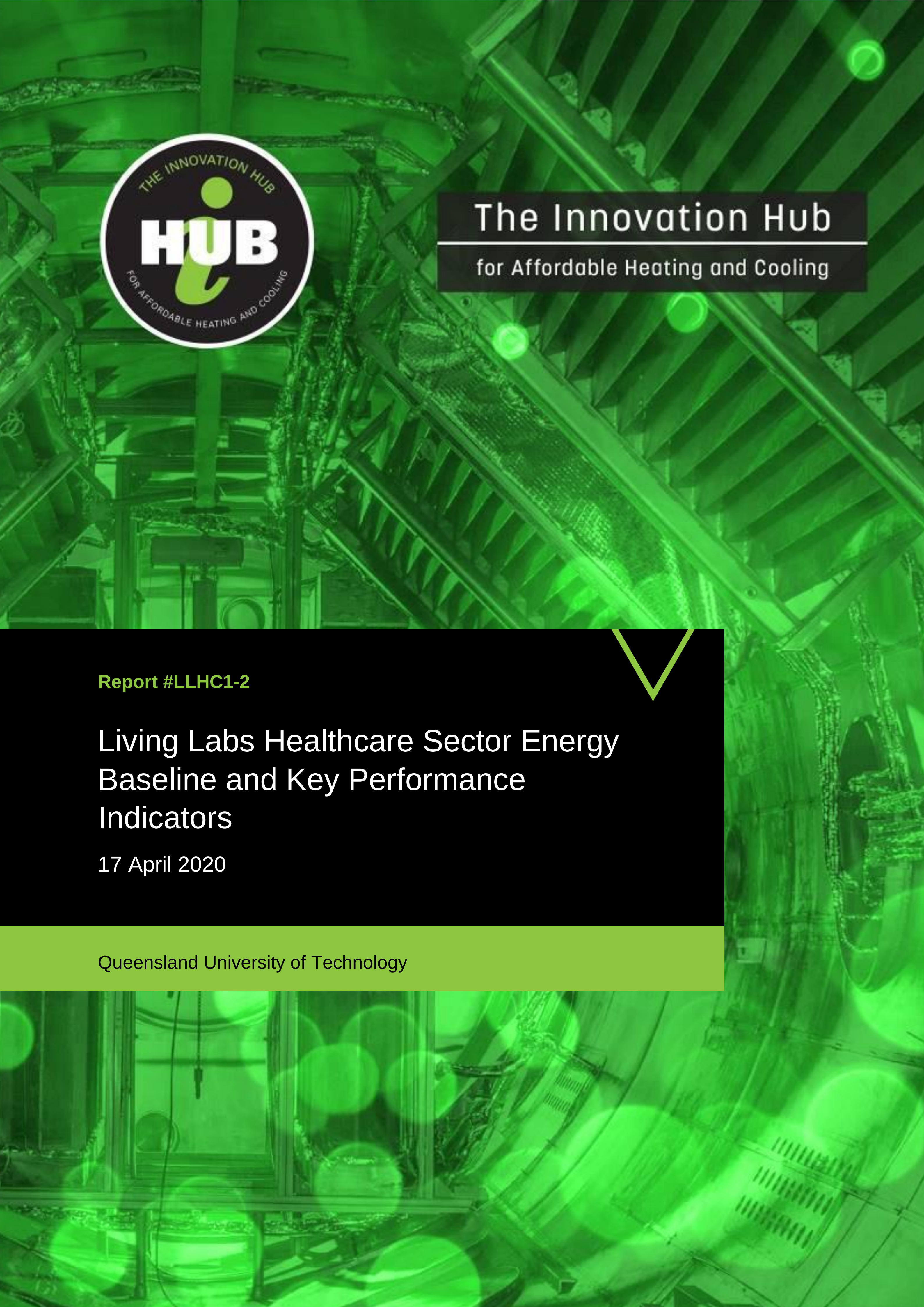

The Innovation Hub

for Affordable Heating and Cooling

Report #LLHC1-2

Living Labs Healthcare Sector Energy Baseline and Key Performance Indicators

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

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

Lead organisation

Queensland University of Technology (QUT)

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1 INTRODUCTION

1.1 Health care sector global emissions

The healthcare sector is responsible for about 4.4% of global net emissions and the US, China and the European Union comprise 56% of these emissions[1].The World Health Organisation defines the healthcare sector as “*all organisations, institutions, and resources that are devoted to producing health actions. A health action is defined as any effort, whether personal health care, public health service or inter-sectoral initiative, whose primary purpose is to improve health*.” The sectors greenhouse gas emissions relate to energy use, transport, and product manufacture, use and disposal (refer to Figure 1-1). 29% emanate directly from health care facilities and vehicles (scope 1 emissions 17%) and indirect emissions from energy sources (scope 2 emissions 12%). Scope 3 emissions include all supply chain emissions. Energy use (electricity, gas, steam and air conditioning) accounts for more than half of the sectors emissions (considering all three scopes), strongly driven by fossil fuel combustion. A key policy recommendation of this report is a transition to clean, renewable energy.

> *The health sector in every country should advocate for a rapid phase-out of fossil fuels and a transition to clean renewable energy so as to help move health care to zero emissions while also protecting public health from both local pollution and global climate change.*

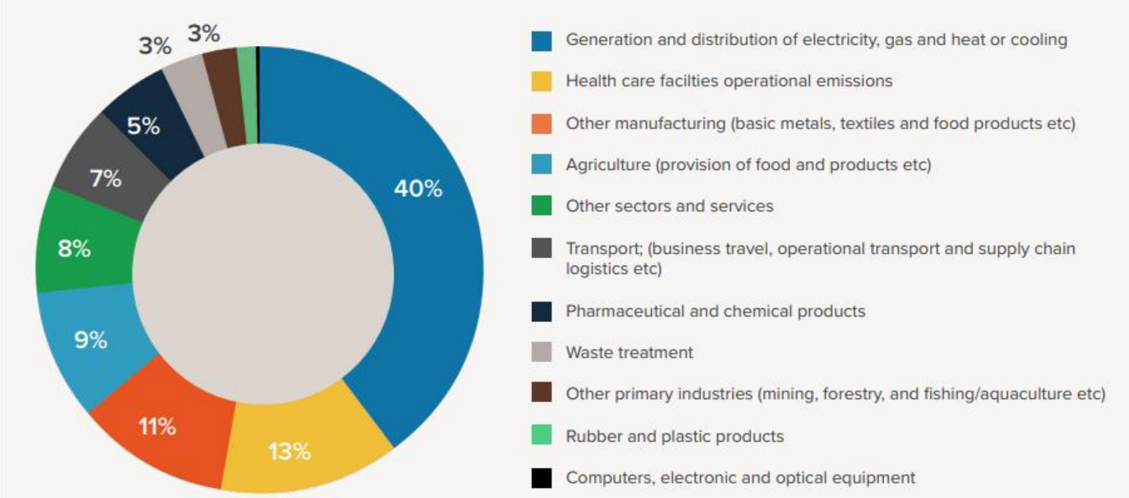


Figure 1-1 Global health care emissions by production sector

Figure 1-2 shows the top ten emitters in the health care sector, and Table 1-1 compares these health care top ten emitters with the top ten total greenhouse gas emitters. Figure 1-3 presents this data per capita, showing Australia’s position in the highest emitter category.

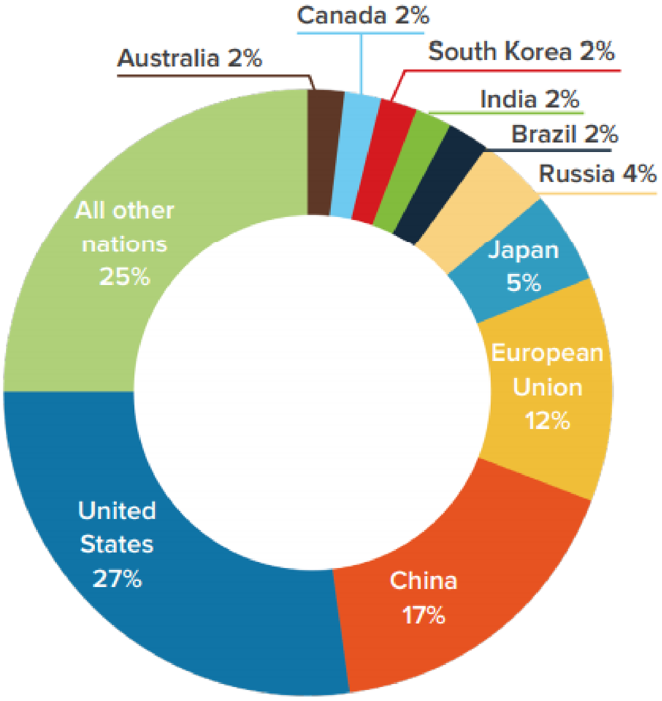
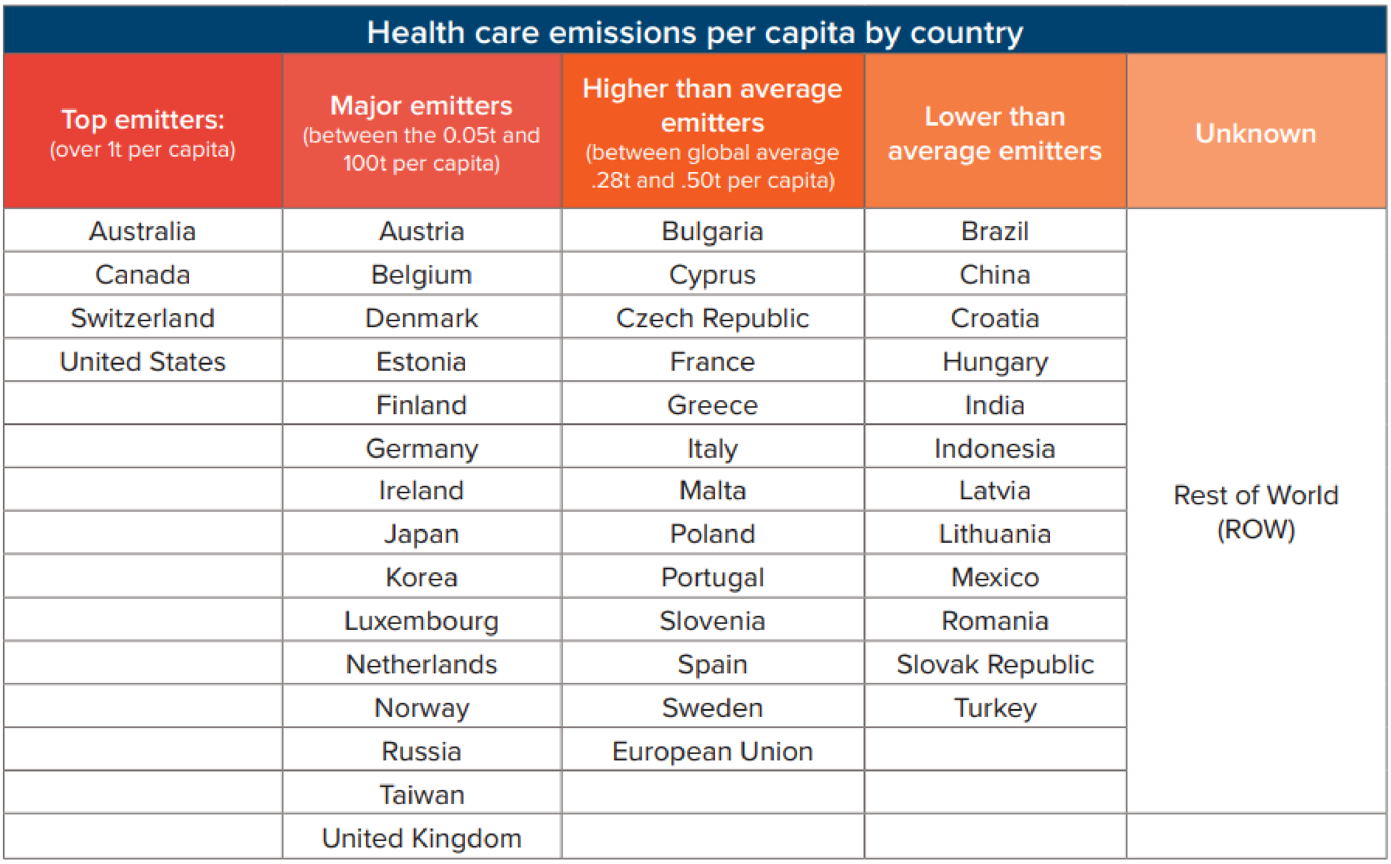


Figure 1-2 Top 10 emitters as percentage of global health care footprint

Table 1-1 Ranking of top ten health care CO2-e emitters compared to total top ten emitters

	Healthcare country/region CO2-e ranking	**Total country/region CO2-e ranking**
1	United States	China
2	China	United States
3	European Union	European Union
4	Japan	India
5	Russia	Russia
6	Brazil	Japan
7	India	Brazil
8	South Korea	Canada
9	Canada	South Korea
10	Australia	Mexico
	Mexico (11)	Australia (17)



Health care emissions per capita by country

Top emitters: (over 1t per capita)	**Major emitters** (between the 0.05t and 100t per capita)	**Higher than average emitters** (between global average .28t and .50t per capita)	**Lower than average emitters**	**Unknown**
Australia	Austria	Bulgaria	Brazil	Rest of World (ROW)
Canada	Belgium	Cyprus	China	
Switzerland	Denmark	Czech Republic	Croatia	
United States	Estonia	France	Hungary	
	Finland	Greece	India	
	Germany	Italy	Indonesia	
	Ireland	Malta	Latvia	
	Japan	Poland	Lithuania	
	Korea	Portugal	Mexico	
	Luxembourg	Slovenia	Romania	
	Netherlands	Spain	Slovak Republic	
	Norway	Sweden	Turkey	
	Russia	European Union		
	Taiwan			
	United Kingdom			

Figure 1-3 Comparison of healthcare emissions per capita

As examples of the high energy use of health care facilities, it is estimated that hospitals and health services consume more than 8% of the U.S. total energy [2] and Victorian health services and hospitals are the largest energy consumer in the state's public facilities [3].

1.2 Aim and purpose of this report

The aim of this report is to collate a range of existing energy key performance indicators (KPIs) and data for the healthcare sector domestically and internationally, in order to better understand (and hence manage) energy use and greenhouse gas emissions. The report reviews published literature, such as government and sector reports, industry papers and academic publications, collating and evaluating healthcare sector related key performance indicators (KPIs). The existing KPIs are evaluated in terms of their effectiveness in enabling renewable energy or energy storage; improving energy efficiency or productivity; reducing peak demand; and managing energy demand. Recommendations of how to select KPIs are provided at the end of the report. The existing KPIs will be used, in the first instance, as a reference for i-Hub Living Lab comparisons. The effectiveness of those current sector energy KPIs will be evaluated for innovative energy technologies in reducing peak demand, energy use or operation expense, enabling renewable energy or energy storage. New KPIs are expected to be developed and tested throughout the i-Hub's Living Lab project duration.

1.3 Scope

For the purposes of this report, the healthcare sector is limited to hospitals and aged care facilities, and the services they provide. Retirement villages are not included. General medical clinics (e.g. doctors' surgeries) are also not included. Energy used in the operation and maintenance of the healthcare providers include electricity, gas (e.g. liquified natural gas (LNG) or liquified petroleum gas (LPG), fuel (e.g. diesel or petrol), or thermal energy. Electricity is often the main energy source for healthcare providers around the world and it is the focus of the report. Gas and fuel is used in some healthcare facilities to provide backup power supply or hot water. Thermal energy may be in a form of solar heat or waste heat (from onsite or from a municipal or industrial site) and it may be used for water and/or space heating. The transportation of patients, occupants or staff may still heavily rely on fuel powered vehicles (internal combustion motors) in Australia. As the vehicle fleet becomes electrified in the future, transport energy could potentially be integrated with stationary energy requirements and solutions.

2 HOSPITAL ENERGY BASELINES

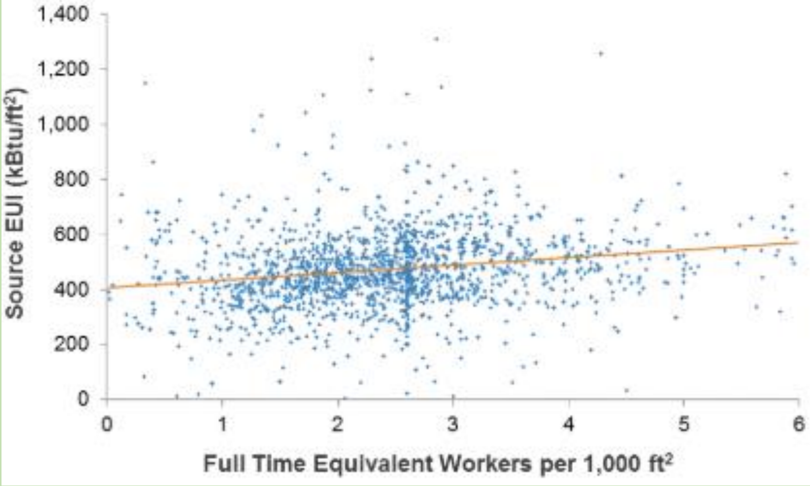
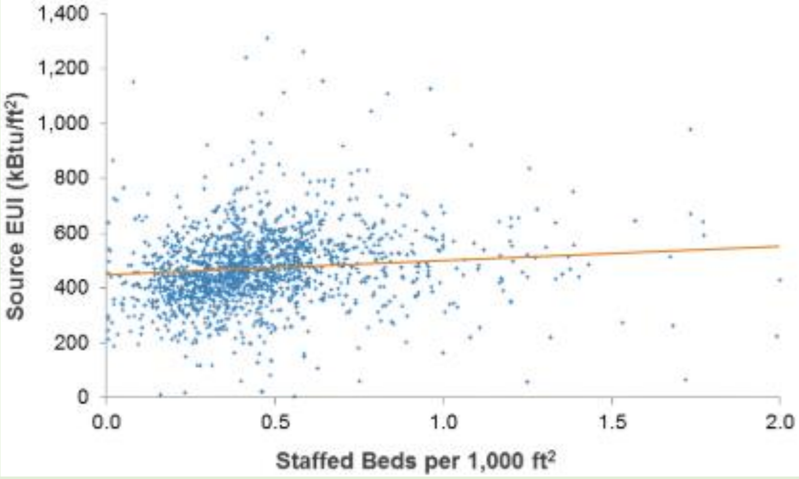
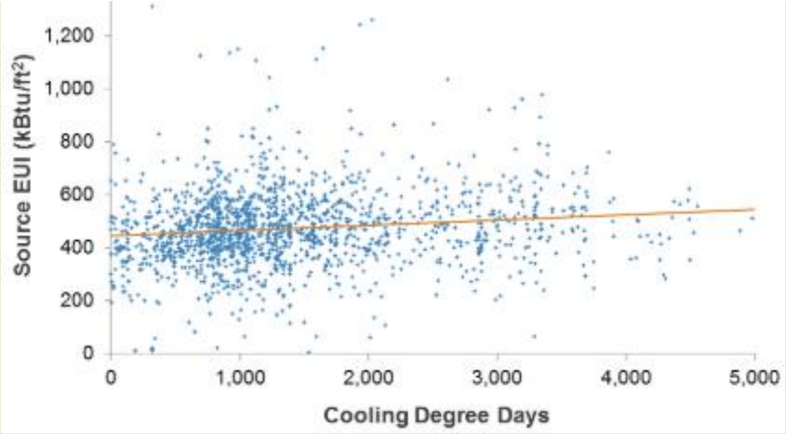
Overall, hospital energy use intensity varies considerably, depending on the climate, the types of hospitals, occupancy rates, equipment etc. Commonly used energy KPIs for energy use intensity are energy per floor areas per annum, energy per bed day per annum, or energy per bed per annum. The following paragraphs first describe these KPIs in reference to international experience (USA, India and China) and for Australia. The effectiveness of these KPIs are evaluated for energy management or energy investment related purposes.

2.1 Current energy status

In the UK, the total energy benchmark for hospitals was 550 kWh/m^2 per year and the good benchmark was 445 kWh/m^2 [4]. Reference [5] reported that in the Wales, for 2003, the consumption baseline for medium to large buildings was 2.24 GJ/m2 (equiv. 622.2 kWh/m^2). However, for 2003, major hospitals in Scotland had a better energy consumption with a mean value of 1.68 GJ/m2 (equiv. 466.7 kWh/m^2).

A study conducted by the EPA in the US analysed the energy data from 3207 hospitals over a 5 year period (until 2013). The mean source energy use intensity (EUI) was 467 kBTU/ft^2 per annum (equiv. 1473.2 kWh/m^2). Interestingly this report provided a range of ways in which EUI was presented. As seen in Table 2-1, the EUI values are slightly positively correlated with full time equivalent workers, number of staffed beds per unit floor area, cooling degree days and number of MRI machines per unit floor area [6].

Table 2-1 Source energy EUI with correlation factors (Adopted from [6])

EUI	Illustration
kBTU/ft^2 per annum VS Full time equivalent staff per 1000ft^2 **(1 kBTU/ft2 =3.2kWh/m2 1000 ft2 = approx. 93m2)**	
kBTU/ft^2 per annum VS staffed beds per 1000 ft^2 **(1 kBTU/ft2 =3.2kWh/m2 1000 ft2 = approx. 93m2)**	
kBTU/ft^2 per annum VS cooling degree days **(1 kBTU/ft2 =3.2kWh/m2)**	

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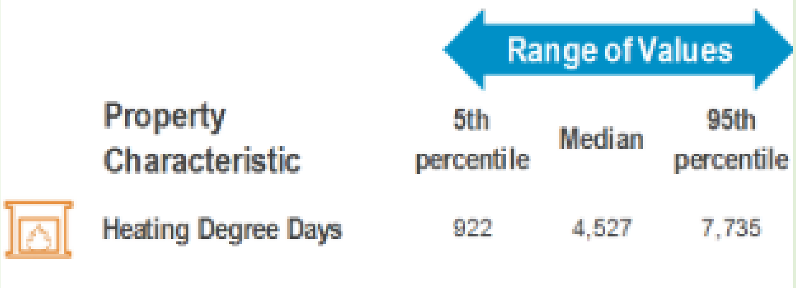
<tr>
<td>kBTU/ft^2 per annum
VS
heating degree days

(1 kBTU/ft2 =3.2kWh/m2)</td>
<td>
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<tr><th></th><th colspan="3">Range of Values</th></tr>
<tr><th>Property Characteristic</th><th>5th percentile</th><th>Median</th><th>95th percentile</th></tr>
<tr><td>Heating Degree Days</td><td>922</td><td>4,527</td><td>7,735</td></tr>
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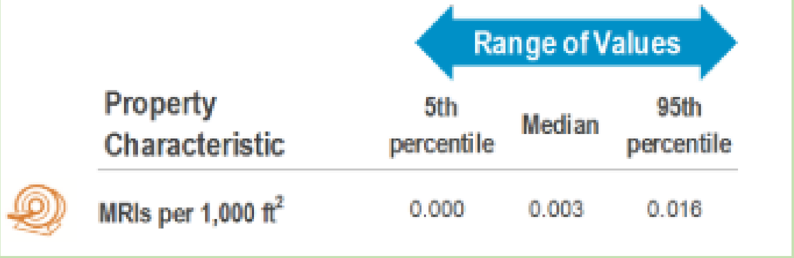
<tr>
<td>kBTU/ft^2 per annum
VS
MRI
per 1000 ft^2

(1 kBTU/ft2 =3.2kWh/m2)</td>
<td>
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<tr><th></th><th colspan="3">Range of Values</th></tr>
<tr><th>Property Characteristic</th><th>5th percentile</th><th>Median</th><th>95th percentile</th></tr>
<tr><td>MRIs per 1,000 ft^2</td><td>0.000</td><td>0.003</td><td>0.016</td></tr>
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</table>

Another US research study included 10,000 inpatient and 147,000 outpatient facilities [7]. This report showed that 51% of US healthcare building end use energy is electricity, followed by natural gas (Figure 2-1). Figure 2-2 shows that the top energy use by service is HVAC (52% of the end use energy), followed by water heating (11%) and lighting (9%). The average EUI for the studied facilities was 544.8 kWh/m2 per annum, higher than European counterparts, such as England or Scotland. Overall, electricity EUI for the studied facilities is 278 kWh/m^2 per annum, which is about 2.89 times the EUI for hospitals in China (96.1 kWh/m^2) and about 1.87 times of the EUI for hospitals in Thailand (148.8 kWh/m^2) [8]. Note that these EUIs are reporting on electricity use only, not total hospital energy use.

One thing to notice is that often electricity EUI cannot be simply compared across regions. One of the reasons is that in cold (or more temperate) area, heating is often provided with gas, not with electricity, e.g. in Northern European countries. However, in Australia, often all HVAC energy requirements (heating and cooling) are from electricity. Therefore, the US EPA’s source energy approach (presented in Table 2-1) may provide a more meaningful comparison.

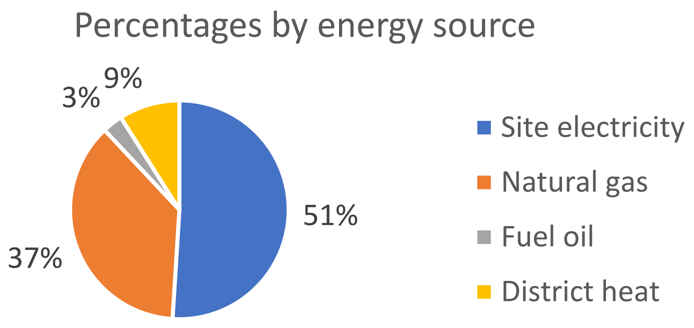


Figure 2-1 U.S. 2012 energy use in healthcare buildings by energy source (adopted from [7])

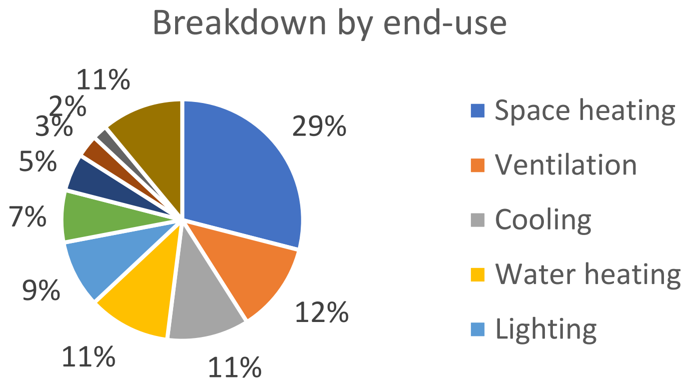
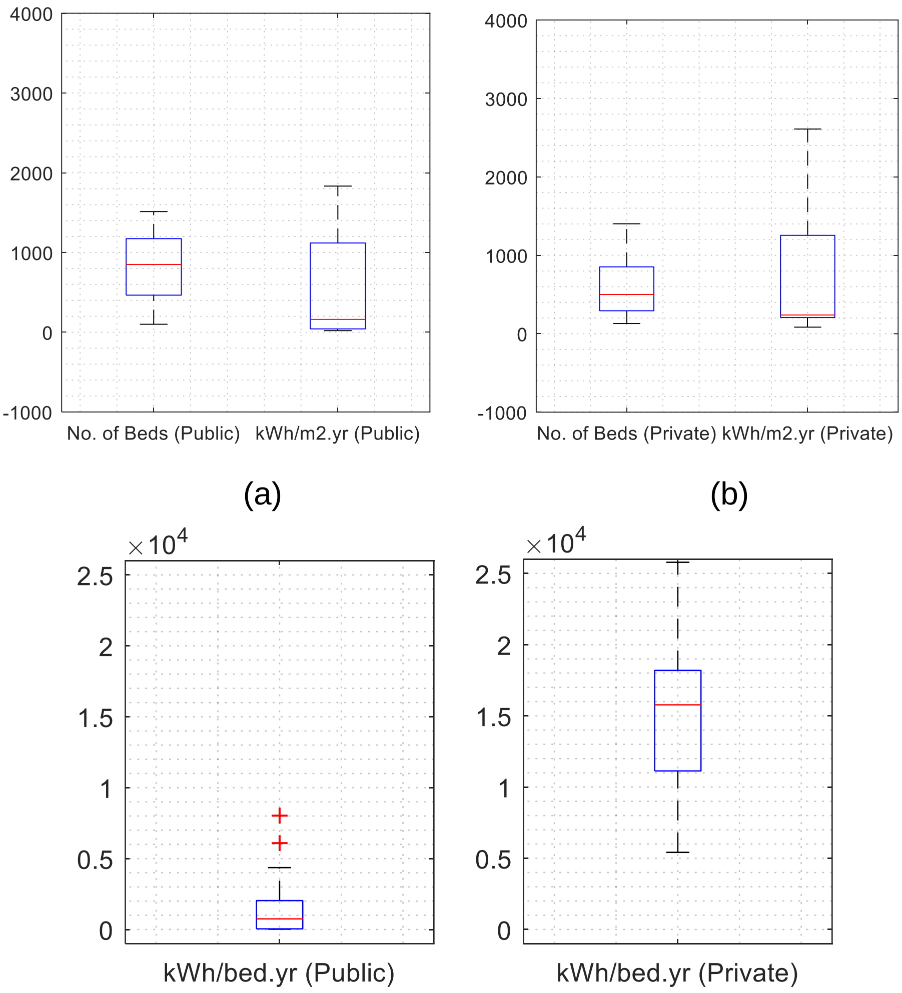


Figure 2-2 U.S. 2012 healthcare buildings energy source breakdown by end use (adopted from [7])

In China, energy data from 100 hospitals across four of five climate zones are studied in [9]. This study found that electricity accounts for 64% of all energy consumption and air conditioning is the largest electricity user by service, especially in the south China region with hot summers and warm winters (similar to the south-east Queensland climate). This study also found that higher grade (more medical services) hospitals always have a higher kWh/m^2 per annum, and hospitals with more beds tend to consume more kWh/bed per annum on the average. The Chinese average annual electricity consumption per unit is 96.1 kWh/m^2 per annum, or 7196.2 kWh/bed per annum.

In India, electricity is often the main energy source for hospitals, accounting for more than 90% of hospital energy use [10]. Figure 2-3 presents two boxplots of the kWh/m^2 per annum and kWh/bed per annum for the surveyed hospitals in India. Significant differences can be observed for the kWh/bed per annum values between public hospitals and private hospitals. This may be attributable to the different service levels provided. The report also identified that HVAC, lighting and water pumping are the highest energy users for five Indian hospitals. In that report, HVAC uses between 30% ~65% of total electricity and lighting uses 30% to 40% of total electricity. Similar findings are found in Greek research where HVAC and lighting account for the major part of the total electrical energy consumption (about 50 to 60%) [11].



(a) (b)

(c) (d)

Figure 2-3 Boxplot of KPIs for 17 public hospitals and 7 private hospitals in India (consolidated data from [10])

In Australia, electricity and natural gas are the largest energy sources for hospitals, and HVAC is the largest electricity user, accounting for an average of 47% of electricity in Australian hospitals [12]. This report differentiated the average end use EUI for different hospital types:

- 1536 MJ/m^2 per annum (equiv. 426.7 kWh/m^2) across all 445 public hospital studied
- 1657 MJ/m^2 per annum (equiv. 460.3 kWh/m^2) for the 322 regional public hospitals
- 1415 MJ/m^2 per annum (equiv. 393.1 kWh/m^2) for the 123 public hospitals in capital cities.

Overall, Australian capital city hospitals were reported to be more energy efficient than regional hospitals. A descending order comparison of the EUI of hospitals as reported in academic literature is shown in Table 2-2.

Table 2-2 Comparison of Hospital EUI by country

Country	kWh/m^2
US	1473.2
Wales	622.2
UK (average)	550.0
Scotland	466.7
Australia (regional public hospitals)	460.3
UK (NHS benchmark)	445.0
Australia (capital city public hospitals)	393.1
India	~200.0
China (electricity only)	96.1

Some possible reasons for the variations between hospitals could include:

- Climate and cultural expectations regarding indoor climate
- Age of building, infrastructure and equipment (and relative energy efficiency of these)
- Degree of medical specialisation
- Size and building configuration of the hospital (e.g. building mass, external wall/roof area)
- National and regional healthcare budgets (e.g. the extent to which HVAC is seen as a necessity)

This comparison highlights the key flaw of the standard hospital KPIs: kWh/m^2 does not provide meaningful information to inform whether a particular hospital is energy efficient and does not enable comparison between facilities (because of the wide range of variables that can influence energy intensity). Similarly, kWh/bed or per bed day does not give an indication of the level of medical services provided by a particular facility, and the cultural or social expectations of indoor environmental conditions.

The next section presents literature review results for hospitals' energy profiles over different seasons and energy use comparison among different departments.

2.2 Energy profiles

Depending on the climate zone, monthly or seasonal energy use can vary significantly. For example, a study investigated energy use of 100 hospitals in China and 22 of them are in hot summer and warm winter (HSWW) climate [9]. Out of the four climate zones, the hot summer and warm winter zone is the one most similar to south-east Queensland's climate (the location of one of the i-Hub's Living Labs). As shown in Figure 2-4 the energy consumption per unit for the HSWW climate is the highest from April in Spring to October in Autumn (7months). The hospitals in the HSWW climate on average have the highest energy consumption per unit of the four climate zones. One reason is that air conditioning is the largest energy consumer (50% of the total electricity consumption) for these 100 hospitals. The HSWW climate requires more months of cooling, provided by air conditioners with high power and energy demand, compared to the other climate zones. Note that the “hot summer cold winter” climate zone has a similar summer cooling load, but the total cooling season is significantly shorter. This study also investigated the end use energy components in outpatient and inpatient areas, however it did not include a detailed analysis of the energy use of different departments within the hospitals.

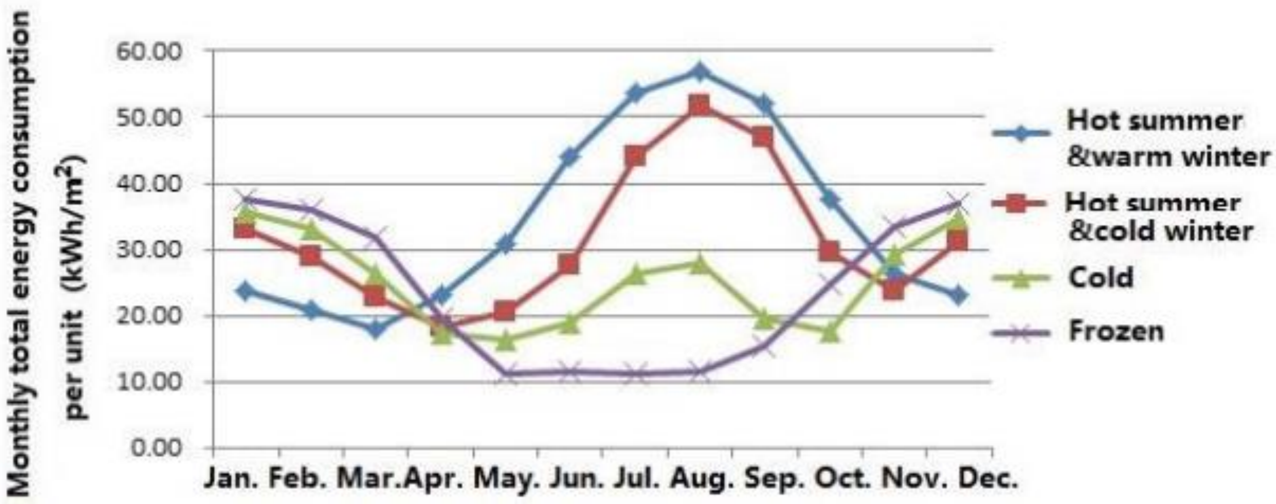


Figure 2-4 Monthly total energy consumption per unit in each climate zone in China
Adopted from [9]

Morgenstern et al [13] conducted EUI analysis for eight medium to large general acute hospitals in England. In total, electricity usage data from 28 departments were collected and analysed. The power demand and energy use analyses by departments offers useful information for energy management, such as information about where power and energy are required across departments and their seasonal or weekday-weekend patterns. The base load and peak load power characteristics of the study are presented in Figure 2-5. Base load is the minimum power demand over a 24h period and peak load is the maximum power demand over a 24h period. On average, operating theatres have the highest peak load and imaging and radio-therapy departments have the highest load factor, indicating that a significant power difference exists between their medical equipment on standby status and operation status. The day clinic has the lowest base load.

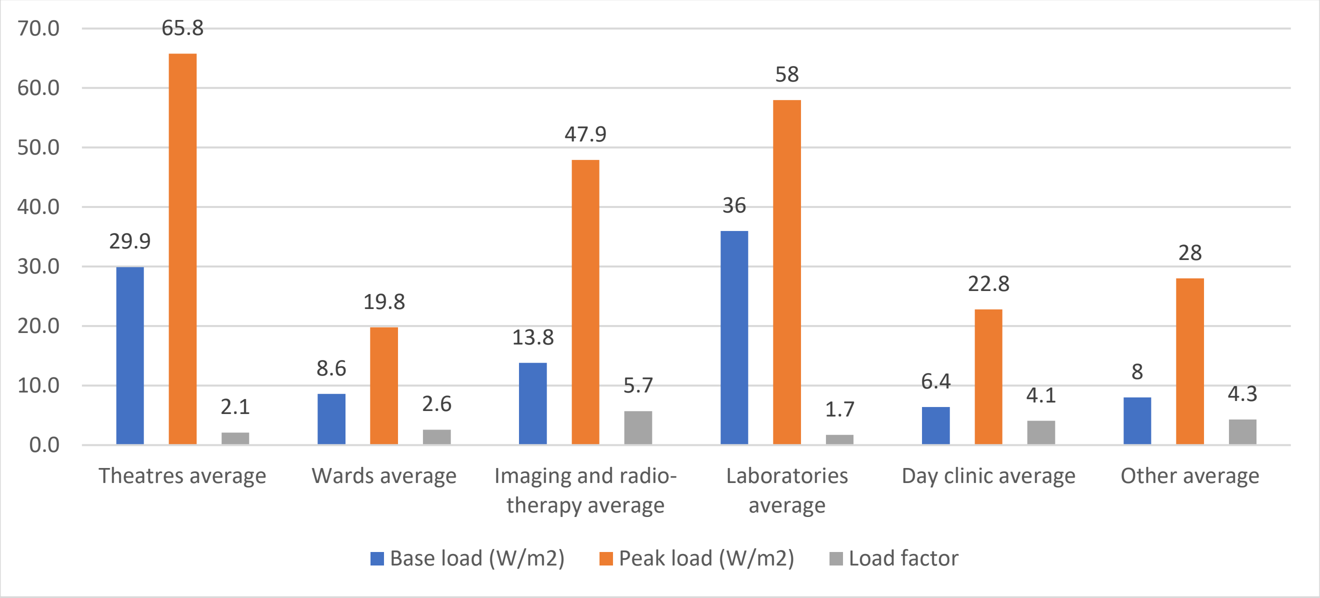


Figure 2-5 Power characteristics of some acute hospitals in England consolidated data from [13]

The energy use characteristics of the same hospitals in [13] are summarised in Figure 2-6. There are similarities and differences when the energy use profile is compared to the power demand profile. Operating theatres on the average use the most energy on weekdays, whereas laboratories use the highest “all days” average and “weekends” average. The highest weekday/weekend ratios are for imaging departments and day clinics. This is likely because some of those departments are quite specialised and not frequently operational over weekends.

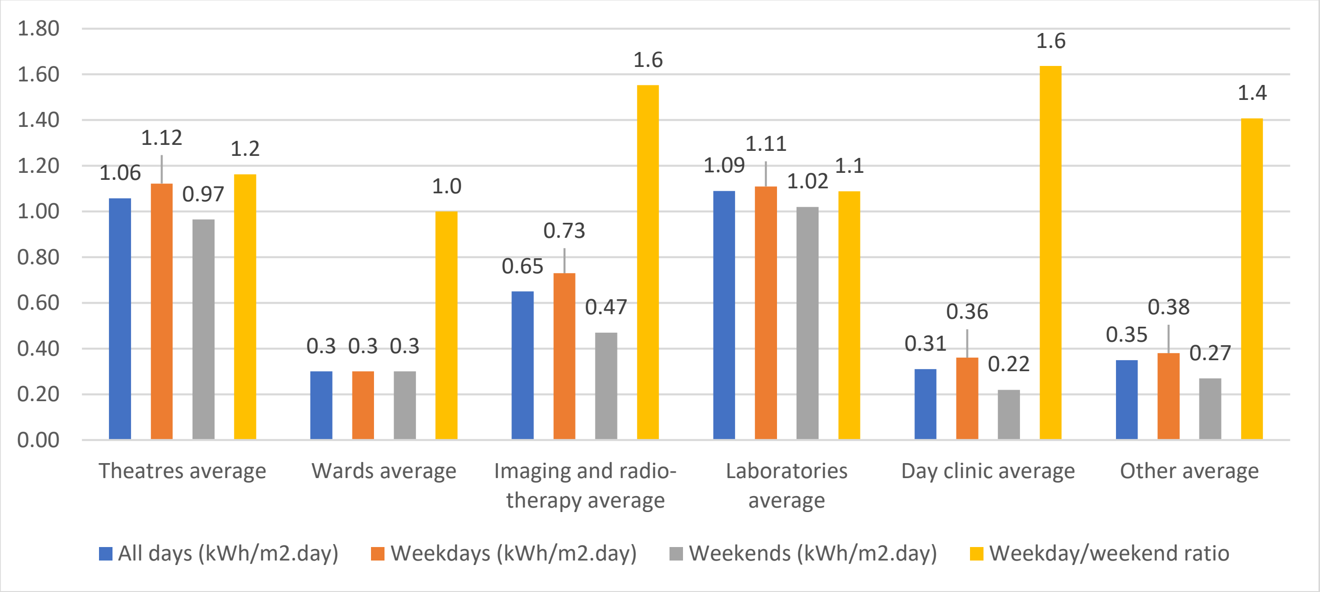


Figure 2-6 Energy characteristics of some acute hospitals in England (consolidated data from [13])

An energy design guide by NREL in the US [14] recommended comprehensive design guidelines for new small healthcare facilities (up to 8360 m^2) to achieve energy savings by 30% compared to the minimum requirements of ASHRAE 90.1-1999 standards. The recommended lighting power density and peak plug loads are summarised in Table 2-3. The table compares ASHRAE baseline models (1999 and 2004) with low-energy models; with advanced energy guidelines; with occupancy sensors; and with measures to reduce peak plug loads. For example, it shows that lighting power density is the lowest when occupancy sensors are adopted.

Table 2-3 Power density for small hospital or surgery centres [14]

	Community hospital	**Surgery centre**
Lighting power density:	W/m^2	W/m^2
ASHRAE 90.1-1999 baseline model	20.45	19.38
ASHRAE 90.1-2004 baseline model	11.84	11.84
ASHRAE 90.1-1999 low-energy model	19.91	20.13
ASHRAE 90.1-2004 low-energy model	11.95	11.41
Small healthcare advanced energy design guide low-energy model	9.903	9.47
ASHRAE 90.1-1999 With occupancy sensors	19.91	20.13
ASHRAE 90.1-2004 With occupancy sensors	11.95	11.41
Small healthcare advanced energy design guide With occupancy sensors	9.472	8.93
Peak plug loads:		
Small healthcare advanced energy design guide	22.6	19.38
Green Guide for Healthcare	10.76	
Surgery centre prototype model		16.15

2.3 Impact of Trends on Energy

2.3.1 Healthcare trends

A number of trends in healthcare could have implications for energy use and energy use intensity in hospitals. First, there is a blurring of lines between facilities that provide temporary and permanent health care. For example, residential aged care facilities are more and more like hospital wards [15], but with private rooms and facilities. This indicates that aged care units may have more specialised medical equipment and HVAC design, differentiating them from other accommodation types. The impact of having more specialised medical equipment is that those facilities' base load may not change much, however, their load profile may have more volatility, meaning higher peak demands and more random occurrence.

Second, regional (and some urban) hospitals are, or are becoming, hubs for medical and surgical services, allied health services, and sometimes with aged care facilities as well. Therefore, those hospitals are no longer the same as traditional hospitals. They are health precincts providing a variety of health and medical services. Energy related design guides for such facilities need to consider provisions for those services, and single or general energy KPIs (e.g. kWh/m^2) for the whole site may not be useful in energy auditing or measuring energy efficiency.

2.3.2 Policy trends

Denmark is a pioneer in hospital reforms, reducing its total number of hospitals by two-thirds over the last two decades. It now has only 32 hospitals. One of the key reasons for this approach was the increasing demand for public funds for hospitals. They believe that a more financially sustainable approach (that also maintains or improves existing health outcomes), is to have fewer hospitals and that these facilities cater for critical and very specialised cases. Primary and ambulatory care are completed at local clinics and in the comfort of people’s homes [16]. It is possible that this policy move will result in lower total energy use formerly attributable to hospitals, but may have impacts on the energy intensity of the three building types where health services are now provided:

- The remaining hospitals will treat more critical medical cases and thus require very specialised equipment and services (likely resulting in a higher kWh/m^2)
- Local clinics are offering services not previously provided, and this may increase their kWh/m^2, at least during opening hours (energy use overnight and on weekends is likely to be less)
- Homes, not previously the principle place of care, may see an increase in energy consumption and energy intensity, depending on the health needs of the patient. If no specialist equipment is provided, the energy use attributable to the patient will likely be indistinguishable from general household energy use.

Another similar policy trend is the move towards telehealth services. The energy implications of telehealth have not been studied.

2.3.3 Equipment/Medical needs

As technology develops, more energy efficiency improvements are applied for lighting, motors, compressors and electronics [17]. However on the other side, as hospitals become more specialised, more potentially high powered medical equipment, such as MRIs, may be used [17]. For hospital baselines and benchmarking purposes, there would need to be a regular review and updating of energy KPIs. If resources allow, there may be a need of considering energy KPIs based on service types or departments. In this way, energy performance improvement opportunities can be identified.

2.3.4 Transport electrification

Patients and staff transportation may be another large energy consumption if a system and holistic approach is taken to evaluate healthcare facilities energy performance. Around the world, transportation electrification is happening. The purchasing price of long-range electric vehicles (EV) is still high compared to fossil fuel vehicles, however the total cost of ownership of EVs is falling quickly, and it may not be far in the future when transport energy use needs to be incorporated into the electrical energy strategy for healthcare facilities. This may particularly be the case for residential aged care facilities that also provide in-home care services.

2.4 Hospital energy KPI effectiveness

Existing KPIs often provide a general overview for healthcare facilities. Three common energy KPIs are summarised in Table 2-4. They are often understandable and the data (especially annual data) is relatively easy to obtain or calculate. Each of those KPIs has benefits as well as a few limitations.

Table 2-4 Existing KPIs overview (summarised from [3] [10] [18])

KPIs	Evaluation
kWh per bed day[1] per annum	**Benefits**: • Demonstrated correlation to energy use. It is a key output measure of health service delivery • Data acquisition and analysis is not significantly difficult **Limitations**: • Only includes hospital admissions. It excludes aged care, non-admitted emergency presentations, out-patient services • Does not account for non-patient activities (e.g. research, support services) • Does not differentiate between types of beds • Does not differentiate between fuel mixes
kWh per gross floor area per annum	**Benefits**: • Widely understood measure • Allows some comparison to other sectors • Data acquisition and analysis is not significantly difficult **Limitations**: • Does not differentiate between types of floor space, hours of use of each type of floor space, fuel mixes (e.g. electricity and gas) • May include non-health care related areas, e.g. car parking, outdoor gardens etc

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[1] Bed day refers to the number of days that a bed is occupied. If a patient leaves a hospital on a particular day, and another patient is allocated that bed, the number of bed days is counted as two. It is an indicator of the occupancy rate of a hospital, compared to its total bed availability.

kWh per separation[2]	**Benefits**: - Demonstrated correlation to energy use. It is a key output measure of health service delivery. - Data acquisition and analysis is not significantly difficult **Limitations**: - Only includes hospital admissions. - Does not account for non-patient activities (e.g. research, support services). - Does not reflect that separations come in different types and lengths. - Does not differentiate between fuel mixes.

If comparison or evaluation is needed for healthcare's environmental impact, carbon emission intensity kgCO2-e/m^2 per annum may be needed as a KPI [19]. However, there are challenges in using or interpreting this KPI. For example, the CO2 emissions per kWh varies across electrical power systems and changes over time (e.g. as the fuel mix in the region adds more renewable energy).. As more electric power systems gradually become decarbonised, the healthcare facilities' co2 metric may improve, without an improvement to its own building energy performance or energy efficiency. The same impact can occur if a health facility enters into power purchase agreements for renewable energy: the carbon emissions decrease but this does not equate to better energy use intensity.

Instead of using kgCO2-e/m^2 per annum, onsite renewable electricity (energy) generation as a percentage of the overall electricity (energy) consumption may be a more suitable KPI to indicate how a healthcare facility has performed environmentally. This onsite renewable generation percentage is an assessment item in LEED 2009 for Healthcare [20]. In addition, because of the high PV penetration in communities and suburbs in some regions [21], procurement of renewable energy from nearby neighbourhood (such as within approx. 5~10km distance) for healthcare use may be included in the onsite renewable KPI calculation. Within this distance, there is no significant energy loss and this sharing encourages more local renewable generation. The advantages of using the renewable energy percentage KPI for evaluating environmental impact are:

- the KPI value can be compared over time for the same facility, without the impact from the electric power system
- it sets up a common ground for comparison with other facilities in different areas
- it reflects the building or facility's own renewable energy status or improvement

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[2] Separation refers to the 'release' of a patient from a hospital, at the end of all treatment (regardless of whether the patient was hospitalised or treated as an outpatient, and has been to the hospital once or multiple times for the same medical condition).

2.5 Recommendations for hospital energy KPIs

In summary, it is important to understand the purpose of energy performance improvements or energy auditing to select purpose-oriented energy performance KPIs. In addition to the KPI evaluations in the previous sections, literature also recommends:

- Using calendar month energy to calculate KPIs, rather than billing month energy [22]
- Using a consistent energy KPI rather than an energy cost KPI [22]
- Understanding energy intensive and non-energy intensive departments and service types to identify energy performance improvement opportunities [23]
- Understand the energy and demand performance of major equipment (in accordance with ASHRAE Level 2 and Level 3 Performance Measurement Protocols (PMP)
- Evaluating seasonal or monthly variation in energy consumption or power demand to better identify and validate the impacts of energy performance improvement opportunities [23].

Further discussion on criteria for selecting energy baseline KPIs and proposed KPIs are included in Sections 3.5 and 3.6.

3 RESIDENTIAL AGED CARE ENERGY BASELINES

3.1 Energy use in Aged Care - International

In contrast to hospitals, there is very little detailed published data about energy use in residential aged care facilities. There is a plethora of publications about Aged Care, but these are predominantly focused on care service provision. Some literature discusses the indoor environment from a thermal comfort perspective, but this literature typically does not discuss the energy issues. Countries with ageing populations and increased service demands from that demographic are seeing increased financial pressures on providing appropriate levels of care services. Reducing overheads, such as through energy efficiency and renewable energy, are ways in which budgetary pressures can theoretically be reduced. Achieving this in a cost effective and systematic way, however, requires better understanding of how and when aged care facilities use energy. Reports from the UK, EU and Japan are described in this section.

The UK's Carbon Trust estimates that the largest proportion of energy use in primary healthcare is attributable to space heating (70%), as shown in Figure 3-1.

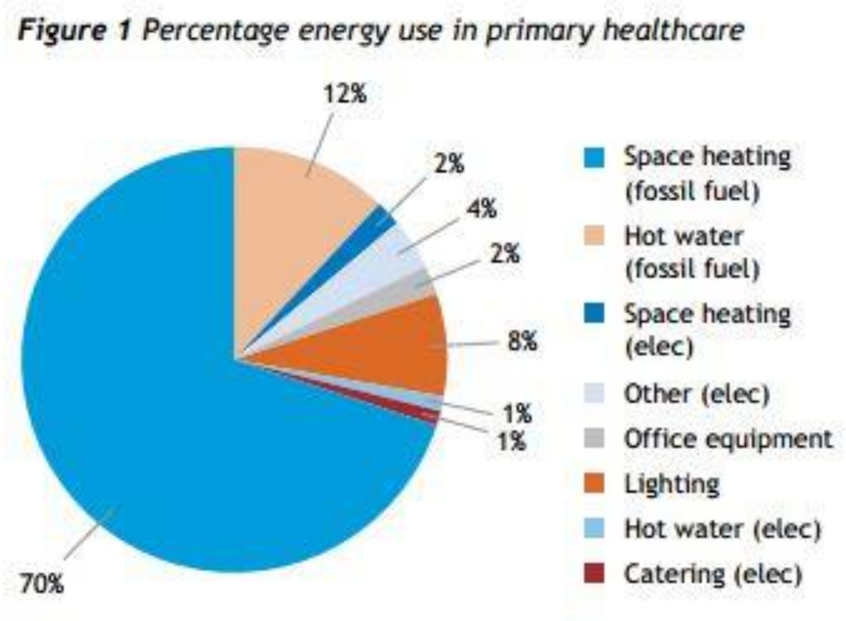

Figure 3-1 Energy use percentages in primate healthcare

Scotland has approximately 1300 care homes, with 916 homes for elderly people who require full time care due to age related health issues (so equivalent to Australia's residential aged care). These facilities are owned and operated by either private companies or local authorities. Care homes, similar to all buildings in the UK, are required by law to provide energy performance certificates (EPCs) indicating their energy 'efficiency' of the building envelope and fixed services. The typical U-values of building envelope elements is shown in Figure 3-2. About 40% of the energy demand for care homes is for space and water heating.

Type of element	Area weighted average U-value for all elements of the same type (W/m^2K)	Individual element U-value (W/m^2K)
Wall	0.27	0.7
Floor	0.22	0.7
Roof	0.2	0.35
Windows/doors, roof windows and roof lights	2	3.3

Figure 3-2 Typical U-values of building areas in Scotland[24]

The EU's Save Age project[25] analysed the energy consumption patterns and energy efficiency measures of 100 residential care homes in 10 countries. It was the EU's first move to establish energy benchmarks for Residential Care Homes for Elderly People (RCHEP). The project involved the collection and analysis of a range of data from each facility:

- Three continuous years of monthly energy use data (2007 – 2010)
- All energy sources (electricity, natural gas, district heating, biomass and fuel)
- Climatic conditions (HDD 15 °C and CDD 20°C)
- Building envelope characteristics (based on year of construction and/or retrofit)
- Floor area
- Number of residents
- Number of staff

All energy data was converted into a common unit (kWh). Heating (space heating and water heating) was the major energy user. All facilities had central heating systems, of different types and running on different energy sources (refer to Table 3-1). Winter set points ranged from 15 °C in Italy to 26 °C in Greece. The control of set points was usually managed centrally, by staff. Few facilities enabled individual control over indoor air temperature.

Space heating accounted for >50% of total energy use in Spain, Italy, Greece, France and Czech Republic, and 40-45% in the other countries. Apart from climatic differences, space heating was considered to be impacted by the building envelope (e.g. the level of insulation and air tightness); set point temperatures; types of controls; and occupant habits.

Space cooling (air conditioning) was not common in all countries. Where it was provided, it was typically applied to common areas only.

Energy sources for water heating also varied, as shown in Table 3-2.

Table 3-1 Energy sources used for space heating in EU care homes

Country	Electricity	Natural Gas	District Heating	Biomass	Fuel
Czech Republic		X	X		
Germany		X	X		
France		X		X	
Greece	X	X		X	X
Italy	X	X			X
Netherlands		X			
Portugal	X	X			X
Slovenia		X	X		X
Spain	X	X			X
Sweden	X	X	X		X

Space heating consumption used two different EUIs: heating kWh per m2 and per resident (per year). The baseline was given by the average consumption in the summer months (June, July, August), and the heating energy calculated from disaggregation of metered energy data.

Table 3-2 Energy sources used for water heating in EU care homes

Country	Electricity	Natural Gas	District Heating	Biomass	Fuel	Solar thermal	PV
Czech Republic	X	X				X	
Germany		X				X	
France	X	X				X	X
Greece					X	X	
Italy		X				X	
Netherlands		X				X	
Portugal	X	X			X	X	
Slovenia	X	X			X	X	
Spain	X	X			X	X	
Sweden	No information available						

The research team used a multivariate linear-regression model approach to correlate EUI with factors that may influence the energy consumption of a building. The variables included HDD, number of residents, number of employees, year of construction and year of retrofit. Occupant variables such as behaviour, awareness and maintenance practices were not included, as they were considered too difficult to quantify or evaluate. The data was then used to provide benchmarks specific to each facility, and to compare each facility's benchmarks to their actual performance. Four KPIs were used to report results. The mean values and the range of values for each of the KPIs are shown in Table 3-3.

Table 3-3 Energy KPI results for EU care homes

KPI	Metric	Mean value	Range (min / max)
EUI1	kWh/m²/yr	252	46 to 551
EUI2	kWh/resident/yr	11711	2215 to 36349
EUI3	kWh heating/m²/yr	129	To 333
EUI4	kWh heating/resident/yr	6109	To 20556

Two Japanese studies[26,27] have sought to quantify energy and water use in nursing homes in order to develop fundamental design data to inform the enhancement of facilities and equipment to improve quality of life of the residents. The two nursing homes studied had an occupant capacity of 51 and 77 respectively, and each had dining rooms, recreation rooms, bathrooms, private rooms and laundries. The studies focused on understanding seasonal, daily and hourly consumption patterns for hot and cold water. The average daily water use for each facility did not vary significantly between summer and winter, but the amount of energy used to heat the water did (refer to Table 3-4). These researchers also found that the purpose of hot water usage changed seasonally (e.g. the ratio of use between the kitchen and the bathing room). Their research demonstrated that energy use (for water heating) in nursing homes is dependent on both the type of equipment used for bathing, and the bathing style of elderly people.

Table 3-4 Hot water energy use in 2 Japanese nursing homes

Nursing Home	Hot water energy source	Hot water type	Water heating energy
Facility 1	Electricity and LPG	Heat storage with heat pump	2640.65 MJ/d winter 1972.86 MJ/d summer
Facility 2	Electricity and LPG	Boiler and storage tank	2860.08 MJ/d winter 1011.74 MJ/d summer

3.2 Energy use in Aged Care (Australia)

As mentioned previously, compiling benchmarking data specifically for Residential Aged Care is a unique case with little collected or publicly reported data. Energy statistics related specifically to Residential Aged Care (RAC) are not as readily available as other similar sectors. A RAC facility is a mix of a residence and a healthcare facility combined with elements of a commercial kitchen and laundry, and office administrative space. Many of these individual elements (commercial office / hospital) have easily accessible and widely reported energy audit information. However, as a combined facility, there is little reported energy use benchmarking. Information pertaining to specific cases of hospital / healthcare and household energy efficiency programs are more easily found, and countless government initiatives have focused on residential household energy efficiency, however a residence is not always a detached house or single-family unit or apartment.

One of the challenging issues for examining residential aged care is that this type of building is different to other types of buildings, making it difficult to develop energy performance benchmarks.

Some of the similarities and differences to other building types are shown in Table 3-5. In all these cases (at least in Australia), the space occupant does not directly pay any energy costs associated with the room. In some cases, the occupant has control over the indoor environment (e.g. the thermostat for heating or cooling), but in other cases the occupant has no control.

Table 3-5 Comparison of other building types with residential aged care

Site	Similarity	Difference
Hotel	Many small rooms with ensuite	Hotel guest have paid a premium for short stay. Not permanent residence.
Prison	Individual rooms (sometimes). Central kitchen / dining / laundry.	Prisoners do not have personal choice (of movement, control)
Hospital	Many rooms. Kitchen / laundry. Healthcare provision	Intended for as short as stay as possible. Not a permanent residence.
University dorm	Short term duration May have ensuite facilities	Long unoccupied hours Younger, more mobile demographic
School	Many rooms. Individually controlled.	Short daily hours. No overnight stay. Younger demographic

The following sections discuss two recent Australian reports relating specifically to energy use in Residential Aged Care. The first was issued by the NSW government, based on site energy audits. Similar to the Resource Efficiency Guide provided by the Scottish government, this report provides advice on energy saving strategies which are considered appropriate to the Residential Aged Care sector. The second report, by Sustainable Living Tasmania, summarises energy audits of nine (9) residential facilities. Of specific interest is the lack of consistent benchmarking metrics. In some cases energy information is presented as ‘proportion of overall energy used’, which is of limited use when comparing sites. In some cases, it is not clear whether a report is referring to electricity use, or overall energy use.

3.2.1 NSW Department of Environment and Heritage

The 2014 NSW government Energy Saver Aged Care Toolkit [28] discusses the findings of 15 energy audits in NSW aged care facilities. Major energy uses are noted along with potential energy saving measures to address specific energy loads. The report does not offer any specific values for benchmarking. Most of the values presented in this report are allocations of total use, rather than energy use per bed[day]. The report shows total energy use, then electricity and gas proportions. Figure 3-3 shows a typical data representation, in this case for electricity.

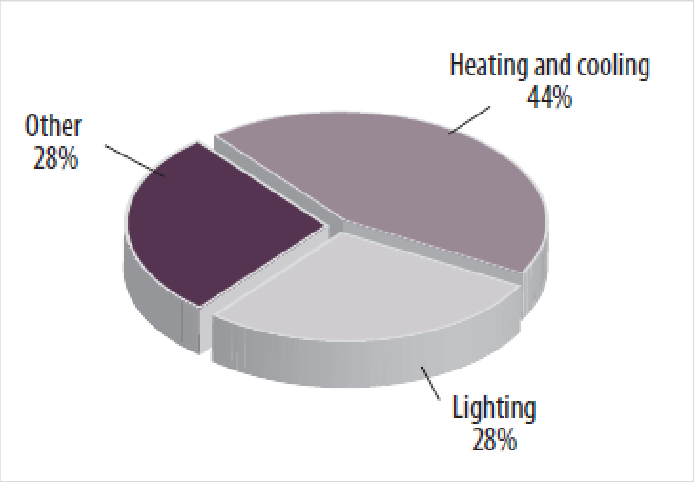

Figure 3-3 NSW Energy Toolkit allocation of electricity end use

This report discusses energy cost as well as energy consumption. This is particularly important as this section includes references to network related costs. Many energy efficiency programs only consider energy use reduction (kWh), not power (kW). This may be because in many jurisdictions, particularly abroad, there is no kW demand charge.

Table 3-6 Site characteristic – range of results (adapted from Table 2.1[28])

Variable	Range: Lower - Upper	Units
Gross floor area	3,100 - 11,764	m^2
Number of beds	40 - 180	Beds
Occupancy	56 - 100	Percent
Annual electricity consumption	291 – 1,482	MWh
Annual gas consumption	66 - 3,507	GJ

Table 3-6 shows a summary of the key variables recorded for audited sites. These parameters are related to energy and give an indication of the variation in the physical size of the sites. The value’s precise nature suggests a detailed raw data set was collected for each site as part of the audit process. Pooling ranges of data prevents assessment of energy performance of any individual site, and therefore comparison between the audited sites and any others. It is not clear why the data is presented in this manner. This format significantly reduces the potential effectiveness as a benchmark against which to compare future findings. The discussion related to facility benchmarking does not offer any energy values, instead introduces ‘degree cooling days’ (CDD). While this importantly recognises the relationship between energy use and outdoor weather conditions, there is no discussion on how this may be applied.

Table 3-7 Benchmark variable correlation, data recreated from NSW toolkit.

Variable	Regression analysis results (degree of correlation %)
Annual occupied bed days	74%
Number of beds	52%
Gross floor area	28%
Age of facility	No correlation

The NSW Energy Saver Toolkit offers several variables against which energy could be benchmarked and the level of correlation. As seen in Table 3-7, occupied bed days is the most closely aligned, however the report does not go to give any indication of typical 'per bed day' energy values against which another facility can be compared.

Table 3-8 Energy values shown in energy saver toolkit[3]

End Use	GJ per bed	kWh per bed
Hot water and drying	14	50
Heating and cooling	11	40
Lighting	7	25
Total		115

Table 3-8 shows a typical high level of ambiguity of information presented. Energy values are presented with no time parameters (e.g. are the figures related to annual energy use) or bed numbers. There is no way to reference these energy values to any other information, such as the 'kWh/bed/day' values shown in Figure 3-4.

This report, while presenting some potentially useful information, highlights the need for clarity and consistency in the selection of KPIs and in the presentation of data. It is important to clearly articulate whether the KPIs are to allow for benchmarking across the sector or are intended for benchmarking within a specific facility.

3.2.2 Sustainable Living Tasmania

The Sustainable Living Tasmania (SLT) report [29] discusses the findings of nine 'Level 2' energy audits in Tasmanian aged care facilities. Sites are anonymised, however energy consumption and cost data are presented with consistent identification codes throughout the report. Figure 3-4 shows data collected and processed into 'per bed per day' energy values.

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[3] Data from Figure 3.1 in NSW Energy Saver Toolkit [28]

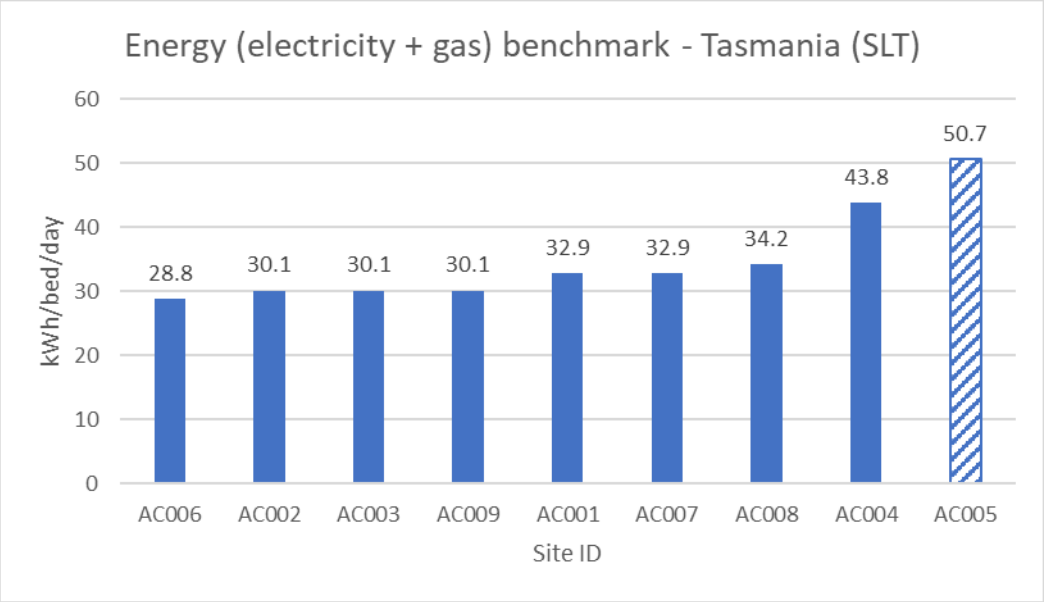

Figure 3-4 Benchmarking values for 9 sites (Sustainable Living Tasmania Energy Audit)

The report naming convention has been transferred to Figure 3-4. Both electricity and gas are combined, using the common unit kWh. Individual energy sources for each site were not presented in the report summary. All sites, with the exception of AC005, have kitchen and laundry facilities. AC005 is recorded as having a swimming pool. Although not specifically noted in the report, it is not uncommon for facilities to share, or even outsource services such as kitchens (cook chill vs cook fresh) or laundries.

Tariffs discussed in this report generally relate only to energy use (kWh), not power (kW). Only one tariff has a kVA demand charge listed. Seven different electricity tariffs were summarised as being used at audited sites. Direct tariff comparison is noted as being notoriously difficult as low unit energy charges may be offset by higher network or equipment maintenance costs. Figure 3-5 shows the variation between the audited sites. No explanation was offered in the report to account for this variation. On several occasions in both audit reports, there can be mismatches between the same data. In this case, the minimum value of ~29kWh is higher than 24kWh quoted elsewhere in the same report. Figure 3-5 shows that bed numbers, and therefore size of the site, does not appear to have an underlying relationship to energy use per resident. This aligns with the NSW government findings as show in Table 3-7.

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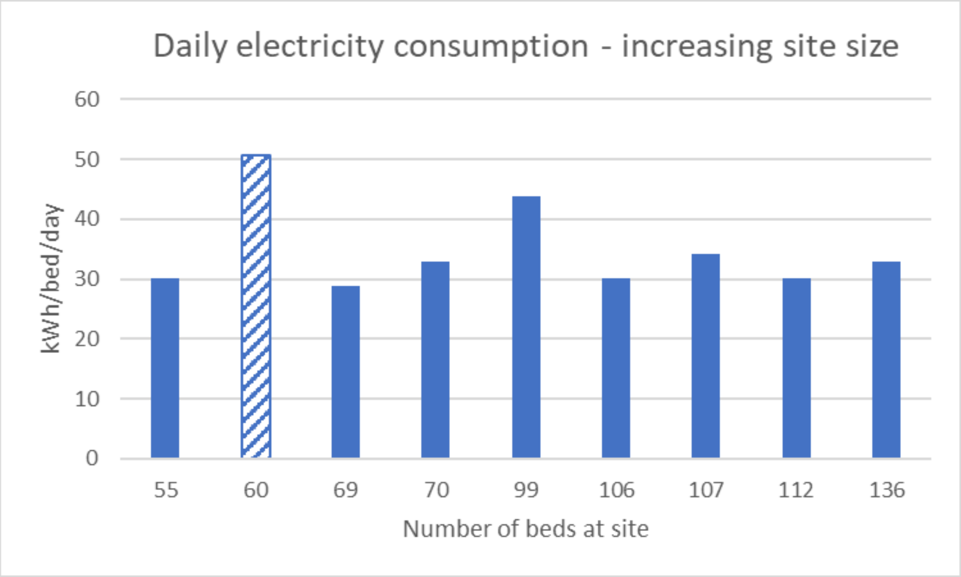

Figure 3-5 Electricity consumption by bed numbers

3.3 Residential Aged Care models and energy implications

A Residential Aged Care (RAC) facility in Australia is defined as facilities that cater to the needs of older persons who have low to high level of care needs, including lower levels of mobility and independence. Unlike retirement villages (housing states for predominantly healthy, mobile and independent people aged 55 and over), the number of type of services provided to residents is high, for example scheduled meal times and 24 h nursing on call. The average age of occupants tends to be higher, and their health care needs result in lower levels of personal mobility. Residential Aged Care facilities are strongly regulated by national laws, in terms of occupancy and associated charges.

Within the RAC sector, there are perhaps four common ‘models’ of accommodation, reflecting different levels of resident health care autonomy and needs, and different cultural expectations of service levels, as shown in Table 3-9. Each of these accommodation models are within a precinct that offers other services such as communal facilities (for dining and recreation), medical and other services (e.g. pharmacy, allied health, hairdressing, café), and administration type services (offices, facilities management).

Table 3-9 RAC models of accommodation in Australia

Accommodation Model	Description
Independent Living Units (ILU)	Apartments or duplexes that are fully self-sufficient. These may be studio units or have 1-3 bedrooms and are typically occupied by a single elderly person or a couple. They can elect the level of care that they require.
Hostels	"Share homes" with independent bedrooms, and shared common spaces. Bathrooms may be ensuite or shared. Small number of residents (e.g. about 10).
Nursing Home	Old style, 'hospital ward' like buildings
Multi-storey 'modern' residential aged care	"Resort style" accommodation where each resident has their own room and ensuite. A variety of shared facilities (e.g. dining, lounge, recreation etc) are provided (similar to a holiday resort). Full nursing care provided.

The following sections describe the energy use patterns of two case studies with different types of accommodation models.

3.3.1 Case study one: independent living units in a micro-grid RAC facility

Case study one is a residential aged care facility that consists of 110 one and two bedroom apartments within a community setting that also includes a heated swimming pool, community centre, dining room, library and gardens. Onsite nursing care is provided 24h/day and a full range of nursing and home help services, from low to high care to palliative care, is available to residents in their own home within this facility. All residents are aged 80+ and most residents live alone.

The single and two storey apartment blocks were constructed between 2005 – 2007. Apartments vary in size from 36m^2 to 74m^2, with a typical floor area of 55-60m^2. The estate has its own electricity distribution network (micro-grid) and is connected to the main electricity grid through two gate meters. The meters at this grid connection record electricity usage at 30 minute intervals. Each of these apartments have gas stoves (although few residents cook their own meals). Hot water is supplied by electricity or gas (depending on the stage at which the apartment was built). All apartments have split air-conditioners. A revenue meter is wired to each apartment, and occupants are charged for their energy use (at a rate nominated by the facilities management, but not more than the regulated price set by the Queensland government).

Figure 3-6 shows the variation in average daily electricity usage, for each month, for 80 apartments connected to one of the gate meters. The data suggests that there is a relatively high cooling load (summer months) and higher heating load (winter), with lower usage in the shoulder seasons. Energy use is in the order of half that seen in Residential Care in the previous section, and for case study two in the following section. One explanation of this is that this RAC facility has the equivalent of a 1kW PV system installed for each residential unit. The electricity generated by these PV systems is self-used on site, so the metered energy use (at the network connection) is the net electricity use, not the total. This site does not have metering to record total PV generation or total electricity use. The PV systems are not registered for any feed-in tariff, so there is no record of any site export. There is no management of the site loads to match PV system performance.

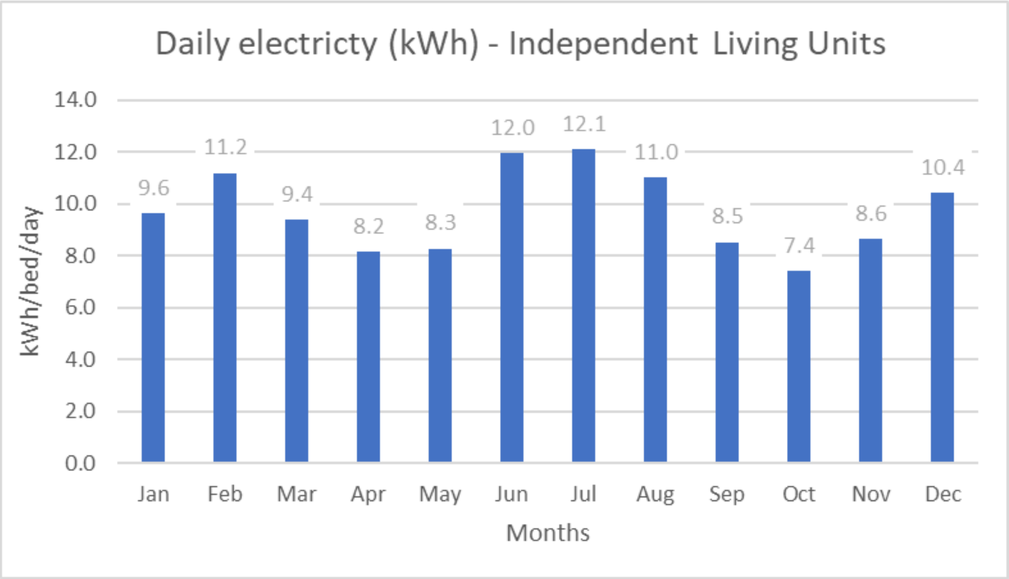

Figure 3-6 Independent Living Unit electricity consumption. SEQ, 2016, 80 units.

The mean monthly electricity use across all 110 apartments was 145 kWh/month (range 28.2 – 410 kWh/month), or 3 kWh/m^2/month (range 1-7 kWh/m^2/month). These EUIs are also equivalent to ‘per resident’, as almost all apartments were single occupancy. Smaller apartments (36m^2) had the highest usage per m^2, and the largest apartments (76m^2) had the lowest usage per m^2. Data seemed to indicate a correlation between energy use and building characteristics, with apartments without direct exposure to the roof had an energy use range of 2kWh/m^2 compared to apartments that had direct exposure to the roof (3kWh/m^2). Eighteen of the top twenty energy use apartments were exposed to the roof (i.e. their ceilings were connected to the roof space).

Although this site does not pay demand charges, the monthly peak demand for the 80 apartments connected to gate meter 1,was calculated (Figure 3-7). This figure shows the seasonal variation in the network component of the electricity cost. For large sites, or sites with significant demand, the monthly peak network demand charges may be a significant portion of the total electricity bill. Figure 3-8 shows the typical daily profile of one summer and one winter day. The winter profile has two distinct peaks, an early morning and evening. The summer peak is only shown in the afternoon / evening. There appears to be little difference to evening peak when averaged over the month: the 20+kW difference between January and February in Figure 3-7 could be attributed to a single day (e.g. a hot day with all air conditioners operating). This RAC facility has not graphed PV generation profile against electricity load profile.

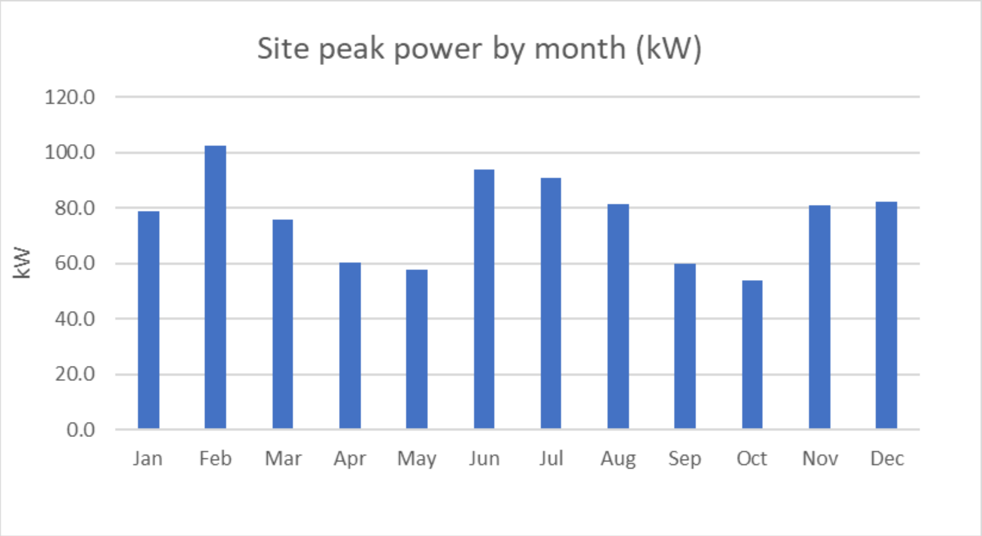

Figure 3-7 Monthly peak demand

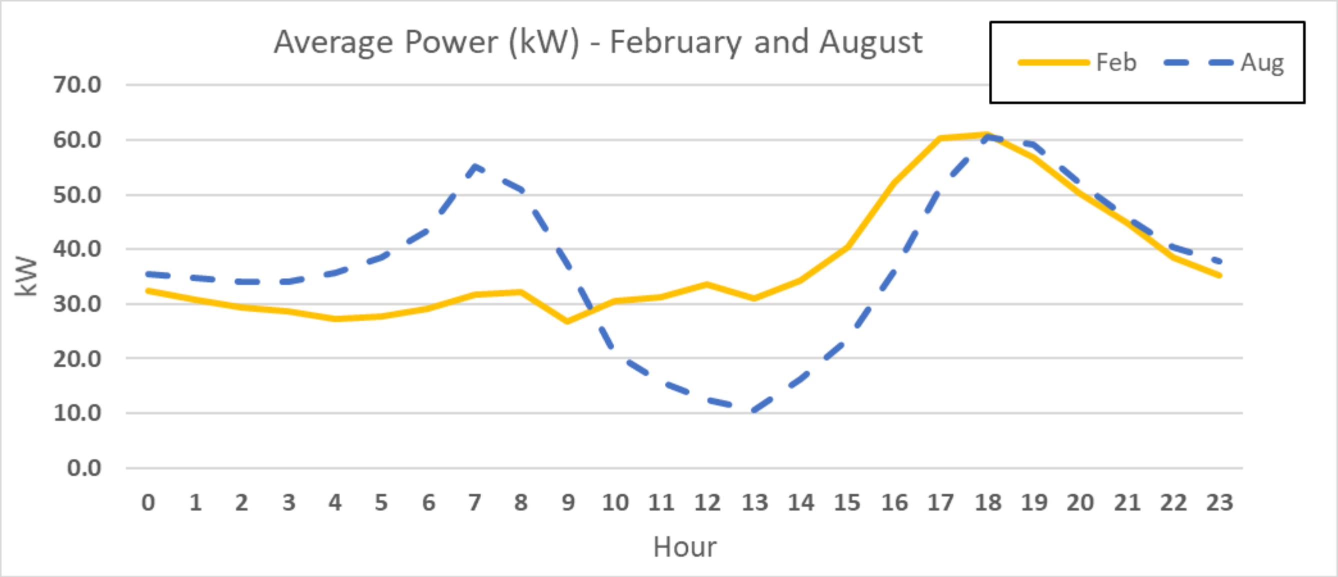

Figure 3-8 Seasonal variation of site demand – total site of 80 units

3.3.2 Case study two: portfolio of RAC facilities

Bolton Clarke is an Australian independent living and aged care service provider. The company was officially formed in 2015 when the former RSL Care and Royal District Nursing Service (RDNS) became a single organization, with origins dating back to 1885 when RDNS was established. Bolton Clarke provides aged care services predominantly in the form of retirement living communities, Residential Aged Care (all four models of accommodation) as well as Home Care visits. The company owns and operates facilities throughout Australia, with expanding offshore interests in New Zealand, the United Kingdom and China. The Australian residential facilities are predominantly located in Queensland, with a presence in most other states. The 2019 annual report indicates Bolton Clarke cared for over 3,400 residents across 25 Residential Aged Care facilities, and around 2,500 residents chose to live in 25 retirement living communities. Additionally, there were also over 3.9 million home care visits for over 52,000 clients. The company's expansion plans discussed in 2019 include 450 new retirement living units and 825 residential aged care beds, predominantly around south-east Queensland.

3.3.2.1 Total portfolio energy

Figure 3-9 shows the calculated total stationary and transport energy used by the Bolton Clarke business according the 2011 National Greenhouse and Energy Reporting Scheme (NGERS) report. Electricity is clearly the predominant energy source. It is important to recognise the other primary sources (gas as well as transport fuels) because future policy changes or technology advances may mean that electricity can replace non-electrical loads, and conversely that electrical loads could be replaced by nonelectrical sources. Examples of this are heat pumps replacing gas hot water or electric vehicles replacing internal combustion engines.

A fuel source replacement may not change overall energy use, however it is noteworthy due to potential impact on building design when considering demand response integration with renewable energy, storage technologies and electricity tariffs. For example, in 2018 Bolton Clarke's vehicle fleet travelled more than 11,000,000 km. The potential electrification of that fleet could impact on the technical and financial considerations for PV and energy storage at their various RAC facilities from which their Home Care services are deployed.

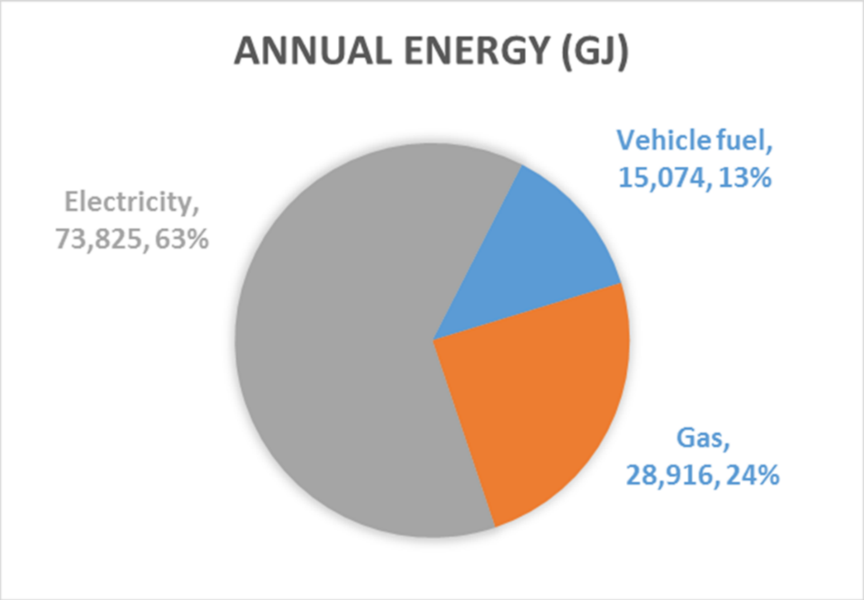

Figure 3-9 Annual energy by primary source, NGERS submission 2011

3.3.2.2 Site energy

Figure 3-10 shows the daily electricity use per bed at 23 sites, based on twelve months of data from ERM Power (Bolton Clarke/s main electricity supplier). Daily electricity use varies from over 45 kWh to less than 15kWh/bed/day[4]. Variations between sites could be explained by a number of contributing factor such as climate zone, age of the facility, construction methods and materials, kitchen services and laundry services. Without further monitoring, energy use can only be calculated on an overall 'per bed' value, with estimations for specific end uses. These estimations are made based on equipment energy rating and operating times.

In order to more fully understand energy consumption, two sites, Talbarra (60 beds) and Fairview (107 beds), were included in a more detailed study. These sites (shown in Figure 3-10 with cross-hatching infill) have sub-metering installed to determine which areas and services within the site use the most electricity, and when electricity is being used. Data available for these sites now spans two summers and one winter (October 2018 – March 2020). The monitoring equipment is still in place and continues to collect data.

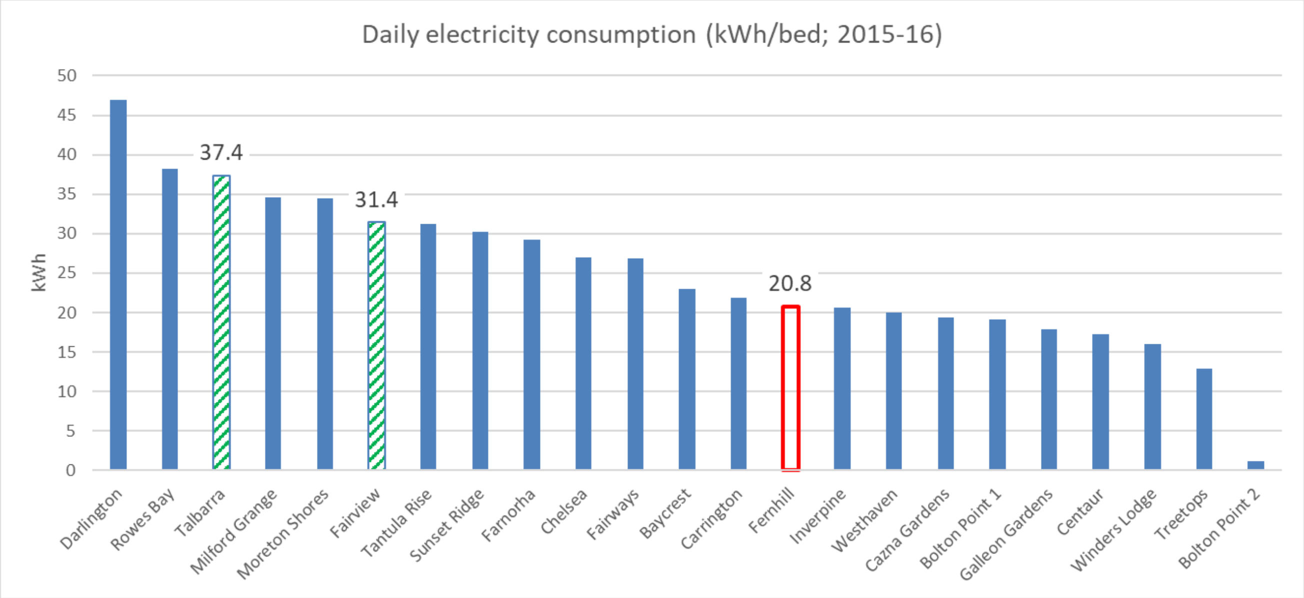

Figure 3-10 Daily energy use by site (ERM Power sites only)

Figure 3-11 compares these two sites (in Brisbane) with the Fernhill site in Caboolture north of Brisbane. The existing Fernhill site (RAC site with nursing home and hostel accommodation) is in the process of redevelopment and the new multi-storey RAC will become the i-Hub Living Lab Fernhill). This figure shows that Fernhill (the current site) uses less electricity than the other two monitored sotes. All sites show relatively stable annual consumption over several years. The dip

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[4] Bolton Point 2 is considered an outlier given there are two meters at this site. Bolton Point 1 consumption is ~20kWh/bed/day, which aligns with many of the other sites.

in Fernhill's consumption in 2018 likely responds to the demolition of a few buildings to make way for the new residential aged care facility.

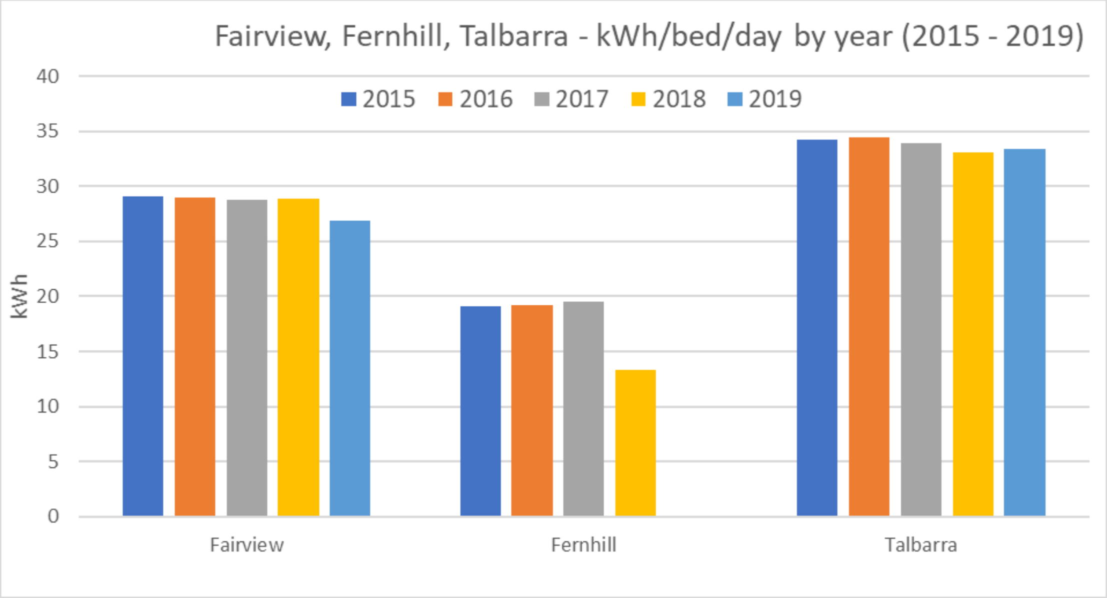

Figure 3-11 Daily electricity consumption 2015 – 2019[5] for Fernhill and two monitored sites

3.3.2.3 Sub-metered energy

Figure 3-12 and Figure 3-13show electrical sub-metering information as recorded at the two Brisbane RAC facilities. It should be noted some of this data is 'sample population', so not a complete site. These charts give an indication of the circuit types available for monitoring and relative contributions. Both sites show air-conditioning to be the major energy use. Averaging data to give a monthly overview may mask relative cost contributions of peak demand. For example, ovens appear to use a relatively small amount of energy on a monthly basis compared to air-conditioning. Ovens have a high-power demand, but only for a short time. They may contribute less to overall energy use, but more significantly to network demand costs.

The individually monitored loads are grouped by broad end use category. Task / appliance is the most reported assignment of energy. A RAC is a hybrid use building where several user groups (residents, staff and visitors) share the same space. In order to develop solutions targeting specific users or technology solutions, it may be beneficial to present the data group differently. These individual loads can be categorised by attributes other than functional end use of the energy. Some possibilities are shown in Table 3-10.

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[5] Fernhill data is not available for 2019 (and some of 2018) due to construction works.

A comparison of the two sites reveals several issues:

- Overall electricity consumption is seasonal, although the extent of the seasonality differs between the two sites
- Airconditioning is the single biggest lead in all seasons

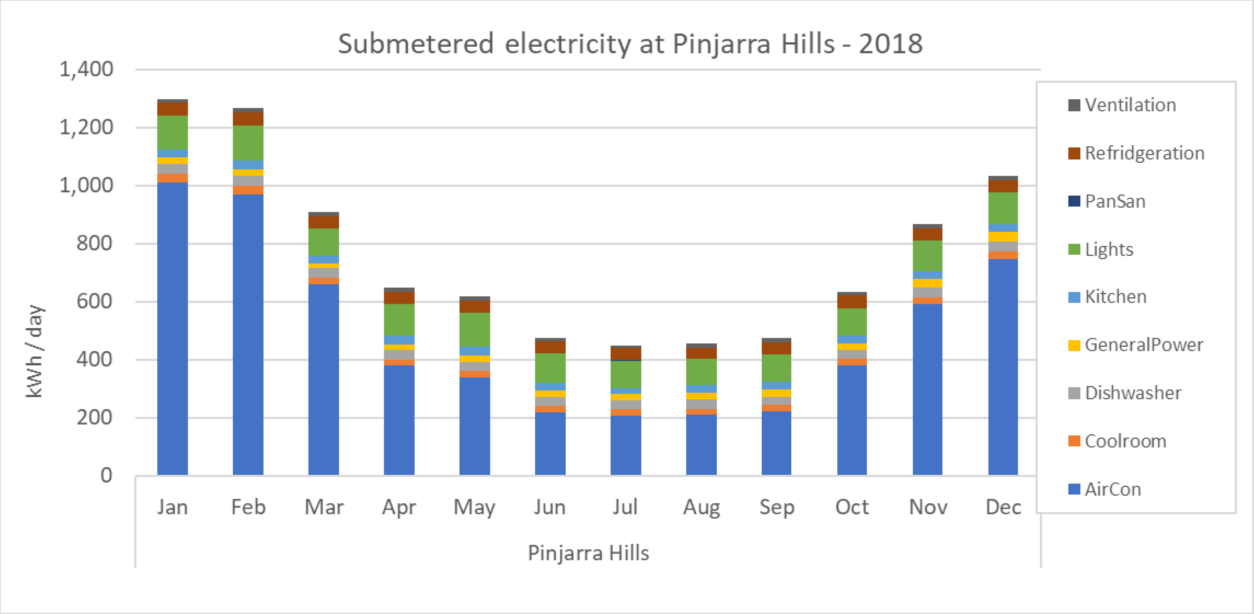

Figure 3-12 Sub-metered electricity as measured at Pinjarra Hills, 2019

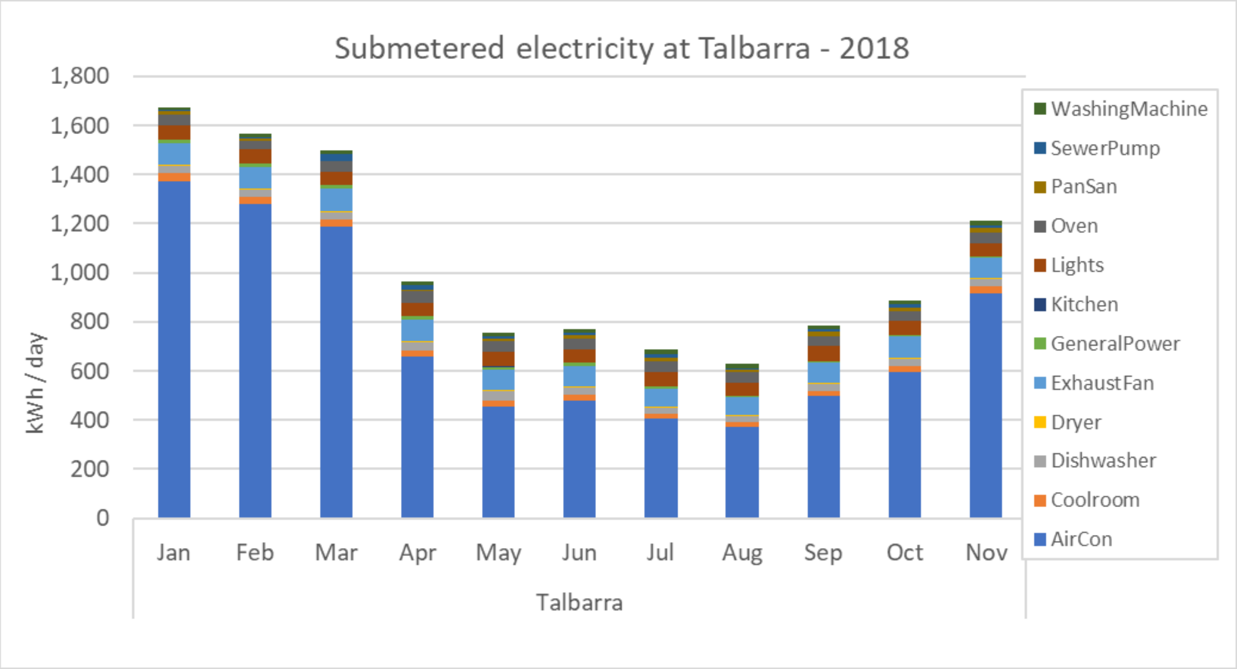

Figure 3-13 Sub-metered electricity as measured at Talbarra, 2019

Table 3-10 Potential attributes or electrical circuits for analysis

Circuit attribute	Category examples	Most useful for
End use category	Load type, task or appliances (as shown in the figures above)	Energy efficiency initiatives
End user	Resident, staff or visitor	Understanding user needs and behaviour
Load characteristics	Deferrable, interruptible, variable	Demand response system design
Building use / characteristics	Accommodation, shared services (kitchen / laundry / auditorium) or office space	Energy association for targeted initiatives in a hybrid building setting

Audits reports document energy use by functional end use. It is interesting to note the same energy data can be allocated using different attributes, depending on the intervention being investigated. Figure 3-14 repeats earlier data with the allocation to user responsible for load control, rather than the end use. Further analysis of this data can show at more specific detail of time day energy is used by each group. By understanding actions of a specific user group, targeted interventions can be developed.

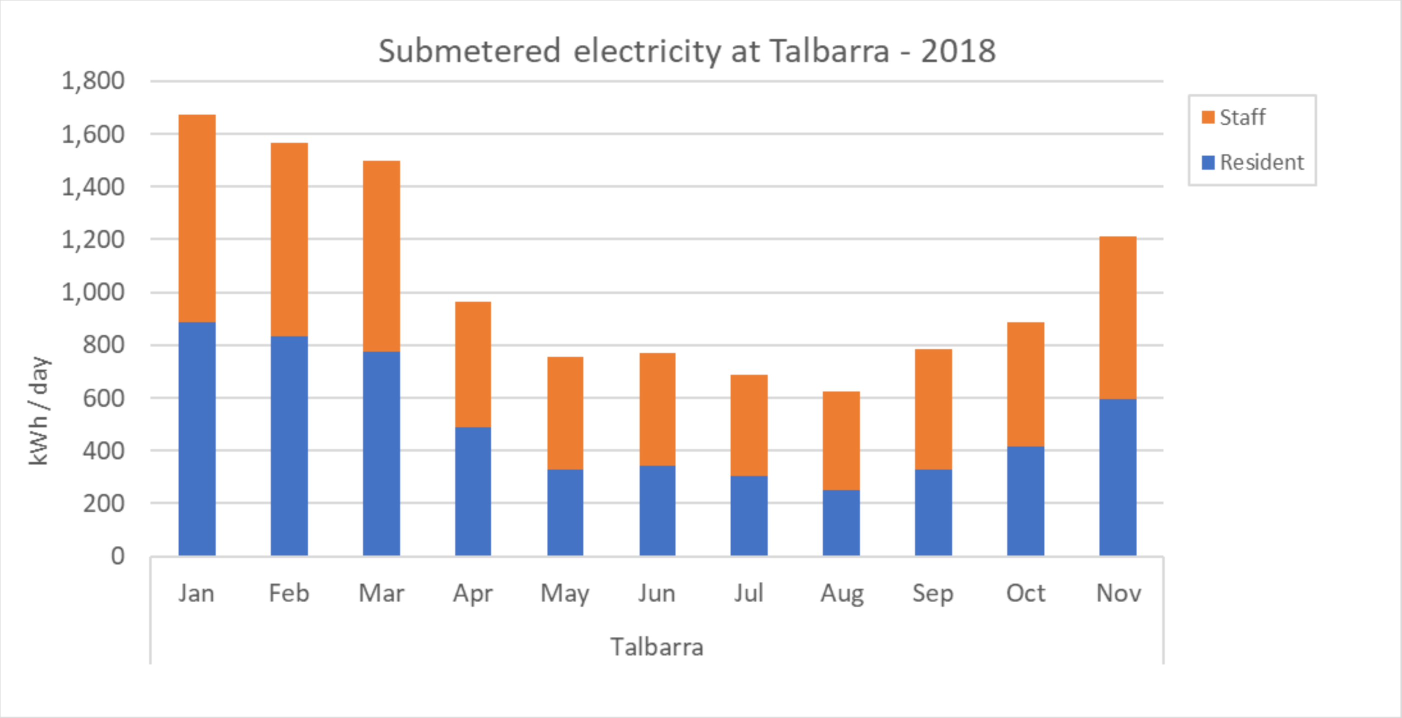

Figure 3-14 Daily site energy use allocated to end user (same data as Figure 3-13)

3.3.2.4 Fernhill RAC

The Residential Aged Care Living Lab site is in Caboolture, north of Brisbane. The 6.6 hectare site has 164 existing residential aged care beds spread between eight hostels and a nursing home. A new multi-storey residential aged care facility is being constructed on site and on completion about August 2020, current residents will be relocated from the existing residential buildings to the adjacent new facility. As this will be the same staff and resident cohort, ‘before and after’ energy measurement comparisons will be directly related to the new building, its energy systems and its operation.

Figure 3-15 shows the average daily energy use, per month, throughout the year at the current Fernhill site. As site daily activities are similar throughout the year, monthly variations can be attributed to air-conditioning loads in line with seasonal temperature variations.

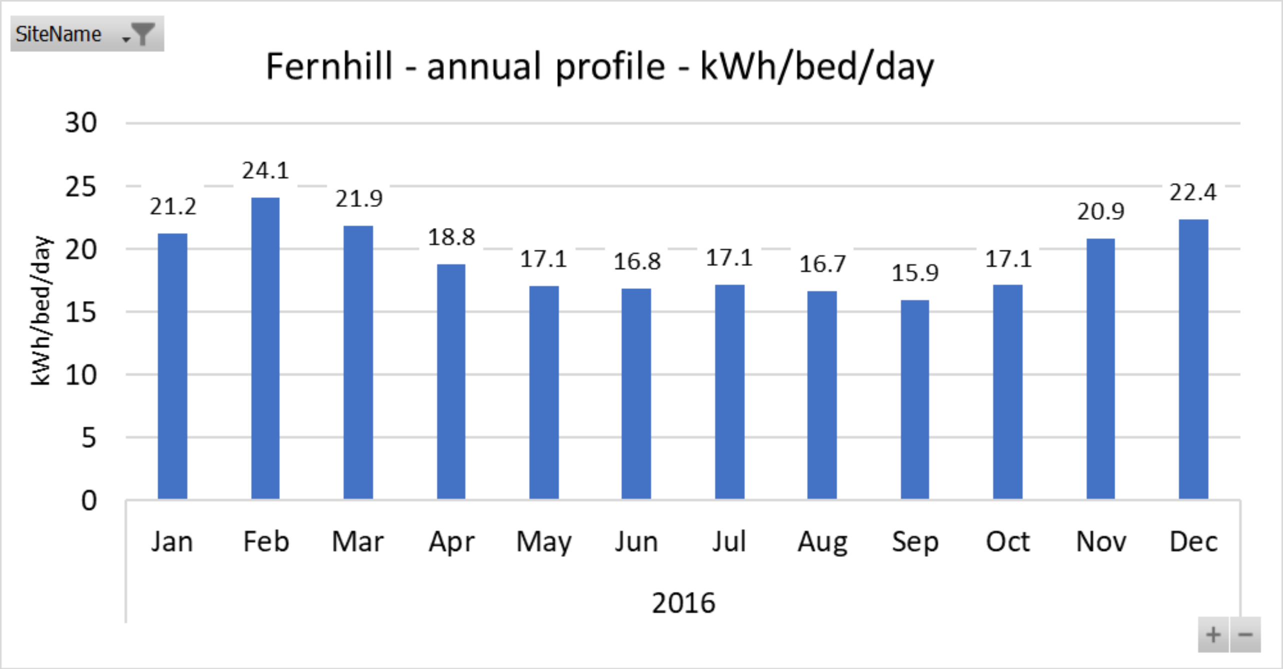

Figure 3-15 Fernhill energy consumption by month (2015-16 data)

Figure 3-16 shows several years of data, allowing patterns to be seen, such as the seasonality of the monthly average of daily energy use profiles. The main differences between years is during the late summer months, likely due to weather patterns. The winter months consistently show lower daily consumption, which is likely due to reduced air-conditioning loads during these cooler months.

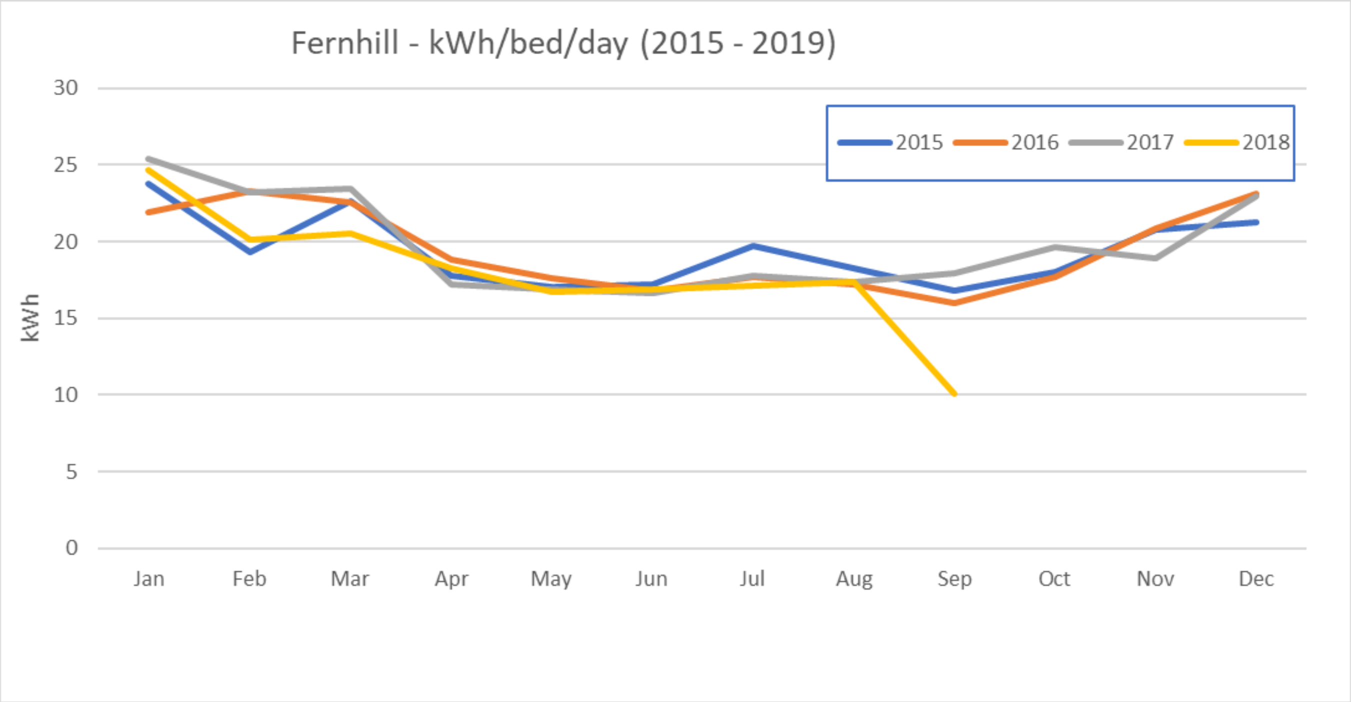

Figure 3-16 Daily per bed electricity readings by month 2015 – 2019, Fernhill Living Labs site

The average daily energy use profiles, however, are not granular enough to determine when the peaks occur. When considering peak demand, time of day is an important consideration for both load identification and assessing the potential suitability of renewable energy input. Figure 3-17 and Figure 3-18 show the daily profile for the 2018 summer and winter days which incurred the peak demand charge. The summer peak likely coincides with the hottest part of the day, and possibly lunchtime kitchen activity.

The typical summertime peak, not surprisingly, occurs during the time of highest heat load. This peak, or load levels near the peak, are maintained for several hours. The significance of this is to appreciate that interventions (embedded generation / storage or load shedding) should be designed to have enough capacity to meet both power (kW) and energy (kWh) requirements to meet a peak reduction target.

The peak winter event day shows the peak occurs early in the morning. Similar seasonal variations to those shown above are noted in the NSW government report. Acknowledging the variation in time of the peak event leads to acknowledging different solutions for renewable energy integration may be needed seasonally. The shorter peak duration, compared to the summer peak, is also of interest.

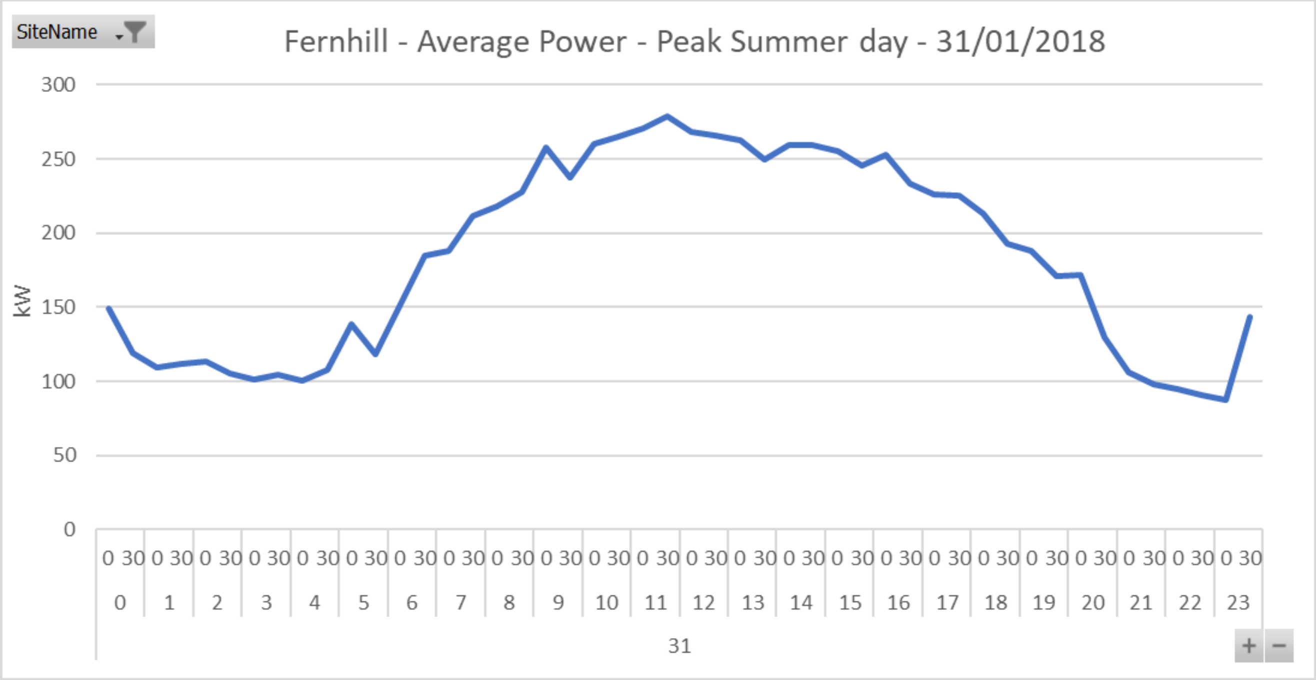

Figure 3-17 Fernhill summer daily electricity profile

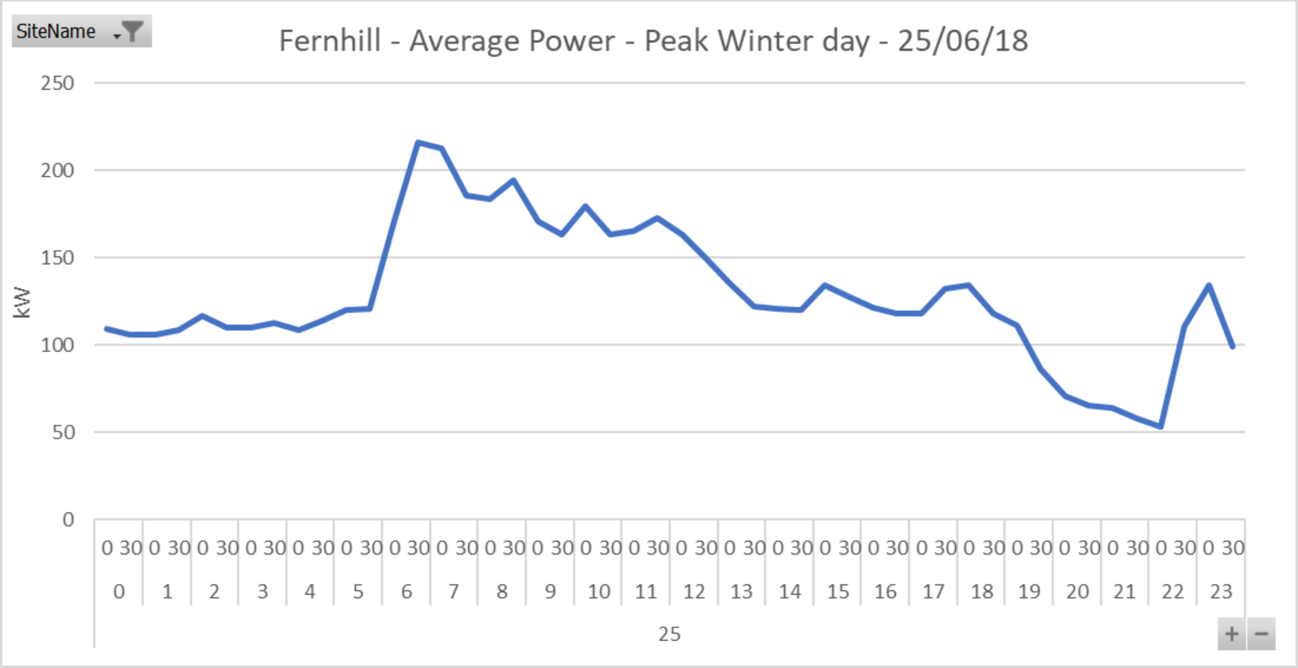

Figure 3-18 Fernhill winter daily electricity profile

3.3.3 Renewable / Distributed Energy Potential for RAC facilities

For billing purposes, only the magnitude of the monthly peak is considered. Load duration at, or near, the peak is not considered. This would however be a consideration when designing an embedded energy system. Two immediately obvious options are available to residential aged care sites:

- Solar PV
- Backup generator.

All RAC sites have emergency generators (a regulatory requirement) which could be operated for short periods to reduce grid demand at peak times. This is likely most effective in conjunction with the local grid operator and assumes a grid-synchronous generator.

Many existing sites, however, are also low set buildings, with a high roof to floor area ratio. Depending on building orientation, this makes rooftop solar a potentially ideal embedded generation solution. To demonstrate this potential, solar PV data from the University of Queensland's PV array at Pinjarra Hills[6] was applied to the electricity load of the Fairview facility (also in Pinjarra Hills, adjacent to the solar array). Figure 3-19 shows a typical sunny day reducing the midday peak demand. The daily peak appears to be earlier (3-4pm) than the typical evening peak expected from a 'working household'. In this instance, solar may still be operating during a higher demand time of day.

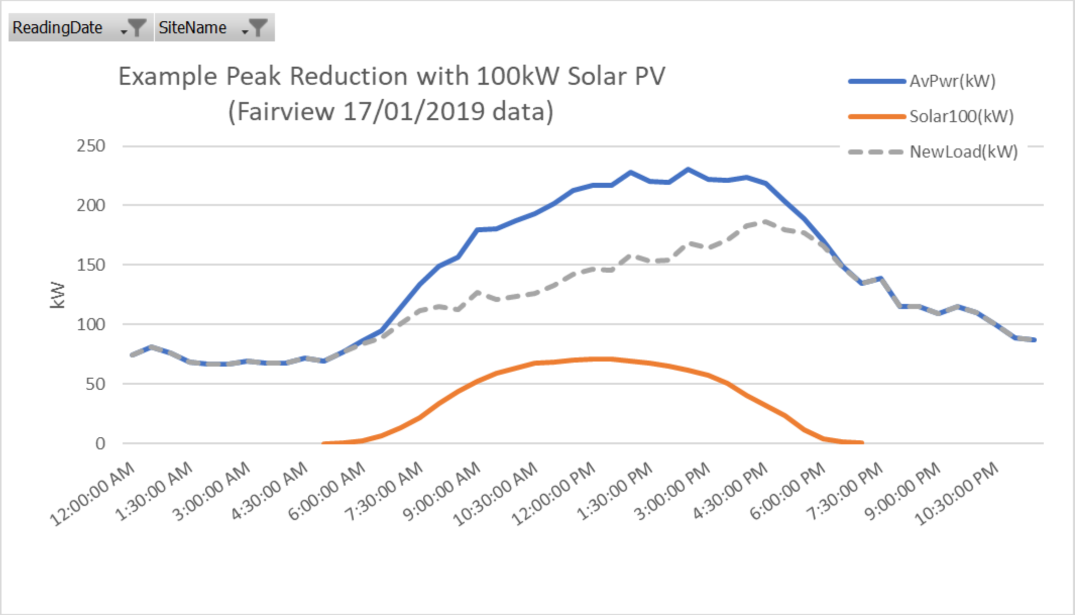

Figure 3-19 Fairview RAC facility load overlaid with adjacent UQ PV output

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[6] 28.8kW capacity scaled to 100kW. Data freely available from https://solar-energy.uq.edu.au/

Savings made from solar installation may not be as simple as the difference between the peak load and peak solar. Often the two do not coincide, as evidenced in Figure 3-19. Obviously, solar can only reduce peak demand during daylight hours. Figure 3-20 shows the seasonal variation where solar is shown to only impact the peak demand during the months with daytime peak loads. Figure 3-18 shows how the typical winter peak will occur before any significant solar generation takes place. In order to take advantage of solar generation for peak reduction, storage would be needed. Regardless of peak reduction, the solar will reduce grid energy consumption during the daylight hours.

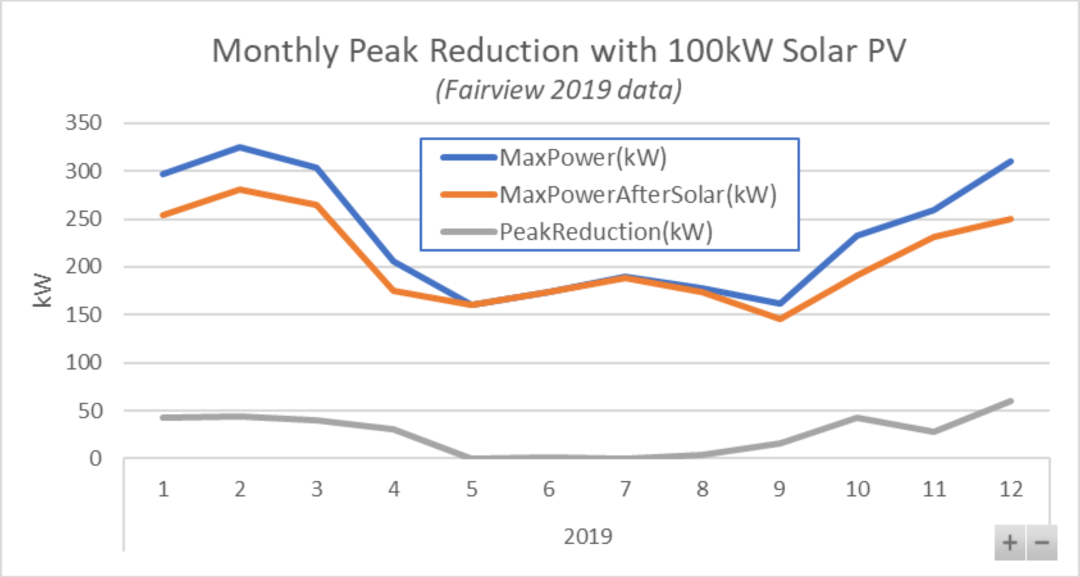

Figure 3-20 Fairview site with adjacent UQ research site solar data

3.4 Impacts of Aged Care trends on energy

As with trends in the hospital sector, there are trends in aged care that will likely impact on energy productivity. One trend is the policy direction of “Aging in Place”. This is similar to Denmark’s move to reduce the number of hospitals, as discussed in Section 2.3.2. This aged care policy aims to try to keep aging Australians at home for as long as possible, providing the appropriate level of health and personal services to the occupant in their own home. This means that Residential Aged Care facilities will increasing become places for the very infirm (just as the Danish hospitals are for critical cases). This may increase the energy intensity of such facilities.

Community expectations regarding the level of care provided in old age are also increasing. Older modes of RAC accommodation, such as nursing homes and hostels, are generally no longer considered appropriate. The push is for more ‘home-like’ options (such as independent living units similar to the general market apartments, or high-rise ‘advanced care’ options similar to that being constructed at Fernhill (i.e. private rooms with ensuites, but with a range of community facilities.

3.5 KPI Effectiveness

The most utilised EUI KPI is kWh/bed/year. This KPI is effective in that the data required to report on this KPI is relatively easily gained. However, as demonstrated in the case studies presented in the previous sections, such a KPI has limited usefulness as an industry benchmark, and does not enable detailed evaluation of the energy efficiency of the site and its systems and services. It also doesn't allow for evaluation of energy uses that contribute to peak demand, nor analysis of options for renewable energy and energy storage solutions.

3.6 Recommendations for KPIs for Residential Aged Care

The Healthcare Living Lab projects will investigate the feasibility and usefulness of additional KPIs that could be useful for enhancing the energy productivity and renewable energy potential for RAC facilities. As the main energy use in RAC facilities is space heating and cooling, a focus will be on KPIs that address cooling energy loads, peak demand and renewable energy and/or energy storage potential.

4 HEALTHCARE SECTOR DISCUSSION

There are conflicting findings in terms of factors correlating strongly with healthcare facilities' energy KPIs (Table 4-1). For example, after examining 15 aged case facilities in NSW, annual occupied bed days has the strongest correlation with energy use, higher than the correlation with the number of beds or the gross floor areas [30]. However, the Victorian auditor-general's report discovered that hospitals' gross floor area has the strongest correlation with energy use, higher than the annual bed days or annual separations [3] . This disparity may be due to different occupancy rates (total beds compared to occupied bed days) between hospitals and aged care facilities, and between individual facilities within each group.

Table 4-1 A conflicting findings

KPIs	References	Description
kWh per bed day per annum	[30] 15 NSW aged care	• Annual occupied bed days has 0.74 correlation with energy use, higher than the correlation from the number of beds and gross floor areas • Number of beds has 0.52 correlation with energy use.
kWh per gross floor area per annum	[3] VIC Hospital audit	• gross floor area has the **strongest correlation to energy use** of the three measures used (bed days, floor areas, and separations).

Hospital energy KPIs need to be adjusted to two factors: climate zones and hospital types (Table 4-2). Facilities in different climates would have different energy performance. To adjust for the climate factor, energy KPIs need to be adjusted. For example, Australia has 71 climate zones based on NABERS Energy and Water for Hospitals rating system [31]. Also, based on the same rating system, hospitals are categorised into 14 types in Australia.

Table 4-2 Energy KPIs adjustment factors [31]

Key factors	Description
Adjusted for different climate zones	Australia has 71 climate zones (NABERS rating system)
Categorised to different types of hospitals	Principal referral hospitals Public acute group A hospitals Public acute group B hospitals Public acute group C hospitals Public acute group D hospitals Public rehabilitation hospital Very small hospitals Women's hospitals Children's hospitals Acute psychiatric hospitals Mixed subacute and non-acute hospitals Other acute specialised hospitals Same day hospitals Other hospitals

For various reasons, energy sustainability in the health care sector is often not considered a priority (even if financial saving is taken into consideration [17]), unless it is related to health and safety [32]. Therefore, to enable more sustainable energy or better energy efficiency in healthcare sector, there may be a need to develop some sustainability KPIs to reflect, or be relevant to, staff and occupants' health or safety. This will be a focus of one of the reports of the Healthcare Sector Living Lab activities.

A US study indirectly pointed out the importance of having health related KPIs in the energy sustainability ratings, e.g. patients' recovery and wellbeing [33]. They discovered that hospitals with high LEED scores may not necessarily be qualified as the optimal green healthcare environment. An European study proposes to use patients' average length of stay (ALOS) as an indicator to evaluate the health benefits of energy renovation or construction of high energy performance buildings as a result of heathier indoor environment quality (IEQ) [34]. This study found that with improved IEQ, ALOS, medication costs and mortality rate can be reduced by 11%, 21% and 19% on the average.

A set of criteria with the acronym **SMARTCHS** is proposed as a guiding principle to design purpose-oriented energy KPIs (Table 4-3). The SMARTCHS criteria are an extension of the traditional SMART principle in management theory [35]. The three added components are C for comparable, H for hierarchical and S for systematic. “Comparable” is included because energy KPIs are typically used for comparison or evaluation purposes (i.e. benchmarking against other facilities or historical data). Any KPIs need to take into account the different levels of Health, Safety and Environment (HSE) considerations and confidentiality (of patients and staff). This means that there may also be a need for hierarchical KPIs that can be used for different levels of disclosure and reporting. This means that the selection and use of KPIs needs to be approached from a systems thinking perspective, incorporating technical, economic and social considerations.

Table 4-3 SMARTCHS Criteria for selection of purpose oriented KPIs

Key criteria	Description
Specific	Be strategic and specific, detailed, and meaningful for desired purposes
Measurable	It can be measured, or calculated based on measurements/data
Attainable	Have tools or resources to attain
Relevant	KPIs need to be relevant to - the energy performance of the technologies under evaluation - health and safety of staff and occupants
Time based	A time period that provides the required resolution for the purpose (e.g. yearly, seasonal, monthly, weekly, daily or hourly)
Comparable	The KPI can be compared with - itself over time - other facilities KPIs - benchmark KPIs
Hierarchical	Due to different risk levels at healthcare facilities, designed to reflect energy performance at different risk/priority levels
Systematic	System thinking in designing energy KPIs

Table 4-4 shows a few purpose oriented KPIs and data requirements when SMARTCHS criteria are applied for healthcare energy performance improvement. These KPIs are organised based on different aspects of the whole healthcare energy system, e.g. power demand, energy usage, building improvement, HVAC technologies, environment, health, safety, and network benefits.

Table 4-4 Purpose oriented KPIs

Purpose	Possible KPIs	Data inputs examples
- Site Peak Demand Reduction **- Reduce demand charge**	Highest kW (or kVA) in every month (or billing period)	Half hourly kW (or kVA) demand profile over at least 12 months' time
- Enabling renewable energy, e.g. rooftop PV **- Reduce energy charge**	Monthly energy consumption	Monthly kWh over at least 12 months' time
- Testing building envelop energy performance improvement technologies e.g. louvre, paint, glazing	- Locational thermal comfort - Locational cooling or heating delivered - Locational energy consumption - Locational peak demand	- Outdoor dry bulb temperature - Indoor dry bulb temperature - cooling/heating during the testing period (air volume and temperature) - kWh over the testing period - interval kW (or kVA) over the testing period
- Testing new HVAC energy efficiency technologies e.g. coolant or water improvement	- Equipment specific cooling or heating output - Equipment specific energy input - Equipment specific	- Outdoor dry bulb temperature - cooling/heating during the testing period (incoming and outgoing water volume and temperature) - kWh over the testing period - interval kW (or kVA) over the testing period

- Assessing environmental impact of energy performance improvement projects	- Greenhouse gas
	- Waste
	    ○ Non-radioactive
	    ○ Radioactive
	- Water and sewage
	- Avoided GHG emission
	- Avoided air pollution
	- VOC level
		- Ratio of onsite renewable energy generation to total consumption
		- Ration of total renewable energy consumption to total consumption
		- Ratio of Renewable generation power to peak demand
		- Waste category and weights
		- Water consumption and sewage amounts
		- Avoided tCO$_2$-e and $
		- Avoided PM_{10}, NO_x, and SO_2

- Assessing health impact of energy performance improvement projects	- Average length of stay (ALOS) - Less onsite infection rates	- Health survey - Medical records
- Assessing safety impact of energy performance improvement projects	- Less safety incidents	- Post-occupancy comfort survey
- Assessing network benefits	- Wholesale cost of peak 30-min electricity demand - Total self-consumption rate - Rate of PV used for HVAC self-consumption - Net facility load factor	- Reduced potential cost if on electricity wholesale market - locally generated renewable and local total power demand and HVAC demand

5 CONCLUSION

This Healthcare Baseline Report has reviewed domestic and international literature to describe, analyse and evaluate a range of the energy baseline KPIs, including kWh/m^2 per year and kWh/bed-day per year

This review has shown that

- the energy sources used in hospitals and aged care facilities can vary significantly
- available energy sources, technology selection and social norms can vary significantly
- the current main energy use intensity KPIs (based on meters squared or number of beds or bed days) do not provide sufficient granularity for benchmarking or for future planning.

The way in which energy KPIs is calculated also varies, making it difficult to compare energy performance across regions or between countries. Some of the ways of calculating energy baseline KPIs internationally include:

- Calculating source energy use KPIs, e.g. US Energy Star program [6]
- Calculating end use intensity, e.g. UK [5], India[10] and China [9]
- Calculating whole site KPIs or departmental energy use KPIs, e.g. research in UK [13]
- Calculating energy use KPIs based on service types, e.g. India[10] and China [9]

A set of SMARTCHS criteria has been proposed to strategically select purpose-oriented energy performance KPIs. To achieve different energy performance improvement goals, different KPIs can be selected for different purposes or priorities, e.g. for testing innovative energy technologies or assessing health and safety performance of energy improvement projects.

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