The Innovation Hub

for Affordable Heating and Cooling

Report #LLHC4-6

Technical Report – Analysis of Hospital Future Energy Use

May 2022

Queensland University of Technology

About i-Hub

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

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

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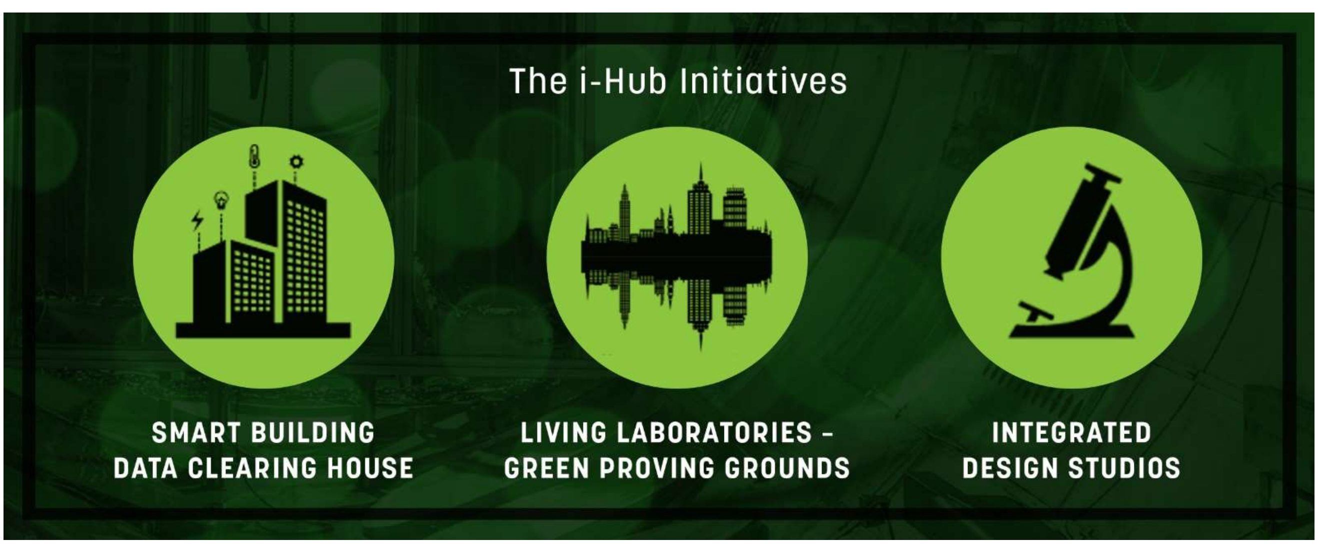
The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.



Healthcare Living Laboratories: Queensland Children's Hospital
The Living Laboratory in Queensland Children's Hospital (QCH) will support the hospital sector to transition to a net-zero energy/demand future. In particular it will validate the impact of emerging technologies in demand reduction, demand management, renewable energy and enabling technologies, in terms of core health services (patient and worker health and comfort), building maintenance and operations, environmental impact and financial management (including participation in energy markets). An estimated 30% reduction in energy/demand (from sector wide baselines) can be achieved through the incorporation new technologies relating to HVAC efficiencies and control, demand management, grid interoperability and renewable energy into hospital policies, plans, operating manuals and procurement processes. It will not only test innovative technologies and processes but will also evaluate the usefulness of new key performance indicators (KPIs) and metrics that link energy performance (especially peak demand, renewable energy and resilience) to core health services.

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1 EXECUTIVE SUMMARY

Queensland Children's Hospital is a specialist state-wide quaternary hospital and health service which provides safe, high-quality and family-centred care for children and young people from across QLD and northern NSW.

Figure 1-1 QCH main hospital building

The QCH precinct comprises of three buildings: the Main Hospital (MH) Building; the Centre for Children's Health Research (CCHR); and the Central Energy Plant (QCH EP) Building. Baseline energy use has been previously reported [1], and four technology evaluations have also been undertaken as part of the iHUB's Living Labs. These reports can be found at www.ihub.org.au.

In this technical report four issues are evaluated for impact on hospital energy use: future climates; hospital electrification (space heating); ventilation effectiveness for aerosol distribution; and changes to the Australian Standards for sterilisation.

1.1 Energy Forecast 2030 - 2090

To future proof QCH energy resilience, sustainability and potential cost impact, energy forecasting was performed for the QCH precinct's electricity usage under 2030 to 2090 scenarios, based on future climate files developed by CSIRO [2]. The forecast was undertaken using a data driven model based on QCH's monthly electricity uses and temperature data from 2015 to 2022. The four major future scenarios utilised were 2030, 2050, 2070 and 2090, with each date representing a predicted typical year climate data for a 20-year period (e.g., 2020 – 2040; 2040 – 2060 etc). Three future scenarios, as utilised by the Intergovernmental Panel on Climate Change, were modelled (RCP2.6 - <1.5^{o}C temperature increase (negative emission); RCP4.5 – middle scenario; and RCP8.5 – business-as-usual scenario).

Key findings:

- As the climate changes, 1℃ temperature increase may lead to 2MWh electricity use increase per day, based on a simple linear fitting between temperature and energy use (Figure 1-2).
- In the business-as-usual scenario, the period 2040 and 2060 (i.e., 2050 climate file) will typically use about 5% more energy every year compared to 2021 (Table 1-1).
- In the business-as-usual scenario, 20 years between 2080 and 2100 (2090 climate file) will typically use about 13% more energy every year compared to 2021 (more details and discussion are in Section 2.4 and Section 2.5).

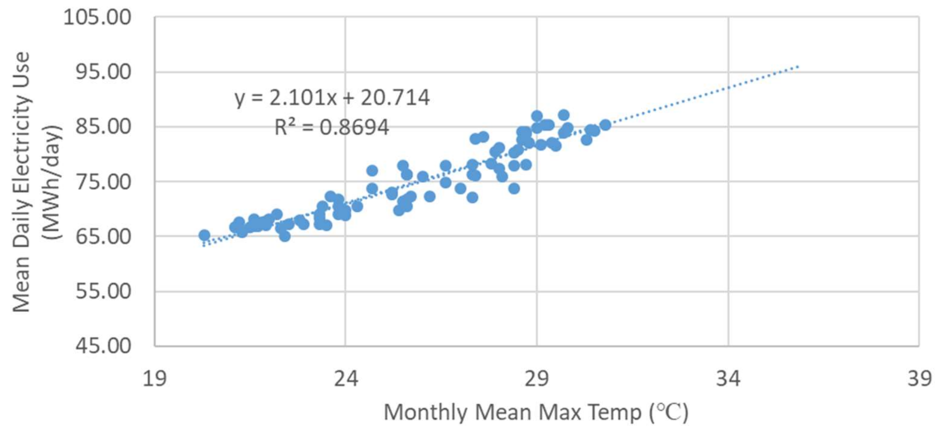


Figure 1-2 Energy use per day in relationship with monthly mean maximum temperature

Table 1-1 Energy forecast into 2030 to 2090 scenarios (polynomial 2nd order model prediction results)

		Typical yearly energy use			
	2021 Energy use	between 2020-2040 (2030 scenario)	between 2040–2060 (2050 scenario)	between 2060–2080 (2070 scenario)	between 2080–2100 (2090 scenario)
Emission Business as Usual scenario (RCP8.5)	26.85 GWh	27.48 GWh	28.06 GWh	29.61 GWh	30.42 GWh
Increase compared to 2021		2.35%	4.51%	9.00%	13.32%

1.2 Electrification of heating

The CCHR building was modelled to determine the impact of replacing the gas boiler with an electric boiler. Under the current climate, dynamic energy simulation showed electrification could reduce annual onsite energy use by 17%, greenhouse gas emissions by 4.7% and annual operational energy costs by 4.2%.

Future climates will increase the HVAC annual energy use of both scenarios (gas-fired boilers and electric boilers), increasing cooling demand and decreasing heating demand. This is seen in the first two rows of Table 1-2. The bottom two rows compare the electric heating load with PV generation, demonstrating that the heating load can be completely covered by the PV system (roof-mounted 109.6kWp) by the period represented by 2050 (i.e., 2040 – 2060). This demonstrates that net-zero-energy space heating is achievable, for this building, in this climate zone.

Table 1-2 Heating energy end use in future climates

	Heating Energy (GJ)	Current weather	RCP8.5 Brisbane 2030	RCP8.5 Brisbane 2050	RCP8.5 Brisbane 2070	RCP8.5 Brisbane 2090
Base case	**Natural gas**	814	717	698	651	617
	Electricity	80	75	71	63	56
Heating Electrification + PV	**Electricity**	733	649	629	585	551
	PV Generation	655	674	686	682	690

1.3 Effectiveness of pandemic mode ventilation strategies

This investigation was undertaken to determine the impact that different mechanical ventilation strategies have on respiratory aerosolised droplet distribution within a typical hospital ward. Computational fluid dynamics (CFD) modelling software was used to determine the comparative quantity of droplets within the ward after a fixed time period, in different mechanical ventilation configurations. The goal of this investigation was to determine what changes produced the greatest reduction in aerosolised droplets within the space. Eight scenarios were analysed (Table 1-3).

Table 1-3 Ventilation CFD simulation scenarios

Scenario	Notable features	Recirculation % considered
Base Case	Two large return air grilles located in common areas. General doors open.	75% + 25% droplet recirculation
100% Outside Air	Geometry and ventilation rates identical to scenario 1 except with no droplet recirculation with the system. General doors open.	0% droplet recirculation
Localised Return	Localised smaller return air grilles in each room as opposed to that considered in scenario 1. Doors closed.	75% + 25% droplet recirculation
Localised Return + air purifiers in populous areas	Identical to scenario 3 with the inclusion of 4x air purifiers located in populous regions within the common spaces. Doors closed.	75% + 25% droplet recirculation
Localised Return + air purifiers in populous areas + individual purifiers per room	Identical to scenario 4 with the inclusion of 15x smaller air purifiers located adjacent to each bed. Doors closed.	25% droplet recirculation

This investigation indicates outside air percentage appears to be irrelevant to the reduction of suspended aerosol mass. and that designers of ventilation systems should potentially consider a shift from traditional ceiling-mounted return/exhaust grilles to local exhaust/filtration systems installed as close as possible to where respiratory activities are taking place.

1.4 Impact of AS4187 Sterilisation on hospital HVAC use

The 'new' standard of sterilisation in Australia A/NZS4187 was released in 2014, became operational in 2016, and mandatory implementation is required by the end of 2021 and 2022. The engineering impact of the standard is discussed, and a case study of a large refurbishment of a hospital Central Sterilisation Service Department (CSSD) is presented. The case study shows the significant impact on electrical maximum demand and on annual electrical consumption for a fully electric CSSD compared to an existing electric / gas CSSD (Table 1-4). A checklist is provided to guide facilities to understanding and scoping an AS4187 upgrade.

Table 1-4 Energy comparison of case study existing and new CSSD

	Existing CSSD	New CSSD
Average Utilisation % During Hours	60%	80%
Operating Hours	18 hrs / day 365 days / year 6,570 Total hours / year	10 hrs / day 365 days / year 3,650 Total hours / year
Electricity Maximum Demand	185 kVA (258A)	618 kVA (860A)
Gas Maximum Demand (MJ/hr)	960 kg/hr Steam (192 per steriliser) 66.2 m3/hr Gas	0
Annual Electricity Consumption	693,000 kWh	**1,714,000 kWh**
Annual Gas Consumption	261,000 m3 / year 9,720 GJ / year	0

2 QCH PRECINCT ENERGY FORECAST 2030 - 2090

The focus of this study was to build a data driven model to forecast the whole QCH precinct energy use into 2030, 2050, 2070 and 2090 climate scenarios. The data driven model was developed based on seven years of actual energy use records at QCH and Australian Bureau of Meteorology's weather observations at Brisbane airport [3]. The data driven model was then used to forecast QCH's energy use using CSIRO's 2030 to 2090 future climate files. These future climate files have been developed based on CSIRO's research outcomes [4][5].

2.1 Future Climate Files

Table 2-1 describes the CSIRO future climate files used in the work. Climate file names do not mean the climate forecast for a specific year. Each climate file represents typical yearly climate in a 20-year period. For example, 2090 climate file represents typical yearly climate between 2080 and 2100; 2090 is the name of the future climate file and is the middle year in the 20-year period.

Table 2-1 Future climate files

<table>
<tr><th>Climate file names</th><th>Description</th><th>Scenarios</th></tr>
<tr><td>2030 climate file</td><td>representing a typical year between 2020 – 2040</td><td rowspan="4">1. Business as usual pathway, Representative Concentration Pathway 8.5 (RCP8.5) [6]
2. Emission middle scenario (RCP4.5)
3. Negative emission pathway (RCP2.6). RCP2.6 is the only pathway to maintain the average temperature increase <1.5°C. [7]</td></tr>
<tr><td>2050 climate file</td><td>representing a typical year between 2040 – 2060</td></tr>
<tr><td>2070 climate file</td><td>representing a typical year between 2060 – 2080</td></tr>
<tr><td>2090 climate file</td><td>representing a typical year between 2080 – 2100</td></tr>
</table>

2.2 QCH Precinct Energy Baseline

QCH precinct gets electricity supply from the local power distribution network and onsite standby generators. Figure 2-1 presents the monthly energy use for the QCH precinct from 2015 to 2021, showing higher energy usage for the summer months and a dip in the winter period from June to August. February shows lower monthly total energy use; however it is worth keeping in mind that this month has fewer days than other months.

To normalise the impact from the varying number of days in each month, mean daily electricity use in each month (MWh/day) is used in Figure 2-2. There is a clear seasonal pattern:

- a summer high demand period from about October to March (6 months)
- a winter low demand period from June to August (3 months)
- a mild demand period for the shoulder seasons (3 months).

The historical total electricity use data are listed in Table 2-2. The yearly electricity use has been quite stable, around 26 to 27 GWh. To make a comparison, 27 GWh of electricity can power 4110 households for a year, considering Southeast Queensland households use about 18 kWh of electricity each day on the average.

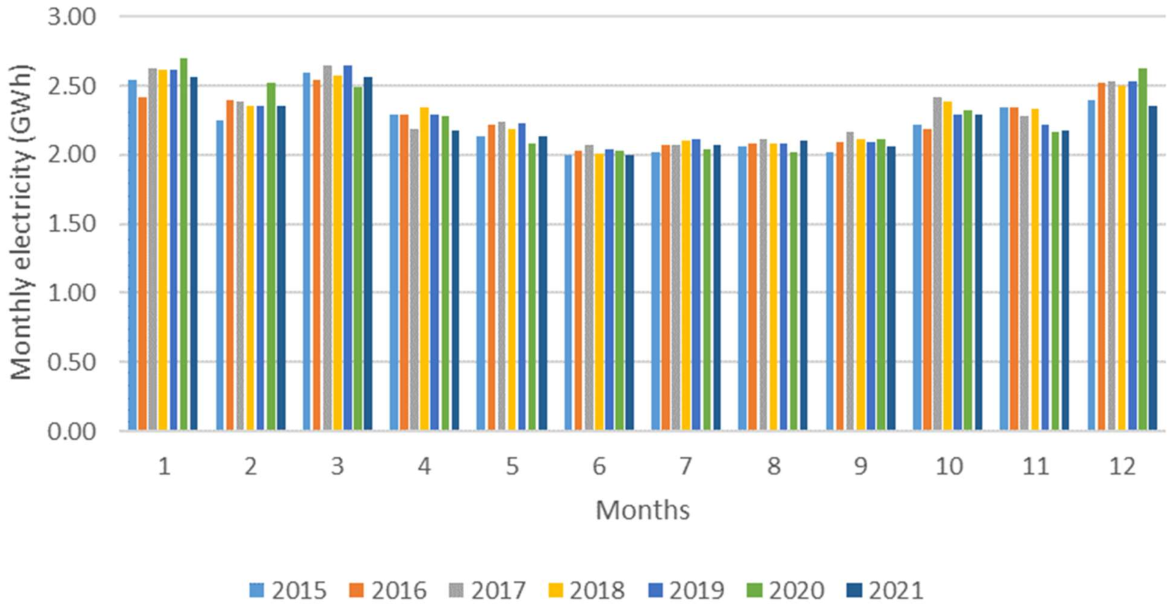


Figure 2-1 Monthly electricity use

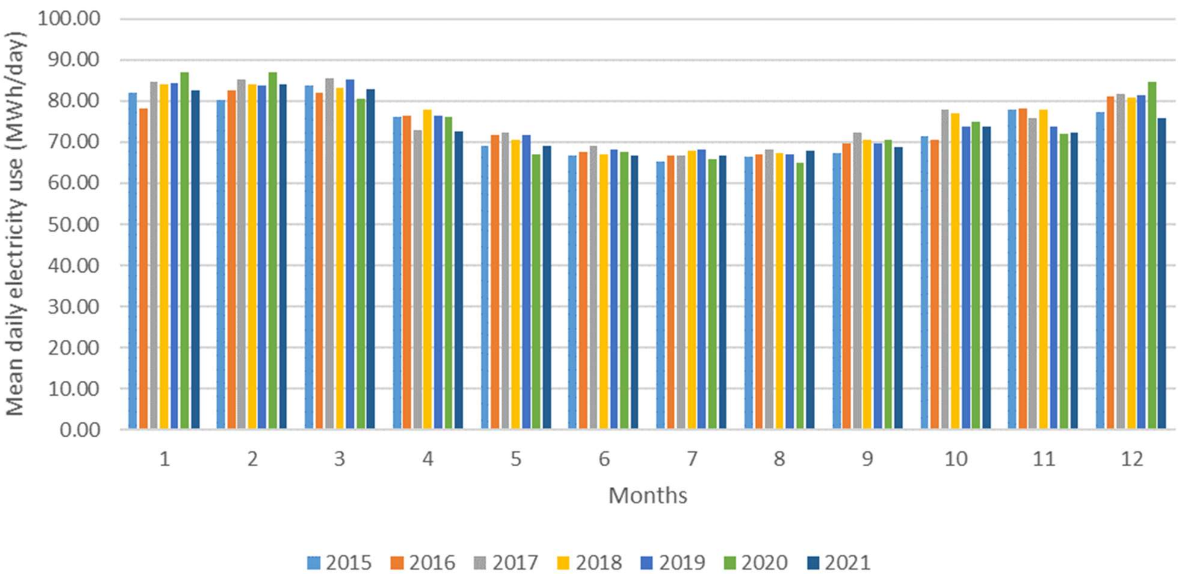


Figure 2-2 Mean daily electricity use in each month

Table 2-2 QCH precinct yearly electricity use

	2015	2016	2017	2018	2019	2020	2021
Yearly electricity use (GWh)	26.87	27.20	27.75	27.60	27.48	27.39	26.85

2.3 QCH Energy Use Modelling

Energy use is generally in trend with temperature changes for commercial buildings and power system level electricity demand [8]. Therefore, temperature is often the most commonly used factor in energy use forecasting [9][10]. Two data driven models – a linear model and a 2nd order polynomial model - were developed based on QCH's 2015 to 2022 monthly electricity use data and temperature data from Australian Bureau of Meteorology. Inputs to the models (independent variables) were monthly mean maximum temperature as shown in Equation (1) and outputs of the models (dependent variables) are mean daily electricity use in each month as shown in Equation (2).

$$\text{Monthly mean maximum temperature} = \frac{sum\ of\ daily\ maximum\ temperatures\ in\ a\ month}{number\ of\ days\ in\ a\ month} \quad \text{Equation (1)}$$

$$\text{mean daily electricity use} = \frac{sum\ of\ all\ electricity\ use\ in\ a\ month}{number\ of\ days\ in\ a\ month} \quad \text{Equation (2)}$$

The fitted linear model is in Equation (3) and shown as the red solid line in Figure 2-3. The input value T is the mean daily maximum temperature in a month. The dependent variables are mean daily electricity use on the left side of the equation.

$$\text{Mean daily electricity use} = 2.101 \times T + 20.72 \quad \text{Equation (3)}$$

To better represent the relationship between mean electricity use per day and mean monthly maximum temperature, a slightly more complicated second order polynomial model was developed through data fitting. The fitted second order polynomial model is presented in Equation (4) and Figure 2-4.

$$\text{mean electricity use per day} = 0.096 \times T^2 - 2.815 \times T + 82.77 \quad \text{Equation (4)}$$

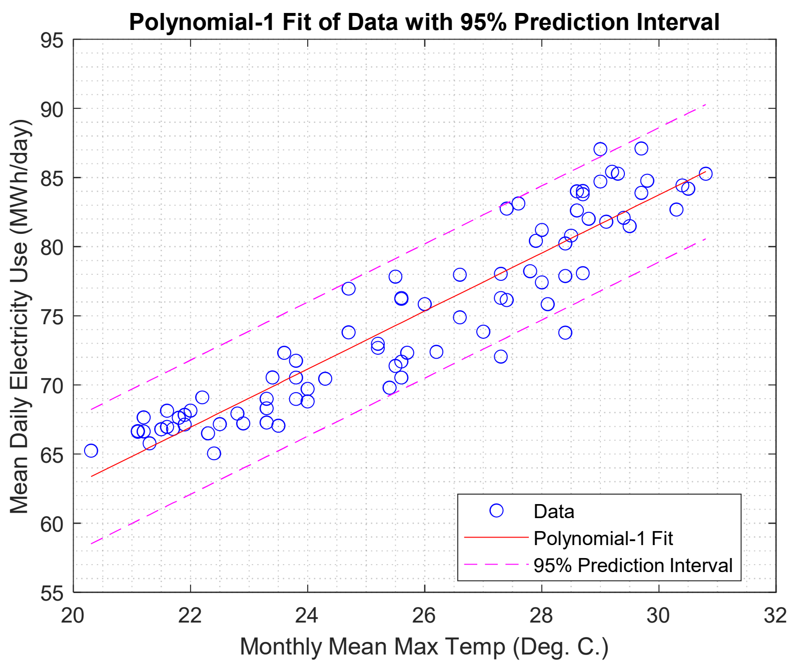


Figure 2-3 Linear fitting of the electricity use and temperature data

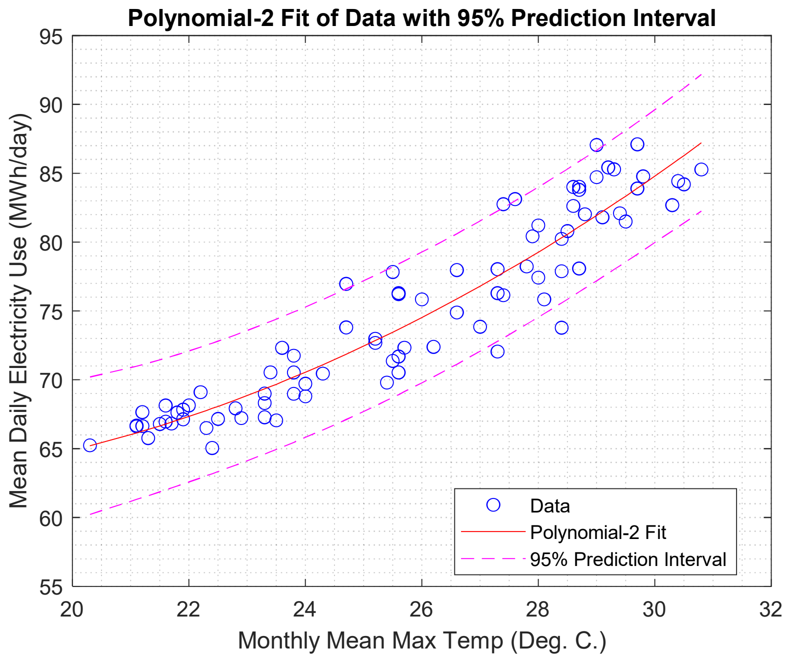


Figure 2-4 A second order polynomial fit of energy and temperature data

To determine which model to use in terms of forecasting the precinct energy use into future scenarios, R square values and root mean squared errors were compared for both the linear model and the second order polynomial model. A more accurate model would have higher R square values and lower root mean squared errors, in this case the polynomial model (refer to Table 2-3). As a result, the second order polynomial model was selected to forecast QCH precinct energy use into future 2030 to 2090 scenarios.

Table 2-3 Model accuracy comparisons

	Linear forecast model Equation (3)	2nd order model Equation (4)
R square values	0.869	0.880
Root mean squared error	2.426	2.338

2.4 Forecasts 2030 to 2090 Scenarios

The assumptions made for these forecast scenarios included:

1) No significant expansion is considered for the QCH precinct. (QCH is the only children's hospital in QLD, serving QLD and northern NSW. The physical site boundary is limited, however there is a spare piece of land allowed for future expansion if needed. On the other side, more development of community health service centres, satellite hospitals, or healthcare services provided by virtual means may relieve some pressure for expanding the existing QCH buildings [11].)
2) Consider like for like replacement for existing facility assets when they are out of service lifetime. (Potentially new assets would have higher efficiency for the same output rating.)
3) Increased energy use due to new clinical equipment is largely offset by other energy efficiency measures.
4) Indoor comfort is maintained through the 2030 to 2090 scenarios. For example, HVAC systems fully meet the thermal conditioning and ventilation needs of QCH buildings.

After applying the second order polynomial model to CSIRO's future climate files, the precinct's energy use in future typical years was estimated (refer to Table 2-4 and Figure 2-5).

Table 2-4 QCH precinct electricity use forecast into 2030 – 2090 scenarios

No.	Description	Emission business as usual (RCP8.5)	Emission middle scenario (RCP 4.5)	Emission negative scenario (RCP2.6)
2030	Typical yearly energy use between 2020-2040	27.47 GWh	27.01 GWh	26.95 GWh
	increase compared to 2021	**2.35%**	0.60%	0.39%
2050	Typical yearly energy use between 2040–2060	28.06 GWh	27.60 GWh	27.42 GWh
	increase compared to 2021	**4.51%**	2.82%	2.13%
2070	Typical yearly energy use between 2060–2080	29.26 GWh	27.87 GWh	27.07 GWh
	increase compared to 2021	**9.00%**	3.81%	0.85%
2090	Typical yearly energy use between 2080–2100	30.42 GWh	28.45 GWh	26.99 GWh
	increase compared to 2021	**13.32%**	5.98%	0.53%

If there is no global collective action to create an impact, the business-as-usual (BAU) pathway (RCP8.5) is a likely scenario to happen. For the BAU, compared to 2021, we are looking at

- 5% electricity use increase for all the 20 years between 2040-60
- 13% electricity use increase for all the 20 years before 2100

30GWh electricity is able to power up 4566 households in the same Southeast Queensland region (SEQ) for a year, considering a SEQ household uses 18kWh electricity a day on the average.

The trends and electricity use forecasts are visually presented in below Figure 2-5.

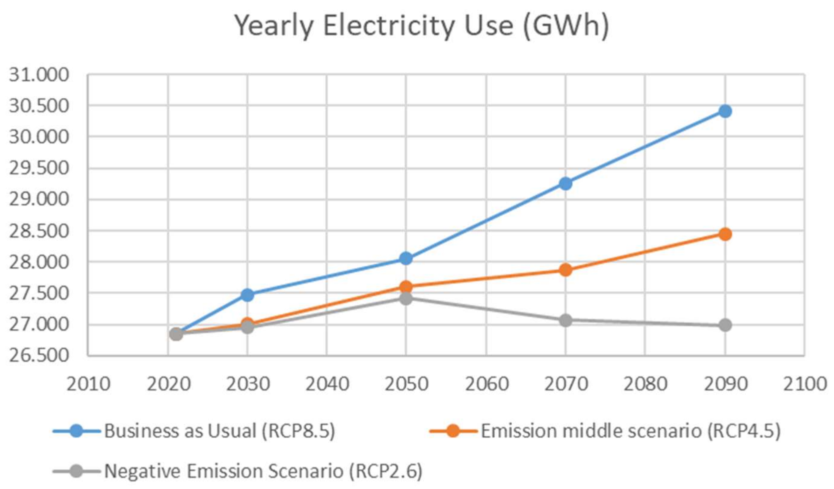


Figure 2-5 QCH precinct electricity use forecast into 2030 – 2090 scenarios

2.5 Discussion and Sector-wide Implications

QCH is one of the major principal referral hospitals in Queensland and in Australia. In Queensland, public health regularly accounts for over 30% the state's budget [12]. As the climate changes, there is a need to better understand the impact of the future climate on energy use, in order to better future-proof energy sustainability and financial sustainability for our healthcare sector.

Across Australia, there are over 1300 public and private hospitals (Figure 2-6). 148 of them are hospitals with over 100 beds [13]. Australia's total hospital expenditure was AU$73billion for the financial year 2017 to 2018 [14][15][16]. Savings through energy sustainability can offer an opportunity to alleviate some of the budgetary pressure.

For decision making in energy sustainability, renewable targets (green power purchase) and cost control, this report's data analysis and forecasting method can be applied to other hospital and healthcare sites.

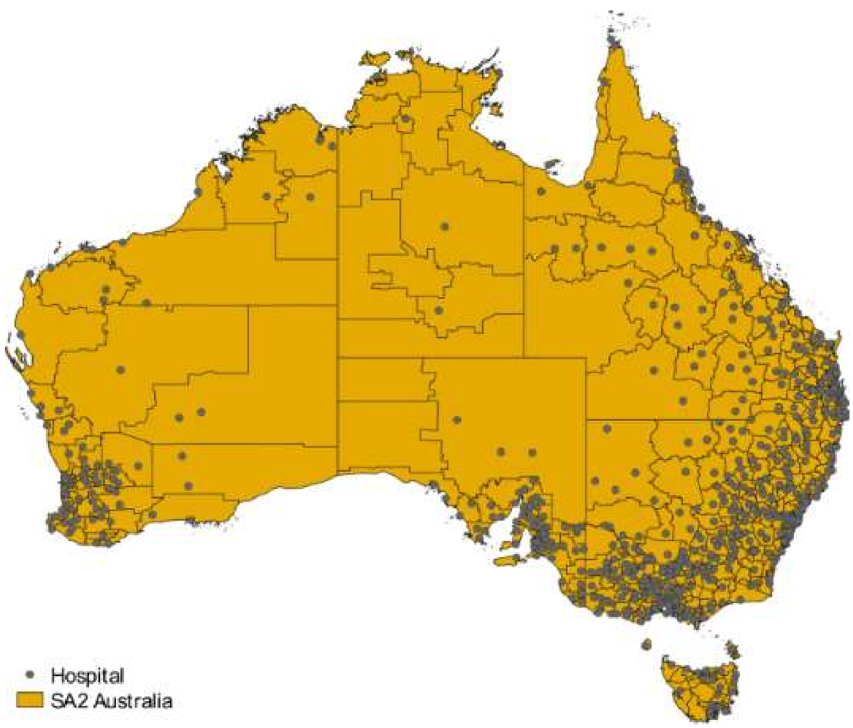


Figure 2-6 Hospital sites on the map of Australia

(SA2: statistical areas level 2, adopted from [17])

The forecast results for the 2030 to 2090 scenarios are for typical years within each 20-year period, rather than for years of extreme events, such as some years with extended periods of heat waves. Higher levels of energy use increase would probably occur in future years with the increased intensity, magnitude and duration of heatwaves as a result of climate change.

2.5.1 Future work

There is a need for the development of 'extreme weather' climate files that take into account events such as heat waves. Such events are known to have an impact on energy, through increased utilisation of air conditioning, reduced efficiency of air conditioners and the electricity network, and increased risk of power failure. Extreme weather climate files would enable modelling and simulation to understand the extent of the energy impacts and make decisions to avoid or limit the negative impacts.

3 ELECTRIFICATION OF SPACE HEATING

Note: this section contains extracts from a paper presented at the Australasian Building Simulation 2022 Conference, Brisbane. Further details of the evaluation can be found in the full paper.

Ma, Yunlong; Liu, Aaron; Zedan, Sherif; Miller, Wendy; Bonney, Bruce; Sanders, Jason; Campbell, Michael (2022) *Heating electrification impacts on commercial HVAC performance today and future: A case study.*

It describes the use of dynamic building energy simulation (DesignBuilder) to evaluate the effect of space heating electrification combined with renewable energy resources. This process is applied to the Centre for Children's Health Research (CCHR), one of the buildings in the Queensland Children's Hospital precinct in South Brisbane. This building's HVAC systems were simulated under current and predicted future Brisbane climates. Roof-mounted solar PV systems were considered as the renewable energy investment combining with heating electrification, which is achieved by replacing the natural gas-powered hot water boiler with an electric hot water boiler in the CCHR's HVAC plant.

3.1 Building description

The CCHR building is a 9-storey building constructed in 2015 with a total floor area of 14,108 m^2 and roof area of 1,740 m^2. Five levels of the CCHR are dedicated to research laboratories and the remaining levels accommodate the QCH Pathology service, office areas, reception, car parking and a COVID19 testing area (Liu et al., 2020). It has five different types of HVAC systems, including CAV systems, VAV systems and chilled water fan coil units (FCUs) serving 41 different zones. Cooling and heating are supplied by a central chilled water plant and a central natural gas fuelled hot water plant, respectively. The building 3D model and its HVAC system diagram in DesignBuilder are shown in Figure 3-1.

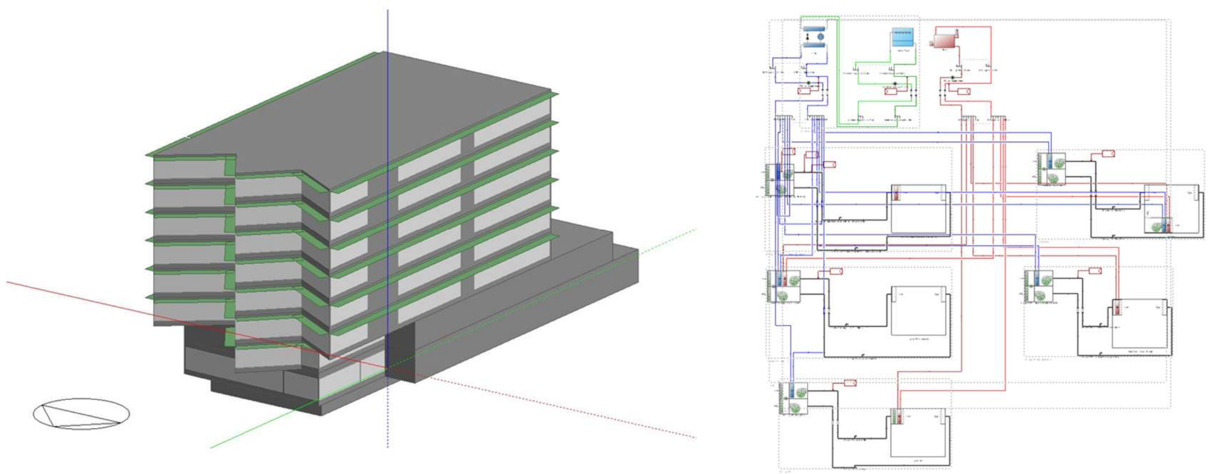


Figure 3-1 The CCHR building and 3D DesignBuilder model

3.2 Simulation parameters

The CCHR building envelope materials and construction are summarised in Table 3-1, which are referenced from the BCA2010 Deemed-to-Satisfy requirements (the relevant code at time of building design). The internal load profiles and schedules for lighting, equipment, occupancy, and infiltration are also referenced from the BCA2010, with infiltration rate of 1 ACH, lighting power density of 9 W/m^2, equipment power density of 15 W/m^2, and occupancy density of 10 m²/person. The HVAC schedules and temperature set-points are shown in Table 3-2, based on the CCHR HVAC system design.

Table 3-1 CCHR building envelope physical properties

Name	Construction (outside to inside layer)	Total U value (W/m² K)
External wall	Concrete block, air gap, R2.7 insulation, 19mm plasterboard	3.3
Roof and Ceiling	Concrete roof tiles, R3.6 roof insulation, 13mm ceiling board	4.2
Floor	Concrete slab on ground, R1.0 insulation	1.25
Window U-value	Aluminum frames	1.56
Window SHGC		0.28 on East and 0.22 on others

Table 3-2 HVAC system schedules and temperature set-points

System type	Schedule	Heating set-point	Cooling set-point
Single Zone CAV	7:00-18:00 & 24/7	21°C	23°C
Multi Zone CAV (with humidity control)	24/7	20°C, 50% RH	
Multi Zone CAV (with local hot water heating coils)	24/7	21°C	24°C
Multi Zone VAV	7:00-18:00	21°C	24.5°C
FCU	7:00-18:00 & 24/7	21°C	24.5°C

Table 3-3 Solar PV parameters

Properties	Parameters
Solar Panel Model	LG420N2W-L5
Module Dimensions (L x W x H)	2,024mm x 1,024mm x 40mm (~2m² active area)
Solar PV area [m²]	1740 x 30% = 522
Cell Properties (Material/Type)	Monocrystalline/N-type
Total solar PV capacity [kW]	109.6
Electrical Properties (STC*)	
Maximum Power (Pmax) [W]	420
MPP Voltage (Vmpp) [V]	42.1
MPP Current (Impp) [A]	9.98
Open Circuit Voltage (Voc, ±5%) [V]	49.7
Short Circuit Current (Isc, ±5%) [A]	10.63
Module Efficiency [%]	20.3
Temperature Characteristics	
NMOT [°C]**	42±3
Pmax [%/°C]	-0.35
Voc [%/°C]	-0.26
Isc [%/°C]	0.025

*STC (Standard Test Condition): Irradiance 1000 W/m², cell temperature 25°C, AM 1.5
**NMOT (Nominal Module Operating Temperature): Irradiance 800 W/m², Ambient temperature 20°C, Wind speed 1 m/s, Spectrum AM 1.5

The proposed solar PV system parameters are listed in Table 3-3. The selected solar PV module is LG's best-selling solar module NeON® 2, reportedly one of the most powerful and versatile modules on the market today[1]. The roof area available for solar PV is assumed to be 30% of the total roof area, taking into consideration roof located cooling towers, other equipment and maintenance activities.

The current and future climate files used for simulation are sourced from CSIRO (Ren et al., 2021a, 2021b). Climate files using the RCP8.5 pathway are chosen for Brisbane 2030, 2050, 2070, and 2090 future climates, due to this scenario being the 'worst-case' scenario (Foo, 2020).

3.3 Effects of heating electrification

Under the current climate, dynamic energy simulation showed electrification could reduce annual onsite energy use by 17% (Figure 3-2), greenhouse gas emissions by 4.7% (Figure 3-3) and annual operational energy costs by 4.2% (Figure 3-4).

These results are based on the following inputs:

Electrification is via a resistive element electric boiler combined with installation of a 109.6 kW PV system which is capable of generating 655 GJ heat (thermal energy) annually.

The annual CO_2 emissions calculation is based on the following formula:

$$M_{CO2} = E_{Gas} \times CO_2factor_{Gas} + E_{Elec} \times CO_2factor_{Elec} \quad (1)$$

where:

M_{CO2} = annual total on-site CO_2 emissions in kg;

E_{Gas} = annual natural gas consumption in GJ;

E_{Elec} = annual electricity consumption in GJ;

$CO_2factor_{Gas}$ = the CO_2 emission factor for natural gas in $kgCO_2$-e/GJ;

$CO_2factor_{Elec}$ = the CO_2 emission factor for electricity in $kgCO_2$-e/kWh.

The emissions factor for natural gas is 51.53 $kgCO_2$-e/GJ and the emissions factor for electricity is 0.78 $kgCO_2$-e/GJ.

The annual operational energy cost is calculated using equation (2). In this study, only the general energy charge in annual consumption is considered (i.e. peak demand charges and connection fees are excluded).

$$OC = E_{Gas} \times c_{Gas} + E_{Elec} \times c_{Elec} \quad (2)$$

where:

c_{Gas} = natural gas price in \$/GJ, and assumes 7 \$/GJ;

c_{Elec} = electricity price in \$/kWh, and assumes 0.12 \$/kWh

[1] SolarDesignTool, LG Solar Panels (PDF).

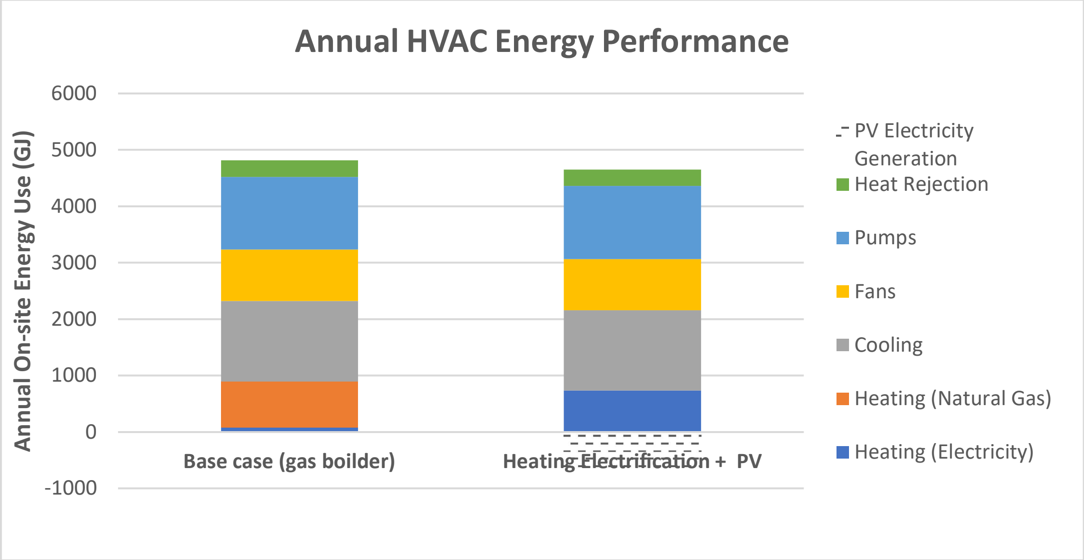


Figure 3-2 Impact on HVAC energy use

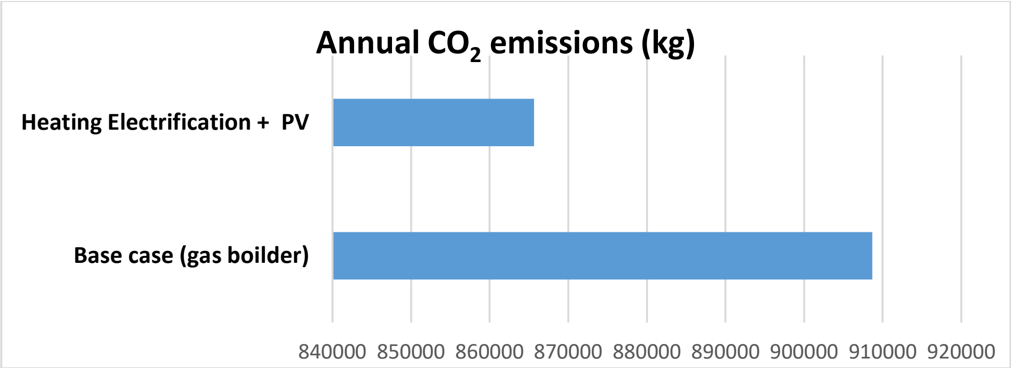


Figure 3-3 Impact on annual greenhouse gas emissions

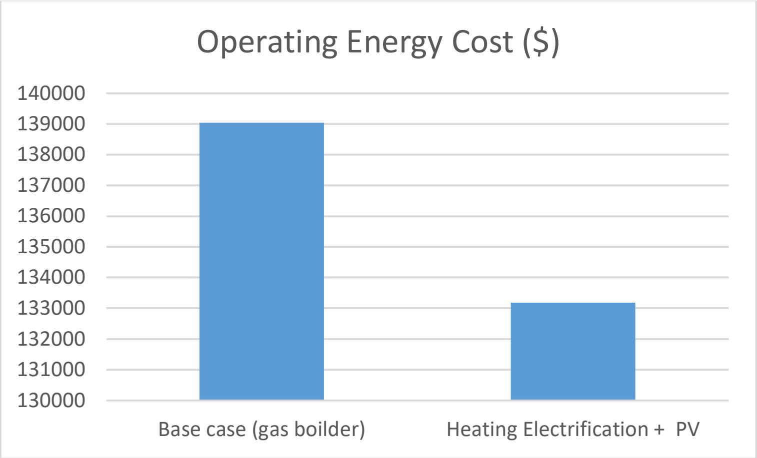


Figure 3-4 Impact on annual operational energy cost

Future climates will increase the HVAC annual energy use of both scenarios (gas-fired boilers and electric boilers), as shown in Figure 3-5. The increase total HVAC energy use for both scenarios under the future climates is mainly due to the increase in ambient temperature, which significantly impacts the cooling energy requirements. The figure clearly shows the current and future benefit of electrification on total HVAC energy use.

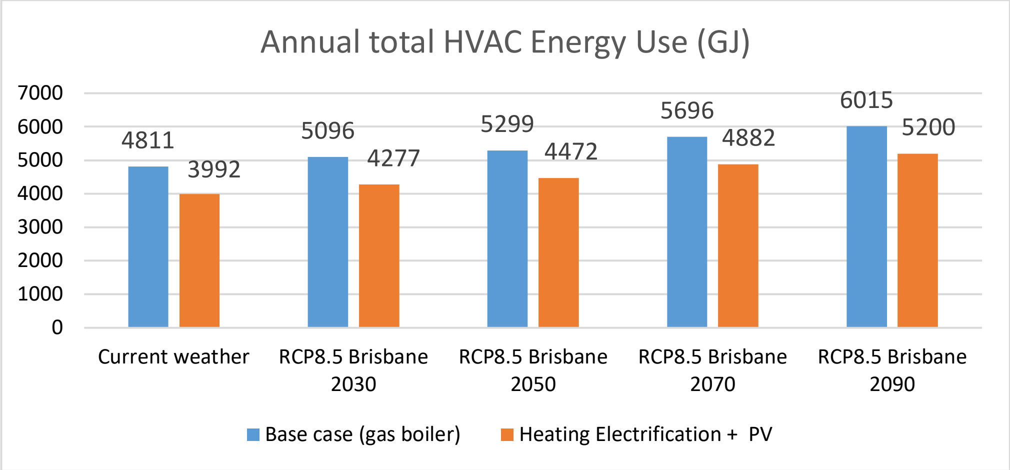


Figure 3-5 Impacts of future climate on HVAC energy performance

Future climate scenarios (RCP8.5) show an increase in cooling demand and a decrease in heating demand, as indicated in the first two rows of Table 3-4. The bottom two rows of the table compare the electric heating load with PV generation, demonstrating that the heating load can be completely covered by the PV system by the period represented by 2050 (i.e., 2040 – 2060). This demonstrates that net-zero-energy space heating is achievable, for this building, in this climate zone.

Table 3-4 Heating energy end use comparison in future climates

	Heating Energy (GJ)	Current weather	RCP8.5 Brisbane 2030	RCP8.5 Brisbane 2050	RCP8.5 Brisbane 2070	RCP8.5 Brisbane 2090
Base case	**Natural gas**	814	717	698	651	617
	Electricity	80	75	71	63	56
Heating Electrification + PV	**Electricity**	733	649	629	585	551
	PV Generation	655	674	686	682	690

3.4 Implications and Future Work

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. This study demonstrates the feasibility of that transition for this building, and that the heating electrification energy load can be met with rooftop renewables by mid-century.

The feasibility of heating electrification 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.

4 EFFECTIVENESS OF PANDEMIC MODE VENTILATION STRATEGIES

COVID 19 raised questions about the operation of HVAC in healthcare settings, in order to limit the spread of respiratory aerosols. Pandemic mode advice has been provided to healthcare facilities, recommending a range of strategies, such as dilution with 100% outside air, use of minimum F9 filters, and maintaining indoor summer conditions to 24-27^{o}C and 50-60% RH. The energy impact of the first two of these strategies is reported in i-HUB report *LLHC5 Net zero energy and resilient hospitals*.

This investigation was undertaken to determine the impact that different mechanical ventilation strategies have on respiratory aerosolised droplet distribution within a typical hospital ward.

4.1 Methodology

Computational fluid dynamics (CFD) modelling software was used to determine the comparative quantity of droplets within the ward after a fixed time period, in different mechanical ventilation configurations. The goal of this investigation was to determine what changes produced the greatest reduction in aerosolised droplets within the space.

4.1.1 Functional area

The chosen modelled region (Figure 4-1) represents a typical ward region, including 15 beds (comprising single and double bed wards), a single one bed isolation room, staff station, office, medication room, lounge area and associated supplied and cleaning rooms. The space is an extract from a hospital currently being constructed in the Melbourne metropolitan area. Some areas have been excluded from the analysis, including but not limited to all services spaces and unventilated cupboards and rooms.

The modelled mechanical system (refer to section 4.1.5) is not representative of the Melbourne metropolitan hospital under construction, as the mechanical ventilation design has not yet been complete. Flowrates simulated are representative of a typical HVAC system configuration for this type of space.

Large furniture objects were included in the model, specifically patient beds and staff station desk. Simplifications were made in regions with non-critical small and/or fine detail. These features were deemed to have minimal impact on the general air flow within the space.

The 3D model generated by the software is shown in Figure 4-2.

Figure 4-1 Extract of modelled region (excluded areas greyed out)

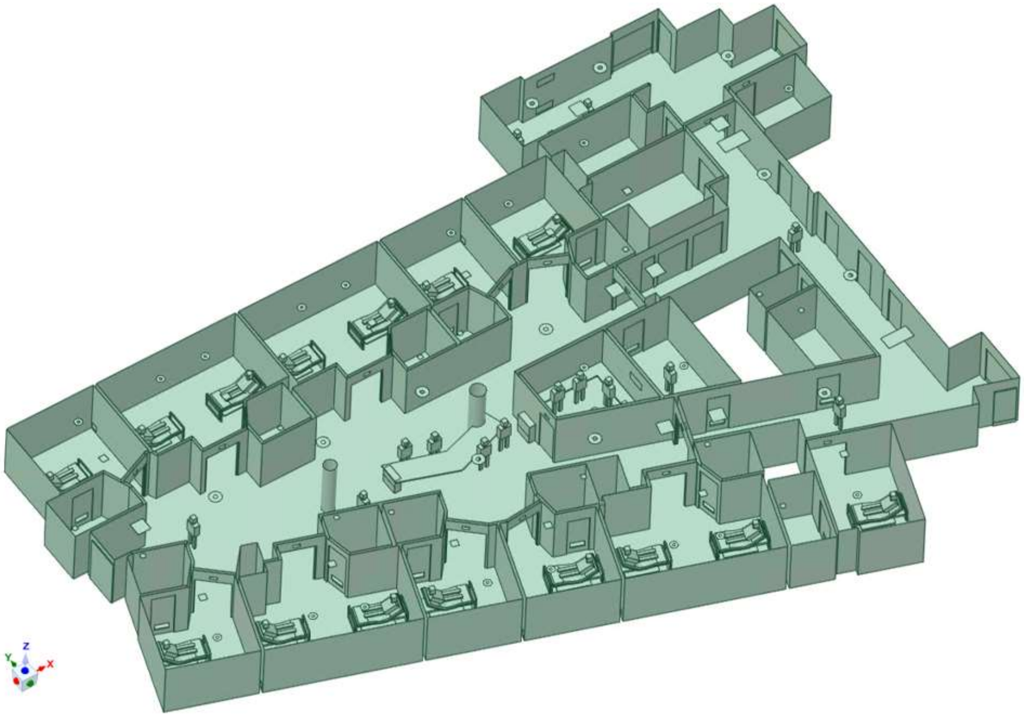


Figure 4-2 Generated model geometry (simulation 1 - base case)

4.1.2 Locations of aerosol generation

As discussed previously, the intent of this investigation was to determine the impact of changes to the mechanical system on aerosolised droplet dispersion within the area. Aerosols were generated within the modelling at the location of occupants, whose positions are shown by the red dots in Figure 4-3.

Figure 4-3 Occupant locations within the model

4.1.3 Nature of the aerosols

During exhalation, people release thousands of aerosolised particles when breathing out, speaking, and coughing. These particles are water-based solutions of salt, mucus, proteins, and other substances from within the respiratory tract, potentially including pathogens, including viruses and bacteria, which may be carried in exhaled aerosolised droplets into ambient air which act as vectors for infecting others.

Different experimental droplet studies have recorded differing droplet size distributions which can affect droplet behaviour in a simulation, with major aerosol size studies summarised in Figure 4-4. The respiratory release used within this modelling exercise is as per the ‘bnm’ figures shown in Figure 4-5, which is representative of breathing in through the nose and out through the mouth. No coughs, sneezes or conversations were simulated.

Droplet sizes in this simulation study were within the range of 0.8 to 5.5 microns in diameter. All simulations consider constant droplet inlet boundaries at occupant mouth locations (as opposed to pulsed). Humans produce larger droplets than what was modelled, however these larger droplets were excluded due to their lack of propensity to aerosolise and travel significant distances indoors.

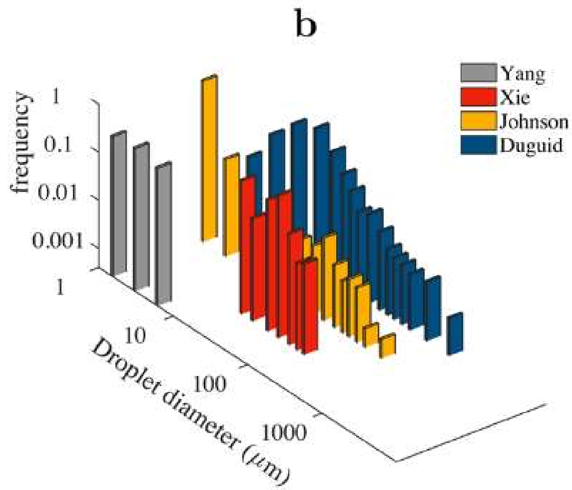
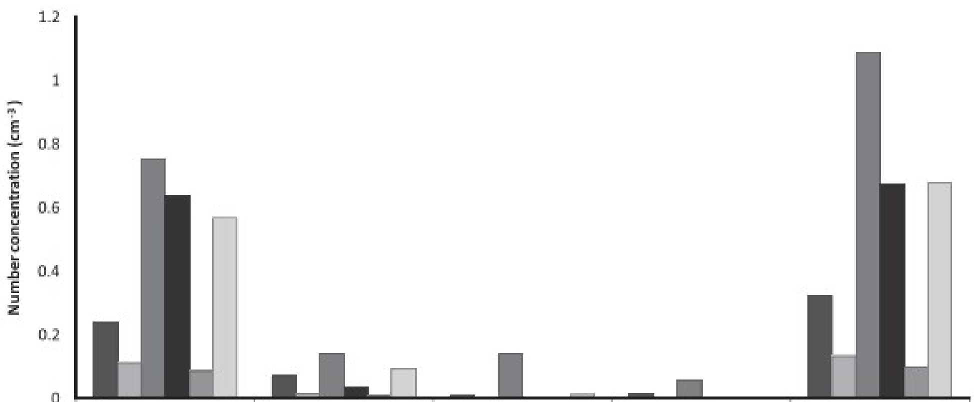


Figure 4-4 Particle diameters observed in prior literature

(Reference: [18])



	A, CMD≤0.80±0.08 μm	B, CMD=1.8±0.3 μm	C, CMD=3.5±0.7 μm	D, CMD=5.5±1 μm	Total
cvp	0.236	0.068	0.007	0.011	0.322
cwp	0.110	0.014	0.004	0.002	0.130
aahvp	0.751	0.139	0.139	0.059	1.088
aahwp	0.636	0.037	0.000	0.000	0.672
bnm	0.084	0.009	0.003	0.002	0.098
cough	0.567	0.093	0.012	0.006	0.678

Figure 4-5 Particle concentrations per size mode, per activity

(Reference: [19])

4.1.4 Simulation Scenarios

A reference model or 'base case' was established, against which all additional modelling could be compared. The setup of the reference model is intended to represent a typical design, balancing minimum compliant design and current design practices for this type of space. Eight scenarios were considered as part of this investigation: 5

differing geometry and mechanical configurations, and two different droplet recirculation rates[2] for three of these configurations. A summary of the scenarios is shown below in Table 4-1. Note that the supply air ventilation configuration, in terms of quantity and location of supply air, is common to all scenarios, with the main changes being to the return and exhaust grille locations, and the addition of air purifiers.

Table 4-1 Summary of simulation scenarios considered

Scenario		Notable features	Recirculation % considered
1	Base Case	Two large return air grilles located in common areas. General doors open.	75% + 25% droplet recirculation
2	100% Outside Air	Geometry and ventilation rates identical to scenario 1 except with no droplet recirculation with the system. General doors open.	0% droplet recirculation
3	Localised Return	Localised smaller return air grilles in each room as opposed to that considered in scenario 1. Doors closed.	75% + 25% droplet recirculation
4	Localised Return + air purifiers in populous areas	Identical to scenario 3 with the inclusion of 4x air purifiers located in populous regions within the common spaces. Doors closed.	75% + 25% droplet recirculation
5	Localised Return + air purifiers in populous areas + individual purifiers per room	Identical to scenario 4 with the inclusion of 15x smaller air purifiers located adjacent to each bed. Doors closed.	25% droplet recirculation

Assumptions

- Given hospitals function 24/7 and in all climatic conditions, to reduce modelling complexity a position was taken for the base simulation to be based on anticipated minimum supply air flowrates that may be applicable in the space. Given that many hospital mechanical ventilation systems are variable air volume, it was proposed that the conservative approach to simulate with anticipated minimum supply air flowrates would provide results that are applicable to many existing hospital systems, and representative of the mechanical ventilation systems that are most sensitive to modifications, upgrades and configuration changes.

- Due to time and complexity restraints, all simulations were considered isothermal. This was considered an acceptable simplification due to the relatively minor impact of buoyancy differences on flow behaviour. Furthermore, buoyancy effects are opposite for summer and winter conditions and as such the omission of such effects could be considered a coarse average of the two conditions.

- This isothermal assumption extends to supply air temperatures as well as outside air boundary conditions considered in all simulations. Consideration of multiple temperature scenarios (e.g., Summer, Winter, Autumn, and Spring) would greatly increase the total required number of scenarios to consider and was not feasible within the timeframe of this project.

Door operation was different between scenarios, with doors generally open in the base case, and generally closed in pandemic mode models.

[2] The term ‘droplet recirculation rate’ pertains to the percentage (%) of respiratory aerosols that survive the journey through the ventilation system and re-appear in the space through supply air diffusers after being sucked into the return air system through a return air diffuser.

4.1.5 Base case mechanical system

The reference model mechanical system has been based on a balance of minimum compliant design and current common design practice for this type of space. Simplifications have been made to the mechanical system, for CFD purposes, as described in Table 4-2.

Table 4-2 Mechanical system simplifications for CFD modelling

Flow rates and locations	Flow rates and locations were implemented per ARENA IDS - FUTURE HOSPITAL RESEARCH PROJECT - MECH SCHEDULES Rev B.xlsx with key details shown in Figure 4-6, Figure 4-7 and Figure 4-8. Supply air flowrates are based on the anticipated minimum turndown of the reference mechanical ventilation system.
Grille locations	Supply, exhaust, and return grille locations are shown in Figure 4-6, Figure 4-7, and Figure 4-8.
Door operation	Door operations are provided in Figure 4-6 considers all obvious doors open (room doors, main doors, toilet offices shut etc.). All other scenarios (3,4,5) consider a majority of doors shut.
Supply air	Supply air is delivered to the space via a combination of Trox FD-400 and FD-600 swirl diffusers. The diffusers have been implemented as annulus shaped inlets with the same inner and outer diameter as the respective Trox product. Swirl at the inlet face was approximated via specifying unique cylindrical velocity components (axial, radial, and theta) for each diffuser. These components were obtained via a separate CFD modelling investigation into physical diffuser performance as compared with approximated diffuser performance via cylindrical velocity component. The approximated diffuser performance was tuned to closely match the actual diffuser performance, at reduced computational expense.
Exhaust air	In room return and exhaust air is achieved via typical 300x300mm or 200x200mm egg-crate grilles, implemented in the modelling as square outlets of the same size. Common area returns were implemented as 1200x600mm, also implemented as rectangular outlets of the same size.
Transfers	Transfers are achieved via ceiling transfers, door grilles, and door undercuts. Ceiling transfers were implemented in the modelling as high-level 300x150mm openings in the wall across the adjacent spaces. Door grilles were implemented in the modelling as 600x300mm openings in the door separating adjacent spaces. No additional pressure drop was implemented across these openings, due to the anticipated low velocities and high free area of the physical products.
Air purifiers	Air purifiers considered within various scenarios of this investigation are not representative of any specific or proprietary product. Rather, a generic shape and assumed realistic flow rate were considered. Air purifiers considered within all simulations were assumed to be 99.97% effective at eliminating droplets from air passing through them, in line with approximated HEPA filter efficiency.
Isolation room	The modelled ward region included an isolation room. Due to the complexities involved in the design of isolation room ventilation systems, it was decided to exclude the isolation room from the analysis. Instead, the expected flow rates generated by the isolation room ventilation systems were applied at the door undercuts for the doors from the main ward to the isolation room and ante room.
Dynamic effects	Due to the specifics of the CFD simulation software used for this investigation, any dynamic effects of the mechanical system (such as ramping up and down) were ignored. The modelled domain finishes at the grilles and does not include air handling units or duct runs not in the modelled region. The modelled region did not include the ceiling space or associated ductwork. The resultant simplification is that all droplet recirculation happened instantly. That is to say that as droplets leave the space via return air grilles, they immediately re-enter the domain via supply air swirl diffusers with the assumed survival rate & outside air dilution accounted for.

Figure 4-6 Mechanical system for scenarios 1 and 2 (100% outside air)

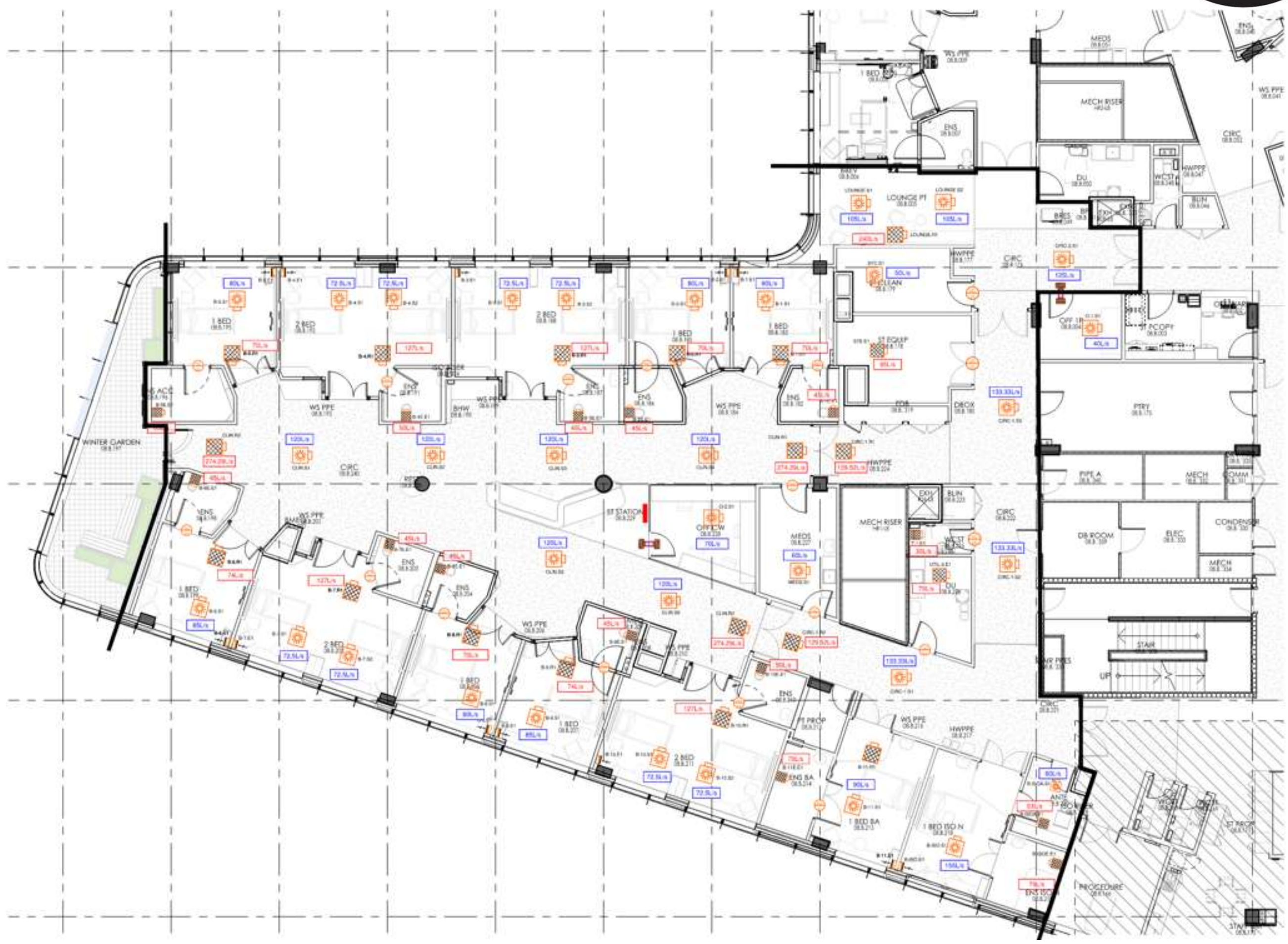


Figure 4-7 Mechanical system for scenario 3 (localised return)

Figure 4-8 Mechanical system for scenarios 4 and 5 (localise return + air purifiers)

(Note Scenario 4 purple dots; Scenario 5 purple and green dots)

4.2 Results

A comparison of the net suspended aerosols after 600s (10 minutes) is shown in Figure 4-9 and Table 4-3 summarises the percentage changes for each scenario relative to the base case. Table 4-4, Table 4-5, and Table 4-6 show the contours of droplet concentrations after 10 minutes, for each of the scenarios.

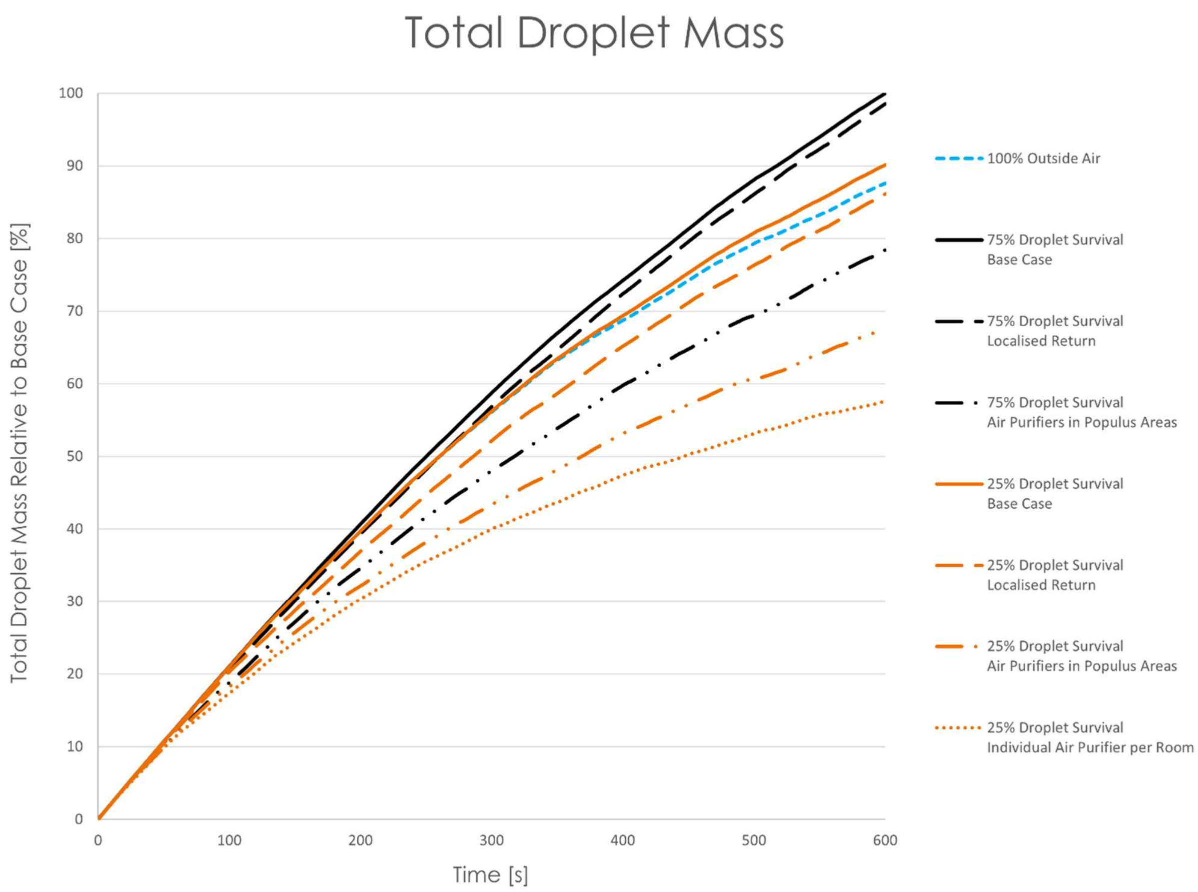


Figure 4-9 Net suspended aerosols after 10 minutes

Table 4-3 Comparison of percentage change in droplet mass

Scenario		75% Droplet Recirculation	25% Droplet Recirculation (Brackets denote relative to 25% base case)
1	Base Case	-0%	-9.89% (-0%)
2	100% Outside Air	-12.38%	-12.38% (-2.77%)
3	Localised Return	-1.45%	-13.86% (-4.41%)
4	Localised Return + air purifiers in populous areas	-21.57%	-32.39% (-24.97%)
5	Localised Return + air purifiers in populous areas + individual purifiers per room	N.A.	-42.38% (-36.06%)

Table 4-4 Contours of droplet concentrations at Z=1.5 AFFL after 10 minutes (scenarios 1 and 2)

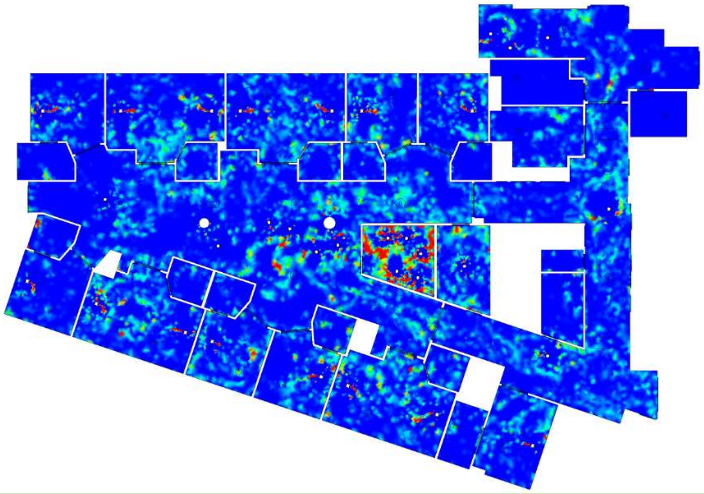
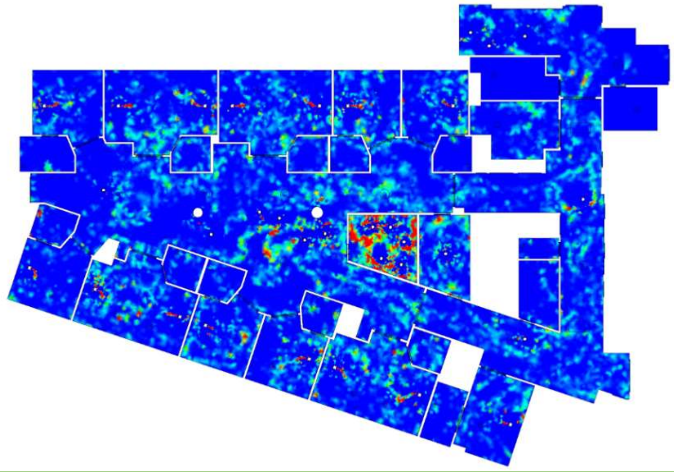
Scenario	1 – Base Case
75% Droplet Recirculation	
25% Droplet Recirculation	
	2 - 100%Outside Air
	

Table 4-5 Contour of droplet concentrations at Z=1.5 AFFL after 10 minutes (scenario 3)

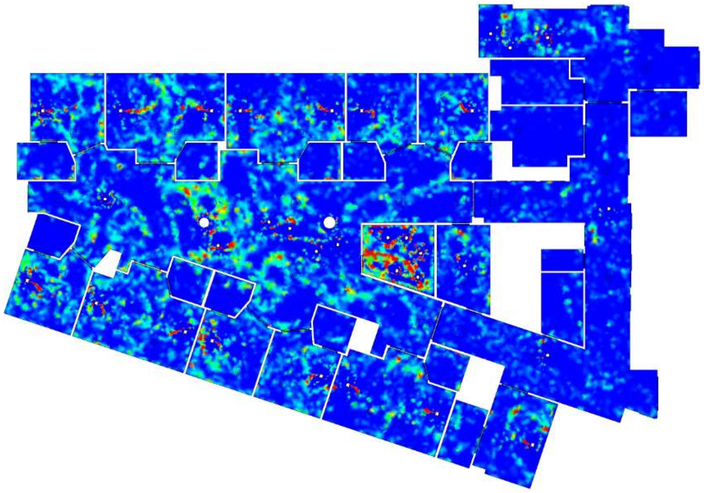
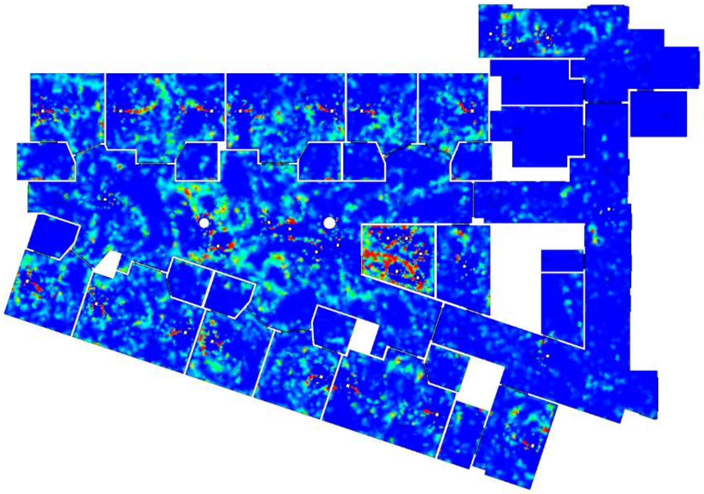
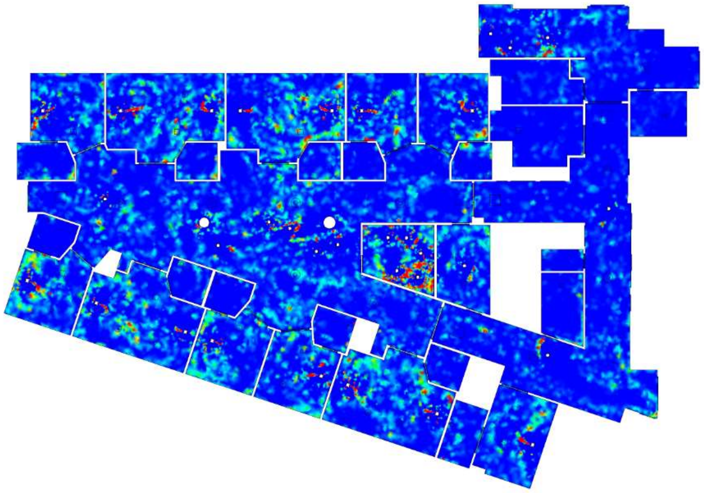
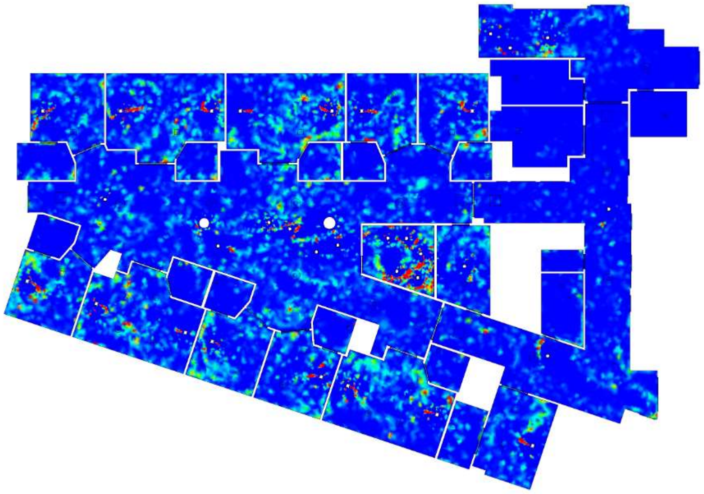
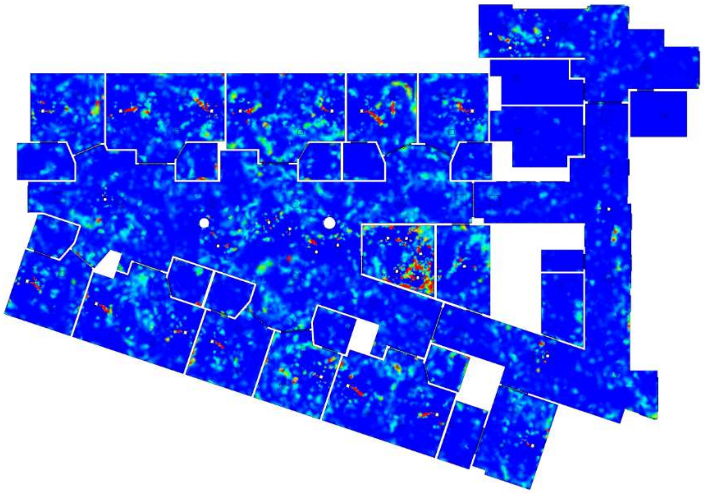
Scenario	3 – Localised Return
75% Droplet Recirculation	
25% Droplet Recirculation	

Table 4-6 Contours of droplet concentrations at Z=1.5 AFFL after 10 minutes (scenarios 4 and 5)

Scenario	**4 – Localised Return + Air Purifiers in Populus Areas**
75% Droplet Recirculation	
25% Droplet Recirculation	
	5 – Individual Retrun + Air Purifiers in Populus Areas + Individual Purifiers per room
25% Droplet Recirculation	

4.3 Discussion

4.3.1 Impact of findings

A key characteristic of industry response throughout the COVID-19 pandemic has been a focus on increasing outside air % within ventilation systems. This imposes significant challenges to the industry, as increasing outside air % triggers an increased cooling / heating load on the system, increased energy consumption and in most cases the ductwork and coil capacities are not appropriately sized for this change without significant upgrades. The capital and operational costs associated with this is at odds with sustainability objectives to reduce material and energy use.

As part of a separate investigation[3], Stantec has quantified the impact of increasing outside air to 100% on this reference model, highlighting a significant penalty of circa 10-20% on annual HVAC energy consumption (depending on climate zone).

This investigation highlights the sensitivity of droplet recirculate rate in determining the effectiveness of increasing outside air %. Any advice regarding increasing outside air as a means of clearing aerosolised particles needs to be considered within the context of the specific ventilation system type and configuration. As an example, for a large multi-zone air handling system with a large extent of return air ductwork, high efficiency filtration etc., the likelihood is that a portion of the recirculated droplets are being deposited within the system. If all of them are being deposited (say 0% droplet recirculation rate), they do not re-appear in the supply air stream and thus the outside air percentage is irrelevant to the reduction of suspended aerosol mass.

This analysis has shown that the application of more ubiquitously distributed return air diffusers local to each bedroom (instead of central large return air grilles in the corridor) has a relatively minor impact on the total quantity of suspended droplet mass, however, does reduce the spread of aerosols from bedroom areas into the corridor.

Another key finding is the superior effectiveness of portable air purifiers in areas of high respiratory activity, such as the staff station in the corridor. The results clearly show that strategically targeted local exhaust and filtration systems could provide significantly more benefit than increasing outside air when considering the quantity and concentration of aerosolised respiratory particles, and from a logistics perspective are considerably easier to achieve in the real world.

Ultimately, the findings of this investigation indicate that designers of ventilation systems should potentially consider a shift from traditional ceiling-mounted return/exhaust grilles to local exhaust/filtration systems installed as close as possible to where respiratory activities are taking place, such as integration with furniture and/or other fixed building elements. This is a paradigm shift from conventional thinking with respect to ventilation system configuration. Ventilation design should consider that people are pollution sources and apply traditional exhaust capture strategies to areas with high respiration rate to support higher air change effectiveness in breathing zones. The effectiveness of filters in capturing aerosols provides an opportunity for these systems to be decentralised from traditional in-ceiling ventilation infrastructure.

4.3.2 Future work

It is proposed that in-duct droplet decay should form a key focus of future research and response in industry. In the absence of research findings to inform what in-duct droplet decay factors are likely to be, for given system types, a simple means to enable broad market uptake of this concept could be correlating the pressure drop through the return air system to an in-duct droplet decay factor. The result would be a more informed basis for being able to recommend increasing outside air percentage for specific ventilation system types.

In terms of additional computational modelling specific to this investigation. We recommend the following additional work to further determine relationship between mechanical system configurations and effectiveness at reducing suspended aerosolised droplets:

- Investigation of more realistic situations to be developed in consultation with clinicians. For example, a cough event from an infected patient and/or the influence of conversations at staff station areas.

[3] Refer to i-HUB report: *LLHC5 – Net zero energy and resilient hospitals*. May 2022.

- Investigation of air purification systems in isolation against the base case simulation. This would enable more accurate quantification of the effectiveness of air purification systems, rather than in combination with other measures.
- Investigation of mechanical displacement ventilation systems. Previous research by Stantec has indicated that these are effective at reducing droplet distance travelled and time suspended, however this research was undertaken in a non-hospital setting. While displacement ventilation systems are unsuitable for retrofit to existing hospitals, they warrant consideration for new builds.
- Investigation of air purifier placement, with a view towards investigating the effectiveness of integrated air purification systems. Portable air purifiers have been demonstrated to be effective, however integrated systems would be more architecturally appealing. The effectiveness of such integrated systems should also be investigated, particularly for cases where an integrated air purifier cannot be installed as close to occupants as portable systems.
- Investigation of lower performance filters instead of HEPAs within the localised purification systems, and with lower flows that may be more achievable with small/micro systems.

4.3.3 Disclaimer

This computational fluid dynamic (CFD) model provides information about flow field and droplet distribution within the simulated domain.

This simulation is based on a necessarily simplified and idealised version of the domain and its contents that does not and cannot fully represent all of the intricacies of the space and its operation. As a result, the model results only represent an interpretation of the potential performance of the space. No guarantee or warrantee of building performance in practice can be based on simulation results alone.

The results generated from this analysis are based on specific assumptions outlined in this document. Any variation from the stated assumptions and inputs may produce a new set of results.

5 EIMPLICATIONS OF AS4187 ON ENERGY PLANT INFRASTRUCTURE FOR AUSTRALIAN HOSPITALS

5.1 History

It is easy to forget that up until the late 19th century, when the principles of germ theory of disease became commonly understood and applied in medicinal practice, that there was no universal tradition of cleanliness.

There are nuanced examples in history of basic sterilisation techniques, such as the ancient practice of boiling water and Galen the Greek boiling 'surgical' instruments in water to save gladiators. However, it was the works of great scholars such as Louis Pasteur, Robert Koch and Joseph Lister who identified that living micro-organisms (or microbes) could be carried in air and by people between spaces, which led to a cleanliness revolution within hospitals.

A hallmark of this transition involved the first mainstream use of sterilising agents such as chlorine or lime in washing hands, spatial planning of hospitals to ensure separation between 'clean' operating rooms and 'dirty' spaces such as autopsy rooms and toilets, and heat-related sterilisation of utensils. Technology progressed quickly with the first pressure steam steriliser in 1880, identification that 'moist' steam is more effective than dry and that sterilising in a vacuum can increase penetration. By the 1930's the technology had developed to include monitoring and control of temperature, pressure cycles as well as chemical disinfection agents such as ethylene oxide and low temperature hydrogen peroxide.

This revolution in medical practice between 1850 and 1950 drastically reduced the instances of hospital acquired infections (HAI's) and not coincidentally the average life expectancy almost doubled during this period in many European countries.

Within the contemporary context, hospital acquired infections are still a major problem and extensive measures are put in place to reduce the impacts. One intrinsic element of how hospitals and healthcare facilities mitigate the risks of HAI's are through Central Sterilisation Service Departments (CSSD's), which clean, disinfect and sterilise reusable medical devices to avoid cross contamination.

Modern CSSD's are sophisticated departments involving a high-density of energy-intense equipment arranged in strategically designed configurations to ensure a flow of cleanliness and physical separation between dirty and clean areas. From an engineering perspective, the services infrastructure provisions required to support a modern CSSD are significant with a large impact on the entire energy usage profile of a modern hospital. For new-build hospitals, the engineering strategies adopted to service the CSSD can often influence entire energy plant strategies for the site.

Best-practice in cleanliness is an evolving field. Though we have come a long way from the 19th century birth of germ theory, the knowledge base surrounding best-practice is ever evolving and within the Australian context the legislative standards surrounding the processing and sterilising of reusable medical devices within CSSD's (AS4187) has changed and this is causing significant implications to existing healthcare facilities around Australia.

This section discusses the standard, presents a case study of a large refurbishment CSSD project, and provides generalised guidance for facilities.

5.2 AS4187

The 'new 'standard of sterilisation in Australia AS/NZS 4187 was released in 2014 then becoming operational in December 2016 with a mandatory implementation by end of 2021 & 2022. The compliance crunch is now.

AS4187's focal points include;

1. Segregation of clean and dirty activities
2. Design of storage areas for sterile stock
3. Replacement of non-compliant cleaning, disinfecting and sterilising equipment
4. Monitoring requirements for water quality

AS4187 is not mandated under the National Construction Code (NCC) but rather Australian Commission on Safety and Quality in Healthcare developed the National Safety and Quality Health Service Standards (NSQHS). These

Healthcare Standards cover high-prevalence adverse events, healthcare associated infections, medication safety, comprehensive care, clinical communication, the prevention and management of pressure injuries, the prevention of falls, and responding to clinical deterioration.

The adoption of AS4187 is directly and inextricably linked to reducing HAI's and improving healthcare outcomes.

The standard applies in a tiered way to all healthcare settings with reusable medical devices, including allied health, dentistry as well as perioperative suites and fully fledged operating theatres. While the standard may cause upgrades to autoclave sterilisers for dentistry and allied health like podiatry, it generally does not result in large infrastructure upgrades or a dramatic energy penalty.

This article focuses on the engineering impact of the standard in a hospital setting. The procedural impacts of AS4187 to staff flow, monitoring, tracking, validation and the like are best discussed with an industry specialist who are part of a burgeoning sterilisation advice industry.

While the engineering of upgrades is challenging, costly, complex and time consuming, it has been deemed required by the commission and is likely outweighed by the social good of reduced suffering and reduced recurring burden on the health system.

Accreditation is necessary, and is awarded on a three or four-year cycle, depending on the accrediting agency. Below is the timeline required to address compliance, with point 3 being at the discretion of the agency.

1. Complete a gap analysis to determine current level of compliance by June 2021
2. Develop and document an implementation plan using a quality improvement framework specifying timeframes, milestones and deliverables to support implementation by December 2021
3. Demonstrate progress toward implementing the plan.

This leaves facilities that are not fully AS4187 compliant by the end of 2022 requiring a case-by-case assessment of their plan underway. This is not guaranteed.

The water quality requirements in AS4187 (Figure 5-1) are adapted from the UK standards.

TABLE 7.2

WATER QUALITY USED FOR PROCESSING RMDs

Substance	Maximum concentration levels	
	Cleaning process	Final rinse*
Appearance	Clear, colourless	Clear, colourless
pH	—	5.5–8.0
Conductivity at 25°C	—	30 µS/cm
Total dissolved solids [TDS]	—	40 mg/L
Total hardness [CaCO3]	60 mg/L	50 mg/L
Chloride [Cl]	120 mg/L	10 mg/L
Lead [Pb]	—	10 mg/L
Iron [Fe]	—	2 mg/L
Phosphate [P2O5]	—	0.2 mg/L
Silicate [SiO2]	2 mg/L	0.2 mg/L
Total viable count [cfu/100 mL]	—	100
Endotoxin [EU/mL]	—	0.25

* The term final rinse refers to the final water rinse conducted on the RMD.

Figure 5-1 Extract of water quality requirements

Steam quality is not defined in AS4187 as the standard references EN 285 Table B1 for the suggested maximum values of steam contaminants (extract shown in Figure 5-2). The steam quality requirement of B1 effectively mandates a high-quality RO system to comply. It also introduces complexity for large site wide reticulated steam generation plant, where as a system is aging, the steam quality may reduce to the point of non-compliance. This potentially triggers complex and expensive upgrades to improve steam quality.

	Feed water	Condensate
Conductivity (at 25°C)	≤ 5 μS/cm	≤ 3 μS/cm
pH value	5 to 7.5	5 to 7
Colour	colourless, clear, no residues	colourless, clear, no residues
Hardness	≤ 0.02 mmol/l	≤ 0.02 mmol/l
Evaporation residues	≤ 10 mg/l	-
Silicates (Si O_2)	≤ 1 mg/l	≤ 0.1 mg/l
Iron	≤ 0.2 mg/l	≤ 0.1 mg/l
Cadmium	≤ 0.005 mg/l	≤ 0.005 mg/l
Lead	≤ 0.05 mg/l	≤ 0.05 mg/l
Heavy metals apart from iron, cadmium, lead	≤ 0.1 mg/l	≤ 0.1 mg/l
Chlorides	≤ 2 mg/l	≤ 0.1 mg/l
Phosphates	≤ 0.5 mg/l	≤ 0.1 mg/l
Note: the use of feed water or steam with constituents higher than the values given in Table B1 can greatly shorten the sterilizer service life and invalidate the manufacturer's warranty or guarantee.		

Figure 5-2 Extract from EN285 Table B1 – steam contaminants

5.3 Case Study

This case study is quite typical for an existing CSSD that over time has been outpaced by clinical demand. It is a large existing facility with around 12 operating theatres, including a hybrid OT, endoscopy suites with plans to build at least two new theatres in the short term, and a large master planned building in the long term. The operating theatres are the engine room of this type of hospital and by association so is the CSSD. Operating theatres cannot run without a functional, reliable and quality sterilising department.

The existing CSSD in question developed over time to adapt to the increased throughput and to improve quality, operating '24/7', adding sterilisers and upgrading RO as part of an initial AS4187 upgrade but at its core is aging infrastructure that for full AS4187 compliance requires a wholesale upgrade.

The initial AS4187 upgrade aimed to improve the simple to address issues within the existing CSSD footprint. It was highly constrained by the existing building form and available services including and end of life gas fired boiler plant.

Further infrastructure upgrades were required to meet water quality, air quality and steam quality requirements of AS4187, this resulted in the comparative CSSD shown in Table 5-1.

5.3.1 Staging of Build

Like many hospitals, 24/7 availability of the theatre complex is crucial to meet the community needs and business of the hospital, meaning the CSSD cannot be shut down for refurbishment works. This leaves facilities with a rather large conundrum, build new or attempt a highly complex staged build.

Sometimes there is no choice, if a suitable space is not available for a new building, facilities are commonly forced down the staging route. While it is possible to achieve a staged build it is incredibly complex and disruptive, and if any link breaks from design to construction it can become a protracted costly experience for all. It is not uncommon for CSSD upgrades to be split into 5 or 7 stages, taking many years to complete.

Rather than attempting a complex staged build the facility opted to relocate the CSSD into an existing department. The facility was fortunate to have a department willing to move to allow the CSSD an expanded footprint.

5.3.2 Energy Analysis

A high-level energy analysis (Table 5-2) was completed to compare the diversified maximum demand of the existing '24/hr' CSSD to the new 7am to 5pm department. This calculation is based on the stated operational assumptions including a 0.95 power factor and an average utilisation rate. The existing CSSD utilisation rate is lower than the new CSSD due to the reduced overnight staffing of the CSSD.

Table 5-1 Comparative CSSD

	Existing CSSD	New CSSD	Infrastructure Change
Washers	4	7	
Trolley Washer	1	1	
Scope Re-processors	0	2 Doubles	
Sterilisers	5 (two single sided)	7	
Low Temp Sterilisers	0	3	
Dryers	1	2	
Electrical Maximum Demand	~185 kVA (258A) (Gas Fired Steam)	Electric – **618 kVA (860A)** Gas – 322 kVA (448A)	New transformer & MSB
Steam Generation	Gas fired (system past end of life) 960 kg/hr Steam	Electric on-board with Sterilisers	
Reverse Osmosis Water	Yes (not AS4187 quality)	Yes (AS4187 quality)	New water softening system New RO plant
Steriliser Cooling Water	Chilled Water	Chilled Water	
Heat Load (incl. cooling water)	~150 to 200 kW	~340 kW	Chiller upgrade
Clean to dirty air flow	No	Yes	New full height walls and increased outside air
Negative Pressure Decontamination Room	No	Yes	New decontamination exhaust
HEPA Filtered Air to Sterile Store	No	Yes	New AHU systems
HEPA Filtered Air to Packing Room	No	Yes	New AHU systems

Table 5-2 Energy analysis of existing and new CSSD

	Existing CSSD	New CSSD
Average Utilisation % During Hours	60%	80%
Operating Hours	18 hrs / day 365 days / year 6,570 Total hours / year	10 hrs / day 365 days / year 3,650 Total hours / year
Electricity Maximum Demand	185 kVA (258A)	618 kVA (860A)
Gas Maximum Demand (MJ/hr)	960 kg/hr Steam (192 per steriliser) 66.2 m3/hr Gas	0
Annual Electrical Consumption	693,000 kWh	**1,714,000 kWh**
Annual Gas Consumption	261,000 m3 / year 9,720 GJ / year	0

5.4 Checklist for facilities

To guide facilities in understanding and scoping an AS4187 upgrade this checklist can be used to set a baseline of understanding what an AS4187 upgrade may mean for a facility.

Check	Yes / No	Spare Capacity
Are the existing sterilisers less than 10 years old and do they operate reliably?		
Are the existing washers less than 10 years old and operate reliably?		
Is there an endoscopy service with separate sterilising? (This may require works as well)		
Where are the sterile storage spaces on site? Nominate and consolidate where possible.		
Is there a masterplan for the site? i.e. will the CSSD require expansion for new services or to meet existing demand.		
Is the CSD location easily accessible for new services? Consider the department above as a possible plant room for efficient services reticulation.		
Is there spare electrical capacity on site?		
Are there backup generators on site? If so, what is their spare capacity?		
Is there a high-quality RO system on site?		
Is there spare chilled water capacity on site?		
Is the chilled water system back up by generators or by other power / chilled water supplies?		
Are the existing sterilisers cooled by chilled water or potable water? Consider chilled water to avoid large potable water consumption.		
Is there and existing gas or electric boiler system on site? Is this system at end of life? if so, consider whole of site heating strategies.		
Does the site have emissions reduction targets? if so, conversion from Natural Gas to electric may be palatable.		
What is the incoming town mains water quality? Consider long term testing and logging.		
Is humidity control a legacy issue in sterile spaces?		
Does the CSSD require redundancy & to what extent? What would happen if the CSSD went down, lost power, lost cooling or similar?		

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