# Post-installation Solar Energy Case Studies and New Installation Recommendations

for

# Dairy Tasmania
# 2020

**Prepared by:**

Duncan Livingston 0488 785 039
Thomas Mills 0490 445 717
**Energy ROI**
duncan@energyroi.com.au
tom.mills@energyroi.com.au

**Client details:**

Johnathan Price
DairyTas
J.price@dairytas.net.au

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## 1 Executive Summary

The aim of this study is to:

1. Quantify the actual performance of solar arrays across a variety of dairy types in Tasmania.
2. Compare the actual performance to forecast performance using the industry standard forecasting tools.
3. Make specific recommendations with respect to system sizing, equipment types and proposed layouts to enable dairy farmers to make better educated decisions when choosing to install solar.

# 2 Individual Site Pre/Post Construction

The following analysis takes the available solar production data at a variety of dairies across Tasmania and compares them to modelled performance. The absolute financial impact of the installation is unable to be specifically quantified as interval data was not available from the majority of the installations assessed. Interval-based analysis is assessed separately in a later section of the report.

The solar modelling for the purpose of this report was performed using the industry standard US National Renewable Energy Lab PV Watts Calculator. The following input parameters were utilized uniformly across all sites included in the analysis:

System Losses (panel fouling, voltage drop etc.): 14.08%
Inverter Efficiency: 96%

## 2.1 Clear Springs, Meander

The site is a 60 cow rotary North of Meander in Northern Tasmania.

Annual production is calculated assuming the following input conditions:

Roof Pitch: 12°
Panel Azimuth: 315°
Panel Alignment: Predominately flush (some rack mounted panels on western roof face)
System Size: 99kW Inverter, 99kW Panels
Panel Type: Jinko 330W
Inverter Type: Solar Edge SE27.6 (x4) with P600 DC optimizers

Installer Estimated Production: 115,927kWh/year
Estimated Production using NREL/BOM Dataset: 127,699kWh/year
Actual Production (Inverter Logger): 126,894kWh/year
Annual Dairy Consumption: 244,000kWh/year

## 2.2 Graeme Arnold Dairy

This dairy is a 15 per side double-up located in Lilydale, Northern Tasmania.

Annual production estimates are calculated assuming the following input conditions:

Roof Pitch: 15°

Panel Azimuth: 070°T
Panel mounting: 48 panels 18° rack mounted, facing 337°T on a 67°T facing roof, 70 flush mounted on a 247°T face.
System Size: 27.6kW Inverter, 30kW Panels
Panel Type: 254W
Inverter Type: Solar Edge 27.6

Installer Estimated Production: Unknown
Estimated Production using NREL/BOM Dataset: 36,705kWh/year
Actual Production (Inverter Logger): 49,555kWh/year
Annual Dairy Consumption: 40,000kWh/year

## 2.3 Active Diaries, Bracknell

This is a 60-stand rotary dairy located West of Bracknell in Northern Tasmania.

Annual production estimates are calculated assuming the following input conditions:

Roof Pitch: 12°
Panel Azimuth: 021°T
Panel mounting: Flush, apart from the southernmost row (22 panels), which is racked.
System Size: 50kW Inverter, 56.32kW Panels
Panel Type: JA Solar 320W (JAM60S03-320/PR)
Inverter Type: ABB ACWB-SX-TRIO-TM-50.0-400

Installer Estimated Production: Unknown
Estimated Production using NREL/BOM Dataset: 49,957kWh January 1st-September 30th, 76,774kWh full year.
Actual Production (Inverter Logger): 43,108kWh January 1st-September 30th 2020, 66,248kWh full year extrapolation.
Annual Dairy Consumption: 150,000kWh/year

## 2.4 Salmon Marketing, Gretna

The site is a 100kW ground-mounted array in southern Tasmania that sits behind the same meter as an irrigation pumping site.

Annual production estimates are calculated assuming the following input conditions

Panel pitch: 32°

Panel Azimuth: 019°T
Panel mounting: Ground mount racked.
System Size: 89kW Inverter, 95.5kW Panels
Panel Type: Hanhwa Q Cells Q.Plus-G4.1 270 (34.02kW), Hanwa Q Cells Q.Plus-G4.1 265 kW
Inverter Type: 2x Fronius Symo 17.5-3-M, 2x Fronius Eco 27.0-3-S

Installer Estimated Production: Unknown
Estimated Production using NREL/BOM Dataset: 128,832kWh/year
Actual Production (Inverter Logger): 114,120kWh year
Annual site consumption: 270,000kWh/year

## 2.5 Berchill Park Robot Dairy, Meander

The site is robotic dairy near Meander in Northern Tasmania.

Annual Production assuming the following input conditions

Roof Pitch: 18°
Panel Azimuth: 073°T and 253°T
Panel mounting: Flush (NE and SW faces)
System Size: 27kW Inverter, 31.5kW Panels
Panel Type: 350W REC
Inverter Type: 27kW Fronius

Installer Estimated Production: 39,511kWh/year
Estimated Production using NREL/BOM Dataset: 38,295kWh/year
Actual Production (Inverter Logger): 39,820kWh/year
Annual Dairy Consumption: 82,000kWh/year

## 2.6 Result Summary

The NREL predictions were on average within 1% actual measured annual production, but with a standard deviation of 16%. The Salmon Marketing installation modelling had a negative impact on the results due primarily to the shading that occurs as a result of the terrain surrounding the installation. Without this shading it is likely that the results would have been closer to the estimated value. It is important to note that only 12 months of data has been included in the analysis, so seasonal (cloud coverage) and regional impacts will influence the results. On a heavily clouded day a solar system can only be expected to output 20% of the output it would produce on a clear day at the same time of year.

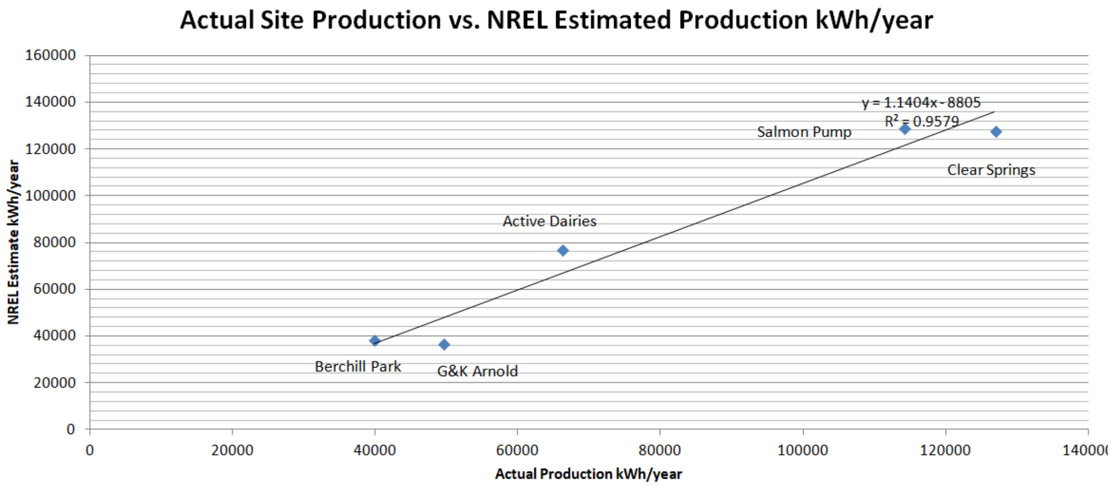


**Figure 1: Site actual solar production compared to NREL PV Watts estimated production.**

# 3 General Solar PV Installation Observations

## 3.1 Production Analysis

A pre-installation production analysis is an important tool for understanding the future financial performance of a solar installation. These analysis vary in format depending on the available data and the accuracy of the modelling performed.

The highest grade of analysis will require the utilization of interval data from the dairies existing electricity meter, assuming a remotely read, advanced meter is installed. This will enable the solar modeller to match a year's worth of 15 minute electricity data from the site with the temperature, wind speed and solar radiation interval data from the nearest Bureau of Meteorology location to provide an extremely accurate estimate of how much solar energy will be self-utilized and how much will be exported to the grid and when. This modelling should be pared with the site's tariff information and contracted rates where applicable.

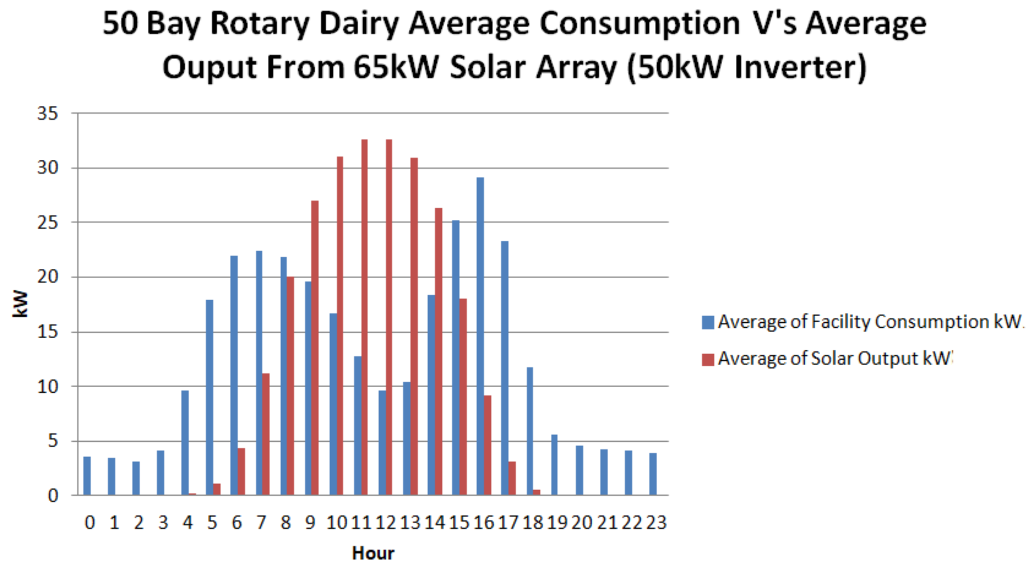


**Figure 2: A 50 stand rotary dairy electrical demand in Northern Tasmania with morning and evening milking overlaid with a 65kW solar array (50kW inverter) average production output.**

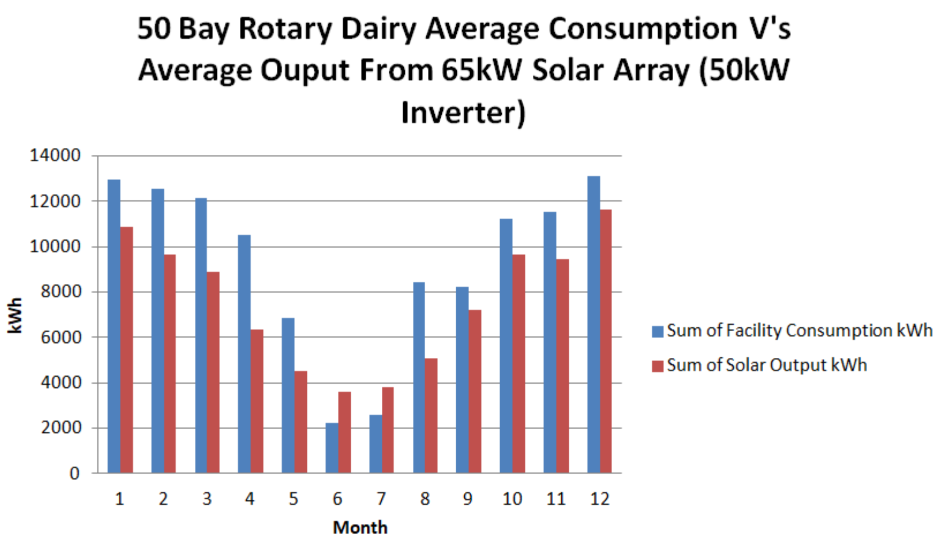


**Figure 3: A 50 stand rotary dairy electrical demand in Northern Tasmania with morning and evening milking overlaid with a 65kW solar array (50kW inverter) average production output, showing that the annual solar variation closely matches the electrical demand of the dairy.**

For the particular Northern Tasmania dairy case modelled in the graphs presented above and utilizing actual 2020 contracted electricity rates and average market system pricing, the financials of the installation are as follows:

Duncan Livingston
Ph. 0488 785 039
duncan@energyroi.com.au

| | |
|---|---|
| Dairy Size | 50 stand rotary |
| Solar System Size (Inverter/Array) | 50kW/65kW |
| Annual Dairy Energy Usage kWh | 112,330 |
| Solar Annual Production kWh (Array 305°T, 18° Slope) | 90,678 |
| Solar output as fraction of annual consumption | 80.72% |
| Solar self utilisation % | 57.27% |
| Solar annual Income/savings $ | $10,662 |
| System Cost | $71,500 |
| Payback (years) | 6.71 |

The next step down in modelling normally occurs when no interval data is available. This will likely involve estimates of how much energy is self consumed and how much is exported.

Finally, the least accurate but most conservative modelling will be performed where it is assumed that all the solar PV generation is exported, an extremely unlikely scenario for most agricultural solar installations.

## 3.2 Equipment Selection

Solar equipment manufacturers can be broken up into three main categories:

Premium Providers: Tindo (Australian made), Sunpower, LG
These providers typically support their panels with a 25 year full replacement guarantee and design their panels to have in excess of a 40 year operational life. They are proven to be extremely reliable, with low degradation rates and almost zero failure rates before end of warranty. They will typically be approximately $40 more expensive than a lower quality panel of the same wattage.

Tier 1 Providers: Q Cells, JA Solar, Jinko Solar, Trina Solar, Hyundai Solar etc.
Tier 1 essentially means that the panels and the organization manufacturing them have been assessed by and independent agency (DNV GL, Bloomberg NEF etc.) and are considered adequately manufactured by a company financially stable enough to support any potential warranty claims. These panels typically come with a 10-12 year full replacement warranty and a less valuable 25 year “production” warranty.

Others: Panels of lesser quality than those mentioned above should be treated with the caution.

A similar situation occurs with respect to inverters, but with a smaller number at the top.

Essentially there are the SMA, Fronius and ABB/FIMER brands available from Europe and SolarEdge available from the US that can be recommended. All others should be treated with extreme caution.

## 3.3 Panel Alignment

Often the available roof space dictates that an ideal North-facing panel alignment may not be available for the desired solar installation. This is not always a bad thing, as East and West facing alignments also have their benefits.

The maximum production in Tasmania actually occurs when the panels are facing approximately 15° east of North, as this gives the peak production in the late morning before daily temperatures peak. Ambient temperature and windspeed have an impact on solar panel efficiency. The higher the panel temperatures, the less efficient the panels will operate. This is known as the Power Temperature Coefficient and specified as a percentage of output lost per °C above the nominal operating temperature of 25°C.

Where inadequate space exists to flush mount the required panels on a North-facing roof face, the option often exists to rack the panels on the southern face of the roof, aligning the rows in such a manner that the panels face north.

Rack angles can be varied to match the demand profile of the site. Typically with a dairy, low rack angles are desired (approximately 20-30°) as this will maximize summer production when the dairy load is the highest. For many businesses in Tasmania, heating load in winter drives demand, which is why panels in Tasmania are often racked between 35° and 45°.

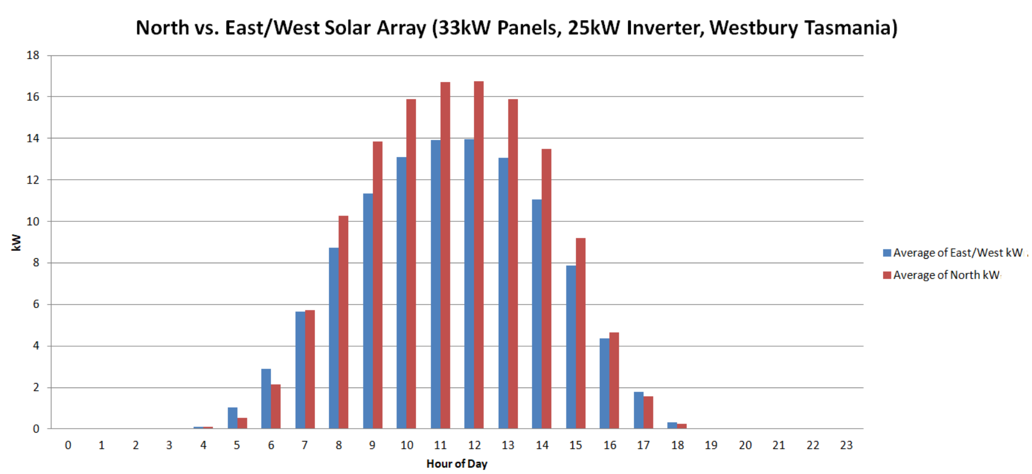


**Figure 4: A North facing solar array compared to an east/west array of the same size, showing that the 14% average production loss is centered around the middle of the day, with minimal impact on morning and afternoon production.**

More importantly in dairy applications however is panel alignment to maximize self utilization during milking events. This is where an East and West-facing array's 14% annual production loss compared to a North-facing array (assuming 20° roof angle) is not so detrimental in the case of a dairy. The typical morning and afternoon consumption bias of a dairy's electricity demand means that much of the midday production is exported to the grid at low feed-in tariffs so minimal financial loss occurs.

## 3.4 Internet Connectivity

Typically inverters have the ability to store a small amount of interval data (approximately one month), error logs and running production totals. What many inverters are incapable of is retaining long periods of interval data.

This is where a WiFi or 4G data connection can be instrumental. It can allow all data to be retained for future analysis, as well as allow easy online access through the inverter manufacturer's website for verifying the system is performing as intended. Cases have been reported where solar PV systems have been isolated by electricians working on neighbouring equipment (pumps etc.), but the solar systems not reconnected after the work is complete. Without a remotely accessible monitoring dashboard, monitoring becomes difficult and is not commonly performed. Most inverters are easily connected to the internet if WiFi is present in the dairy, otherwise a small 4G modem can be purchased for as little as $150 and a $15/year SIM card (Aldi Mobile) will have adequate data capacity, assuming the data is only used for the inverter.

Above and beyond the basic option, the opportunity exists to purchase third-party monitoring tools for approximately $10/month (e.g. solaranalytics.com) which will notify you should immediately should your system not be producing as anticipated.

## 3.5 Selecting a solar installer

Like any purchase, solar is a case of buyer beware, but there are plenty of resources out there to help buyers make the right decisions. Like any acquisition, you should seek competing quotes, however make sure that all quotes are direct comparisons so that you don't incur unexpected costs as you proceed with the project. Items to watch for may include the following:

1. System production/income analysis
2. Quality/brand/model of the panels and inverters.
3. Permitting fees
4. Mounting arrangements (are racks included for flat roof scenarios).

5. Costs of any underground cable runs.
6. STC rebate pricing.
7. Quality of workmanship
8. After installation support, maintenance and monitoring

It is strongly recommended that a company with a permanent Tasmanian presence is selected to ensure ongoing warranty support is available should it be required.
Whilst resources such as the Clean Energy Council and commercial websites such as Solar Quotes exist, often the best resource is your neighbour or someone you know in the state that already has a solar PV installation, as most people are willing to talk about their solar installation experience, be it good or bad.

## 3.6 System Size

The ideal system size will depend on the following key components:

1. Dairy electricity consumption and demand profile
2. Desired payback period
3. Overall system desired income/offset
4. Available inverter sizes
5. Appetite for the required expenditure

Whilst smaller systems will typically have a better payback, they will not offset as much of your electricity bill as a larger system.

Typically, systems on dairies will be limited based on their available roof space:

- For a smaller dairy (e.g. a 15 bay swing-over) this may be a 13kW solar array paired with a 10kW inverter.
- For an intermediate sized dairy (e.g. 30 bay) this will typically be a 25kW inverter paired with a 33kW array.
- For 50 bay rotaries or larger, this will likely mean the use of two 25kW inverters and 65kW of panels.

Systems sized as above can be expected to output approximately 50-80% of the dairies annual energy consumption, depending on the level of efficiency of the dairy and the dairy throughput.

For systems larger than those specified above, it is likely that there will be insufficient suitable roof space on the main dairy shed. If the desire exists to add more, the possibility exists to place them on neighbouring sheds behind separate inverters, however they must all be fed into the dairy's metering point in order to maximize the self-utilization rate.

In most situations, the solar panel output should be approximately 1.3 times the rated capacity of the inverter. In Tasmania it is rare that the sun is positioned in such a manner that the solar panels are running at their full-rated capacity. Subsequently, it is common to have more kW of panels installed than the size of the inverter. There will be times when the system does achieve the rated capacity of the inverter, at which point some of the solar energy will be lost, however these losses will be minimal when compared to the economic benefit of better inverter utilization. Additionally, STC rebates are paid based on the panel capacity, not the inverter size, so this helps drive the financial benefit of more panels than inverter capacity. The maximum allowable solar panel limit is 1.33 times the inverter size.

## 3.7 Typical Pricing and System Payback

System pricing will vary depending on location, complexity of installation, equipment selected and the installer utilized. Typical pricing for flush mount systems may be found in the chart below. If the system is required to be placed on racks, this will typically add 15% to the price. Ground mounted systems will add 25% or more:

| System Size | Tier 1<br>(12 year warranty) | Premium<br>(25 year warranty) |
|---|---:|---:|
| 10kW Inverter, 13kW Array | \$13.5k-\$14.5k | \$15k-\$16k |
| 25kW Inverter, 33kW Array | \$33k-\$35k | \$37k-\$39k |
| 50kW Inverter, 65kW Array | \$62k-\$66k | \$70k-\$74k |

Payback periods will vary based on the demand profile of the dairy and subsequent self utilization rates. The early morning, late afternoon demand peaks from most dairies is not ideally matched to solar when compared to more typical 9am-5pm businesses, however the peak summer demand of dairies does match the seasonal variation of solar. Subsequently, where a 9-5 business may see a 4-5 year payback on a solar system, a dairy is more likely to see paybacks in the 5 -7 year range.

## 3.8 Electricity Tariff Selection

With a suitably sized array, the most optimal tariff for a dairy equipped with solar is TAS94 Business Time of Use. This has peak rates from 7am to 10pm during the week, shoulder rates in the weekend daytime, and off-peak all evenings. An adequately sized solar array will provide the majority of the electrical needs during the peak and shoulder pricing periods in summer months. During the evenings off-peak rates are available at less than half the peak rates, making it ideal for off-peak water heating. TAS94 timing typically means that half the electricity consumption associated with a morning milking occurs at the off-peak rate. The TAS94 tariff offers a lower cost in almost every case than TAS22/43 tariff for dairies without solar and always for dairies with solar.

For sites on the TAS75 irrigation tariff, the shoulder weekday rates throughout the summer months result in an approximately 4c/kWh reduction in apparent value of the solar energy produced when compared to TAS94. This, combined with the additional cost of placing panels on ground mounted racks rather than typical roof mounting significantly impacts the financials associated with such an installation. This will take the typical payback period of a suitably sized array from 5-7 year typical of a dairy shed installation out to 9-10 years.

## 3.9 Solar Feed-In Tariff Rates

The Office of the Tasmanian Economic Regulator sets the rate for solar energy exported to the grid for installations less than 30kW. This rate is set based on the average energy component of the wholesale electricity prices at the time the rates are set. Often, this over values the solar energy that is exported, as solar energy has one major Achilles heel compared to Hydro, gas and to some extent coal in that it is not dispatchable.

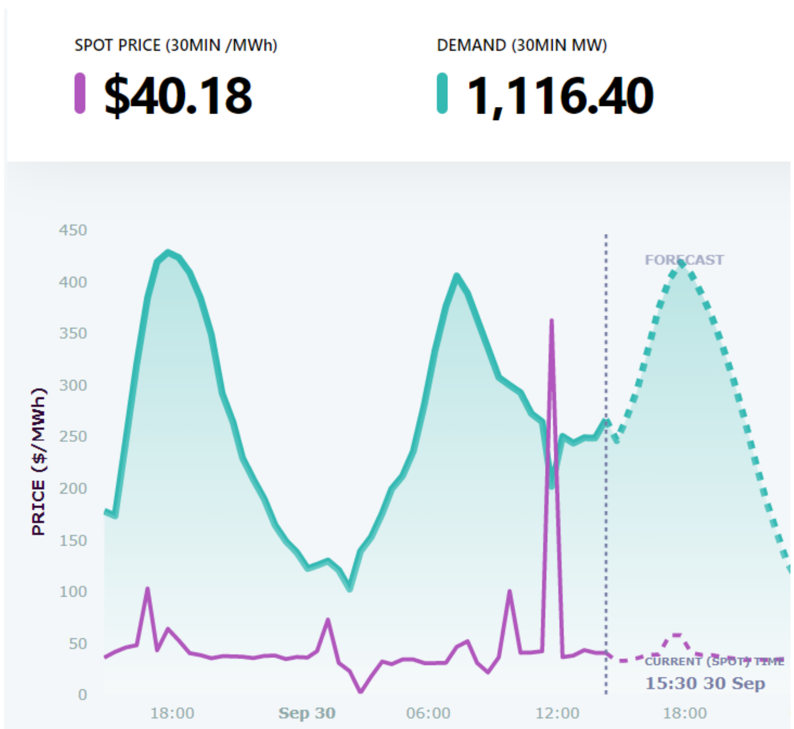


**Figure 5: Tasmanian demand and price for the 29th and 30th of September 2020 (source: AEMO), showing the 330% variation in demand through the day, demonstrating the need for dispatchable power sources.**

Dispatchable power means that it can be called upon when required, such as during peak winter morning and evening periods when a solar system is non operational. A premium for dispatch able power is paid not based on the generation source, but how well that power meets demand.

Whilst penetration rates for solar are still low (7.9% nationally) this variation in solar supply is not a significant issue. As solar installations increase in the future they will likely be accompanied by electric vehicles. With bi-directional charging and the average vehicle able to store 3 days-worth of household electricity usage, this risk of grid instability caused by solar will become less significant.

That said, solar is a disruptive technology, in that it is transforming the way the grid has normally operated. Due to this, traditional generators are no longer in the positing of control that they used to have and subsequently there is pressure to limit future solar installations, either through midday clipping or rated export capacity. Tasmanian solar feed-in allowances are generous when compared to other states and may well be restricted for future solar installations.

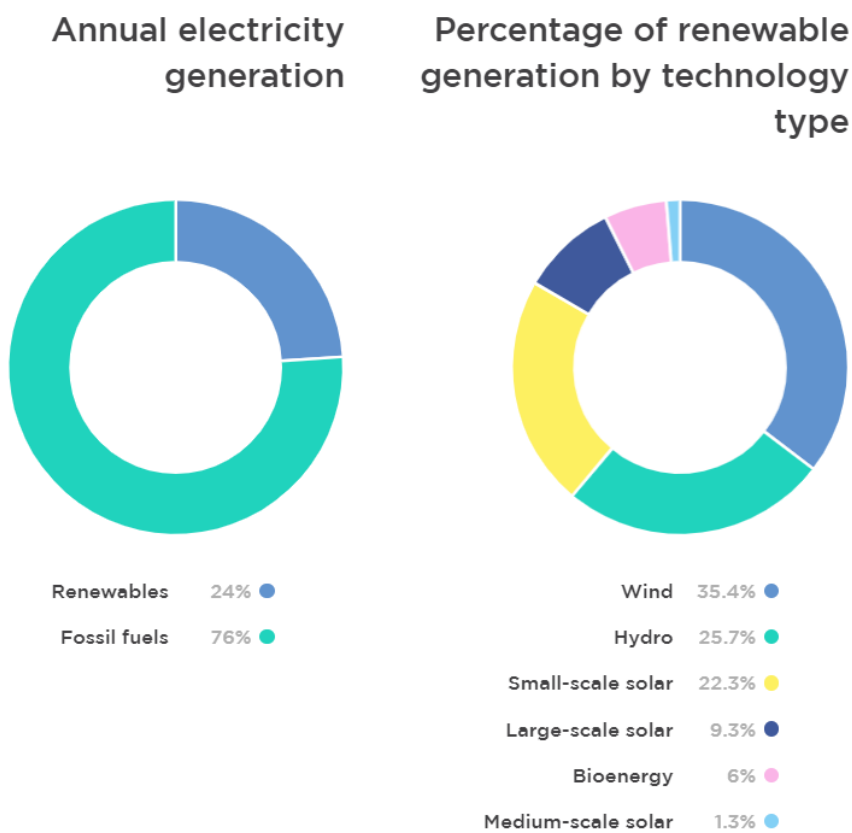


**Figure 6: 2019 Electricity Generation in Australia by Type. Solar Accounts for 7.9% of Australia's Total Generation. Source: Clean Energy Council Australia**

This Tasmanian regulated rate for solar feed-in is currently 8.471c/kWh for sites on Standing Offer (non contracted) tariffs.

For sites with installations above 30kW (10kW per phase) or for sites on contract, the feed-in rate becomes "negotiable" between the retailer and the solar system owner. Subsequently retailers will offer significantly less than the regulated rate so it is prudent to shop around. Typical rates are in the order of 6c/kWh peak, 4c/kWh off-peak.

## 3.10 STC Impact and Battery Installations

Small Technology Certificates (STC) are analogous to a pot of money that Australians have been contributing to for more than a decade every time they pay their electricity bills. Funds can be claimed back from this pot when installing solar PV systems up to 100kW per site or domestic heat pump hot water systems. STC's on a solar installation typically paid approximately 1/3rd of the cost of the total system, however this incentive is being ramped down on January 1st every year until 2030 by which point it will no longer contribute anything toward the cost of the installation.

Now that wind and solar are the lowest cost forms of new energy generation, they are no longer under the same pressure to continue to reduce their production costs that they were a decade earlier. Subsequently the small reductions in solar cell costs now achieved are being cancelled by the reduction in the STC incentive. In light of this the total installed system costs of solar arrays has begun to plateau, so it is pointless to delay installations with the hope of achieving reduced pricing in the future.

A completely different situation exists with batteries, where the 2017 to 2018 cost reduction was 18% (Source: Bloomberg NEF) and that trend is looking likely to continue well into the future as the mass production of electric vehicles accelerates. It is not currently economically feasible on Tasmanian electricity tariffs to store electricity in peak solar production periods for use in off-peak times. Grid tied batteries are only a logical choice where seamless backup integration is desired. Until longer life, lower cost batteries are available; these funds are better spent on solar arrays, or saved for electric vehicle acquisitions in coming years.

## 3.11 Solar $CO_2$ Emissions

There will be emissions involved with the production of solar panels, from a mining, processing, manufacturing, transport, installation and decommissioning perspective. Most quality panels have a 40 year design life (verified using accelerated lifetime testing) and can be expected to last well beyond that in the more temperate Tasmanian climate. Should only a 25 year life was achieved (the typical warranty period of the higher end panel suppliers), then total emissions can be expected to be the equivalent of approximately 41g of CO2 for every kWh of electricity generated (source: IPCC 2014). The longer the life of the project, the lower the emissions, so high quality equipment is preferential from an environmental perspective. To put these emissions in perspective, the average $CO_2$ emissions from the National Electricity Market grid, to which Tasmania is connected via Basslink, is 820g $CO_2$-e/kWh (source: 2019 National Greenhouse Accounts Factors), so solar systems are typically at least 20 times less than polluting than the average power source in Australia.

A typical solar system on a Tasmanian dairy with a 50kW inverter and 65kW of panels can be expected to offset approximately 73 tonnes of $CO_2$ emissions per year by forcing Coal and Gas off the Australian grid.

### 3.12 Recycling at End of Life

The basic elements in a solar panel are not overly complex and are subsequently comparatively easy to recycle. The perimeter frames are aluminium, the primary surface is high strength glass, the cells are predominantly silicone, and conductors are copper and tin. There is a solar panel recycling facility in Melbourne and likely more will appear in the future as demand dictates. Panel recycling is now mandatory in Victoria as the State Government has passed legislation banning the disposal of e-waste in landfill from July 1st 2019.

## 4 Summary

The analysis above indicates that the installation of solar PV is a worthy addition to most dairy installations, as long as systems are correctly sized and sourced at typical market prices. It is important to have realistic expectations of payback periods and ensure that a second opinion is obtained prior to executing on a solar installation if the most optimal return and long term performance is desired.

With quality components and correct installation, solar PV on a dairy farm can prove to be an extremely low maintenance, long term investment with payback periods of 5-7 years for typical dairy shed installations and 9-10 years for irrigation pumping applications.

# 5 Disclaimers and assumptions

This report has been prepared with reliance on data, analysis and reports provided by the contributing sites and from freely available market sources.

Pricing provided in the reports are 50$^{th}$ percentile and based on current market averages. Except as otherwise stated in this report, Energy ROI has not verified the accuracy of the obtained information. The passage of time, manifestation of latent conditions or impacts of future events may result in the actual contents differing from that described in this report.

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