Renewable Energy across Queensland's Regions

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1 Introduction

Political leaders in Queensland and across Australia have tended to focus their attention on how difficult it might be for us to transition our electricity supply to low polluting alternatives. The emphasis has often been not on imagining the future we'd like to create and how new technology and ideas could get us there. Instead we've been trapped letting the past define what our future can be, rather than our abilities, our natural assets and our scientific understanding and technological capability. Our thinking has been dominated by what we might lose through change rather than what could be gained.

This report provides a different perspective. Advancements in renewable energy technology have opened-up new possibilities for how Queensland and the country more broadly can power our economy and our way of life.

Around Queensland many households and businesses are seizing the opportunities opened by these technological advancements. They are taking the initiative, some by installing solar on their rooftops. At a larger scale they are identifying areas rich in renewable energy resources. They are also working with communities, farmers, engineers and grid operators to prepare sites to host power stations that will produce copious amounts of energy without the pollution that undermines our children's future.

This report has sought to document the initiatives taking place in Queensland which are creating a new energy future. It details how these initiatives are now at a scale that could produce much of the electricity we need. In building this new energy future we will also provide significant employment and economic gains to regions all around the state.

To help readers appreciate how these initiatives and the opportunities that flow from them are distributed around Australia, we have provided a break-down by several geographic regions detailed in Figure 1-1. The local government authorities that make up each of these regions are detailed in Appendix A.

Transforming our energy system to one powered by renewable energy without pollution undoubtedly presents challenges, but they are challenges that we can overcome.

Figure 1-1 Geographical boundaries defining regions used in this report

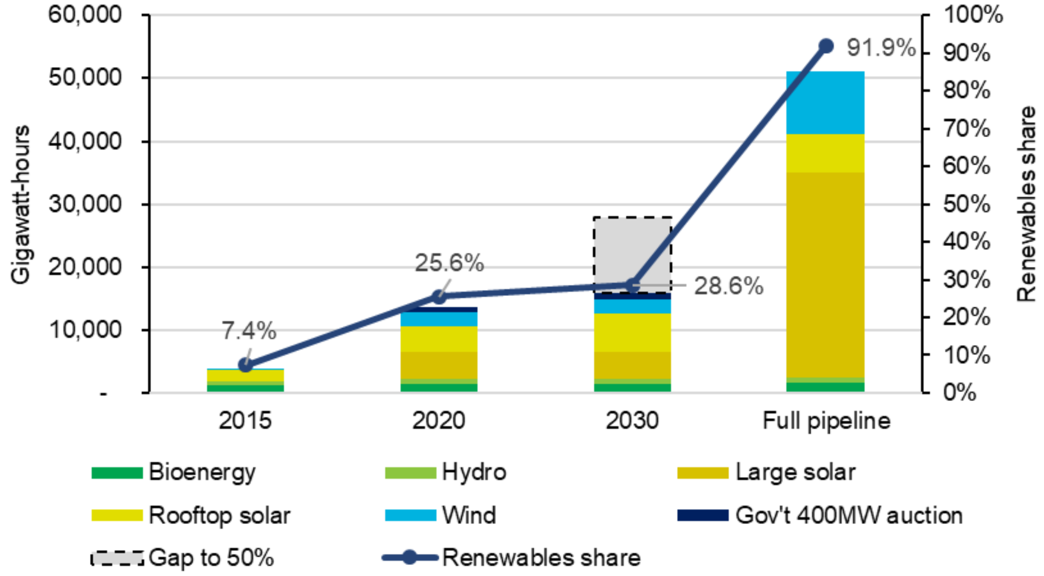
2 Overview of Renewable Energy across Queensland

Queensland has experienced a dramatic expansion of renewable energy project development activity within the space of just 3 years. At the same time its rooftop solar sector, which has led the rest of the country for many years, has experienced a revival of growth.

Based on projects under construction, expected uptake of rooftop solar and the Queensland Government successfully concluding its 400MW renewable energy tender, renewable energy will surge from 7.4% of Queensland electricity consumption in 2015 to 25.6% by 2020 (see Figure 2-1). After 2020 we can expect to see ongoing installations of rooftop solar PV, however there is no clear ongoing commercial incentive to install additional megawatt-scale utility projects after 2020. Consequently, it is highly likely that Queensland will fall well short of the government's 2030 target for renewable energy to supply 50% of electricity consumption. Instead generation representing under 30% of electricity consumption is likely without new policy.

However, this is not for lack of potential projects. This report details that Queensland's pipeline of projects under development totals almost 15,000MW. While there are a range of constraints that would need to be overcome, if all projects proceeded they would be capable of producing an amount of electricity per annum equal to more than 90% of Queensland's forecast 2030 electricity consumption.

Figure 2-1 QLD renewable energy power generation and share of consumption



Sources: Total electricity consumption is based on "native" electricity consumption taken from Australian Energy Market Operator's March 2018 National Electricity Forecasting report as is expected electricity generation from rooftop solar in 2030. Rooftop solar generation in 2020 is based on Green Energy Markets estimates of likely installed solar PV capacity by 2020 multiplied by average capacity factors for rooftop solar. Generation for other fuel types is based on a combination of historical averages for renewable energy projects currently in operation, plus Green Energy Markets estimates of likely generation from projects under construction plus a likely fuel mix from the Government's 400MW auction.

Achieving 50% renewable energy by 2030 would have appeared to be a very difficult task when compared against what was in place in 2015. Yet in just the three subsequent years industry and government have put in place investments and processes to increase renewables output by 9,800GWh by 2020. Given what has been achieved in this period, the remaining gap to 50% of 11,900GWh no longer appears so difficult, especially given the state has a 12-year lead time.

According to economic modelling by Jacobs for the Queensland Government's Renewable Energy Expert Panel, the cost of long-term power purchase agreements to support the financing of new projects to achieve the 50% target would be entirely offset by reductions in the wholesale price of electricity. Table 2-1 sets out the results from this modelling on how the 50% target would slightly reduce retail prices faced by different electricity consumer groups in Queensland. This was the case under two pathways considered: one that involved a building a constant amount of capacity each year (linear); and another that sought to defer much of the construction until closer to 2030 (ramp).

Table 2-1 Impact on retail electricity prices of 50% renewable energy target

	Linear pathway	Ramp pathway
Residential tariffs: Average price change (2020-2030)	-1.1%	-1.2%
Commercial tariffs: Average price change (2020-2030)	-1.2%	-1.3%
Industrial tariffs: Average price change (2020-2030)	-0.7%	-1.5%

Source: Queensland Renewable Energy Expert Panel (2016) Credible pathways to a 50% renewable energy target for Queensland – Final Report

The analysis by Jacobs indicated that the influx of additional supply from renewable energy projects would create substantial additional competition for the existing generators, forcing them all to reduce their market bid prices. This then flows through as lower energy costs in consumers' retail bills. These lower wholesale electricity market prices then offset the extra cost consumers would bare through paying new renewable energy generators a long-term contract price to support financing and construction of these projects.

It is worth noting that since the Expert Panel report was published it has become apparent that their cost assumptions for wind and solar were too high. Over the past twelve months power contract prices developers have been able to finance projects for are about 30% to 40% lower for wind, and about 50% lower for solar projects than what was thought to be the case when the Expert Panel produced their report. Part of the explanation for this large discrepancy is that in the lead-up to the development of Expert Panel report there had been very few projects built in Australia over the preceding two years. In addition, Australia's construction and financing costs for the small number of large solar farms built at that time were abnormally high compared to international best practice. Since November 2016 there has been a considerable number of wind and solar projects committed to construction that have provided a much-improved picture of wind and solar farm economics.

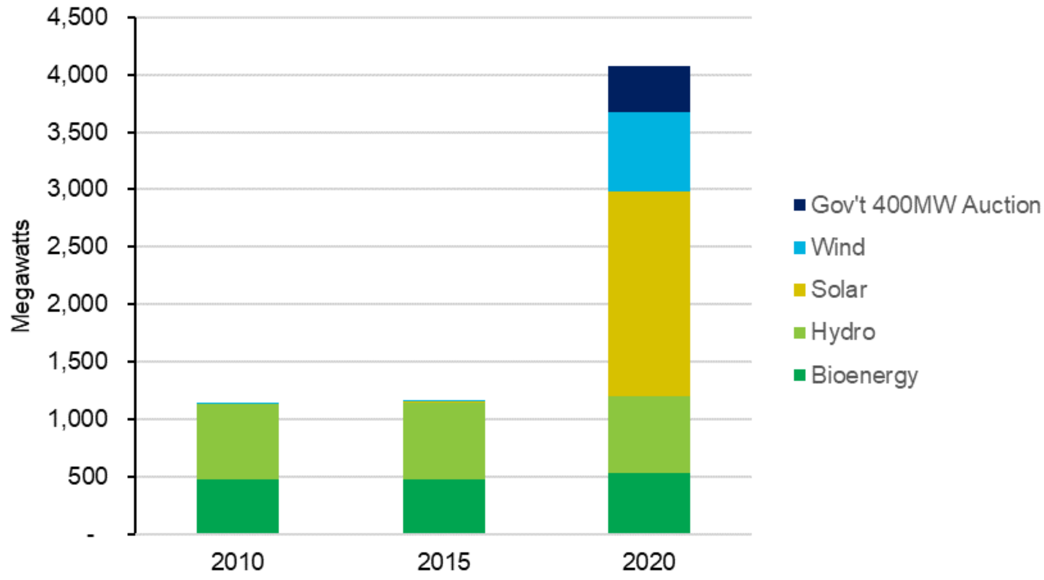
Section 2.1 provides further detail on the dramatic growth that has occurred in Queensland's large-scale renewable energy sector. This concentrates on projects that are typically above 1 megawatt in capacity, but in some cases involve large rooftop solar installations greater than 100 kilowatts. Section 2.2 then details growth in Queensland's smaller rooftop solar PV sector (projects below 100 kilowatts).

2.1 Large-scale projects

The chart below illustrates that between 2010 and 2015 there was almost no growth in the amount of large-scale renewable energy capacity in the state. Much of the state's renewable energy generating capacity was a legacy of hydro and bioenergy power plants first installed many decades ago. Historically there was a general belief that Queensland would capture only a small proportion of the investment stimulated by the national large-scale Renewable Energy Target, due to the higher wind speed sites available across other states.

However, the outlook has dramatically changed. As illustrated in Figure 2-2, by the end of 2020 the amount of large scale renewable energy projects installed in the state will have grown three and half times above what it was in 2015.

Figure 2-2 Queensland large-scale installed renewable energy by 2020 compared to past



Note: the installed capacity for 2020 includes projects that have become operational since the beginning of 2016 or are already committed to construction, plus the 400MW of projects that will flow from the Queensland Government's current reverse-auction tender. Source: Green Energy Markets Power Plant Register

Since the beginning of 2016, 2,445MW of renewable energy projects (larger than a megawatt) have either become operational or been committed to construction. As some context Queensland's entire gas generating capacity is almost 2900MW and the coal fleet is 8,126MW. A regional breakdown on where this capacity is located, as well as the jobs and investment associated with these projects is provided in Table 2-2. These projects have created construction work that will stimulate over 5,600 job-years of employment. A job year represents a person working a 37.5-hour week for a year minus four weeks annual leave plus public holidays. It is estimated they will also provide around 273 ongoing full-time jobs in operating and maintaining these power projects (The geographical boundaries for the regions in the table below are shown in the map in Figure 1-1).

On top of this we can also expect a further 400MW of project commitments flowing from the Queensland Government's tender to award long-term contracts to new plants.

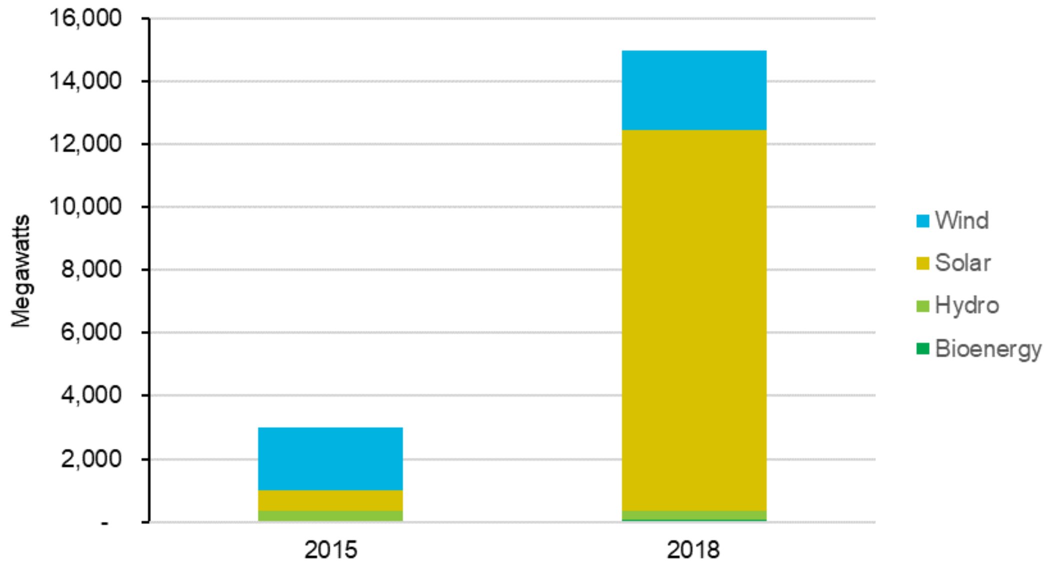
Table 2-2 Jobs and investment from projects built or under construction post-2015

Region	Capacity (MW)	Construction jobs (job-years)	Operational jobs (FTEs)	Total project investment ($m)
Central Queensland	169	372	18	$255
Darling Downs - Condamine	765	1,864	78	$1,422
Far North Queensland	215	541	43	$470
Mackay-Whitsunday	498	1,095	50	$746
South East Queensland	25	55	4	$41
Townsville - Dry Tropics	569	1,268	57	$879
Western Queensland	50	110	5	$75
Wide-Bay Burnett	174	383	18	$263
TOTAL	**2,465**	**5,687**	**273**	**$4,150**

Source: Green Energy Markets' Power Plant Register. For details on how employment estimated see section 3.4 of this report.

While the capacity being committed to construction has dramatically surged, the amount of additional capacity being identified and pursued for development managed to substantially outpace it. Even with about 2,500MW of additional capacity being converted from development to construction, the amount of renewable energy capacity in the development pipeline is almost five times larger than what it was in 2015 and now stands at just under 15,000MW (see Figure 2-3). A project under development can vary in terms of readiness from simply having a site identified and land-holder consent, to a project that has obtained all government approvals, a grid connection agreement and is on the verge of being financed. Within the development pipeline over half the capacity already has government development approval while another quarter have submitted applications for approval. However, the vast majority of these projects will only proceed to construction if there is new government policy to encourage further carbon pollution reductions in the electricity sector or the closure of existing power plants.

Figure 2-3 Renewable energy projects under development in Queensland in 2015 versus 2018



Sources: 2015 projects and capacity under development taken from Australian Energy Market Operator, data for 2018 taken from Green Energy Markets' Power Plant Register. A project under development can vary in terms of readiness from simply having a site identified and land-holder consent, to a project that has obtained all government approvals, a grid connection agreement and is on the verge of being financed.

Table 2-3 provides a regional breakdown (see Figure 1-1 for map of these regions) on the distribution of the renewable energy capacity under development, as well as the associated construction and ongoing employment these projects would create if they were to proceed.

Table 2-3 Jobs and investment from projects currently under development

Region	Capacity (MW)	Construction jobs (job-years)	Operational jobs (FTEs)	Total project investment ($m)
Central Queensland	1,853	4,077	185	$2,780
Darling Downs - Condamine	4,269	9,396	427	$6,411
Far North Queensland	1,553	3,537	184	$2,570
Mackay-Whitsunday	1,896	4,490	190	$3,323
South East Queensland	1,515	3,333	152	$2,273
Townsville - Dry Tropics	2,936	7,282	340	$5,765
Western Queensland	85	187	9	$128
Wide-Bay Burnett	761	1,673	76	$1,141
TOTAL	**14,867**	**33,975**	**1,562**	**$24,389**

Source: Green Energy Markets' Power Plant Register. For details on how employment estimated see section 3.4 of this report.

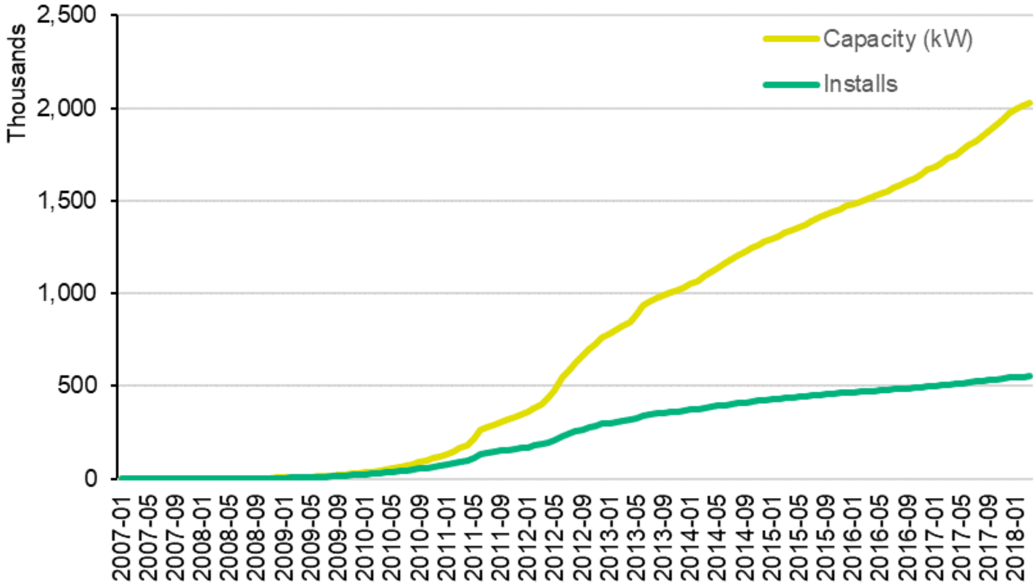
Readers should note that we have not included any solar thermal project within the development pipeline. While a number of companies, including Solar Reserve and CWP Renewables, are actively investigating development of such projects, no specific sites have been publicly identified. However, we expect solar thermal development sites will be announced in the future given this technology is:

- Technically well advanced with field-tested operational performance;
- Has the important advantage of being able to store energy relatively cheaply to dispatch power on demand independent of weather conditions; and
- the Queensland Government has offered $50m of funding support for solar thermal.

2.2 Rooftop solar photovoltaics

As shown in Figure 2-4, the uptake of rooftop solar PV systems in Queensland began to rise significantly since 2010. The cumulative capacity at just over 2,000MW is now noticeably larger than any individual conventional power station in the state (the biggest is Gladstone at 1,680MW).

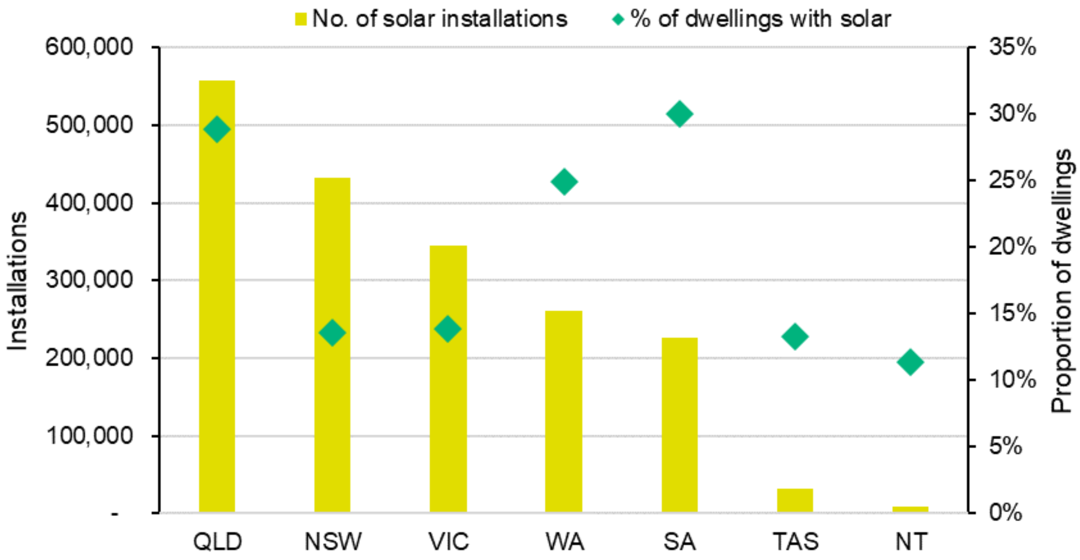
Figure 2-4 Queensland cumulative solar PV rooftop capacity and number of installations



Sources: Number of installations taken from Clean Energy Regulator's installation data by postcode. Information as at March 2018.

Queensland has the highest amount of rooftop solar capacity and the highest number of installations in the country. As shown in Figure 2-5, there are around 550,000 systems installed in the state, with systems installed on 29% of all residential dwellings in the state (including flats and apartments). This is exceeded by just South Australia where 30% of all dwellings have a solar system. These two states have the highest rate of household solar system ownership in the world.

Figure 2-5 Number of solar PV systems and proportion of dwellings with solar by state



Sources: Number of installations taken from Clean Energy Regulator's installation data by postcode as at March 2018. Percentage of dwellings is derived from combining the installation data with the Australian Bureau of Statistics 2016 Census data on number of dwellings excluding non-permanent structures such as caravans but including flats and apartments.

The average capacity residential system in Queensland (3.3kW) would be expected to deliver an average electricity bill saving of approximately $721 per annum based on a composite of the 3 major retailers' cheapest electricity tariffs (Origin Energy, EnergyAustralia and AGL). The average sized solar system on commercial premises (32.7kW) would be expected to save approximately $3,104 per annum. The overall state-wide saving solar-system owners would make on electricity costs is estimated to be $414 million (based on current market tariffs and excluding the extra benefit of premium feed-in tariffs).

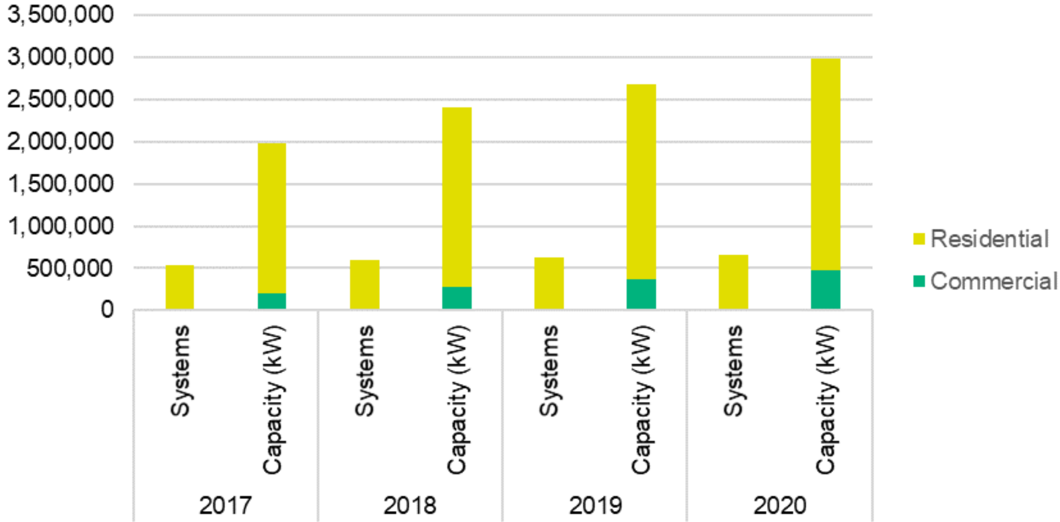
Table 2-4 Estimated annual bill savings per solar system and state-wide

Sector	Ave. system size (kW)	Annual generation (MWh)	Average annual bill saving per system	Statewide annual bill savings
Residential	3.3	4,077	$721	$387,091,174
Commercial	23.6	9,396	$3,104	$26,876,461
TOTAL				**$413,967,635**

Sources: Generation of systems based on Clean Energy Regulator estimates for average capacity factors. Electricity prices for imports and exported feed-in based on an average of the AGL, Origin and EnergyAustralia lowest post-discounted published offer as at January 2018. Commercial systems assumed to only save the price of electricity paid under feed-in tariffs. Proportion of residential system generation self-consumed or exported based on advice from the Alternative Technology Association.

Figure 2-6 below details the actual number of systems and capacity in place in 2017 and then Green Energy Market's projections of the cumulative capacity and systems to be installed in Queensland over the period to 2020, broken down by residential and commercial. The number of commercial systems are very small relative to residential and aren't visible in the chart below, however in terms of generating capacity, the commercial segment becomes increasingly significant to 2020.

Figure 2-6 Projected cumulative rooftop solar capacity and systems to 2020



Source: Green Energy Markets analysis

Our estimates suggest that Queensland is on track to install close to the Queensland Government's capacity target of 3,000MW of rooftop solar. However, the number of systems we estimate will be installed by the end of 2020 - at close to 666,000 - falls short of the government's target for 1 million systems. To achieve 1 million systems would require a five-fold increase in system installation rates over 2019 and 2020 compared to what we currently expect to occur.

Table 2-5 details our estimates of the expected employment created in the sale, design and installation of rooftop solar over the corresponding period. Solar installs have surged in recent times driven by what have been large rises in wholesale electricity prices and considerable media and political attention on electricity prices. Consequently, we believe employment over 2018 will rise above 2017 levels to peak at approximately 1452 full time equivalents.

Table 2-5 Estimated employment in sales, design and installation of rooftop solar in QLD

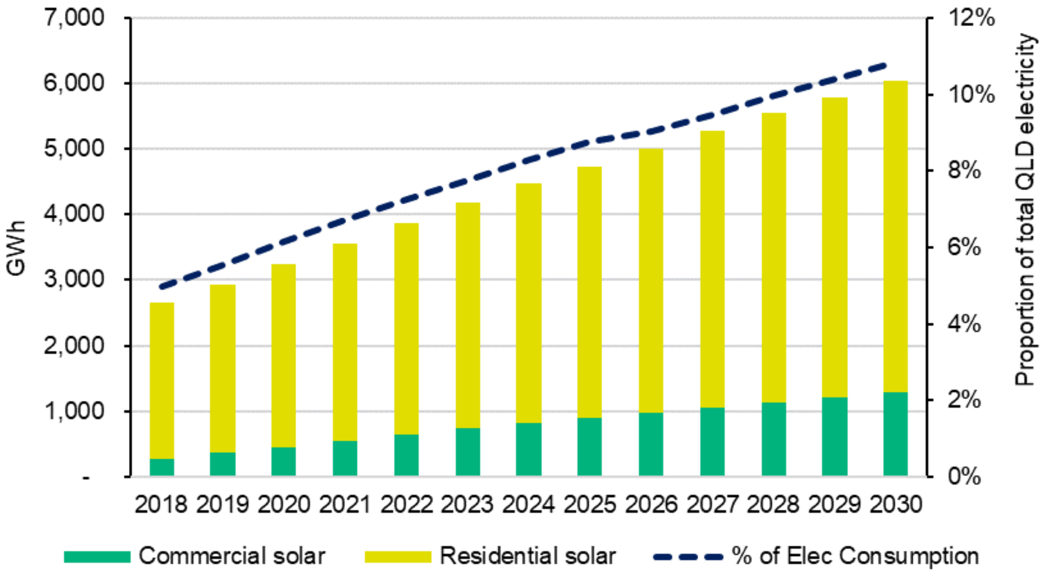
Period	Jobs (FTEs)
2017	1,209
2018	1,452
2019	1,105
2020	1,118

Source: Green Energy Markets Analysis

However, wholesale prices have begun to fall over the last 12 months and are expected to continue to fall due to the large influx of additional renewable energy capacity completing construction over the next year, not just in Queensland but across the National Electricity Market (NEM). This should ultimately flow through to end consumers' bills in the next few months and reduce the incentive and motivation for consumers to install solar. Solar will still provide an attractive financial return for many consumers, but the decline in retail power prices will mean the amount of systems and capacity installed in 2019 and 2020 will be lower than 2018 and employment will fall slightly to around 1,100 full-time equivalents.

Figure 2-7 illustrates the Australian Energy Market Operator's (AEMO) forecast of the amount of electricity Queensland will produce from rooftop solar systems to 2030. Our own analysis indicates they have probably underestimated growth in solar capacity over the next 3 years, but over the longer-term their forecast does not appear to be unreasonable. They forecast that Queensland rooftop solar will provide 6,000 gigawatt-hours of electricity in 2030 which would represent almost 11% of Queensland electricity consumption that year.

Figure 2-7 AEMO projected rooftop solar power generation and share to 2030

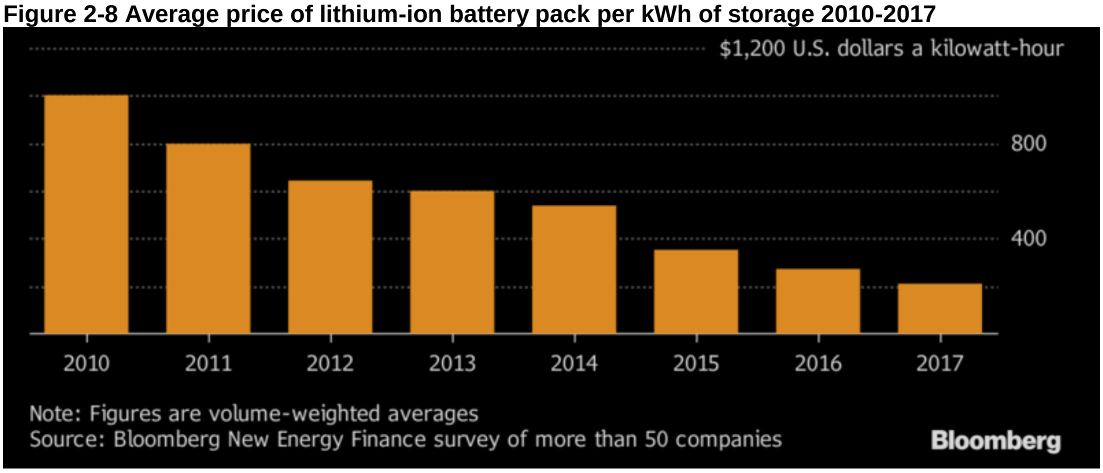


Source: Australian Energy Market Operator National Electricity Forecasting Report – March 2018. Proportion of total QLD electricity consumption based on AEMO's "native" electricity consumption.

2.3 Batteries-Energy Storage

At this stage battery technology has only been deployed in small numbers. Although, as illustrated in Figure 2-8 given the trajectory of substantial cost reductions of lithium-ion batteries, they are expected to become an increasingly competitive option within the next decade.

Figure 2-8 Average price of lithium-ion battery pack per kWh of storage 2010-2017



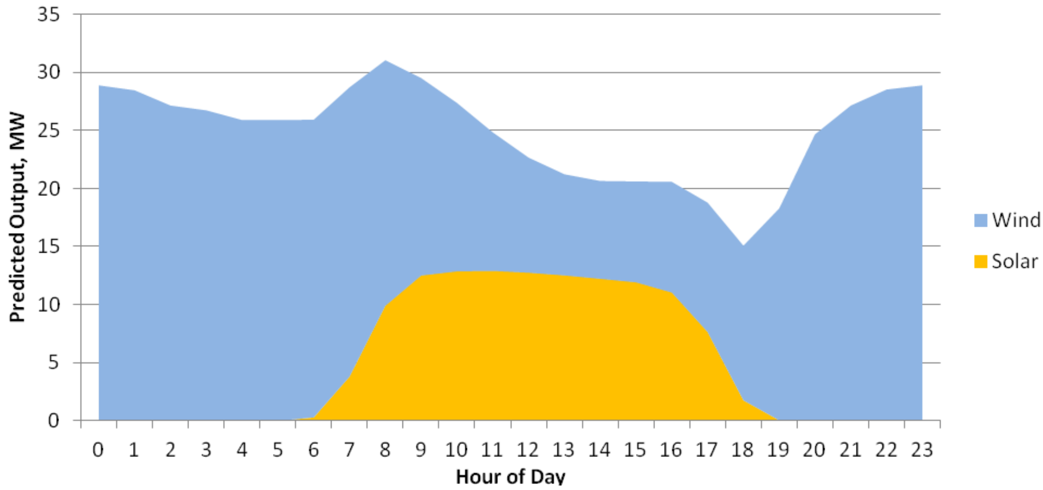
Note: these are wholesale prices for battery packs for electric vehicles offered to car companies buying in bulk. They do represent the retail price of a fully installed residential battery system.

So far in Queensland there are just two examples of utility-scale battery deployments built in conjunction with renewable energy plants. Both of them were supported through funding from the Australian Renewable Energy Agency (ARENA).

The Lakeland solar project near Cooktown includes a battery system that allows this solar power station to reinforce the network to improve power system reliability and quality at this remote fringe of the national grid. This includes the ability to provide power to the local area in the event it is disconnected from the main electricity system.

The other utility-scale battery is under construction as a sub-component of stage 1 of the Kennedy Wind and Solar Energy Park near Hughenden. As shown in Figure 2-9 the Kennedy Energy Park is characterised by wind patterns that tend to rise late in the evening and stay high overnight before subsiding over the day. Meanwhile the solar farm delivers power over daylight periods. Given this natural weather pattern, the battery only needs to provide a short period of storage that helps bridge the dip in output over the hours of 17:00 to 20:00 (5pm to 8pm).

Figure 2-9 Average daily pattern of output from Kennedy wind turbines and solar farm



Source: Windlab (2018) Kennedy Energy Park Knowledge Sharing Report (Financial Close).

While batteries haven't yet dropped enough in cost to represent a viable commercial option, most renewable energy projects recently proposed for development in Queensland include plans that provide for the future incorporation of a battery system.

Batteries also provide the potential to offset the substantial cost involved in building and maintaining electricity network infrastructure, particularly for residential homes. This may represent the most viable option initially for the use of batteries. Their viability is also assisted by the fact some households see batteries not just as a financial investment, but also one that provides peace of mind and other non-financial benefits. At this stage data on deployment of batteries in smaller scale residential and business premises in Queensland is poor. Feedback from solar installers and battery suppliers is that uptake to date is at a small scale of a few thousand systems per year in Queensland.

It is important to note that we don't need to wait until batteries drop further in cost before deploying further renewable energy. The Australian body representing scientific and engineering researchers – The Australian Council of Learned Academies – released a report in 2017 which found that even with renewable energy representing 50% of electricity supply, the amount of energy storage required to ensure reliability and security of supply was relatively small (see Figure 2-10)[1]. By the time Australia might be expected to reach 75% renewables share – it's reasonably likely batteries will have achieved substantial cost reductions that allow it to be affordably deployed at large scale. In addition, pumped hydro and solar thermal can provide large-scale energy storage at costs cheaper than batteries at present.

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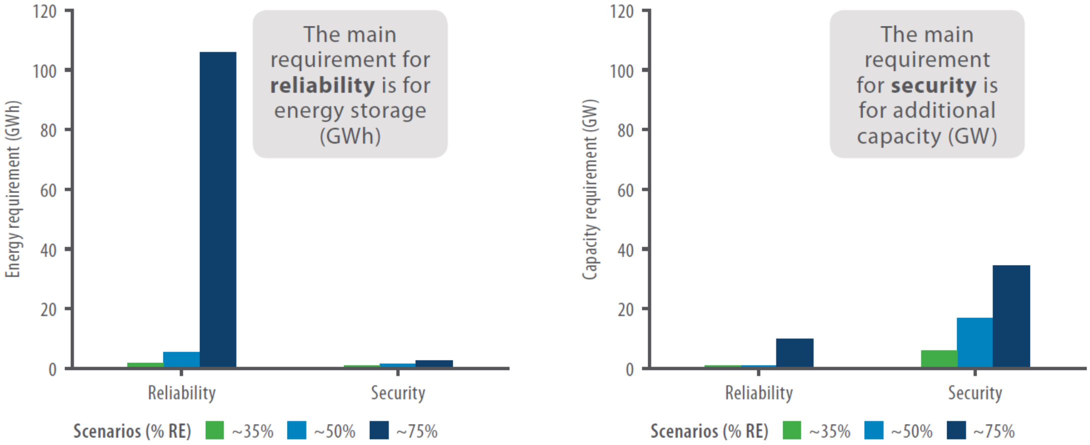
[1] Godfrey, B., Dowling, R., Forsyth, M., Grafton, R.Q. and Wyld, I., (2017) *The Role of Energy Storage in Australia's Future Energy Supply Mix*. Report for the Australian Council of Learned Academies., www.acola.org.au

Figure 2-10 Amount of energy storage required to ensure reliability and security at high levels of renewable energy share of supply



Source: Godfrey, B., Dowling, R., Forsyth, M., Grafton, R.Q. and Wyld, I., (2017) The Role of Energy Storage in Australia's Future Energy Supply Mix. Report for the Australian Council of Learned Academies., www.acola.org.au.

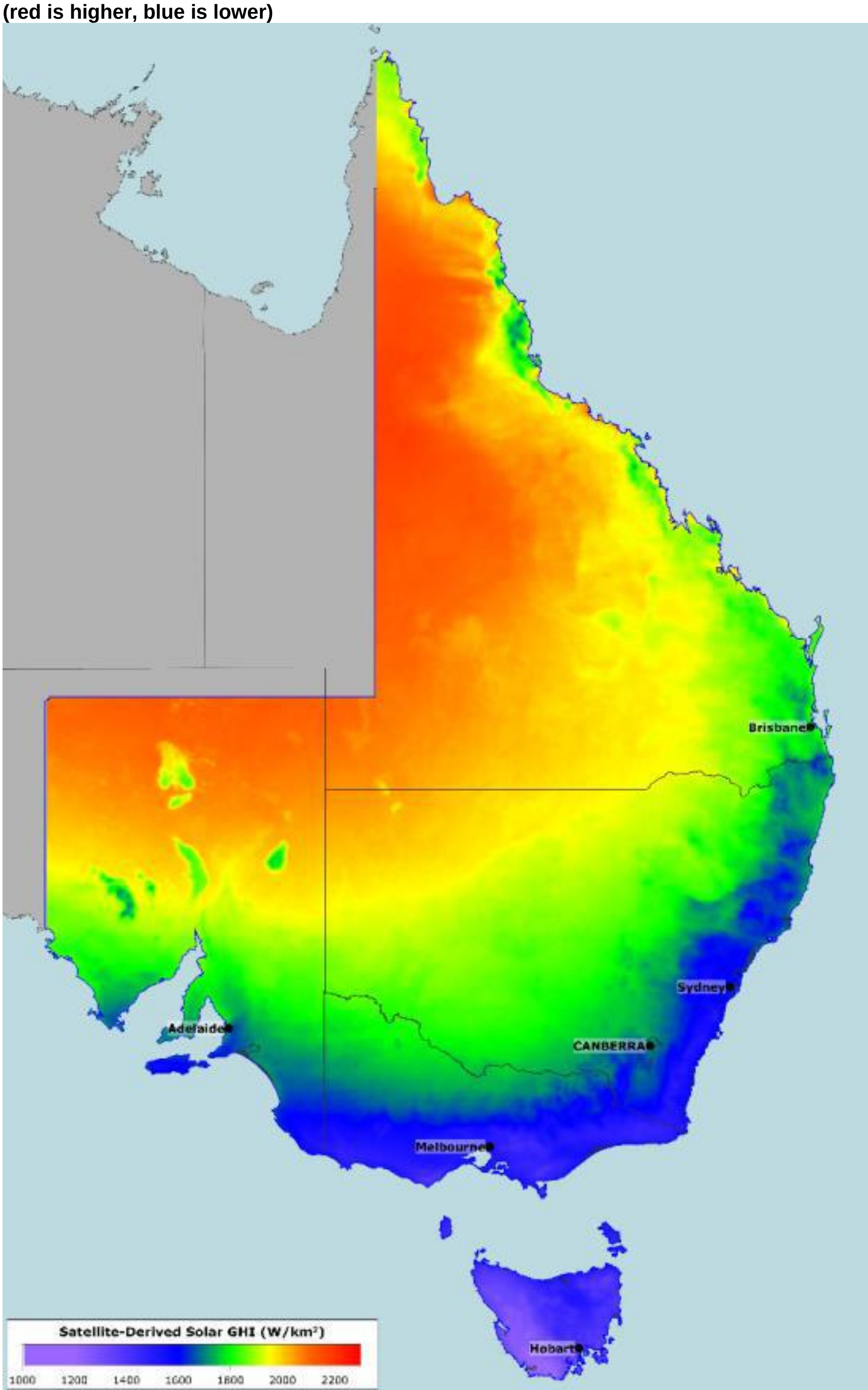
The other major development of interest in batteries is the proposal to establish a battery manufacturing facility in Townsville. The Imperium3 consortium, which includes a battery technology company called Boston Energy and industrial equipment manufacturer Siemens, is proposing a 15-gigawatt-hour per annum production plant plus space for associated component manufacturers to set up nearby. According to the consortium the facility would create up to 1000 direct jobs, plus an additional 1000 jobs in direct support businesses. In April 2017 the Townsville City Council signed a memorandum of understanding with Boston Energy to investigate the financial viability of the project and has offered land at the former CSIRO Lansdown research station at Woodstock. In addition, the Queensland Government committed $3.1 million towards a feasibility study for a battery factory in Townsville.

2.4 The renewable energy resource

Solar

Figure 2-11 provides a map illustrating the intensity of solar radiation and therefore energy hitting the surface across the states in the National Electricity Market. As you'd expect the further north you go generally the higher the amount of solar energy available (darker red colour). In addition the further you head away from the coast the higher the amount of solar energy because there are less cloudy and rainy average conditions.

Figure 2-11 Intensity of solar radiation across the NEM states (red is higher, blue is lower)



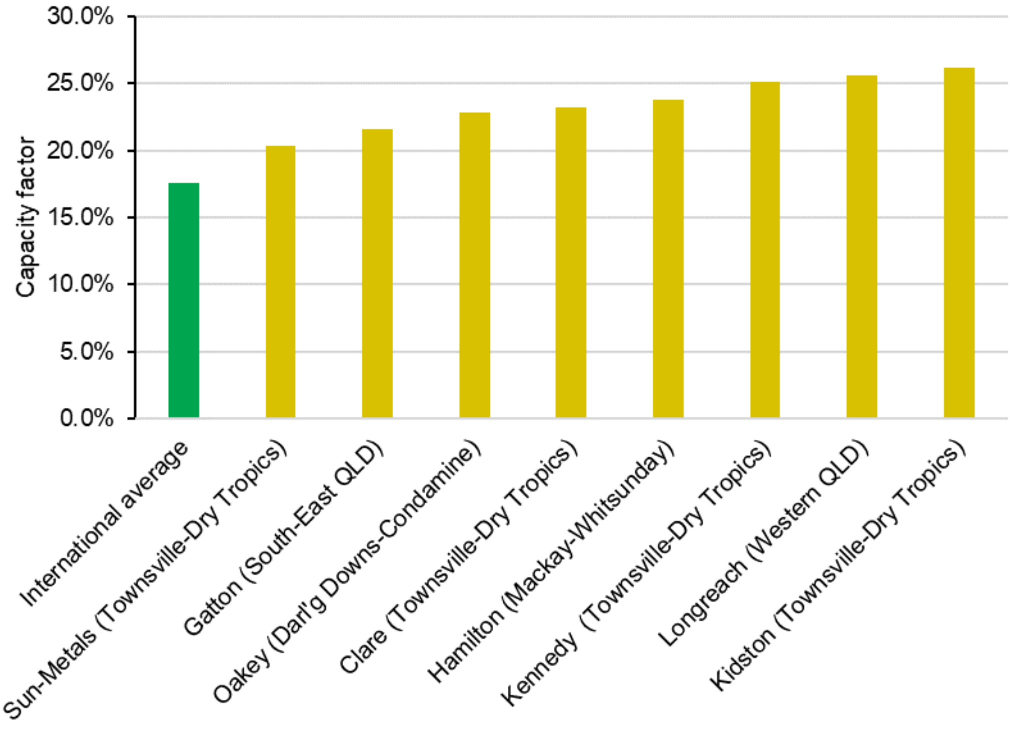
Source: Australian Energy Market Operator (2017) Integrated System Plan Consultation

Given Queensland's northern orientation it naturally possesses a higher quality resource than the other states within the NEM. This has been one of the primary reasons it has attracted the vast majority of investment in solar farms so far across Australia. It has also been a key factor in making rooftop solar PV financially attractive to both householders and businesses to install. And it has made the state attractive to develop new solar farms.

What is worth noting is that Queensland's high quality renewable energy resource provides a major competitive advantage not just relative to other states in the NEM but far more significantly in comparison with other countries. In practical terms this higher intensity of solar energy means that for a given financial investment in solar modules, Queensland sites will tend deliver more electricity generation over the year.

As illustrated in Figure 2-12, solar farms that spread across a wide area of Queensland from Gatton Solar Farm in the south-east, to Kidston Energy Hub inland from Townsville, and Longreach Solar Farm in the west, achieve levels of electricity output that are far superior to the 2017 international solar farm average per unit of solar panel capacity installed.

Figure 2-12 Capacity factors of solar farms across Queensland compared to the international average of 2017 installations



Note: Capacity factors are a function of the annual AC electricity output divided by the rated DC panel capacity of the solar farm operating at full capacity over an entire year. Electricity output is prior to the effect of transmission losses.
Sources: International average capacity factor sourced from IRENA (2018) Renewable power generation costs in 2017; Green Energy Markets Power Plant Register for Australian solar farms.

Even though Gatton Solar Farm is within the green zone of the solar radiation map it generates 23% more electricity per kilowatt or solar panel capacity than the international average. Oakey Solar Farm within the Darling Downs-Condamine region generates 30% more, Hamilton Solar Farm in Mackay-Whitsunday region generates 35% more, Longreach Solar Farm in western Queensland generates 45% more and the solar component of the Kidston Energy Hub will generate 49% more power than the international average.

Wind

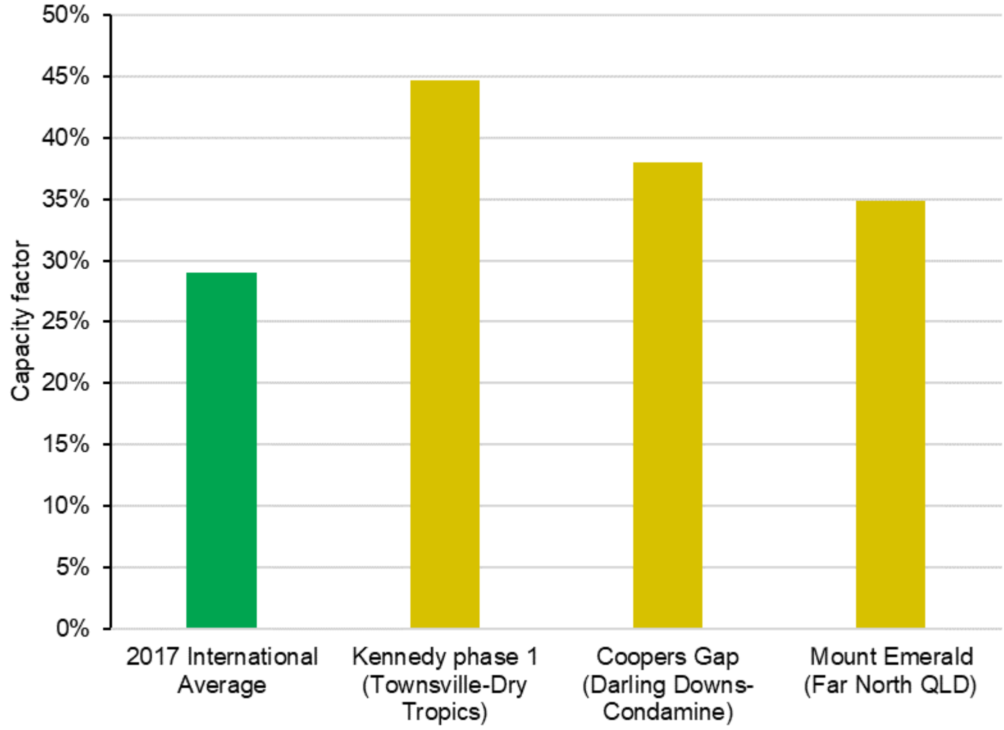
Figure 2-14 overleaf provides a map illustrating the distribution of the wind resource across the NEM states with red areas indicating area subject to high average wind speeds and blue to purple indicating low wind speed areas, with green lying in between.

Historically wind farm development and investment in Australia has mainly been focussed on: the yellow to red band near the Flinders Ranges fringing around Adelaide and to its north; the yellow and red area to the west of Melbourne; and the yellow and red band along the Great Dividing Range between Sydney and Canberra.

However, in the last two years Queensland has also attracted some significant wind farm investment and developer interest. This was exemplified in August 2017 by the decision of AGL to commit to construction Coopers Gap, Australia's largest ever wind farm at the time at 453MW. The other two major wind farm investments in Queensland have been Mount Emerald and phase 1 of the Kennedy Wind Farm development – both of which are located in the red and yellow zone that lies to the west of Cairns and Townsville in the north of the state.

Figure 2-13 illustrates that these three wind farms committed to construction in the last two years will achieve levels of output per unit of installed capacity that substantially exceed the international average of wind farms installed in 2017 as tracked by the International Renewable Energy Agency.

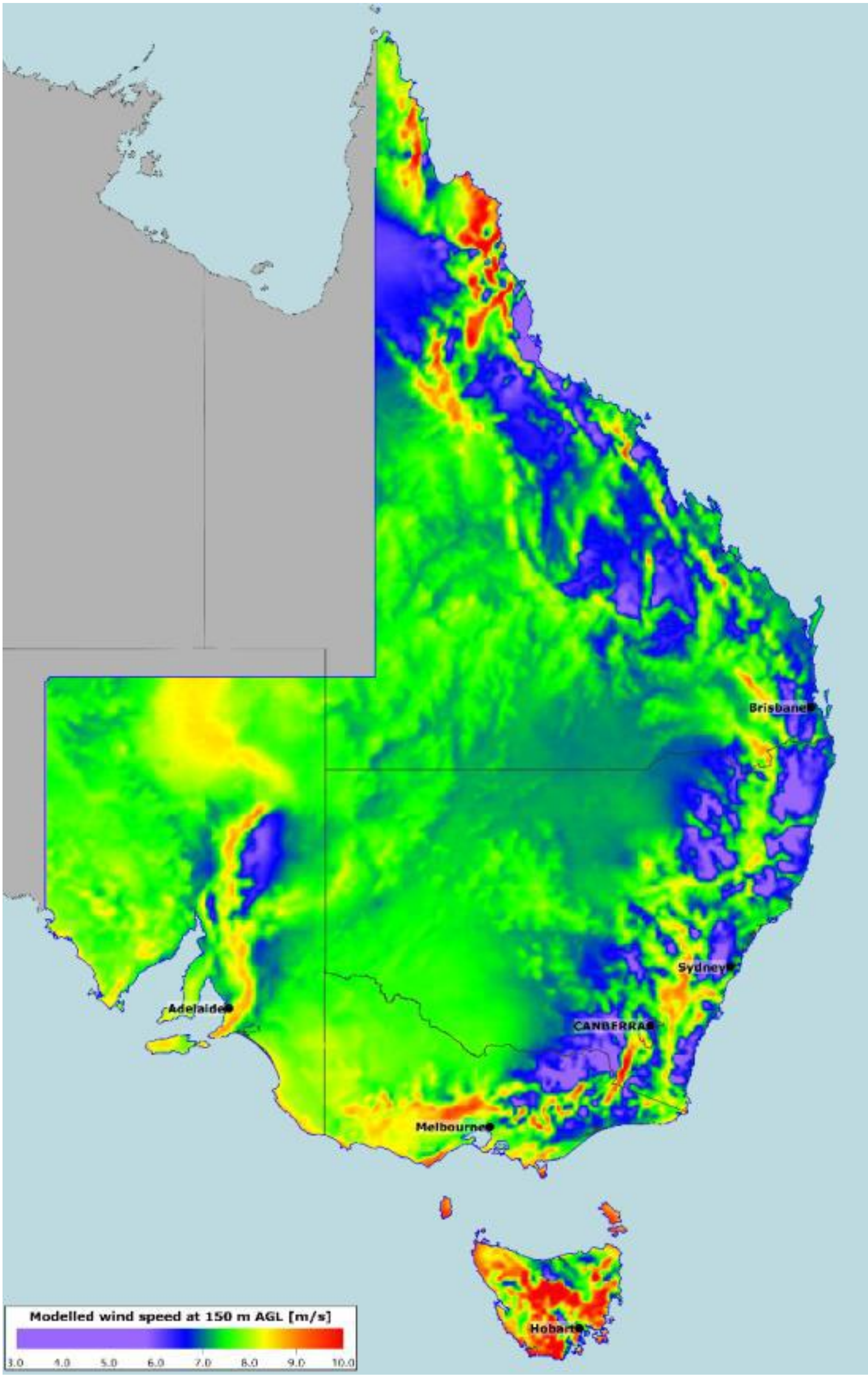
Figure 2-13 Capacity factors of Queensland committed wind farms compared to the international average of 2017 installations



Note: Capacity factor is a measure of annual average electricity generation compared to the output of a power station if it operated at its maximum rated capacity across the entire year. In other words it is a measure of the utilisation of a power plant's total installed capacity. Chart above is based on estimated generation prior to the effect of transmission losses.
Sources: International average capacity factor sourced from IRENA (2018) Renewable power generation costs in 2017; Green Energy Markets Power Plant Register for Australian wind farms.

Mount Emerald Wind Farm, in the Far North Region near Cairns is expected to generate 20% more power than the international average, Coopers Gap Wind Farm 31% more and the wind turbines at the Kennedy Energy Park will generate 54% more.

Figure 2-14 Average wind speeds across the NEM states
(red is higher, blue is lower)



Source: Australian Energy Market Operator (2017) Integrated System Plan Consultation

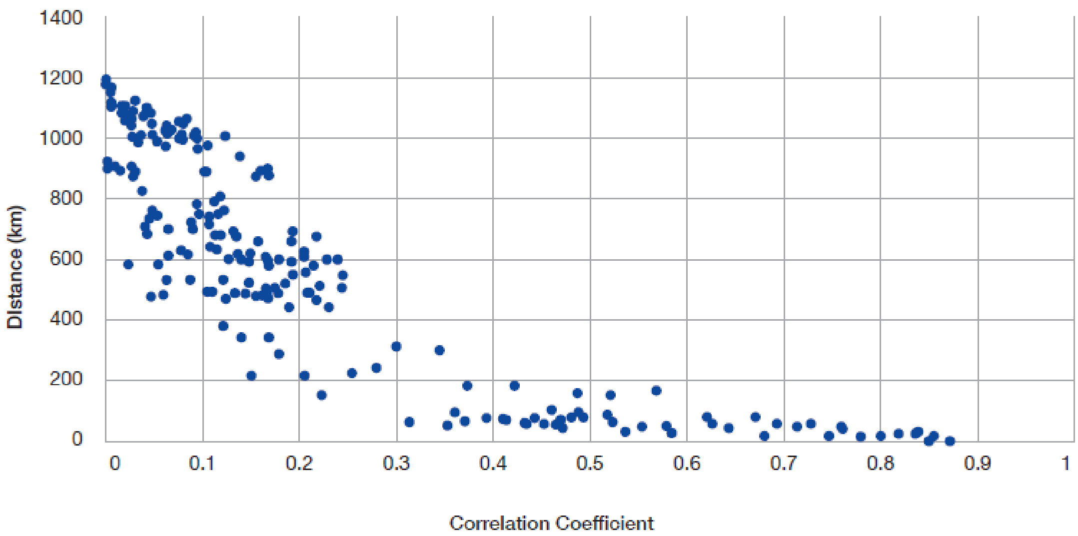
What makes the exceptional international performance of the Kennedy Energy Park's stage 1 wind farm of particular interest is that is part of a far larger wind farm development site of 1,200MW. As explained in section 2.5 of this report on transmission infrastructure, this energy park mega development (which is also planned to incorporate a very large solar farm), can only be unlocked with substantial upgrades to transmission line capacity.

While it is only recently that Queensland has seen noticeable investment in wind farms, the state has two major advantages that add to its attractiveness for wind farm investment over other states.

The first is that developers of wind farms are now also looking to maximise the value of their grid connection infrastructure by adding solar capacity. This means the financial attractiveness of wind farm projects are now influenced by the quality of the solar resource nearby to the grid connection. Queensland's superior solar resource provides an important advantage in this respect.

The second is that Queensland's wind conditions are driven by different weather systems than those driving the power output of wind farms in southern states. Put simply, the wind in Queensland will often blow at high levels at different times than the wind in South Australia, Victoria and NSW. This improves the financial attractiveness of wind farm development in Queensland because it means they will producel electricity at different times and are less likely to have to compete against the now quite substantial wind farm capacity installed in southern states. Figure 2-15 illustrates that as wind farms are distanced further apart the likelihood of them having similar levels of output at the same time (per unit of capacity) declines.

Figure 2-15 Correlation of 2015/16 power output across wind farms in NEM relative to distance apart



Source: Transgrid NSW (2018) Integrated System Plan Submission. The correlation coefficient is a measure of the likelihood that two wind farms will have the same level of output at the same time.

With several thousand megawatts of wind farm capacity operating or under construction across Victoria and South Australia, they have the potential to have a very significant impact in lowering prices when subject to windy conditions. This is the case not just in their own state, but also other states around the NEM because they will export power interstate. Because these two states' wind farms are relatively close to one another they tend to have high levels of output at the same time and so receive lower power prices. Because Queensland wind farms are less likely to be generating at the same levels as Victorian and South Australian wind farms simultaneously, they will therefore be more likely to avoid these high wind-low power price events.

This has an important benefit for consumers in that as wind farm capacity expands in Queensland, overall output across all wind farms in the NEM will become more steady. If transmission capacity interconnection across the states is expanded it will mean overall power across all wind farms is similar to a baseload coal generator, but without the pollution.

Hydro

The existing Burdekin Dam is being evaluated for the addition of a 50MW hydro power plant however, like much of the rest of Australia, Queensland is not considered to have significant potential for expansion of conventional large hydro-electric dams. This is due to concerns over downstream effects on water systems and soil salinity from irrigation, reliability of rainfall, loss of natural habitat and economic feasibility.

However, what is considered feasible is the addition of smaller pumped hydro facilities which act much like a battery.

Such facilities involve a closed loop water system with two water storage reservoirs. Water from a reservoir located at the bottom of a hilly/mountainous area is pumped up to a reservoir higher up. This pumping up of the water would occur at a time when supply of power was plentiful and cheap, which in the future might be during sunny or windy periods. Then when power was less plentiful or demand was high, the water would be released downhill to drive a hydro generator to produce electricity. Because such a system reuses water over and over again, it shouldn't adversely affect riverine eco-systems, or downstream farming activities, and is less vulnerable to droughts.

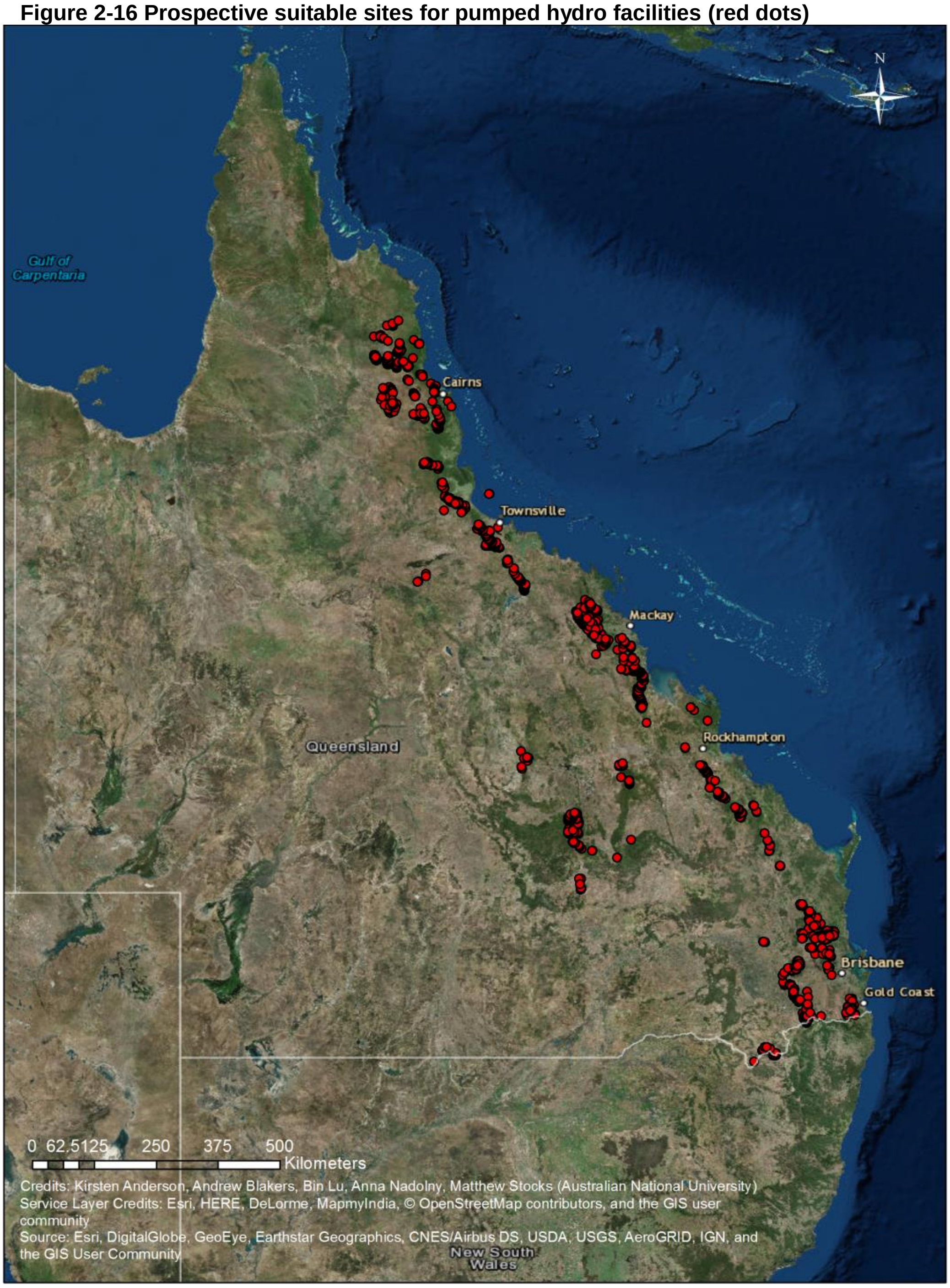
Australian National University has mapped the states of the National Electricity Market to identify sites that would be suitable for pumped hydro facilities. These involve a large height difference over a short distance (mountainous areas) and are located outside of ecologically sensitive areas such as national parks or can make use of existing water storages that don't currently have a pumped system in place. Figure 2-16 shows in the red dots sites they identified as suitable for pumped hydro plants. This includes a very large number of sites around the east coast of Queensland that are reasonably proximate to grid infrastructure. According to the lead researcher Professor Andrew Blakers, this analysis indicates that, "Australia has so many good sites for PHES [pumped-hydro energy storage] that only the best 0.1% of them will be needed [to accommodate a power system of 100% renewable energy]."[2]

The Queensland Government's Powering Queensland Plan[3] includes a feasibility study to assess options for the deployment of new hydro-electric and pumped storage generation capacity in the state, but the report is yet to be released.

[2] Blakers (2017) There are 22,000 possible sites for pumped hydro storage across Australia, ARENA Wire - https://arena.gov.au/blog/andrew-blakers/

[3] Powering North Queensland Plan - https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0003/1253541/Fact-sheet-Powering-North-Queensland-Plan.pdf

Figure 2-16 Prospective suitable sites for pumped hydro facilities (red dots)



Source: Australian National University College of Engineering and Computer Sciences (2017) Atlas of Pumped Hydro Sites - http://re100.eng.anu.edu.au/research/phes/

2.5 Transmission

Queensland's transmission business Powerlink recently assessed the amount of generating capacity it believes could be supported at various sections of its network, as shown in the map at Figure 2-17 Table 2-6 converts this into numerical form to provide a quantification of the total amount of renewable energy capacity that could be supported across different sections or sites within the transmission network.

Table 2-6 Number of transmission sites that can support different levels of new generating capacity

Non-Synchronous Supportable Capacity (MW)	Number of sites	Total MW
50-100	18	1,350
100-150	13	1,625
150-200	6	1,050
200-250	3	675
250-300	3	825
300-350	4	1,300
350-400	3	1,125
400+	8	3,200

Note: This tally is not comprehensive because it leaves out the high voltage 275 and 330kV substations which Powerlink believes will generally accommodate generation levels in excess of 400MW as well. Wind and solar farms use power conversion technology that is "non-synchronous".

The table and map suggest there is room to support substantial additional renewable energy capacity in the network. However, it is important to note that determining how much new power generation can be feasibly and economically connected to the network is complex and there are interaction effects that can come into play.

As detailed earlier in Table 2-3 the pool of projects that developers are seeking to pursue in Queensland is very large at close to 15,000MW. This comes on top of the almost 3,600MW already operational or under construction plus the 2,000MW and growing rooftop solar. To put this into context the current average annual electricity demand of Queensland is 6,050MW and peak demand has historically fallen below 9,000MW.

While the more than 20,000MW of combined renewable energy capacity would never come close to generating at maximum capacity all at the same time, this large imbalance between what is proposed and overall demand is suggestive of notable physical constraints for many projects within the development pipeline. Expansion of network capacity both within Queensland and better interconnection across the overall NEM will assist in effectively harnessing the available wind and solar resources and smooth out variability.

For a number of locations within Queensland it is already evident that network capacity would need to be upgraded to enable further projects currently in development to proceed. It is important to note that since Powerlink's assessment was prepared, a number of projects have already been connected that reduce the remaining capacity that can be absorbed without curtailment. While there remains available capacity on the main transmission trunk there is also an issue of increasing transmission losses. Transmission lines lose some of the electricity they transport as heat, with losses tending to be greater the longer the distance from the generator to the electricity load and the closer the line is to its capacity limits.

Figure 2-17 Powerlink assessment of the generation capacity that can be absorbed on the QLD transmission system excluding 275kV and 330kV substations

Source: Powerlink (2017) Generation Capacity Guide – June 2017

Table 2-7 provides five examples of solar farms recently completed in Queensland that have incurred large downgrades in the transmission loss factor applying to their output compared to the prior year. The loss factor is the proportion of the power plants' output that AEMO believes will be left over for end consumers after transmission losses. In the case of Clare Solar Farm close to 13% of its output is expected to be lost via transmission. For all the others, more than 10% of generation will be lost.

Table 2-7 Recently completed solar farms with large downgrades to loss factors

Project	Region	New loss factor	Old loss factor	% change
Barcaldine	Western QLD	0.8934	0.9689	-7.8%
Clare	Townsville-Dry Tropics	0.8727	0.9823	-11.2%
Hughenden	Townsville-Dry Tropics	0.8979	1.0115	-11.2%
Kidston	Townsville-Dry Tropics	0.8979	1.0115	-11.2%
Longreach	Western QLD	0.8934	0.9689	-7.8%

Note: Loss factors greater than one are possible because in some cases a generator – if not too big – located in an area distant from other generation sources will actually reduce the level of transmission losses involved in serving the nearby electricity load.
Source: Australian Energy Market Operator.

Such levels of transmission losses aren't necessarily a show-stopper for the viability of these projects. But they indicate that if any further projects sought to connect nearby, they would see losses increase to very high levels. These act to nullify any advantage from the high quality solar resource available in the area and would likely be of such a high level that they would make further projects unviable.

In addition to challenges over losses, there are projects or collections of projects within a resource rich region where the size of projects proposed are an order of magnitude greater than the available grid capacity.

A prime example lies in a region inland in between Cairns and Townsville and above Hughenden. The wind resource map in Figure 2-14 and solar resource map in Figure 2-11 illustrate it is characterised by areas of red indicating both high intensity wind and solar resources. The region has two projects already connected or about to be connected to the network – the 50MW Kidston Phase 1 Solar Farm and phase 1 of the Kennedy hybrid wind-solar park (combined 58.2MW). The high capacity factor of Kidston's solar farm (see Figure 2-12) and Kennedy's wind farm (see Figure 2-13) provide a practical demonstration of the world class nature of the renewable resources in this area.

However, both these projects have vastly larger amounts of capacity identified for future development. Kidston's phase 2 involves a 250MW pumped hydro plant as well as a 270MW solar farm. In addition, a 150MW wind farm is also being evaluated. Phase 2 of Kennedy involves a hybrid wind and solar park of 1,200MW. In addition another wind farm in the region– Forsayth – is under development.

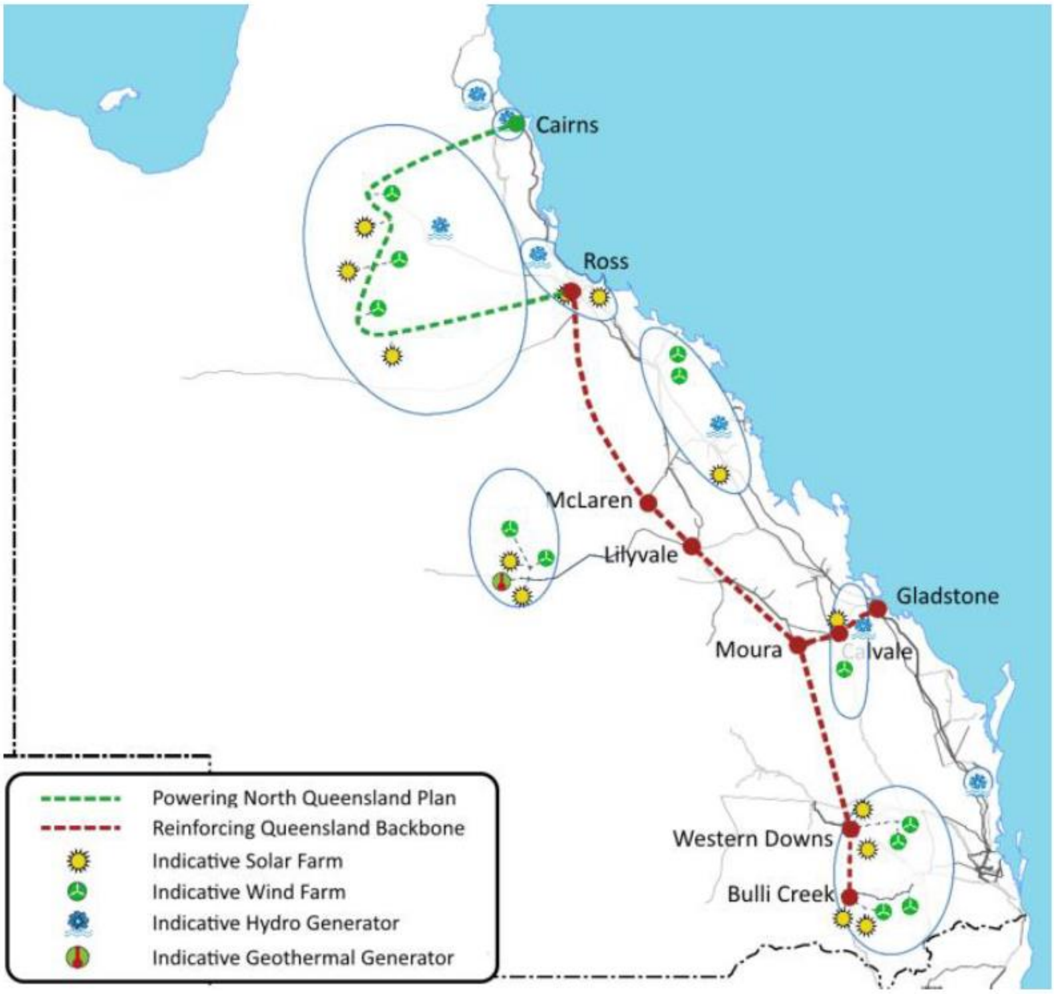
These projects are distant from the main transmission backbone illustrated in Figure 2-17. For the far larger potential of these projects to be exploited, as well as other projects in the Far North, significant upgrades to transmission infrastructure will be required. Powerlink is undertaking the 'Genex Kidston Connection Project'[4] to plan a

[4] Genex Kidston Connection Project see: https://www.powerlink.com.au/projects/genex-kidston-connection-project

possible new 275kV transmission line for stage 2 of the Energy Hub but no final decision on this project has been made. Alternatively, Kidston could connect to a longer multi-project transmission line being considered by the Queensland Government.

The Powering Northern Queensland Plan includes a study examining the feasibility of a major new inland transmission loop between Ross (near Townsville) and Cairns. The Australian Energy Market Operator in developing its Integrated System Plan for the National Electricity Market has identified how such a new transmission loop line (see green dashed line in Figure 2-18) as well as reinforcement of Queensland's transmission backbone could allow for development of several geographic zones possessing high quality renewable energy resources.

Figure 2-18 New transmission lines (dashed) identified by AEMO to support exploitation of areas with high quality renewable energy resources

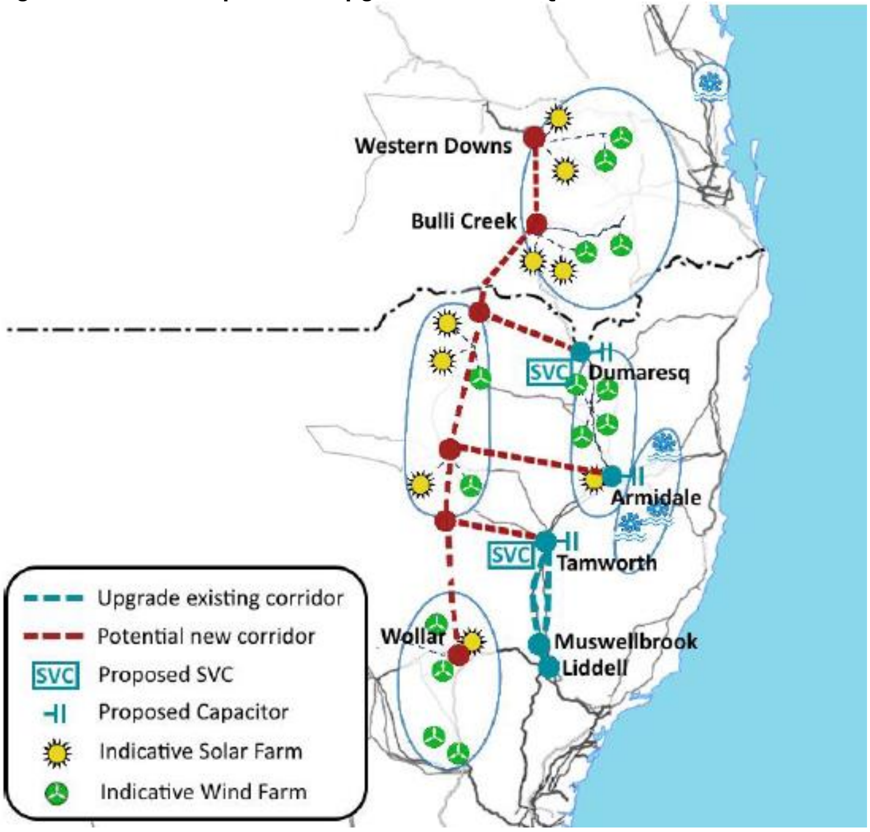


Source: AEMO (2017) Integrated System Plan Consultation for the National Electricity Market

The consultation paper for AEMO's Integrated System Plan also highlighted that upgrades of the interconnector between Queensland and NSW could assist the integration of larger amounts of renewable energy capacity. This would enable greater sharing of generation across the states, and also possibly provide a new transmission corridor that could support the connection of several major solar and wind projects proposed for south-east Queensland and north-east NSW.

It should be noted that there is likely to be further ongoing opportunities to connect new projects without major upgrades to the transmission network. While there will be significant benefits from transmission upgrades, these will need to be balanced against the extra costs and other alternative options.

Figure 2-19 AEMO options to upgrade the NSW-Queensland Interconnector



Source: AEMO (2017) Integrated System Plan Consultation for the National Electricity Market

3 The renewable energy supply chain

3.1 Construction activity

The pipeline of renewable energy projects under construction or under development is dominated by wind and solar projects, with bioenergy and hydro making up a much smaller proportion of proposed capacity. The construction of wind and solar farm projects require much the same skills and businesses that are involved in any civil and electrical construction project. This will typically involve the following elements:

- Geotechnical and survey work to assess what will be required in terms of earthworks and creation of stable foundations for module racking and wind turbine towers.
- There will then be a range of earthworks to build site access roads, prepare the site or sites for installation of the wind towers or the module racking stands, and trenching for electrical cables.
- Concrete and aggregate/quarry supplies will be involved for building foundations for wind turbine towers and also electrical substations that will connect either solar or wind projects to the grid.
- Installation of wind towers or module racking stands takes place and then the modules or turbines are also installed. In the case of wind turbines there is also the need for large crane operations given the height of the towers and associated turbine units.
- Electrical cabling, switching, transformers and computer control gear will need to be installed and connected throughout the project and the associated substation.
- In some cases there may also be a need for installation of overhead powerlines to transport power from the site to the main grid connection substation. There may also be upgrades undertaken to the main transmission line trunk in order to accommodate connection of extra new generating capacity.
- All of the equipment involved in the above steps will need to be transported to site including port operations for the imported components. This is a particularly involved process for the wind turbine blades because of their long length, which will exceed 50 metres. This can require additional road works and modifications along the route to accommodate the unusually long length of the blades being transported.

While the core power generation equipment is imported (further detail on equipment sources is detailed below), a large proportion of the power project investment will be spent domestically due to the extensive construction work required in installing these projects and connecting them to the electricity network.

3.2 Equipment manufacture - Solar

The construction of solar farms is made up of the following major pieces of equipment:

- Solar module or panel – which converts the photons of light from the sun into direct current electrical energy.
- Framing and stands to hold the panel to the site which can be fixed in one place or in many cases will have the capability of rotating, usually on a single axis, to follow the path of the sun.
- Inverter which converts the power from the solar panel that is in direct current into alternating current that is compatible with the form of electricity on the main grid.

- Transformers which will adjust the voltage of the power to a level that is consistent with the transmission or distribution powerline the plant is connecting into.
- Switching gear and electrical wiring to facilitate and control the flow of power.

At present solar modules and inverters are imported from overseas. The Chinese tend to dominate solar module manufacture but significant manufacturing plants for modules and solar cells are also located in the United States, Singapore, Malaysia, Japan, Mexico, Korea, India and Taiwan. Inverters tend to originate from Germany, Austria, Italy, China and the United States.

What many may not realise is that Australia used to be a significant producer of solar modules in the past and small levels of module production continue at Tindo Solar in South Australia. Australia is also a niche producer of specialised inverters for battery-hybrid off-grid capable systems through the company Selectronic. In addition, a number of the key technologies that have been employed in solar modules were developed at Australia's University of NSW. For example, a particular, higher efficiency version of the solar cell (which is the core electrical generating component of the solar module) known as the PERC cell (passivated emitter rear cells) was invented by University of NSW researchers. The PERC cell technology was used in a quarter of all solar modules produced in 2017. By 2022 it is expected to be the dominant cell type used by manufacturers as the major producers are shifting their production plants to PERC technology over the next few years. Furthermore, a number of the executives that were the pioneers in establishing China's now dominant solar production received their technical training in solar technology at the University of NSW.

So, Australia certainly has the know-how to produce both solar modules, and the major inputs to modules, as well as inverters. Also it's worth noting that production of these products is typically highly automated, so labour costs are not the determining factor of competitiveness.

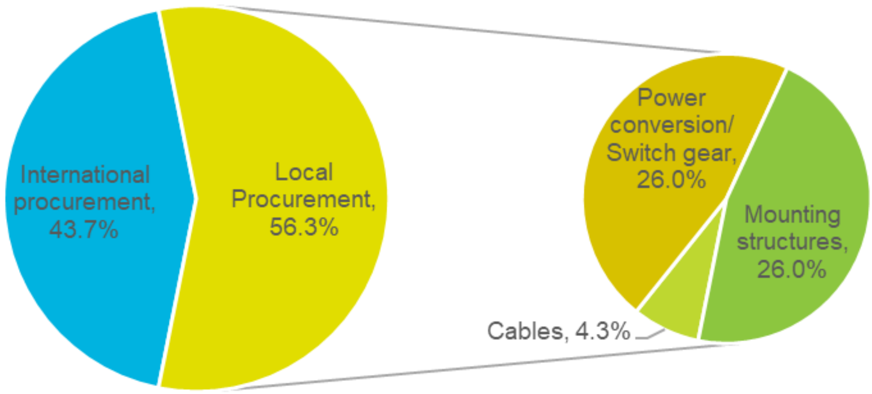
However, production of these products are subject to substantial economies of scale. Individual production plants for modules and solar cell will often have annual production capacities greater than Australia's entire annual demand for solar PV. As an indicator of the scale involved, in just the month of November 2017, solar manufacturers announced annual production capacity expansions of 20,000 megawatts[5]. By way of comparison Queensland entire fossil fuel generating fleet is less than 12,000MW. If Australia was to establish competitive manufacturing facilities it would have to be focussed on export and it would require very large, long term capital commitments to achieve the necessary economic scale.

In terms of some of the other components, there are a range of Australian companies involved in metal fabrication that could produce the racking and framing for solar farms. As an example the company IXL, which had been a supplier to Australian car manufacturers was the supplier of the racking for Australia's first 3 significant solar farms – Greenough River, Broken Hill and Nyngan. Also Australian manufacturer Wilson Transformers provided transformers for Broken Hill and Nyngan.

First Solar provided a breakdown in Figure 3-1 of the proportion of equipment costs outside of the solar module that were spent on international versus local equipment in the construction of Broken Hill and Nyngan Solar Farms.

[5] PVTech (2018) Solar manufacturing capacity expansion announcements in Q1 2018, reached 24.8GW, https://www.pv-tech.org/editors-blog/solar-manufacturing-capacity-expansion-announcements-in-q1-2018-reached-24

Figure 3-1 Breakdown of locally versus internationally sourced equipment (non-module) used in Broken Hill and Nyngan Solar Farms



Source: First Solar (2016) Industry Development and Job Creation in Australia

3.3 Equipment manufacture - wind

A wind farm is made up of the following major components:

- Generator, gear box and nacelle housing;
- Turbine blades;
- Tower;
- Foundations;
- Transformers; and
- Electrical wiring and switching gear

The generator, associated gear box and turbine blades are all imported at present. Australia had a wind turbine blade manufacturing facility in Portland operating in the mid 2000's. However, with the Federal Government at the time ruling out any long-term commitment to expanding renewable energy, Vestas was unable to justify continuing to operate the facility. Major producers of the wind turbine generators and blades include the United States, Germany, Denmark, China, Italy, and Spain.

The turbines tend to make up about 60% of the overall capital cost of the wind farm, with the remainder of the cost made up of equipment and services which can either only be supplied locally or have the ability to be met by Australian suppliers.

A number of wind farms constructed in recent times have had their towers manufactured in Australia. While towers are also imported, as recently as 2012, 80% of all wind farm towers had been manufactured locally. Wilson Transformers has also been engaged by a number of wind farms to supply transformer equipment even though they face challenging competition from overseas suppliers.

Unfortunately, the stop-start and highly uncertain nature of energy and climate change policy in Australia has made it difficult for renewable energy product suppliers to plan and invest to service the recent renewable energy construction boom. Long term Investment commitments are especially difficult when the policy outlook and likely future build of renewable energy capacity remains incredibly uncertain beyond the next two years.

Foundations are as you would expect constructed on site while the electrical components and switching gear are composed of a mixture of local and imported equipment.

3.4 Estimating employment from renewable energy projects

In this study, the amount of employment created during the construction of a new renewable energy power plant is measured in job years. If 50 people worked full time for 6 months to build a solar farm, that would be the equivalent of 25 job years (50 people multiplied by 0.5 years = 25 job years).

1 job year = one person working a standard 37.5-hour work week for one year minus four weeks annual leave plus public holidays.

Once the renewable energy power plant is built and starts to generate electricity, the amount of ongoing employment in operation and maintenance is measured in full time equivalents (FTE).

1 FTE = one full-time job (37.5 hours per week with 4 weeks annual leave and public holidays, ongoing for the life of the power station).

There are a number of different ways to calculate the total amount of employment created by new renewable energy power plants. The company that is developing a new plant often puts forward their own figures for how many jobs it will create - however companies will often adopt different ways of measuring a single job created by the project. This might be the same as the approach used in this report of a job-year, but sometimes if might be the average number of people on site over the life of the construction project which might last 9 months in the case of a small solar farm or maybe as a long as 2 years in the case of a hydro project or large wind farm.

To provide a more consistent estimate, this study uses the following basis for calculating the average amount of employment created per megawatt of large scale renewable energy generation capacity by fuel type:

Wind Farms

For wind farms we assume they require an average of 1.22 people full-time in construction per megawatt of capacity over an 18 month duration. Most of these people will be on-site but some will work mainly offsite in an engineering, supporting or supervisory role in the construction company, the wind turbine supplier and the company that is financing and owns the project. In addition to this employment we also take into account some employment in wind tower manufacture which adds a further 0.8 of a job year per megawatt of capacity. This is based on a review of employment estimates from a range of Australian wind farms and data on employment involved in tower manufacture[6].

Ongoing operations and maintenance employment was sourced from ROAM Consulting/Ernst & Young research undertaken for the Clean Energy Council which estimated 0.1 FTEs per megawatt installed.[7]

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[6] This employment estimate per megawatt is noticeably lower than the job factors used by the Australian Bureau of Statistics for its assessment of renewable energy employment and a prior study undertaken for the Clean Energy Council by ROAM Consulting (both of which have informed Green Energy Market's prior editions of the Renewable Energy Index). Discussions with industry participants indicate that with the increasing megawatt capacity of individual wind turbines and possibly some scale and learning effects in Australia's construction industry, wind farms can be constructed faster and with less labour than what occurred in the past.

[7] ROAM Consulting (2014) Report of the Clean Energy Council – RET Policy Analysis

Solar farms

For solar farms we assume they require an average of 2.2 people working full time in construction per megawatt of capacity over a 12 month duration. Again, like wind farms most of these people will be on site but with a some offsite in an engineering, supporting or supervisory role in the construction company, the technology suppliers and the company that is financing and owns the project. This estimate is based on discussions with solar PV industry participants.

Ongoing operations and maintenance employment was sourced from ROAM Consulting/Ernst & Young research undertaken for the Clean Energy Council which estimated 0.1 FTEs per megawatt installed[8].

Hydro-electric plants

Construction employment was sourced from analysis undertaken by University of Technology Sydney for the Climate Institute which estimates 3 job years per megawatt. Ongoing operations and maintenance employment was also sourced from this study which estimates 0.2 FTEs per megawatt[9].

Bioenergy plants

Construction employment was sourced from analysis undertaken by University of Technology Sydney for the Climate Institute which estimates 2 job years per megawatt. Ongoing operations and maintenance employment was also sourced from this study which estimates 1 FTE per megawatt[10]. Bioenergy has noticeably higher operations and maintenance employment due to the need to gather and process the biomass fuel supply, the smaller size of the power plants and the nature of their thermal combustion technology which requires greater maintenance than other renewable technologies that don’t involve high temperature combustion to create electrical energy and involve less moving parts.

[8] ROAM Consulting (2014) Report of the Clean Energy Council – RET Policy Analysis
[9] Climate Institute (2011) Clean Energy Jobs in Regional Australia - Methodology
[10] Climate Institute (2011) Clean Energy Jobs in Regional Australia - Methodology

4 Regional Profiles – Mackay-Whitsunday

4.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 46 full time jobs across the Mackay-Whitsunday region. The total installed base of solar systems across the region indicates that around 22% of all residential dwellings have a solar system installed.

Table 4-1 Uptake of rooftop solar PV in Townsville-Dry Tropics Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
16,289	22%	71	98,184	77,565

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator. Number of dwellings taken from the 2016 Census.

4.2 Utility-scale projects

Utility-scale renewable energy projects in the region have so far centred within the region's sugar mills where they produced power and heat from the waste residue from sugar production (bagasse) as well as other bioenergy waste material. These projects are expected to produce an average of just over 300,000MWh per annum, which is equivalent to the annual electricity consumption of 57,535 Queensland households.

Table 4-2 Operational large-scale power projects in Mackay-Whitsunday Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bagasse	5	110	301,486	238,174	57,535

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

In addition to these projects that are already operational, Table 4-3 details that there are another 19 projects either in construction or under development in the region. These projects' 2,393 megawatts of capacity are capable of producing 6.3m megawatt-hours per annum. This is equal to 11.9% of Queensland's entire 2017 annual electricity consumption, and equivalent to the annual average electricity consumption of nearly 1.2m Queensland households.

Table 4-3 Projects under construction and development in Mackay-Whitsunday Region

	Solar		Wind	
	No. plants	MW	No. Plants	MW
Under construction	7	498	-	-
Development - planning approved	6	496	1	800
Development - yet to be approved	6	600	-	-
TOTAL	19	1,593	1	800
Annual generation (MWh)	3,828,041		2,452,800	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 4-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $4.1 billion of investment in these projects could be expected to support 5,585 job years of employment building these projects plus 239 ongoing full time jobs.

Table 4-4 Employment, investment and emissions abatement flowing from projects under construction and development in Mackay-Whitsunday Region[11]

	Solar	Wind	TOTAL
Construction employment (job-years)	3,505	2,080	**5,585**
Operations employment (FTE)	159	80	**239**
Investment ($m)	$2,390	$1,680	**$4,070**
Equivalent households powered	730,542	468,092	**1,198,634**
CO2 avoided (tonnes)	3,024,152	1,937,712	**4,961,864**

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[11] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

5 Regional Profiles – Townsville and the Dry Tropics

5.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 68 full time jobs across the Townsville Dry Tropics region. The total installed base of solar systems across the region indicates that around 28% of all residential dwellings have a solar system installed.

Table 5-1 Uptake of rooftop solar PV in Townsville-Dry Tropics Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
27,386	28%	119	163,811	129,411

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

5.2 Utility-scale projects

Until just recently the utility-scale renewable energy projects in the region were centred within the region's sugar mills, where they produced power and heat from the waste residue from sugar production (bagasse) as well as other bioenergy waste material. These projects still represent the bulk of electricity production, but have been joined by 3 solar farms. We estimate that construction of these 3 solar farms created 374 job-years of employment over 2016 to 2018. Altogether these 9 operational projects are expected to produce about 939,496 MWh per year on average, which is equivalent to the electricity consumption of just over 179,000 average Queensland homes.

Table 5-2 Operational large-scale power projects in Townsville-Dry Tropics Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bagasse	6	172	544,998	430,548	104,007
Solar	3	170	394,498	311,653	75,286
TOTAL	9	342	939,496	736,043	179,293

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

In addition to these projects that are already operational, Table 5-3 details that there are another 18 projects either in construction or under development in the region. These projects' 3,335 megawatts of capacity are capable of producing 8.2m megawatt-hours per annum (excluding pumped-hydro which is a net consumer of electricity). This is equal to 15.6% of Queensland's entire annual electricity consumption in 2017 and equivalent to the annual average electricity consumption of nearly 1.6m Queensland households.

Table 5-3 Projects under construction and development in Townsville-Dry Tropics

	Solar		Wind		Hydro		Bioenergy	
	No. plants	MW	No. Plants	MW	No. plants	MW	No. plants	MW
Under construction	4	355	1	43	-	-	-	-
Development - planning approved	6	1,175	1	75	-	-	-	-
Development - yet to be approved	-	-	2	1,350	3	320	1	16
TOTAL	10	1,530	4	1,468	3	320	1	16
Annual generation (MWh)	3,657,678		4,512,854		65,700		56,064	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 5-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $6.4 billion of investment in these projects could be expected to support 8,176 job years of employment building these projects plus 380 ongoing full-time jobs.

Table 5-4 Employment, investment and emissions abatement flowing from projects under construction and development in Townsville-Dry Tropics region[12]

	Solar	Wind	Hydro	Bioenergy	TOTAL
Construction employment (job-years)	3,367	3,817	960	32	**8,176**
Operations employment (FTE)	153	147	64	16	**380**
Investment ($m)	$2,296	$3,083	$960	$50	**$6,388**
Equivalent households powered	698,030	861,232	12,538	10,699	**1,582,499**
CO2 avoided (tonnes)	2,889,566	3,565,155	51,903	44,291	**6,550,914**

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

Worth noting is that the Kennedy Energy Park's wind and solar farm under construction in the region will also incorporate a substantial battery system of 2MW peak output and 4 megawatt-hours of energy storage. The employment associated with installing this system has not been estimated. In addition, we understand there are investigations into the potential to establish a solar thermal power plant in the region. However, because a specific site is yet to be confirmed it has not been included in the estimates within our tables.

5.3 Battery manufacturing

The other major development of interest that is an extension of the global move towards renewable energy is the proposal to establish a battery manufacturing facility in Townsville. The Imperium3 consortium, which includes a battery technology company called Boston Energy and industrial equipment manufacturer Siemens, is proposing a 15-gigawatt-hour per annum production plant plus space for associated component

[12] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

manufacturers to set up nearby. According to the consortium the facility would create up to 1000 direct jobs, plus an additional 1000 jobs in direct support businesses. In April 2017 the Townsville City Council signed a memorandum of understanding with Boston Energy to investigate the financial viability of the project and has offered land at the former CSIRO Lansdown research station at Woodstock. In addition, the Queensland Government committed $3.1 million towards a feasibility study to evaluate a potential battery factory in Townsville.

6 Regional Profiles – Far North Queensland

6.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 77 full time jobs across the Far North Queensland region. The total installed base of solar systems across the region indicates that around 21% of all residential dwellings have a solar system installed.

Table 6-1 Uptake of rooftop solar PV in Far North Queensland Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
23,635	21%	107	147,359	116,414

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

6.2 Utility-scale projects

The Far North has a mixture of operational projects across Bionergy (all sugar mills), Hydro, a small and relatively old wind farm, and more recently two solar farms (at the Weipa Mine and the hybrid battery installation at Lakeland near Cooktown). Altogether these 12 operational projects are expected to produce 990,000 MWh per year on average, which is equivalent to the electricity consumption of 189,000 average Queensland homes.

Table 6-2 Operational large-scale power projects in Far North Queensland Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bioenergy	5	68.6	163,708	129,329	31,242
Hydro	4	160.9	772,709	610,440	147,464
Solar	2	12.5	26,630	21,038	5,082
Wind	1	12.0	27,814	21,973	5,308
TOTAL	12	254.0	990,861	782,781	189,096

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

In addition to these projects that are already operational, Table 6-3 details that there are another 11 projects either in construction or under development in the region. These projects' 1,758 megawatts of capacity are capable of producing 4.6m megawatt-hours per annum. This is equal to 8.7% of Queensland's entire annual electricity consumption and equivalent to the annual average electricity consumption of just under 880,000 Queensland households.

Table 6-3 Projects under construction and development in Far North Queensland

	Solar		Wind		Bioenergy	
	No. plants	MW	No. Plants	MW	No. plants	MW
Under construction	-	-	1	181	1	24
Development - planning approved	4	207	2	234	1	32
Development - yet to be approved	1	1,000	1	80	-	-
TOTAL	5	1,207	4	495	2	56
Annual generation (MWh)	2,854,796		1,517,363		238,272	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 6-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $3 billion of investment in these projects could be expected to support 4,054 job years of employment building these projects plus 226 ongoing full-time jobs.

Table 6-4 Employment, investment and emissions abatement flowing from projects under construction and development in Far North Queensland region[13]

	Solar	Wind	Bioenergy	TOTAL
Construction employment (job-years)	2,655	1,287	112	**4,054**
Operations employment (FTE)	121	49	56	**226**
Investment ($m)	$1,811	$1,039	$174	**$3,024**
Equivalent households powered	544,808	289,573	45,472	**879,853**
CO2 avoided (tonnes)	2,255,289	1,198,717	188,235	**3,642,241**

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[13] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

7 Regional Profiles – Darling Downs

7.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 62 full time jobs across the Darling Downs region. The total installed base of solar systems across the region indicates that around 27% of all residential dwellings have a solar system installed.

Table 7-1 Uptake of rooftop solar PV in Darling Downs Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
28,585	27%	114	159,526	126,026

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

7.2 Utility-scale projects

The Darling Downs region has just 2 relatively small utility-scale projects operating at present. A power plant utilising agricultural waste at Tong Park and a solar system installed at University of Queensland's Toowoomba campus. These projects are expected to produce almost 6,000 MWh per year on average, which is equivalent to the electricity consumption of 1,132 average Queensland homes.

Table 7-2 Operational large-scale power projects in Darling Downs Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bioenergy	1	1.2	4,303	3,399	821
Solar	1	1.1	1,631	1,288	311
TOTAL	2	2.3	5,934	4,688	1,132

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

However, the region will soon be home to 5 substantial solar farms and the second largest wind farm in the country at Coopers Gap. Table 7-3 also details that there are another 12 under development in the region. These projects' 5,032 megawatts of capacity are capable of producing 12.4m megawatt-hours per annum. This is equal to 23.4% of Queensland's entire annual electricity consumption and equivalent to the annual average electricity consumption of nearly 2.4m Queensland households.

Table 7-3 Projects under construction and development in Darling Downs

	Solar		Wind	
	No. plants	MW	No. Plants	MW
Under construction	5	310	1	453
Development - planning approved	11	4,255	1	14
Development - yet to be approved	-	-	-	-
TOTAL	16	4,565	2	467
Annual generation (MWh)	10,838,236		1,551,698	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 7-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $7.8 billion of investment in these projects could be expected to support 11,256 job years of employment building these projects plus 503 ongoing full time jobs.

Table 7-4 Employment, investment and emissions abatement flowing from projects under construction and development in Darling Downs region[14]

	Solar	Wind	TOTAL
Construction employment (job-years)	10,043	1,213	**11,256**
Operations employment (FTE)	456	47	**503**
Investment ($m)	$6,847	$980	**$7,827**
Equivalent households powered	2,068,366	296,125	**2,364,491**
CO2 avoided (tonnes)	8,562,206	1,225,841	**9,788,048**

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[14] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

8 Regional Profiles – Wide-Bay Burnett

8.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 89 full time jobs across the Wide-Bay Burnett region. The total installed base of solar systems across the region indicates that around 35% of all residential dwellings have a solar system installed which is the highest of any region in the State.

Table 8-1 Uptake of rooftop solar PV in Wide-Bay Burnett Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO_2 Savings (tonnes)
44,867	35%	154	212,421	167,812

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

8.2 Utility-scale projects

The main source of renewable energy in the Wide-Bay Burnett region has historically been bagasse residue from 3 sugar mills. The region also has a small landfill gas plant and also a power plant producing power from waste macadamia nut shells and a small hydro plant. Altogether these 6 operational projects are expected to produce about 77,000 MWh per year on average, which is equivalent to the electricity consumption of 14,706 average Queensland homes.

Table 8-2 Operational large-scale power projects in Wide-Bay Burnett Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO_2 (tonnes)	Households powered
Bioenergy	5	40.0	76,304	60,280	14,562
Hydro	1	2.7	756	597	144
TOTAL	6	42.7	77,061	60,878	14,706

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

Table 8-3 details that there are another 8 projects either in construction or under development in the region. These projects' 934 megawatts of capacity are capable of producing almost 2.2m megawatt-hours per annum. This is equal to 4.1% of Queensland's entire annual electricity consumption and equivalent to the annual average electricity consumption of 418,466 Queensland households.

Table 8-3 Projects under construction and development in Wide-Bay Burnett region

	Solar	
	No. plants	**MW**
Under construction	2	173
Development - planning approved	3	610
Development - yet to be approved	3	151
TOTAL	8	934
Annual generation (MWh)	2,192,759	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 8-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $6.4 billion of investment in these projects could be expected to support 2,054 job years of employment building these projects plus 93 ongoing full time jobs.

Table 8-4 Employment, investment and emissions abatement flowing from projects under construction and development in Wide-Bay Burnett region[15]

	Solar
Construction employment (job-years)	2,054
Operations employment (FTE)	93
Investment ($m)	$1,400
Equivalent households powered	418,466
CO2 avoided (tonnes)	1,732,280

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

15 *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

9 Regional Profiles – Central Queensland

9.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 51 full time jobs across the Central Queensland region. The total installed base of solar systems across the region indicates that around 24% of all residential dwellings have a solar system installed.

Table 9-1 Uptake of rooftop solar PV in Central Queensland Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
23,107	24%	91	126,383	99,842

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

9.2 Utility-scale projects

Central Queensland has just one operational renewable energy project, powered by landfill gas which is expected 6,132 MWh per year on average, equivalent to the electricity consumption of 1,170 average Queensland homes.

Table 9-2 Operational large-scale power projects in Central Queensland Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bioenergy	1	1.0	6,132	4,844	1,170
TOTAL	1	1.0	6,132	4,844	1,170

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

Table 9-3 details that there are another 12 solar projects either in construction or under development in the region. These projects' 2,021 megawatts of capacity are capable of producing 4.8m megawatt-hours per annum. This is equal to 9.1% of Queensland's entire annual electricity consumption and equivalent to the annual average electricity consumption of 916,707 Queensland households.

Table 9-3 Projects under construction and development in Central Queensland region

	Solar	
	No. plants	MW
Under construction	2	168
Development - planning approved	5	976
Development - yet to be approved	5	877
TOTAL	12	2,021
Annual generation (MWh)	4,803,546	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 9-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. The $3 billion of investment in these projects could be expected to support 4,446 job years of employment building these projects plus 202 ongoing full-time jobs.

Table 9-4 Employment, investment and emissions abatement flowing from projects under construction and development in Central Queensland region[16]

	Solar
Construction employment (job-years)	4,446
Operations employment (FTE)	202
Investment ($m)	$3,032
Equivalent households powered	916,707
CO2 avoided (tonnes)	3,794,801

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[16] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

10 Regional Profiles – South East Queensland

10.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 809 full time jobs across the South East Queensland region. The total installed base of solar systems across the region indicates that around 30% of all residential dwellings have a solar system installed.

Table 10-1 Uptake of rooftop solar PV in South-East Queensland Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO2 Savings (tonnes)
390,273	30%	1,385	1,914,557	1,512,500

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

10.2 Utility-scale projects

Outside of the very large installed base of rooftop solar in the densely populated South-East, it also has 17 operational renewable energy projects above a megawatt in scale. This is dominated in capacity terms by the 500MW Wivenhoe Hydro facility which incorporates pumping capability. However, the Wivenhoe facility has historically not been operated close to its capacity due to a large excess of coal generation in Queensland that substantially exceeds average demand. Interestingly the solar plants, which are a small fraction of Wivenhoe, generate almost three times the electricity. Although most of the renewable energy comes from the ten bioenergy plants – with about half the electricity coming from landfill gas and the other half from the Rocky Point facility which is fuelled by a variety of biomass waste materials. The combined annual average generation of 229,145 MWh is equivalent to the consumption of 43,730 average Queensland households.

Table 10-2 Operational large-scale power projects in South-East Queensland Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO2 (tonnes)	Households powered
Bioenergy	10	49.1	182,673	144,312	34,861
Hydro	1	500.0	12,241	9,670	2,336
Solar	6	22.6	34,231	27,043	6,533
TOTAL	17	572	229,145	181,025	43,730

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

Table 10-3 details that there is another 6MW project in construction and another 3 under development in the region. These projects' 1,521 megawatts of capacity are capable of producing almost 3.6m megawatt-hours per annum. This is equal to 6.8% of Queensland's entire annual electricity consumption and equivalent to the annual average electricity consumption of 685,437 Queensland households.

Table 10-3 Projects under construction and development in South-East Queensland region

	Solar	
	No. plants	MW
Under construction	1	6
Development - planning approved	1	10
Development - yet to be approved	2	1,505
TOTAL	4	1,521
Annual generation (MWh)	3,591,688	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 10-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. The $2.3 billion of investment in these projects could be expected to support 3,346 job years of employment building these projects plus 152 ongoing full time jobs.

Table 10-4 Employment, investment and emissions abatement flowing from projects under construction and development in South-East Queensland region[17]

	Solar
Construction employment (job-years)	3,346
Operations employment (FTE)	152
Investment ($m)	$2,282
Equivalent households powered	685,437
CO2 avoided (tonnes)	2,837,433

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[17] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

11 Regional Profiles – Western Queensland

11.1 Rooftop solar

Over 2017 we estimate rooftop solar installations supported 8 full time jobs across the Western Queensland region. The total installed base of solar systems across the region indicates that around 34% of all residential dwellings have a solar system installed, which is the second highest in the state.

Table 11-1 Uptake of rooftop solar PV in Western Queensland Region

Number of installations	Proportion of dwellings with solar	Capacity (MWs)	Estimated Generation (MWh)	CO_2 Savings (tonnes)
3,935	34%	22	33,422	26,403

Sources: Number of installations, capacity and generation derived by data published by the Clean Energy Regulator as at March 2018. Number of dwellings taken from the 2016 Census.

11.2 Utility-scale projects

Due to its superior solar resource the Western Queensland Region has led the state in the establishment of solar farms, with 5 in operation. These were all constructed within the past 2 years and we estimate created 104 job-years of employment. Altogether these solar farms are expected to produce about 111,194 MWh per year on average, which is equivalent to the electricity consumption of 21,220 average Queensland homes.

Table 11-2 Operational large-scale power projects in Western Queensland Region

Fuel type	No. plants	MW	Annual generation (MWh)	Avoided CO_2 (tonnes)	Households powered
Solar	5	47.1	111,194	87,844	21,220
TOTAL	5	47.1	111,194	87,844	21,220

Sources: Number of projects, their capacity and generation from Green Energy Markets Power Plant Register. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.

In addition to these projects that are already operational, Table 11-3 details that there are another 2 projects in construction and another 3 under development in the region. These projects' 89 megawatts of capacity are capable of producing 207,262 megawatt-hours per annum which is equivalent to the annual average electricity consumption of almost 40,000 Queensland households.

Table 11-3 Projects under construction and development in Western Queensland region

	Solar	
	No. plants	MW
Under construction	2	4
Development - planning approved	2	55
Development - yet to be approved	1	30
TOTAL	5	89
Annual generation (MWh)	207,262	

Source: Green Energy Markets Power Plant Register for project capacity and generation.

Table 11-4 provides estimates of the employment, investment and emissions abatement these projects could be expected to provide if they were all to proceed. All up the $134 million of investment in these projects could be expected to support 196 job years of employment building these projects plus 9 ongoing full-time jobs.

Table 11-4 Employment, investment and emissions abatement flowing from projects under construction and development in Western Queensland region[18]

	Solar
Construction employment (job-years)	196
Operations employment (FTE)	9
Investment ($m)	$134
Equivalent households powered	39,554
CO2 avoided (tonnes)	163,737

Note: job estimates indicated above are not taken from specific estimates for each project cited by developers due to inconsistent methods for estimating a single job between companies. See section 3.4 for information on how employment is estimated.

[18] *Sources: See section 3.4 for information on how employment is estimated. Avoided CO2 based on generation displacing the average grid emissions intensity of Queensland electricity according to the Australian Government's National Greenhouse Accounts Factors – July 2017. Households powered derived on the average Queensland household's annual electricity consumption according to the Australian Energy Market Commission's 2017 Residential Electricity Price Trends publication.*

12 Appendix A – Definitions of regional boundaries

The regional areas referred to in this report are shown in Figure 12-1 overleaf.

The Local Government Areas included in each region are listed below with (C) denoting a Council; (R) denoting a Regional Council; and (S) denoting a Shire

South East Queensland

Brisbane (C); Redland (C); Moreton Bay (R); Logan (C); Ipswich (C); Sunshine Coast (R); Noosa (S); Gold Coast (C); Scenic Rim; Somerset; Lockyer Valley

Darling Downs - Condamine

Toowoomba; Southern Downs; Goondiwindi; Western Downs; Maranoa (R); Balonne (S)

Wide-Bay Burnett

Gympie; Fraser Coast; Bundaberg (R); North Burnett (R); South Burnett

Central Queensland

Gladstone (R); Rockhampton (R); Livingstone (S); Banana (S); Woorabinda (S); Central Highlands (R)

Mackay-Whitsunday

Mackay (R); Whitsunday (R); Isaac (R)

Townsville - Dry Tropics

Townsville (C); Hinchinbrook (S); Burdekin (S); Charters Towers (R); Palm Island (S); Etheridge (S); Flinders (S)

Far North Queensland

Cairns (R); Yarrabah (S); Douglas (S); Mareeba (S); Cook (S); Cassowary Coast (R); Tablelands (R); Torres Strait Island (R); Weipa (T); Torres (S); Northern Peninsula Area (R); Aurukun (S); Kowanyama (S); Hope Vale (S); Pormpuraaw (S); Lockhart River (S); Mapoon (S); Wujal Wujal (S)

Western Queensland

Paroo (S); Bulloo (S); Murweh (S); Barcoo (S); Quilpie (S); Blackall-Tambo (R); Barcaldine (R); Longreach (R); Boulia (S); Winton (S); Diamantina (S); Richmond (S); Burke (S); Croydon (S); McKinlay (S); Doomadgee (S); Cloncurry (S); Mount Isa (C); Carpentaria (S); Mornington (S)

Figure 12-1 Geographical boundaries defining regions used in this report

The Local Government Areas included in each region are listed below with (C) denoting a Council; (R) denoting a Regional Council; and (S) denoting a Shire

South East Queensland

Brisbane (C); Redland (C); Moreton Bay (R); Logan (C); Ipswich (C); Sunshine Coast (R); Noosa (S); Gold Coast (C); Scenic Rim; Somerset; Lockyer Valley

Darling Downs - Condamine

Toowoomba; Southern Downs; Goondiwindi; Western Downs; Maranoa (R); Balonne (S)

Wide-Bay Burnett

Gympie; Fraser Coast; Bundaberg (R); North Burnett (R); South Burnett

Central Queensland

Gladstone (R); Rockhampton (R); Livingstone (S); Banana (S); Woorabinda (S); Central Highlands (R)

Mackay-Whitsunday

Mackay (R); Whitsunday (R); Isaac (R)

Townsville - Dry Tropics

Townsville (C); Hinchinbrook (S); Burdekin (S); Charters Towers (R); Palm Island (S); Etheridge (S); Flinders (S)

Far North Queensland

Cairns (R); Yarrabah (S); Douglas (S); Mareeba (S); Cook (S); Cassowary Coast (R); Tablelands (R); Torres Strait Island (R); Weipa (T); Torres (S); Northern Peninsula Area (R); Aurukun (S); Kowanyama (S); Hope Vale (S); Pormpuraaw (S); Lockhart River (S); Mapoon (S); Wujal Wujal (S)

Western Queensland

Paroo (S); Bulloo (S); Murweh (S); Barcoo (S); Quilpie (S); Blackall-Tambo (R); Barcaldine (R); Longreach (R); Boulia (S); Winton (S); Diamantina (S); Richmond (S); Burke (S); Croydon (S); McKinlay (S); Doomadgee (S); Cloncurry (S); Mount Isa (C); Carpentaria (S); Mornington (S)

13 Appendix B – Listing of large-scale renewable energy projects in Queensland

Table B-1. Operating large scale renewable energy plants May 2018

Fuel type	Project Name	Company	Capacity (MW)	Locality
Far North Queensland				
Bagasse	Mossman Mill	Mackay Sugar Limited	11.85	Mossman
Bagasse	Mulgrave Mill	The Mulgrave Central Mill Co Ltd	9	Mulgrave
Bagasse	South Johnstone Sugar Mill	The Maryborough Sugar Factory Limited	19.3	South Johnstone
Bagasse	Tableland Mill	The Maryborough Sugar Factory Limited	7	Arriga
Bagasse	Tully Sugar Mill	Tully Sugar Limited	21.4	Tully
Hydro	Barron Gorge Hydro	Stanwell Corporation Limited	66	Kuranda
Hydro	Kareeya Hydro	Stanwell Corporation Limited	86	Tully
Hydro	Koombooloomba Hydro	Stanwell Corporation Limited	7.3	Tully
Hydro	Tinaroo Hydro	Sunwater Limited	1.6	Tinaroo
Solar	Lakeland Solar & Storage	Lakeland Solar & Storage Pty Ltd	10.8	Lakeland
Solar	Weipa Solar Farm	Weipa Solar Farm Pty Ltd	1.7	Weipa
Wind	Windy Hill	Windy Hill Wind Farm Pty Ltd	12	Ravenshoe
Mackay-Whitsunday				
Bagasse	Farleigh Mill	Mackay Sugar Limited	13	Farleigh
Bagasse	Marian Mill	Mackay Sugar Limited	18	Marian
Bagasse	Plane Creek Mill	Wilmar Sugar Pty LTd	14	Sarina
Bagasse	Proserpine Sugar Mill	Wilmar Sugar Pty LTd	17	Proserpine
Bagasse	Racecourse Mill	Mackay Sugar Limited	48	Racecourse
South East Queensland				
Bagasse	Rocky Point Sugar Mill	FPC 30 Limited	30	Woongoolba
Hydro	Wivenhoe Hydro	Stanwell Corporation Limited	500	Wivenhoe Pocket
Landfill gas	Browns Plains LFG Power Plant	EDL LFG (Qld) Pty Ltd	2.18	Heritage Park
Landfill gas	Caboolture LFG	LGI Limited	2.134	Caboolture

Landfill gas	Rochedale LFG	LMS Energy Pty Ltd	4.492	Rochedale
Landfill gas	Stapylton LFG	LMS Energy Pty Ltd	2.1	Stapylton
Landfill gas	Ti Tree LFG Willowbank	Veolia Environmental Services (Australia) Pty Ltd	3.3	Willowbank
Solar	Gatton Solar Research Facility	The University of Queensland	3.275	Gatton
Solar	Sunshine Coast Solar Farm	Sunshine Coast Regional Council	15	Valdora
Townsville - Dry Tropics				
Bagasse	Inkerman Mill	Wilmar Sugar Pty LTd	12.5	Home Hill
Bagasse	Invicta Mill	Wilmar Sugar Pty LTd	50.3	Giru
Bagasse	Kalamia Mill	Wilmar Sugar Pty LTd	9	Brandon
Bagasse	Macknade Mill	Wilmar Sugar Pty LTd	8	Macknade
Bagasse	Pioneer Mill	Wilmar Sugar Pty LTd	67.8	Brandon
Bagasse	Victoria Mill	Wilmar Sugar Pty LTd	24	Victoria Plantation
Solar	Clare Solar Farm	Clare Solar Farm Pty Ltd	100	Clare
Solar	Hughenden Solar Farm	BayWa R.E. Solar Project Pty Ltd	20	Hughenden
Solar	Kidston Solar One	Genex (Solar) Pty Ltd	50	Einsleigh
Western Queensland				
Solar	Barcaldine Solar Farm	Barcaldine Remote Community Solar Farm Pty Ltd	20	Barcaldine
Solar	Dunblane Solar A	Kinelli Pty Ltd	3.8	Barcaldine
Solar	Dunblane Solar B	Kinelli Pty Ltd	3.8	Barcaldine
Solar	Longreach Solar Farm	Diamond Energy Pty Ltd	15	Longreach
Solar	Normanton Solar Farm	Normanton Solar farm Pty Ltd	4.5	Normanton
Wide-Bay Burnett				
Bagasse	Isis Central Sugar Mill	ISIS Central Sugar Mill Co Ltd	25	Isis Central
Bagasse	Maryborough Sugar Factory	The Maryborough Sugar Factory Limited	7.5	Maryborough
Bagasse	Millaquin Sugar Mill	Bundaberg Sugar Ltd	5	Bundaberg North
Hydro	Paradise Dam Mini Hydro	Burnett Water Pty Ltd	2.7	Coringa

Note: projects under 2 MW capacity not included in this table

Table B-2. Large scale renewable energy projects under construction May 2018

Fuel type	Project Name	Company	Capacity (MW)	Locality
Central Queensland				
Solar	Emerald Solar Farm	RES	68	Emerald
Solar	Lilyvale Solar Farm	Fotowatio Renewable Ventures	100	Tieri
Darling Downs - Condamine				
Solar	Darling Downs Solar Farm	APA Group	110	Beelbee
Solar	Chinchilla Solar Farm	Impact Investment Group	19.9	Chinchilla
Solar	Oakey 2 Solar Farm	Foresight Group	55	Oakey
Solar	Oakey Solar Farm	Canadian Solar (Australia)	25	Oakey
Solar	Yarranlea Solar Farm	Risen Energy	100	Yarranlea
Wind	Coopers Gap Wind Farm	AGL	453	Cooranga
Far North Queensland				
Bagasse	Tableland Mill upgrade	The Maryborough Sugar Factory Limited	24	Arriga
Wind	Mount Emerald	RATCH - AUSTRALIA	180.5	Walkamin
Mackay-Whitsunday				
Solar	Clermont Solar Farm	Wirsol	75	Clermont
Solar	Collinsville Solar Power Station	RATCH Australia Corporation	42.5	Collinsville
Solar	Daydream Solar Farm	Edify Energy	150	Collinsville
Solar	Hamilton Solar Farm	Edify Energy and Wirsol	57.5	Collinsville
Solar	Hayman Solar Farm	Edify Energy	50	Collinsville
Solar	Rugby Run	Adani Renewables	65	Moranbah
Solar	Whitsunday Solar Farm	Edify Energy and Wirsol	57.5	Collinsville
South East Queensland				
Solar	Brisbane Airport	Epho Pty Ltd	6	Brisbane City
Townsville - Dry Tropics				
Solar	Haughton Solar Farm stage 1	Pacific Hydro	100	Upper Haughton
Solar	Kennedy Energy Park - Solar	Windlab	15	Hughenden
Wind	Kennedy Energy Park - Wind	Windlab	43.2	Hughenden
Solar	Ross River Solar Farm	ESCO Pacific & Palisade Investment Partners	116	Kelso

Solar	Sun Metals -Solar- Qld	Sun Metals Corporation Pty Ltd	124.4	Stuart
Western Queensland				
Solar	Doomadgee 1MW Upgrade	Ergon Energy	1	Doomadgee
Solar	South32 Cannington Silver and Lead Mine	South32/Energy Developments	3	Mckinlay
Wide-Bay Burnett				
Solar	Childers Solar Farm	Elliott Advisers	75	Childers
Solar	Susan River Solar Farm	Elliott Advisers	98	Susan River

Table B-3. Large scale renewable energy projects in the development pipeline May 2018

Fuel type	Project Name	Company	Capacity (MW)	Locality
Central Queensland				
Solar	Baralaba Solar Farm	Fotowatio Renewable Ventures	100	BARALABA
Solar	Bluff Solar Farm	Infigen Energy	100	BLUFF
Solar	Crinum Creek	Adani Renewables	100	TIERI
Solar	Bouldercombe Solar Farm	Eco Energy World	280	BOULDERCOMBE
Solar	Tieri Solar Farm	Fotowatio Renewable Ventures	96	TIERI
Solar	Comet Solar Farm	Hadstone Energy	235	COMET
Solar	Raglan Solar Farm	Eco Energy World	350	RAGLAN
Solar	Rodds Bay Solar Farm	Renew Estate	300	BOROREN
Solar	Yarwun Solar Farm	Renew Estate	27	YARWUN
Solar	Aldoga	Acciona Energy	265	ALDOGA
Darling Downs - Condamine				
Solar	Bulli Creek Solar Farm Stage 1	Solar Choice Pty Ltd	1000	BULLI CREEK
Solar	Bulli Creek Solar Farm Stage 2	Solar Choice Pty Ltd	1000	BULLI CREEK
Solar	Dalby Solar Farm	Fotowatio Renewable Ventures	30	DALBY
Solar	Western Downs Solar Farm	Tilt Renewables	250	HOPELAND

Solar	Wandoan South Solar Project	Global Infrastructure Partners (Equis)	1000	WANDOAN
Solar	Delga Solar farm	Shell	250	WOLEEBEE
Solar	Columboola Solar Farm	Luminous Energy	310	COLUMBOOLA
Solar	Oakey stage 2	Canadian Solar	55	OAKEY
Solar	Beelbee Solar Farm (Darling Downs II)	APA	240	BEELBEE
Solar	Chinchilla -First Solar	First Solar	100	CHINCHILLA
Wind	Rabbit Ridge	Tm Lucas	13.6	DALVEEN
Solar	Baking Board Solar Farm	Eco Energy World	20	CHINCHILLA
Far North Queensland				
Solar	Cape York Solar Farm	Lyon Group	55	LAKELAND
Solar	Mareeba Solar Farm	Cleangen	60	MAREEBA
Wind	High Road	Ratch Australia	80	RAVENSHOE
Wind	Lakeland Wind Farm	Windlab	104.4	LAKELAND
Bioenergy	South Johnstone Mill (expansion)	MSF Sugar	32	SOUTH JOHNSTONE
Solar	Lakeland Solar farm stage 2	Conergy	17	LAKELAND
Solar	Desailly Renewable Energy Park	DP Energy	1000	DESAILLY
Solar	Chewco Solar Farm	Tilt Renewables	75	MAREEBA
Wind	Kaban Green Power Hub	Neoen	130	KABAN
Mackay-Whitsunday				
Solar	Kelsey Creek Solar Farm	KCSF Consortium	50	PROSERPINE
Solar	Bowen Solar	Infigen Energy	30	BOWEN
Solar	Collinsville North Solar	Equis-Global Infrastructure Partners	100	COLLINSVILLE
Solar	Gumlu Solar Farm	RJ Gordon Solar	20	GUMLU
Solar	Nebo Solar Farm	Tilt Renewables	50	NEBO
Solar	Dysart Solar farm	Tilt Renewables	100	DYSART
Solar	Paget Solar Farm	BOMA Group	20.6	PAGET
Solar	Rugby Run Stage 2	Adani Renewables	105	MORANBAH
Solar	Middlemount Solar Farm	Overland Sun Farming	34	MIDDLEMOUNT
Solar	Clarke Creek Solar Farm	Pacific Hydro	350	CLARKE CREEK
Solar	Clarke Creek Solar Farm	Lacour Energy	200	CLARKE CREEK
Wind	Clarke Creek Wind Farm	Lacour Energy	800	CLARKE CREEK
Solar	Collinsville Solar Stage 2	Ratch Australia	36	COLLINSVILLE

South East Queensland				
Solar	Ebenezer Solar Project	Juwi Renewable Energy	10	EBENEZER
Solar	Gold Coast Solar Farm	Ormed Investments	5	ORMEAU
Solar	Harlin Solar Farm	Sunshine Energy Australia Pty Ltd.	1500	HARLIN
Townsville - Dry Tropics				
Hydro	Burdekin Hydro Power Station	QLD Government	50	RAVENSWOOD
Wind	Kidston Wind Farm	Genex Power Ltd	150	EINASLEIGH
Hydro	Kidston Pumped Storage Hydro	Genex Power Ltd	250	EINASLEIGH
Solar	Kidston Solar Stage 2	Genex Power Ltd	270	EINASLEIGH
Hydro	Mount Leyshon pumped hydro	Leyshon Resources Ltd/Elementos	20	SEVENTY MILE
Solar	Rollingstone Solar Farm	ESCO Pacific	110	ROLLINGSTONE
Solar	Koberinga Solar Farm	ESCO Pacific	55	HOME HILL
Solar	Majors Creek (Woodstock)	Edify Energy	200	MAJORS CREEK
Solar	Haughton Solar Farm Stage 2	Pacific Hydro	400	UPPER HAUGHTON
Solar	Burdekin Solar Farm	CleanGen	140	CLARE
Wind	Forsayth Wind Farm	Infigen Energy	75	FORSAYTH
Wind	Kennedy Energy Park Stage 2 & 3- Wind	Windlab	1200	HUGHENDEN
Bioenergy	Pentland Bioenergy project	Renewable Developments Australia Pty Ltd	16	PENTLAND
Western Queensland				
Solar	Cloncurry Solar Farm	Infigen Energy	30	CLONCURRY
Solar	Winton Solar farm	Solar Choice Pty Ltd	5	WINTON
Solar	Barcaldine Stage 2	Elecnor	50	BARCALDINE
Wide-Bay Burnett				
Solar	Aramara	Eco Energy World	140	ARAMARA
Solar	Bundaberg Solar Farm	Denzo Group	58	BUNDABERG
Solar	Teebar Solar Farm	Teebar Clean Energy	52.5	TEEBAR
Solar	Lower Wonga Solar Farm	SolarQ	350	LOWER WONGA
Solar	Kingaroy Solar Farm	Terrain Solar	40	KINGAROY
Solar	Munna Creek Solar Farm	REST Energy	120	BAUPLE