The Innovation Hub
for Affordable Heating and Cooling

Report #LLHC4-2

Healthcare Living Laboratories: Queensland Children's Hospital – Baseline Data

17 April 2020

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.

**This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.
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Healthcare Living Laboratories: Queensland Children's Hospital – Baseline Data

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.

This report records baseline energy data for the QCH precinct.

Lead organisation
Queensland University of Technology (QUT)

Project commencement date
1 July 2019

Completion date
30 June 2022

Date published
17 April 2020

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QLD CHILDREN'S HOSPITAL – BASELINE DATA

This report includes baseline energy performance data for the Queensland Children's Hospital precinct. It reports energy use in February 2020, detailed analysis of 2019 energy use, and historical trends (since Feb 2018)

1 INTRODUCTION

QCH 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. The Living Lab will not only enable the testing of innovative technologies and processes, but it will also 'test' the potential usefulness of new key performance indicators (KPIs) and metrics that link energy performance (especially peak demand, renewable energy and resilience) to core health services (e.g. patient numbers or length of hospitalisation or staffing levels or occupant health). Outputs from this Living Lab will feed into the iHUB's Healthcare Sector Wide project (LLHC1).

2 SITE DESCRIPTION

The Queensland Children's Hospital precinct is comprised of three buildings:

- the Main Hospital (MH) Building;
- the Centre for Children's Health Research (CCHR); and
- the Central Energy Plant (QCH EP) Building.

Chilled water, heating water, gas, power, communications, security monitoring and a pneumatic tube system are provided on a precinct basis, connecting all three buildings. The HVAC system is essential for not only thermal comfort conditions (controlling temperature, relative humidity and ventilation), but also for control of airborne infection transmission.

2.1 QCH Main Hospital (MH) Building Description

The Queensland Children's Hospital is a public children's hospital in Brisbane, Queensland. It opened on 29 November 2014. The main hospital building consists of 19 levels (consisting of 12 clinical levels, 3 levels for general health services and 4 levels of basement carpark). The total floor area of 112,000 m^2, including approximately 80,000 m^2 of clinical space to accommodate 359 public hospital beds (overnight and same day). There are seven retail tenancies within the QCH MH building, providing a range of food and other retail services for the patients, families and staff. Other facilities include roof garden areas and garden terraces, a play and performance areas and a school.

The building was designed to be welcoming (not 'hospital-like), safe and environmentally sustainable. It features a well-sealed façade (1-2m^3/hr/m^2 at 50Pa), a curtain wall façade system with external fins to provide shading, use of natural light, and two large full-height atria.

Three main types of HVAC systems condition the various spaces:

(i) Constant-air-volume (CAV) systems are used for critical departments that have even loads, such as the emergency department, medical imaging and the paediatric intensive care unit (PICU);
(ii) Variable-air-volume (VAV) systems are used in load varying spaces such as outpatient areas, consulting rooms and offices where some form of localised control is required;
(iii) Active chilled beam systems are used in areas where 100% fresh air is desirable such as patient wards. The chilled beam systems also offer the additional benefit of being able to provide individual temperature control to rooms.

Carbon dioxide sensors are used in some areas as a proxy for occupancy levels, in order to enable modification of ventilation rates to match occupancy.

In addition to the main HVAC systems, a number of small packaged air conditioning (PAC) systems are utilized in non-clinical areas, such as 9 PAC systems for the kitchen area on Level 3.

The MH building also features more than 60 fire compartments and 80 smoke compartments, with some floors having up to nine compartments each. It has more than 200 air-handling units (AHUs), about 1000 motorised fire dampers, 73 smoke exhaust fans and 13 stair pressurisation fans.

Figure 2-1 QCH Main Hospital Building

2.2 Centre for Children's Health Research (CCHR) Description

The Centre for Children's Health Research (CCHR), is a 9-storey building which unites children's health research and services with the hospital. Five levels of the CCHR are dedicated to research spaces and include:

(i) wet and dry laboratories;
(ii) a gait laboratory;
(iii) a nutrition laboratory; and
(iv) the Queensland Children's Tumour Bank, which provides a tissue repository for national and international cancer research.

The remaining levels accommodate the QCH Pathology service, office areas, facilities management staff, reception, car parking and a COVID19 testing area.

The ARF building has a total floor area of 14,108 m^2. The HVAC system for this building consists of CAV systems, VAV systems and fan coil units (FCUs), serving different zones.

Figure 2-2 Centre for Children's Health Research (CCHR)

2.3 Central Energy Plant (EP) Building Description

The QCH EP building consists of five levels with the total floor area of 4,500 m^2. Its function is to house the equipment that provides the entire power, heating, cooling and steam requirements to the QCH MH building and the CCHR building. The energy plant consists of

(i) a central chilled water plant, supplying chilled water to the QCH precinct;
(ii) a central natural gas fuelled hot water plant, for HVAC and domestic hot water needs;
(iii) a central natural gas fuelled steam boiler plant (two boilers rated at 1958 kg/hr) used primarily to supply steam for the central sterilisation process of the MH and for humidification within the HVAC system;
(iv) a condenser water plant for heat rejection;
(v) six cooling towers including water treatment plant for the cooling towers;
(vi) a natural gas fuelled power generation (trigeneration) facility (decommissioned 2019);

(vii) other items ancillary to the central plant (e.g. ventilation and other air conditioning);
(viii) a standby power plant (12MW) consisting of four diesel powered continuous-rated generators of 3.0MVA (2,400kWe) each. This provides QCH with full power security;
(ix) a chlorine dosing plant located within the basement carpark of the MH; and
(x) three 7MW each, 11kV electrical cables feeding the EP from the local supply authority (Energex). This provides an N+2 redundancy for the electrical supply to the precinct.

Figure 2-3 QCH Central Energy Plant (QCH EP) Building

2.3.1 Cooling and Heating

This central energy plant supplies the hospital and research facility with their chilled water and heating hot-water requirements.

The chilled water plant comprises one 1,100kWr low-load swing variable-speed drive (VSD) low-voltage electric centrifugal chiller, and five VSD low-voltage electric centrifugal chillers of 3,315kWr each, with a full-load minimum coefficient of performance (COP) of 6.7. These are configured in an N+1 redundancy arrangement. Combined, the total chilled water capacity of the central energy plant is up to 20MWr.

The central-heating hot-water plant consists of seven 1,110kW gas-powered hot-water heating boilers that have been sized to meet the total heating load. These are configured in an N+1 redundancy arrangement, and serve air conditioning, heating and dehumidification, as well as domestic hot water.

2.3.2 Steam

The central energy plant also provides the entire hospital site with its steam requirements, typically used for cleaning, disinfection and sterilisation. This is achieved by two natural-gas-fired steam boilers of 1,300kW each, configured in a duty/stand-by arrangement.

2.3.3 Trigeneration

The trigeneration system designed for the building was decommissioned in 2019, due to the high price of gas. The trigeneration system originally featured two gas-powered 2,400kWe turbine generators combined with hot water heat exchangers providing 5,400kW of heating hot water, and two single-stage lithium bromide absorption chillers of 1,100kWr each. Two selective catalytic reduction (SCR) systems were also provided, featuring 15,000L of urea storage providing nitrous oxide (NOx) emission control for each generator. The trigeneration could supply most of the hospital's power, heating, cooling and steam requirements, which also reduced the demand on the local electricity grid by 60 per cent during peak consumption period.

The decommissioning of the trigeneration system came about as the result of a whole of government electricity procurement process with one of the government owned generators that locked in a single electricity supply for all government departments for a 10-year period from January 2019. The low price of energy (network prices remained untouched) has meant that the trigeneration plant is no longer economical to operate when fuel and maintenance costs are factored in.

Previously, the trigeneration plant was used to off-set peak electricity prices when gas prices were low. This is no longer the case with gas prices being higher than the price of electricity taken from the grid.

The lithium bromide chillers and SCR systems have also been decommissioned.

2.3.4 Other Plant

The central energy plant facility also accommodates the site's stormwater treatment and reuse plant. It features two ultrafiltration modules and an ultraviolet disinfection system with chlorine dosing. This plant is able to treat and supply 65,000L of high-quality recycled water that is then used as make-up water by the site's six 4,951kW crossflow induced-draft cooling towers.

2.3.5 Monitoring

A Trend Building Management System (BMS) is used in the QCH precinct to control and monitor the buildings' climate and other controllable devices and variables, such as Air Handling Units (AHUs), Fan Coil Units (FCUs), and ancillary items of HVAC plant. The monitored system includes: chilled water plant, condenser water plant, hot water plant, trigeneration system, air conditioning system, ventilation, hydraulic equipment, and fire services.

Monitoring of the electrical energy throughout QCH EP is split into two packages – The BMS monitoring all Mechanical Electrical kWe Meters (54 × ION/6200 EPL), and the EMS monitoring all Distribution Electrical Meters (55 × CET PMC 660).

3 SITE BASELINE ENERGY DATA

3.1 Site energy composition and usage - 2019

This section provides an initial analysis of the QCH Precinct's 2019 electrical energy use and peak demand.

3.1.1 Site electrical energy use

Table 3-1 summarises the monthly electrical energy use for the QCH precinct by building type and major energy sources, for 2019. The three buildings are the energy plant building (EP Building), QCH MH Building and the CCHR Building. The three sources of electrical energy were site import (through Energex network, and with a power purchase agreement), and self-consumed onsite electricity generation using gas and diesel. Note that there has been no gas-powered electricity generation since April 2019, when the trigeneration plant was fully decommissioned.

Table 3-1 Site electricity energy use in 2019

Total (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Site Energex Import	2602801	2327742	2638798	2267107	2213731	2035173	2112287	2073437	2086117	2279833	2372280	2518246
EP Building	988940	852039	987640	695175	557370	444707	444192	424182	494118	628978	765663	891394
QCH MH Building	1466637	1340606	1480513	1429252	1498001	1443177	1503778	1497927	1439638	1487180	1447744	1462831
CCHR Building	171953	163801	183124	173181	177911	166243	174342	169645	168490	180773	176020	181702
Gas Generation	6482	21157	0	12884	0	0	0	0	0	0	0	0
Diesel Generation	7979	0	4998	8643	10365	8638	1	8639	7977	7973	7976	7976
Total Import + Generation	2617262	2348899	2643796	2288634	2224096	2043811	2112288	2082076	2094094	2287806	2380256	2526222
Total Site Consumption	2627530	2356446	2651277	2297608	2233282	2054127	2122312	2091754	2102246	2296931	2389427	2535927

Figure 3-1 demonstrates the monthly total building electricity energy consumption in each building in 2019. The energy use of the EP building varied seasonally: high in the summer months (December to March) and low in winter months (June to August). Jan 2019 to Aug 2019 electricity consumption ratio is 2.3. The likely explanation for this large variation is the variation in heating and cooling demand (assuming no significant change in the number of patients visits to the hospital across winter and summer seasons.) The QCH MH building had the largest total electricity electrical energy use, but it is relatively consistent throughout the year (i.e. no seasonal variation). The ARF building uses the least energy, and usage is also consistent across all month. The non-seasonality of the MH and ARF makes sense in that cooling loads are accounted for in the EP.

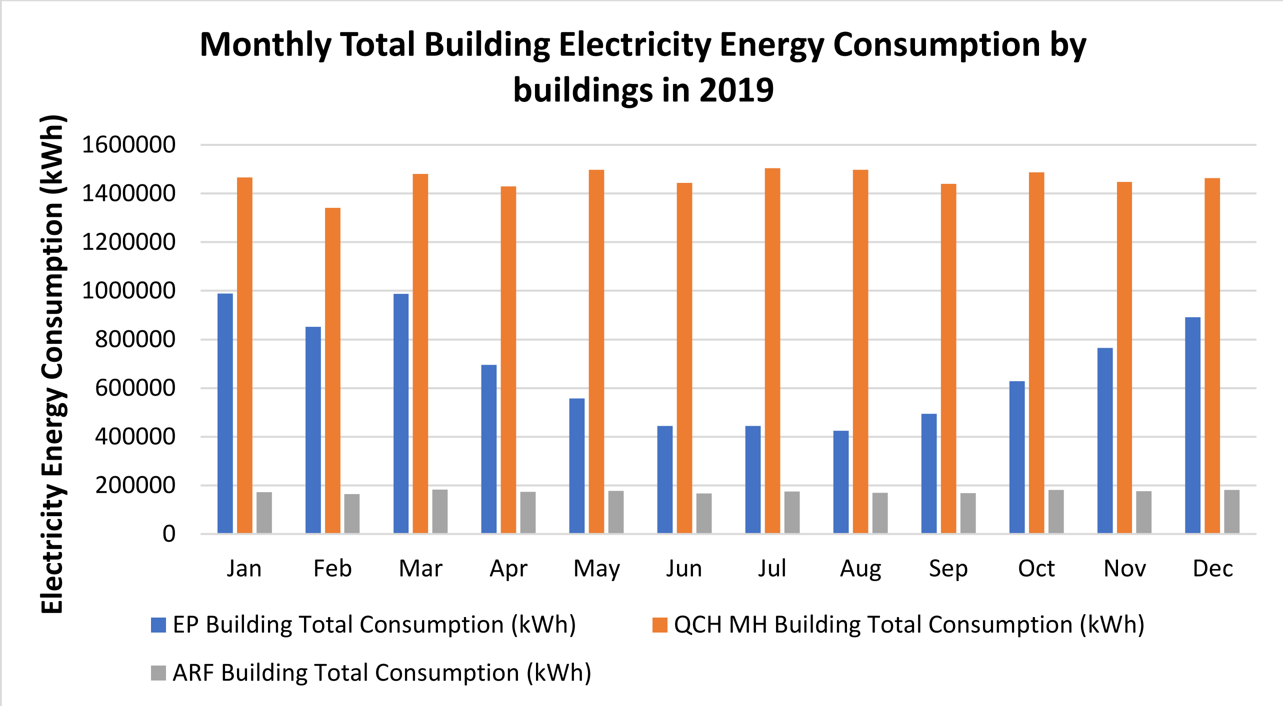


Figure 3-1 Monthly total building electricity energy consumption by buildings in 2019

Figure 3-2 is a visual presentation of the total site Energex import shown in Table 3-1. It shows four months of high electricity use in summer (December to March), low use in winter and early spring (June to September), and two shoulder seasons of two months each. The total electricity import for 2019 was almost 25,636 MWh.

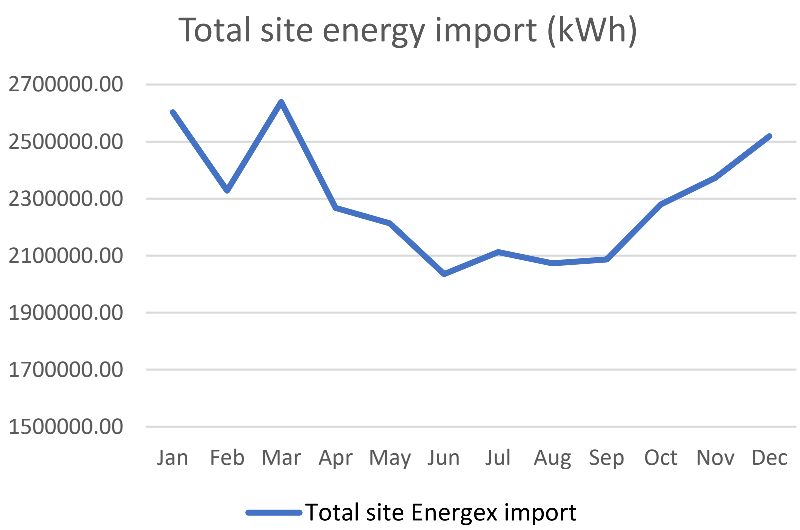


Figure 3-2 QCH Precinct Energex energy import by month

3.1.2 Demand profile

Demand (or power demand) shows how fast energy is used. Demand tariffs are often applied to businesses and large organisations and demand charges can be calculated on the highest demand (30 minute) in a month (e.g. in kilowatts kW). The QCH precinct's highest demands of each month for 2019 are listed in Table 3-2 and visually presented in Figure 3-3. Feb 2019 had the highest monthly peak demand, 134% higher than the lowest monthly peak demand (July 2019).

Table 3-2 Site building peak demand profile in 2019

30-min peak (kW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
QCH precinct	4721	4915	4672	4208	4000	3840	3667	3733	4005	4491	4541	4578

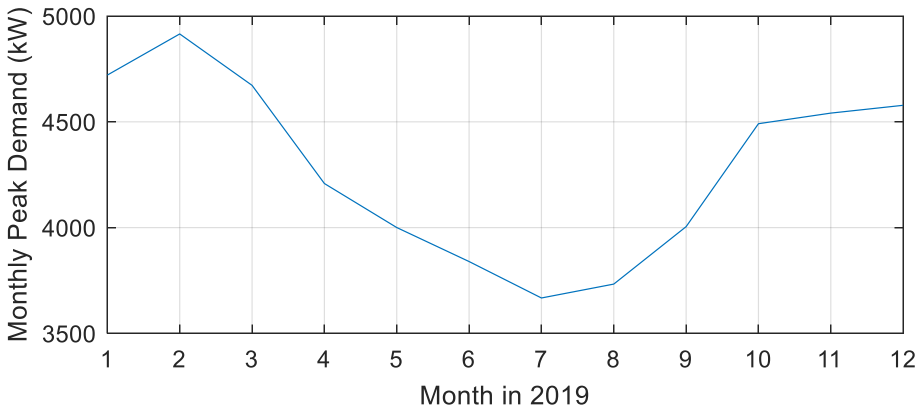


Figure 3-3 QCH Precinct peak power demand by month

Figure 3-4 shows the boxplots of four month's demand profile in 2019. The demand is the total demand (kW) in 30min interval, including electricity imported from three Energex feeders and onsite generation from diesel generators and gas generators. The boxplots show three different seasonal demand profiles: a high demand profile in summer, a low demand profile in winter, and medium demand profiles in the shoulder seasons. The likely reasons for this relate to Brisbane's climate which has a mild winter (and therefore minimum energy required for HVAC loads), and a hot and humid summer (and therefore more energy and power required to keep buildings cool). This initial data analysis strongly suggests that the variation of electrical demands is largely related to HVAC loads for cooling.

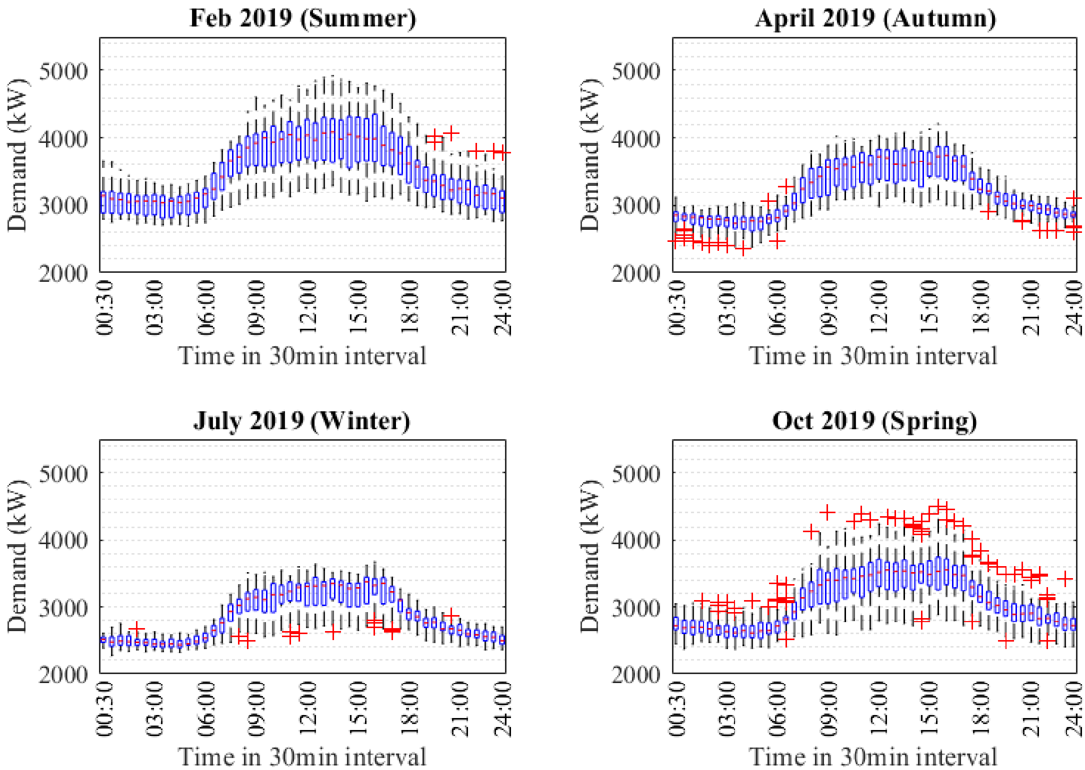


Figure 3-4 QCH Precinct 30min power demand profile in four months

3.2 Site energy use and composition – February 2020

3.2.1 Precinct energy use

The electricity, gas, chilled water and heating hot water use for each building, for February 2020, is shown in the following four tables. Usage from February 2019 is provided for comparison.

Table 3-3 February 2020 electricity use per building (MWh)

Building	Feb 2020	Feb 2019
Main hospital	1372.01	1340.61
CCHR	175.45	163.80
Energy Plant	984.20	852.04

Table 3-4 February 2020 gas use per building (GJ)

Building	Feb 2020	Feb 2019
Main hospital	1.9684	4.8602
CCHR	0	0.133
Energy Plant – water boilers	4273.03863	3918.22767
Energy Plant – steam boilers	1345.00716	1563.2316

Table 3-5 February 2020 chilled water use per building (MWh)

Building	Feb 2020	Feb 2019
Main hospital	3834.03	3356.64
CCHR	329.31	316.46
Energy Plant	59.67	55.22

Table 3-6 February 2020 heating hot water use per building (MWh)

Building	Feb 2020	Feb 2019
Main hospital	749	706
CCHR	140	134

Figure 3-5**Error! Reference source not found.** shows the precinct's energy flows (grid electricity, diesel and grid gas) for February 2020.

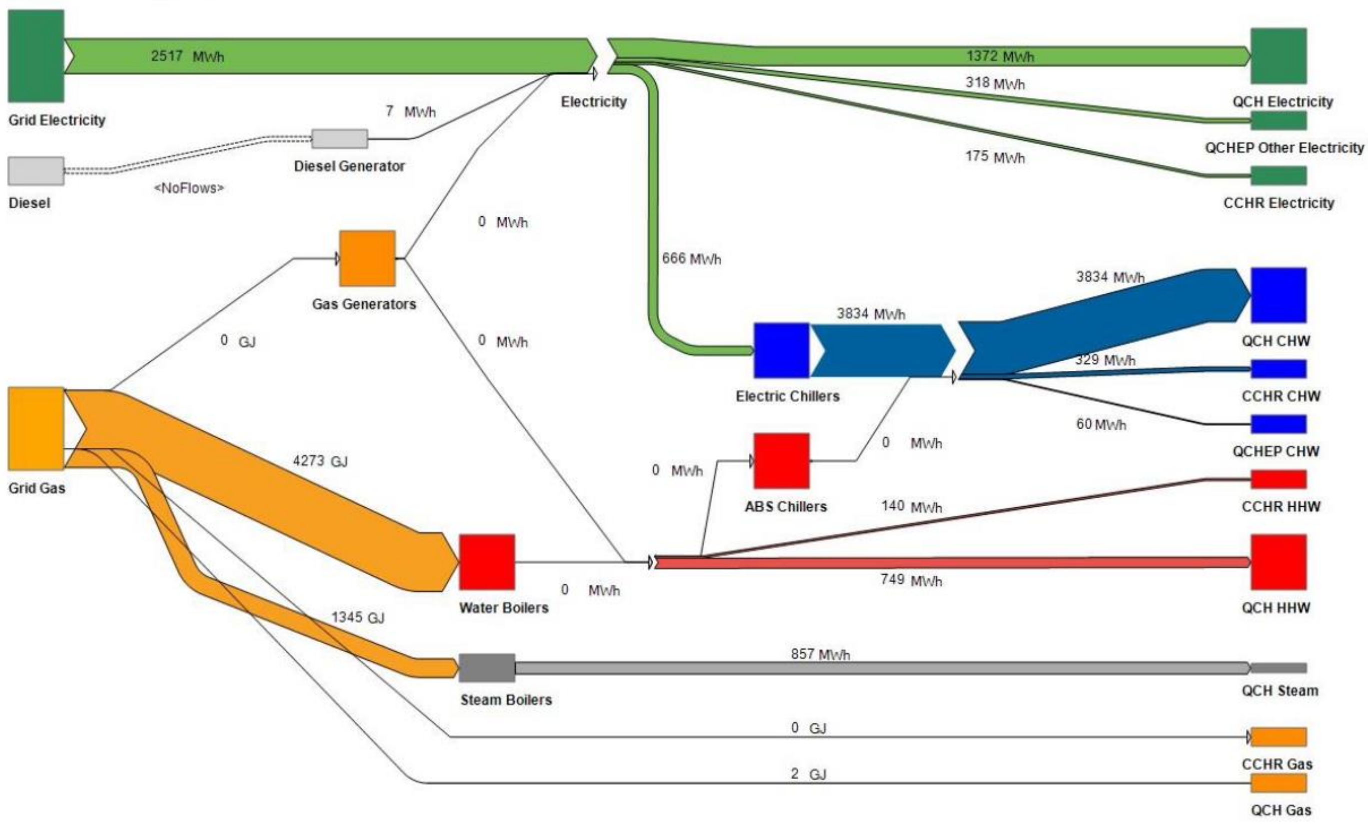


Figure 3-5 QCH precinct energy flow Sankey diagram for February 2020

The energy use of the CCHR specifically, for Feb 2020 and 2019 is shown in Table 3-7. This building will likely be the site of the first product testing for the Living Laboratory.

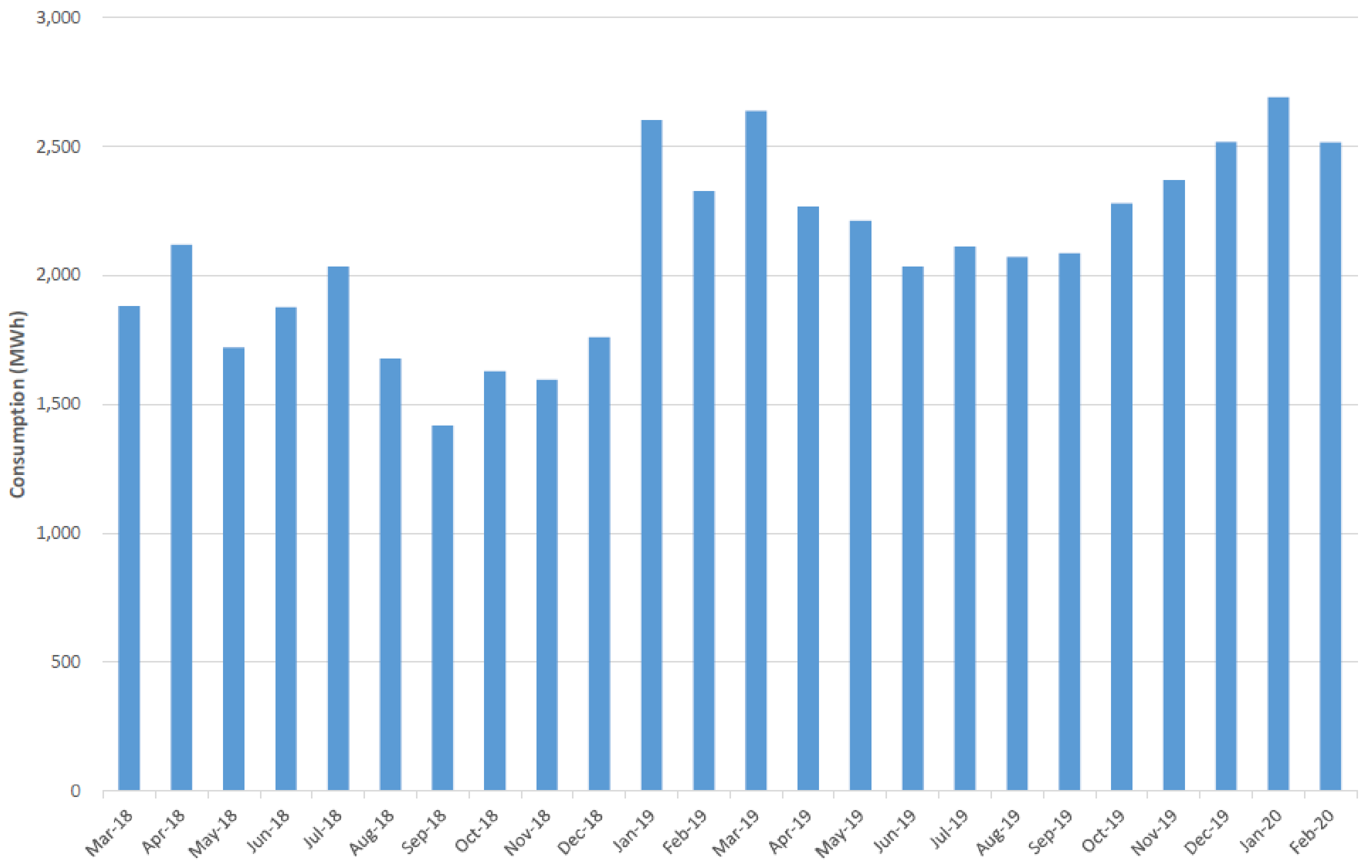
Table 3-7 CCHR energy use Feb 2020 and 2019

	Feb 2020	Feb 2019
Electricity (MWh)	175.45	163.80
Gas (GJ)	0.00	0.13
Chilled Water (KWh)	329.31	316.46
Heating Hot Water (MWh)	140.00	134.00

3.3 Precinct energy use – trends

3.3.1 Electricity use

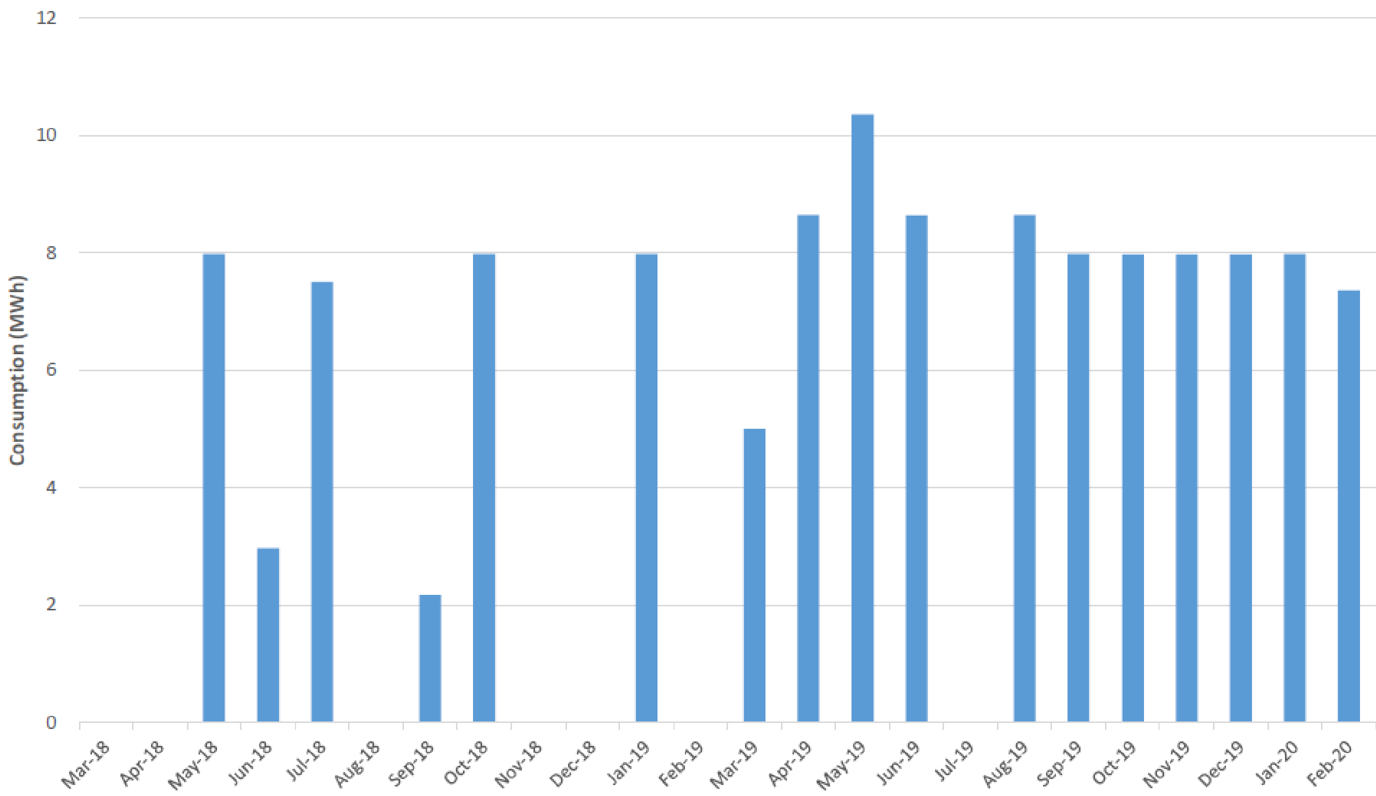
The precinct's grid electricity use, from March 2018 to Feb 2020 is shown in Figure 3-6. It shows some seasonality in electricity use (higher in summer months) and the impact of the winding down of the trigeneration system (during 2018, with decommissioning in March 2019).



	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	1881.01	2119.12	1719.86	1877.17	2034.28	1677.72	1418.61	1629.97	1597.05	1761.65	2602.80	2327.74	2638.80	2267.11	2213.73	2035.17	2112.29	2073.44	2086.12	2279.83	2372.28	2518.25	2692.10	2517.09

Figure 3-6 Precinct grid electricity use over time

The precinct's diesel generation for the same period is shown in Figure 3-7. It is unclear at this stage whether the graph is showing missing data, or whether there was no diesel generation for a number of months. No discernible pattern can be seen at this stage.

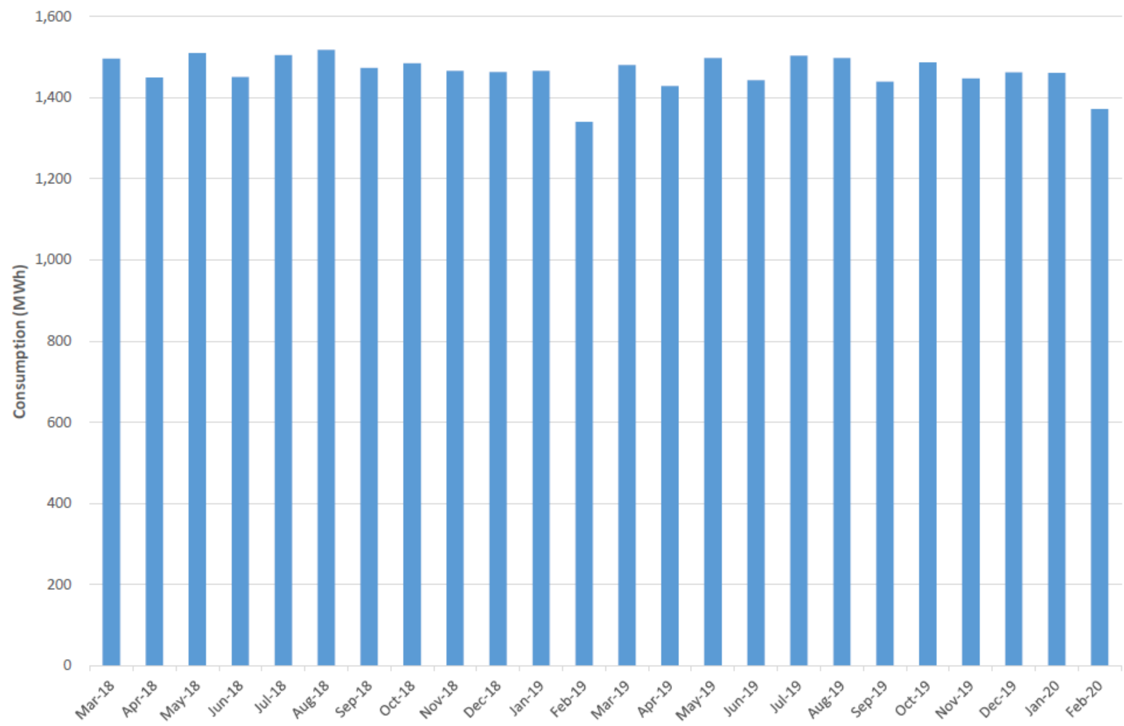


	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	0.00	0.00	7.98	2.97	7.51	0.00	2.17	7.98	0.00	0.00	7.98	0.00	5.00	8.64	10.37	8.64	0.00	8.64	7.98	7.97	7.98	7.98	7.98	7.36

Figure 3-7 Precinct diesel generation over time

3.3.2 Main hospital trends

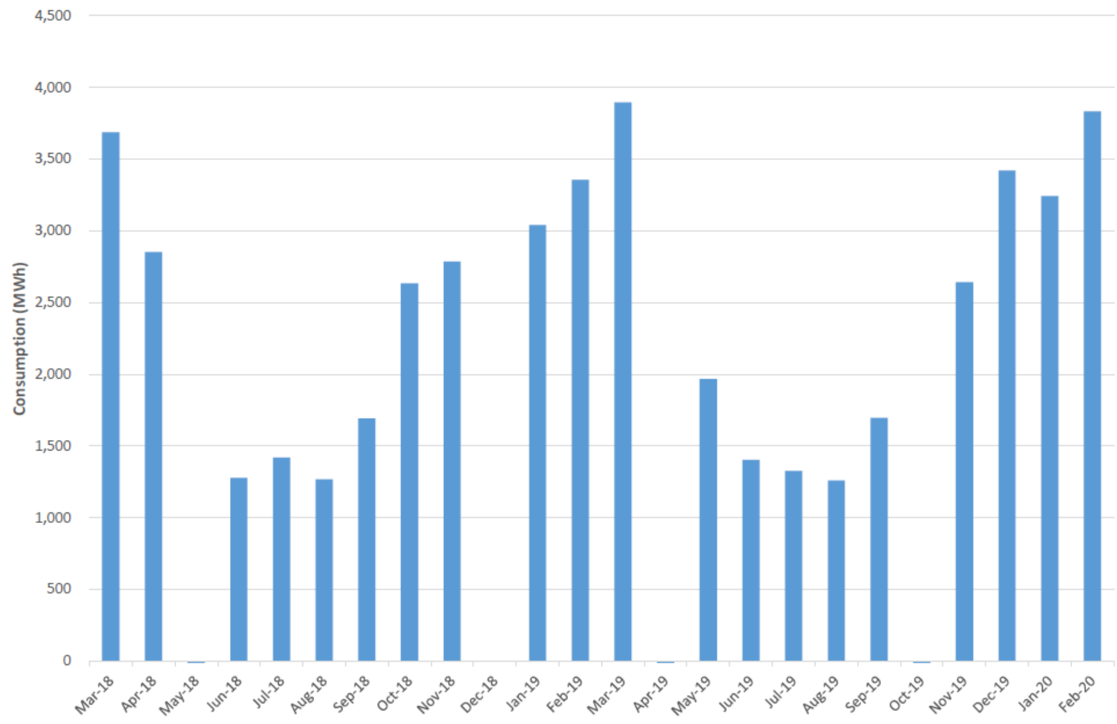
Historical electricity use and chilled water use of the main hospital are shown in Figure 3-8 and Figure 3-9 respectively. Similar to the 2019 analysis shown previously, these graphs confirm that electricity use is relatively consistent on a monthly basis, while chilled water use is seasonal (highest in summer months). There appears to be missing data, as it is unlikely that there are months where no chilled water is used.



	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19
This Year	1496.75	1449.53	1510.46	1451.05	1504.98	1518.37	1473.44	1485.33	1466.24	1464.06	1466.64	1340.61

	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	1480.51	1429.25	1498.00	1443.18	1503.78	1497.93	1439.64	1487.18	1447.74	1462.83	1461.60	1372.01

Figure 3-8 Main hospital trends in electricity use



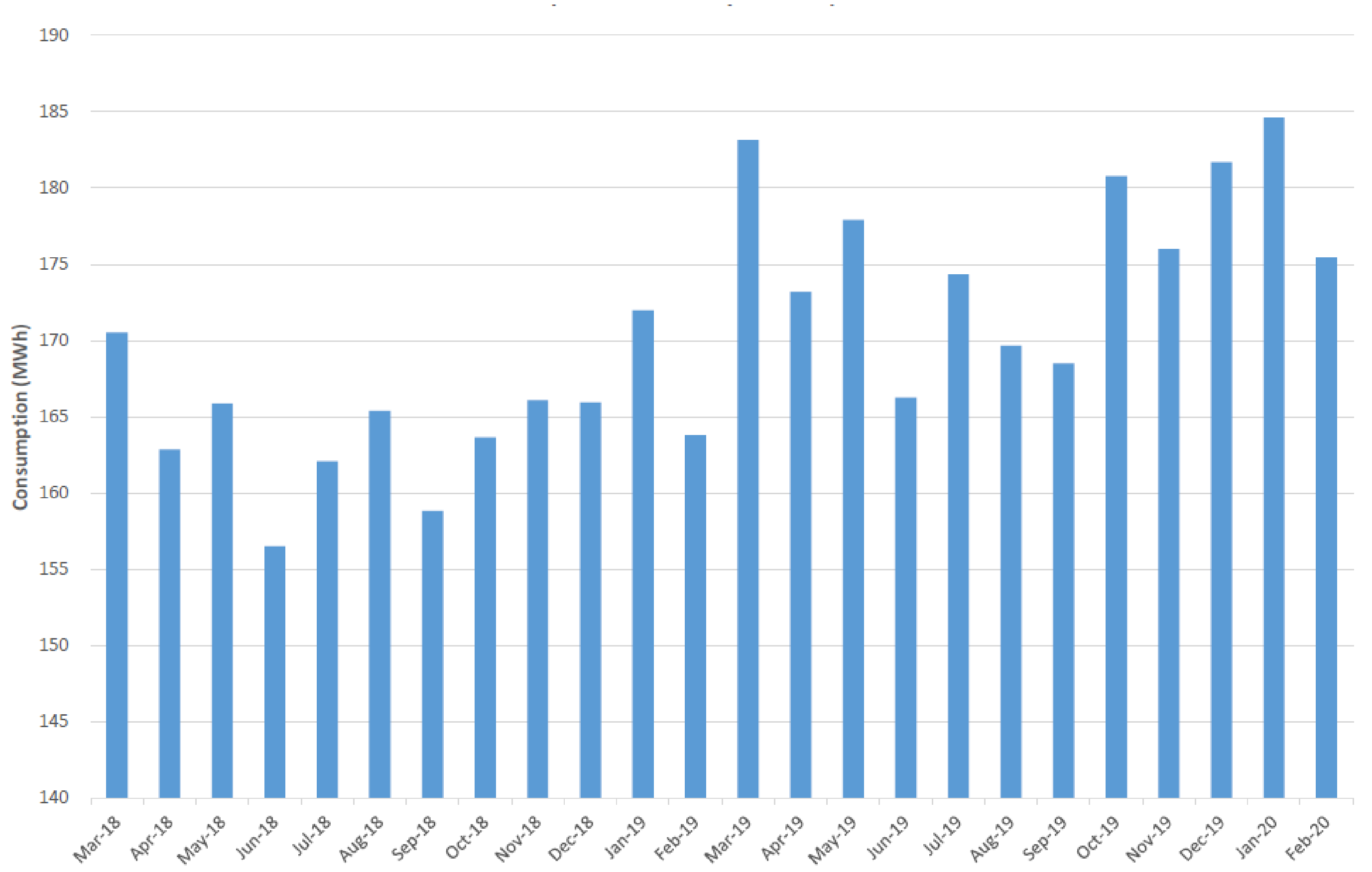
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19
This Year	3687.93	2851.62	-53125.	1277.65	1417.87	1266.17	1690.72	2634.05	2785.84	0.00	3039.94	3356.64

	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	3895.79	-25960.	1966.82	1403.22	1326.39	1257.77	1695.04	-7994.5	2641.81	3421.75	3243.91	3834.03

Figure 3-9 Main hospital trends in chilled water use

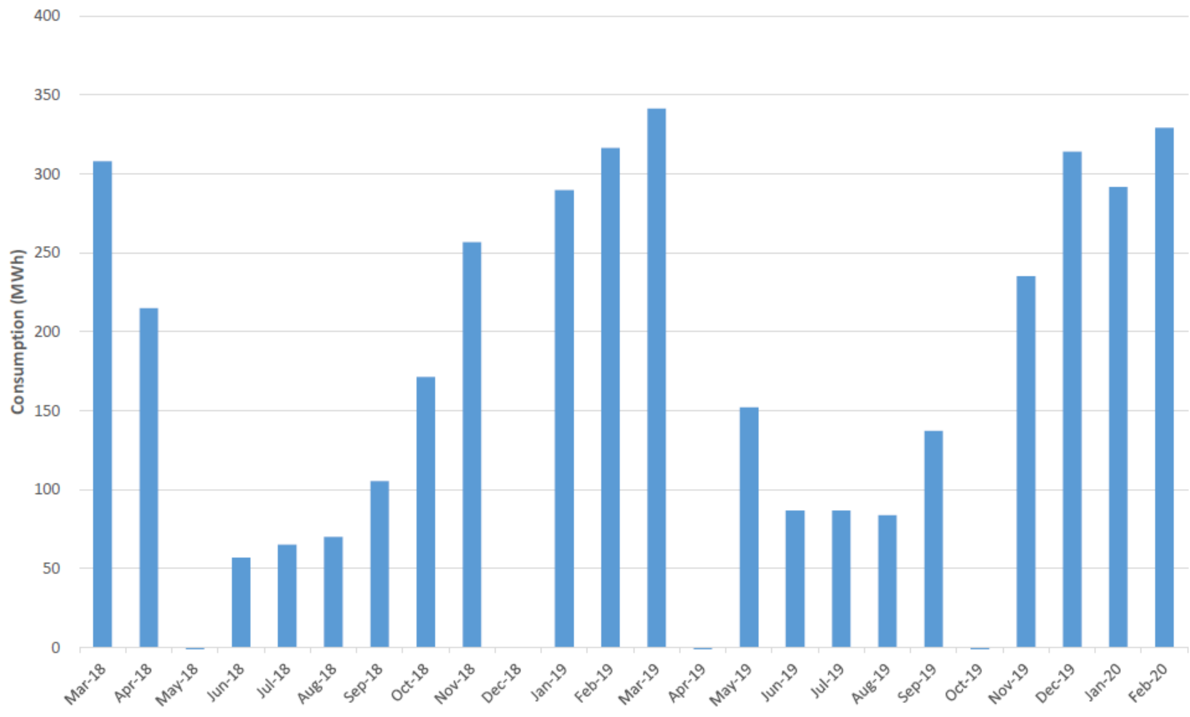
3.3.3 CCHR trends

Similarly, historical electricity, chilled water and HVAC hot water use are shown in Figure 3-10, Figure 3-11 and Figure 3-12 respectively. Electricity use is much more variable than in the main hospital, perhaps a reflection of different tenancy rates and tenant activities. This will need further investigation. Similar to the main hospital, the chilled water use shows strong seasonality (highest in summer), with the inverse HVAC hot water load highest in winter.



	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	170.53	162.83	165.86	156.51	162.06	165.39	158.81	163.66	166.08	165.94	171.95	163.80	183.12	173.18	177.91	166.24	174.34	169.65	168.49	180.77	176.02	181.70	184.61	175.45

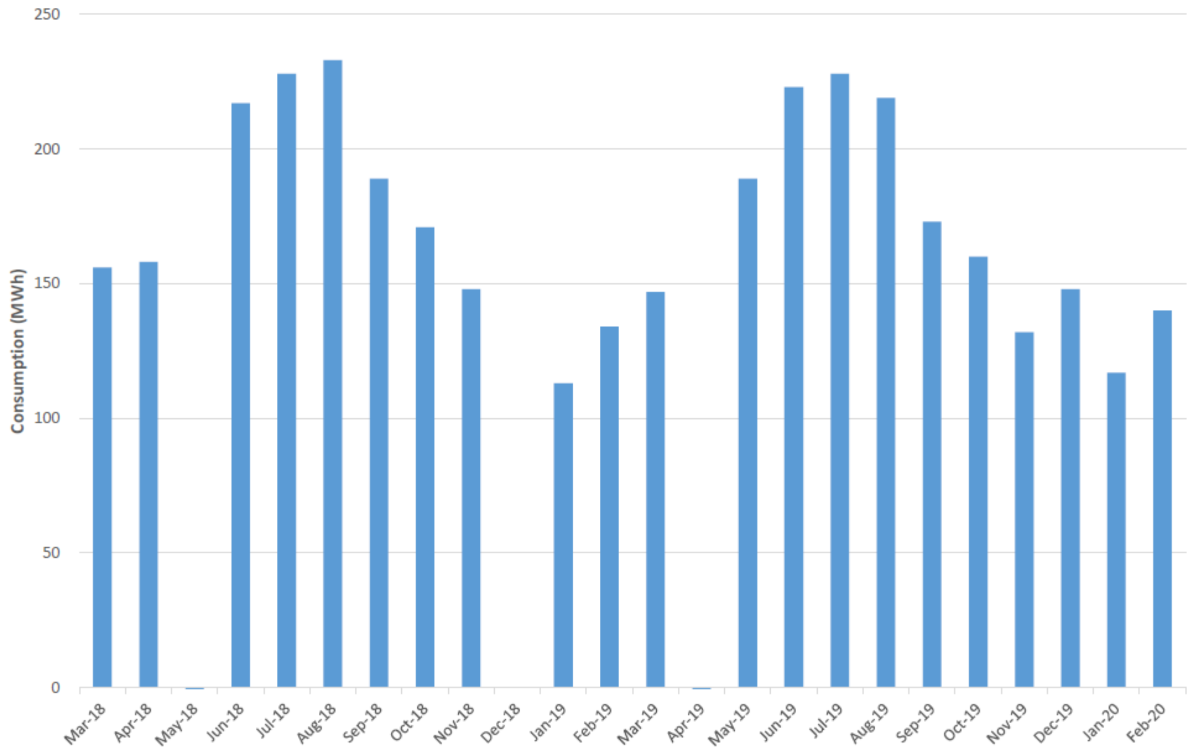
Figure 3-10 Electricity use trends in the CCHR



	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19
This Year	308.03	215.02	-4429.0	56.86	65.26	70.00	105.39	171.41	256.83	0.00	289.77	316.46

	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	341.43	-2059.5	152.26	86.84	86.69	83.91	137.31	-558.14	235.21	314.14	291.71	329.31

Figure 3-11 Chiller water trends in the CCHR



	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19
This Year	156.00	158.00	-3255.0	217.00	228.00	233.00	189.00	171.00	148.00	0.00	113.00	134.00

	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
This Year	147.00	-1865.0	189.00	223.00	228.00	219.00	173.00	160.00	132.00	148.00	117.00	140.00

Figure 3-12 HVAC hot water trends in the CCHR

3.4 Current Key Performance Indicators (KPIs)

The three commonly used KPIs for energy use intensity in hospitals are energy use per floor area per annum (kWh/m^2/yr), energy use per bed day per annum (kWh/bed day/yr) and energy use per separation (kWh/c). Each of these has its own benefits and limitations, as outlined in the Healthcare Baseline Energy Report. NABERS Energy and Water Use for Hospitals adjusts annual energy use figures by hospital characteristics including annual occupied bed days, annual separations, hospital peer group (types of services offered) and climate.

The analysis in this section relates to 2019 data. Table 3-8 shows the monthly and annual (2019) energy use intensity (EUI) in kWh/m^2 of each of the QCH precinct buildings. The total QCH precinct EUI ranges from 125 kWh/m^2 in August to 252 kWh/m^2 in March. The ARF building has the lowest annual EUI of 148 kWh/m^2/yr. followed by the MH building of 219 kWh/m^2/yr and the EP building of 1817 kWh/m^2/yr. The total QCH precinct energy intensity is 2183 kWh/m^2/yr. These results seem to indicate that the MH's EUI is well under the mean EUI of Australian hospitals[1] (426.7 kWh/m^2/yr), however it should be remembered that the cooling load of the MH building is not included in this figure: it is accounted for in the EP building. The total QCH precinct EUI is approximately five times the mean EUI of Australian hospitals, however the precinct has a research building that is not typical in all hospitals, and as a quaternary hospital potentially has more energy intensive medical diagnostic equipment than is typical in other hospitals. The wide range of EUIs reported by hospitals nationally and internationally highlight one of the problems with this metric. Floor area alone cannot explain differences in energy use intensity. Variations in EUI could conceivably be due to differences in climate, types of clinical services provided, and the presence of various high power medical diagnostic equipment. This is one reason why the NABERS for Hospitals data adjusts data as explained previously. QCH's energy data will be compared to NABERS Energy and Water Use for Hospitals data when it becomes available.

Table 3-8 Energy consumption intensity (kWh/m^2) in QCH precinct by month in 2019

Total (kWh/m2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Building	219.8	189.3	219.5	154.5	123.9	98.8	98.7	94.3	109.8	139.8	170.1	198.1	1817
QCH MH Building	18.3	16.8	18.5	17.9	18.7	18.0	18.8	18.7	18.0	18.6	18.1	18.3	219
CCHR Building	12.2	11.6	13.0	12.3	12.6	11.8	12.4	12.0	11.9	12.8	12.5	12.9	148
Total precinct	250	220	252	184	156	129	130	125	140	172	200	229	2183

Table 3-9 Energy consumption intensity (kWh/bed) of the QCH MH building in 2019

Total (kWh/bed)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
QCH MH Building	4085	3734	4124	3981	4173	4020	4189	4172	4010	4143	4033	4075	48739

Table 3-9 demonstrates the monthly energy use in kWh/bed for the QCH MH building in 2019 and the annual energy use intensity of 48,739 kWh/bed/yr. Note that the monthly energy use intensity

[1] Council of Australian Governments (COAG), Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia. Department of Climate change and Energy Efficiency, Canberra, 2012.

for this building is relatively stable, at around 4,000 kWh/bed. This is another indicator that the cooling load of the MH is not accounted for in these figures.

Another common way of communicating energy use intensity is correlation with heating and/or cooling loads. The annual Cooling Degree Days (CDD18) in Brisbane is 1129 (45 years data 1967-2012) based on RMY2012 weather data. The kWh/CDD18 were calculated for each of the buildings and the precinct, as shown in Table 3-10. It shows that the ARF building has the lowest kWh/CDD18, and the main hospital has the highest. It is not clear, at this stage, whether this metric by itself provides useful information for managing energy demand and consumption. For example, 2019 weather data would need to be analysed to calculate actual CDD to compare with actual electricity use for that year. Actual CDDs would also need to be compared with historical CDDs to determine trends due to a warming climate, and then determine the impact of such trends on cooling loads.

Table 3-10 Energy use data in kWh/CDD18 of the QCH precinct in 2019

Energy intensity (kWh/CDD18)	Annual
EP Building	7240
QCH MH Building	15498
ARF Building	1849
Total precinct	24,587

4 SITE POTENTIAL FOR ENHANCED ENERGY PRODUCTIVITY

This section outlines the site’s potential for renewable energy and enabling technologies and services in line with the i-Hub objectives.

4.1 Potential technologies that could be in-situ tested

The energy plant load variation is most likely HVAC dominated. A range of new and emerging technologies could be applied to this site, such as technologies or applications that:

- Can be retrofitted to existing plant to improve the efficiency and performance of HVAC systems, such as water treatment, compression cycle efficiency, innovative heating-cooling mechanisms, filters;
- Can be retrofitted to the existing buildings to improve building envelope thermal performance (external thermal loads), such as roof or wall coatings, smart glazing, or internal/external shading devices;
- Can integrate with building management systems to optimise building operation, such as demand management, load shifting, predictive maintenance, and continuous commissioning;
- Can reduce internal heat loads, such as smart lighting controls
- Can provide onsite or neighbourhood renewable energy that can be utilised, stored and managed to meet site demands;

- Can enable demand response capability and other energy market trading mechanisms.

4.2 Potential Key Performance Indicators

Current hospital sector KPIs are often based on energy use per annum, as demonstrated in the previous section. To assist with energy management decisions, more detailed or purpose oriented KPIs may be needed. As indicated previously, the hospital precinct's energy use and power demand are seasonal and highly correlated to HVAC. Therefore, monthly KPIs or HVAC related energy KPIs can be helpful. Some possible KPIs that may be examined are presented in Table 4-1. Additional KPIs may be identified and tested over time, including KPIs that relate to health outcomes.

Table 4-1 Potential KPIs for QCH

Sector	Benefit	Possible KPI
Site benefits	Energy bills saved	$ saved per month or per year
	Reduced energy intensity	kWh/m^2
	Increased load shifting capability	kW or kWh
	Predictive control of load	kW
	Self-sufficiency / Resilience	% of self-sufficiency rate Or N-X contingency
Renewable energy	Energy bill saved from locally generated renewable	$ saved per month or per year
	Increased value proposition	% of energy from renewable
Environmental benefits	Avoided greenhouse gas emissions	tCO2-e $/ tCO2-e
	Avoided air pollution (PM10, NOx, and SO2)	Reduction in (PM10)/MWh Reduction in (PM10) ppm
Network benefits	Peak 30 minute electricity demand	Peak kW/month (season, annual)
	Wholesale cost of peak 30 minute electricity demand	Wholesale $/KW at time of site peak demand
	Total self-consumption rate of local generation, e.g. renewable	%
	HVAC self-consumption rate of local generation, e.g. renewable	%
	Net Facility Load Factor	Peak demand to average demand ratio
	Demand response capacity	kW
Sector benefits	Energy cost reduced	$ per year
	Power Purchase Agreements - % of renewable energy	kWh of renewable energy purchased as a % of total PPA purchase
	Renewable energy fraction	kWh of renewable energy generated on precinct / neighbourhood