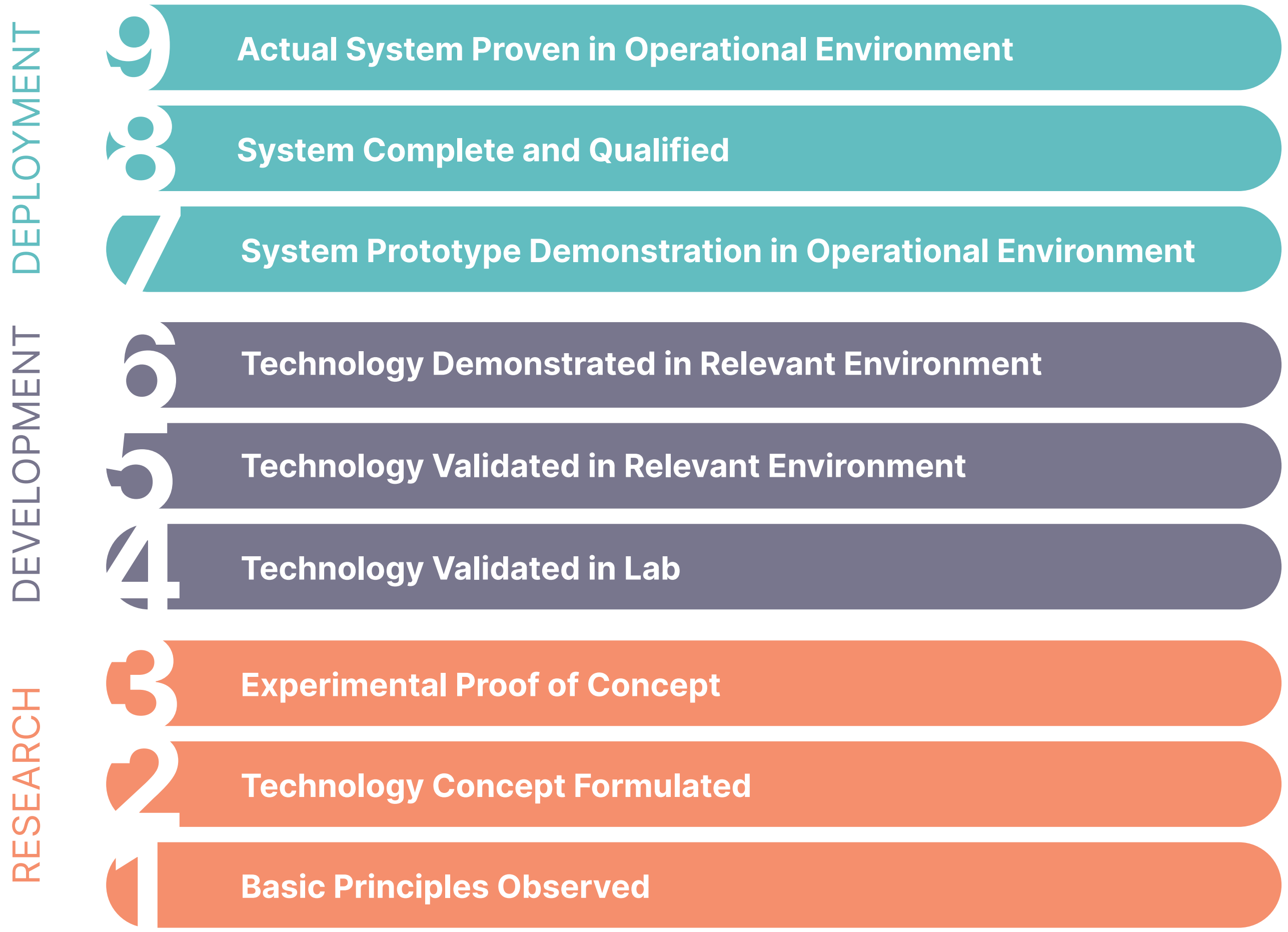


Figure 4.4 **Technology Readiness Levels**[22]

[22] https://www.twi-global.com/technical-knowledge/faqs/technology-readiness-levels

4.1.6 Demand response

Demand response can be an important carbon mitigation strategy and a means to reduce energy costs and/or earn income to help support further decarbonisation strategies. The following information is taken from a demand response study undertaken by Stantec, for the i-Hub and AHIA. The full report – *Net Zero Energy and Resilient Hospitals – considerations of future climate, pandemics and demand management* – will soon be published on the i-Hub website.

There are three main participation pathways, each with different mechanisms and considerations, as summarised in Table 4.7. Reducing network demand charges (the first pathway shown in the table) is an in-house management strategy to keep maximum demand below a pre-set limit. This can be achieved through switching off loads (e.g. short-term switching of parts of the HVAC system, without impacting thermal environment of occupants), use of thermal storage (e.g. hot or cold storage systems, or pre-cooling of some areas prior to a peak); or the use of the backup generator/s. The remaining participation options typically relate to the use of the diesel generators.

Participation Pathway	Main mechanism	Considerations
No Third Party or AEMO registration required	DNSP Demand charges (price and type vary across networks).	Peak Monthly Demand Peak Annual Demand Seasonal Demand
Participation through a Retailer	NEM wholesale market (Spot Market)	Automatic control or opt-in/out control Trigger price to participate Revenue sharing split Hours of operation control each year
Participation by registering with AEMO or through a Third-Party Aggregator	Wholesale Demand Response Mechanism (WDRM) (from Oct 2021)	Aggregators can bid into 5 minute NEM wholesale market and must respond to dispatch instructions from AEMO Revenue sharing between aggregator and customer
	Frequency Control Ancillary Services (FCAS) • Regulation (minor deviations) market • Contingency (major event) market	Operate on 5 minute intervals. MW available to add/take off the network Payment for availability, even if services not required Require high speed metering and data transfer
	Reliability and Emergency Reserve Trader (RERT)[23]	Emergency research called on by AEMO during extreme events; no payment if not called on.

Table 4.7 **Demand Response Participation Pathways**

[23] RERT activation trial and outcomes reported by ARENA at https://arena.gov.au/blog/dr-january-activation/

The greenhouse gas emissions impact of operating diesel generators for DR market participation, at this current point in time, is justified. Diesel has an estimated emissions factor of 0.65 kg CO_2-e/kWh, which is lower than the 2021 GHG emissions for electricity networks in NSW, ACT, VIC and QLD, but higher than emissions in SA and TAS (which have a higher renewable energy penetration). Diesel emissions are close to the GHG emissions of the entire NEM (by volume of dispatched generation), 0.68 kg CO_2-e/kWh.

All states have a target of a minimum of 50% renewable energy by 2030, so the GHG intensity of the state networks and the NEM is likely to reduce over the next decade. Over time, healthcare facilities will need to evaluate options for addressing the carbon emissions from the generators.

To complete a DR participation assessment (either in-house or through a third party), requires the collation of site-specific information, as well as modelling software and the targeted DR markets for participation. Do you have the following information?

- ☐ Meter interval data
- ☐ Electricity contract and bills
- ☐ Generator / load shedding capacity
- ☐ Network connection details
- ☐ Electricity infrastructure details

The decision on whether to participate in DR also requires consideration of the benefits, the barriers and the risks. In addition to the financial benefits that could accrue to your facility, the system-wide benefits of using backup generators for DR include the avoidance of load shedding and blackouts; and the provision of grid stability services, allowing for more renewable energy to connect to the network.

The four main technical barriers are summarised in Table 4.8 and the risk and mitigation strategies shown in Table 4.9.

Broad Barriers	Key issues
Network Connection Requirements	Each DNSP has their own set of connection rules and requirements. The type of connection will impact on ability to participate in DR.
AEMO Registration	Capacity thresholds for registering as a Generator with AEMO. Exemptions may be granted based on genset characteristics (nature, size, type, operation).
Infrastructure Upgrades	May be required to meet DNSP embedded generation requirements and/or AEMO registration requirements. Examples include protection systems, switchgear, metering and monitoring, control systems). Capital costs of these upgrades are dependent on • site connection voltage • type, capacity and connection type of embedded generator • targeted DR market.
Minimum Generator Size	FCAS requires minimum 1MW to participate Facilities with smaller embedded generators will often need to operate through an aggregator

Table 4.8 **Technical Barriers to Demand Response Participation**

Key Risks / Considerations	Proposed Mitigation Strategies
DR Revenue / Return on investment of infrastructure upgrades	• Majority of DR revenue relies on extreme events on the NEM. The quantity and scale of these events vary each year, and future revenue forecasts are not guaranteed • Third party agreements can be negotiated with a fixed payment per year for available DR capacity rather than a share of dispatch revenue, if desirable. However particular terms & conditions are required to be met.
Loss of control of generators or forced load shedding by a third-party	• Third party agreements can be made with optional rather than mandatory participation to allow flexibility to choose whether to participate in a particular DR event or not • Third party agreements have limits of the hours of operation for DR participation
Unattended plant can start and stop at any time	• Procedures, education and labelling will promote awareness when someone enters an area with an automatic generator and provide information on what safety precautions need to be taken • Third party can send notification via text message and/or email before a dispatch event occurs
Constant starting and stopping of generators	• Due to the nature of most DR, dispatch can be for very short intervals of time, which may cause generators to constantly start and stop, causing additional wear and tear. A minimum run time can be built into a DR agreement with a third party, such as running the generators for at least 30 mins when dispatched, to reduce stress on equipment
Underloading a generator	• In order to extract the most value out of DR, generators are often run at or near their peak capacity. However, a protection system can be setup to ensure the generator shuts down if underloaded
Running generators more, causing additional wear and tear	• Generators are required to be run regularly as part of their maintenance program to ensure internal parts remain lubricated, the carburettor is functional, and the batter is charged. • DR often requires higher levels of monitoring of the equipment than typical stand-by equipment would have. Therefore, more monitoring can lead to better preventative maintenance programs to avoid major faults.
Refuelling	• If generators are use more frequently because of DR, refuelling schedules may need to be revised or additional fuel storage may be required to ensure adequate fuel is available for stand-by events. Monitoring of fuel supplies and alerts can eb setup to manage this. • Not running a generator regularly can also cause the fuel to go stale, which can cause issues, so running a generator more keeps the fuel source fresh.
Greenhouse Gas Emissions	• DR using fossil fuel based generators will result in GHGE which may conflict with an organisation's emissions or net zero targets, as the electricity network becomes cleaner into the future. • Alternative options such as load shedding, or technologies such as battery storage which is charged from renewable sources, could be used. • However, it is important to note that participation in DR markets for short periods of time with fossil fuel powered generators can facilitate a larger uptake in variable renewable energy on the NEM. Whilst fossil fuel generators are inferior to battery storage DR based solutions from a GHG perspective, the low run hours when compared with the benefit provided to the network must be considered.

Table 4.9 **Risks and Mitigation Strategies**

4.2 Summary of Technical Options

Healthcare Technology Roadmap

	NEW BUILDINGS	EXISTING BUILDINGS	OPERATION & MAINTENANCE	HEALTH CO-BENEFITS	PROCUREMENT
BUILDING ENVELOPE	Design Life / Adaptable Design Passive Design Design for Deconstruction Model for future climates Energy intensity benchmark kW/m² Roof solar reflectance Air tightness	Insulation upgrade Glazing upgrade Window shading (ext & int) Energy intensity benchmark kW/m² Roof solar reflectance Air tightness	Reed switches (doors & windows) Landscape design and maintenance Energy intensity benchmark kW/m² Roof cleanliness Weatherstripping	Reduced Urban Heat Island Effect (UHIE) Resilience (passive survivability) Glare control	Design Brief and Design Guidelines Total Cost of Ownership Asset register Building plan register / storage
HVAC SYSTEMS	HVAC – boiler (elec., heat pump) Variable capacity & airflow Natural & Mixed-Mode Ventilation Zoning & Smart Controls Real time visibility Access for servicing Occupancy schedules (real) Water storage & filtration	HVAC – boiler (elec., heat pump) Locate to minimise UHIE Locate above flood lines Protection (hail, ash, corrosion) Electronics and PCB protection Access for servicing Occupancy schedules (real) Water storage & filtration	Ventilation Mode Outdoor Air Supply % Filters & Air Purifiers Start-up / Shut-down procedures Set points & dead bands Continuous commissioning Predictive maintenance Water compliance	Indoor Air Quality Thermal Comfort Personal Controls	Technology Readiness Level Design Brief Performance guarantee Total Cost of Ownership O&M contract Performance report /data accessibility
LIGHTING SYSTEMS	Optimise natural light Lighting circuits parallel to windows + PE sensors	LEDs Lighting Levels (variable) PE sensors	Lighting Schedules (real) Lamp Replacement Schedule Automated controls + manual override	Visual Comfort Glare control Personal control	Performance brief Total Cost of Ownership
STERILISATION SYSTEMS	AS4187 (new) Electrification potential Impact on site demand (kW) and energy use (kWh)	AS4187 (new) Electrification potential Impact on site demand (kW) and energy use (kWh)	Impact on HVAC system components, sizing and operation	Infection control	Impact on NZE / Renewable Energy Master planning
MONITORING & CONTROL SYSTEMS	Next-Gen BMS	Next-Gen BMS	Digital Twins & Artificial Intelligence Data /Records Management and Analysis Processes	Fast response to occupants Easier reporting	Staff training CEO/Board reporting Third party contracts – data access
DEMAND RESPONSE SYSTEMS	Next-Gen Sensors, controls, connectivity, communication	Next-Gen Sensors, controls, connectivity, communication	Opt in – opt out mechanisms Discretionary loads Income	Supports electricity grid	Internal policy 3rd party aggregator CEO/Board reporting
RENEWABLE ENERGY & STORAGE SYSTEMS	Rooftop PV & inverter capacity Warranty and typical life Chemical & thermal energy storage (batteries, water, thermal mass) Ownership and control mechanism	Rooftop PV & inverter capacity Warranty and typical life Chemical & thermal energy storage (batteries, water, thermal mass) Ownership and control mechanism	PV cleaning schedule Accessibility Area required (size, safety, accessibility) O&M contract or process	Resilience (power outages) Reduced carbon emissions	Onsite availability m² Offsite options Acceptability of carbon offsets Total cost of ownership

Figure 4.5 **Roadmap Technology Options**

05

Useful Resources

5.1 Websites

Air Infiltration and Ventilation Centre (AIVC), IEA EBC Annex 5 (https://www.aivc.org/)

Alliance for Deep RENovation in buildings. www.aldren.eu

ASHRAE www.ashrae.org

Australian Institute of Air-conditioning, Refrigeration and Air Handling (AIRAH) (www.airah.org.au)

Australian Building Codes Board (ABCB) (www.abcb.gov.au)

Global Green and Healthy Hospitals (https://www.greenhospitals.net)

IEA Annex 80 Resilient Cooling in Buildings (www.annex80.org)

Illuminating Engineering Society (www.ies.org)

Indoor Environmental Quality Global Alliance (www.ieq-ga.net)

5.2 Technical Notes and Guidelines

AIRAH Design Application manuals

- DA04 Air System Balancing – in HVAC (June 2021)
- DA24 Hydronic System Balancing – in HVAC (June 2021)
- DA07 Criteria for Moisture Control Design Analysis in Buildings (August 2021)
- DA19 HVAC&R Maintenance (2019)
- DA15 Air Filters and Cleaning Devices (2019)
- DA20 Humid Tropical Air Conditioning (2016)
- DA27 Building Commissioning

AIRAH Best Practice Guides

- Best Practice Guide for water saving from cooling towers
- Resilience Checklist
- Best practice guides HVAC Hygiene

Illuminating Engineering Society (IES)

- Lighting Practice: Designing Quality Lighting for People and Buildings (LP-1-20)

5.3 Health Facilities Guidelines

Australian Health Facilities Guidelines https://healthfacilityguidelines.com.au/standard-components

ASHRAE Advanced Energy Design Guide for Large Hospitals, 2012

- Recommendations for achieving 50% energy savings below 2004 baseline standard

ASHRAE Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities, 2009

- Recommendations for achieving 30% energy savings below 1999 baseline standard

ASHRAE Standard 170 – 2021 Ventilation of Healthcare Facilities

- Includes temperature standards in clinical settings; filter specifications

ASHRAE HVAC Design Manual for Hospitals and Clinics, 2nd Edition, 2013

CEN/TC 156 (Ventilation for buildings) and ISO / TC 205 (Building environment design)

- These two standards focus on design aspects of natural and hybrid ventilation and ventilative cooling tackling both overheating and indoor air quality issues.

EN 16798 Part 3 and 4 – performance requirements for ventilation of non-residential buildings

- Under development (Working group 2020, AIVC/IEA Annex 62): this standard deals with a technical specification on "Natural and hybrid ventilation systems in non-residential buildings" that focuses on indoor air quality aspects and overheating prevention.

International Health Facility Guidelines (v 4.2 Oct 2019) https://www.healthfacilityguidelines.com/

ISO /TC 205 Design process of natural ventilation for reducing cooling demand in energy-efficient non-residential buildings

Whole Building Design Guide (www.wbdg.org)

5.4 Reports

IRENA (2021), World Energy Transitions Outlook: 1.5°C Pathway, International Renewable Energy Agency, Abu Dhabi. www.irena.org/publications

Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., Deverell, J. (2017) Low Emissions Technology Roadmap. CSIRO, Australia. Report No. EP167885. www.csiro.au/letr

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