SOLAR ENERGY

POLICY SETTING AND APPLICATIONS TO COTTON PRODUCTION

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CottonInfo

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Report outline

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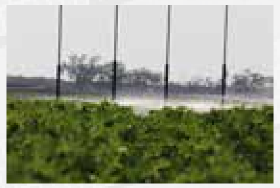
Executive Summary

Energy is at the forefront of agricultural issues in Australia. Two key concerns dominate the discussion of agricultural energy: pricing volatility of energy and government policy supporting renewable energy. Together these concerns have resulted in a stimulated interest in the potential substitutes for fossil fuels. A scarcity in energy sources (particularly crude oil) has highlighted the dependence of energy-related agricultural inputs such as fertilizer, electricity and fuels for farm plant and irrigation pumping. As government policies develop, environmental concerns related to global climate change and market signals from the consumer to improve sustainability have encouraged investigation of alternative energy sources to transform the relationship between the energy and agriculture sectors.

Policy initiatives such as the Emission Reductions Fund (ERF) and Renewable Energy Target (RET) create incentives for businesses to contribute to the national effort of reducing emissions under the Kyoto Protocol. Subsidies from the RET and increasingly affordable solar technology could potentially be aligning to deliver both economic benefits to the grower and co-benefits to the environment. Irrigated cotton growers have minimal opportunities to modify their energy consumption pattern, as it is often dictated by crop water requirements and river management regulation. Those growers relying on groundwater for irrigation enjoy water security. However, rising electricity costs create challenges for an already high input and capital intensive system. Seasonal energy demand during irrigation of installed renewable generation lends itself to wider applications of surplus energy. The use of electric passenger vehicles as a substitute for fossil fuel powered vehicles may utilise out-of-season and surplus generation, reduce emissions and add diversity to businesses increasingly reliant on imported oil as an on farm energy source.

This report provides the background context for ongoing feasibility studies of hybrid renewable installations on irrigation farms.



1 ENERGY IN AGRICULTURE

Energy Use in World Agriculture

Increasingly energy is at the forefront of agricultural issues throughout the world. There are two separate trends in energy use in world agriculture. Firstly, developed countries are seeking to shift to lower intensity energy use in agriculture i.e. higher output per unit of energy consumed. Secondly, developed and developing countries alike are seeking alternative energy sources. The interrelated issues of price volatility and government policy are driving these trends.

In recent years, fluctuations in energy commodity prices have highlighted the dependence of agriculture on energy inputs such as fertilizer, electricity and fuels for pumps, and fuel and oil for trucks and tractors (UCA 2009, BECA 2015). In a study of Californian agriculture, Roland-Holst and Zilberman (2006) note that agricultural energy price vulnerability can be broken down into direct and indirect effects. The direct effect comes from on-farm energy use such as from powering machinery. The indirect effect includes upstream use from inputs such as fertilizers and pesticides and downstream use for processing and distribution. Increasingly, indirect effects are exceeding direct effects, making the agricultural sector particularly vulnerable to price spikes.

Within this context, three ways to reduce energy dependence and vulnerability on farms have been identified;

1. through structural adjustment away from energy-intensive agricultural activities
2. through altering supply chain arrangements to minimise indirect energy consumption
3. adopting new on-farm processes and technology to increase energy security

While still lower than its indirect effect, cotton production is identified as having a higher relative direct effect compared to other agricultural activities, indicating that new on-farm energy practices and technology could have a greater impact in reducing energy price vulnerability (Foley, Sandell et al. 2015).

The second major factor influencing the trend to lower intensity energy use comes from increased socio-political pressure (UCA 2009). The agricultural sector, along with the rest of the global economy, is being encouraged to reduce its dependence on fossil fuels in order to limit the effects of climate change and air pollution (Mekhilef, Saidur et al. 2011). A reduced dependence on fossil fuels is being encouraged through two main approaches. Firstly, through reduced agricultural energy intensity, by addressing direct and indirect energy use. Secondly, through the adoption of alternative energy sources such as renewables. Both of these approaches have been supported by policies including carbon trading and taxes, and renewable energy subsidies and incentives (Kelley, Gilbertson et al. 2010).

Together, increased energy price vulnerability within agriculture, coupled with government policies supporting reduced dependence on fossil fuels, are driving technological developments providing a wider range of cost-effective technologies and practices. Among the alternative energy options, small scale solar Photo Voltaic (PV), with particular application to irrigation pumps, has long been identified, implemented and studied (Barlow, McNelis et al. 1993, Roul 2007). More recently, studies have found that there is no technological impediment to implementing large-scale solar PV pumping systems. Kelley et al (2010) showed that with the inclusion of a carbon tax, but with no additional financial incentives and subsidies, large-scale solar PV can be economically viable compared to diesel and grid powered pumping systems. Furthermore, the advantages of solar are predicted to increase as the both solar and battery technology becomes more cost-effective.

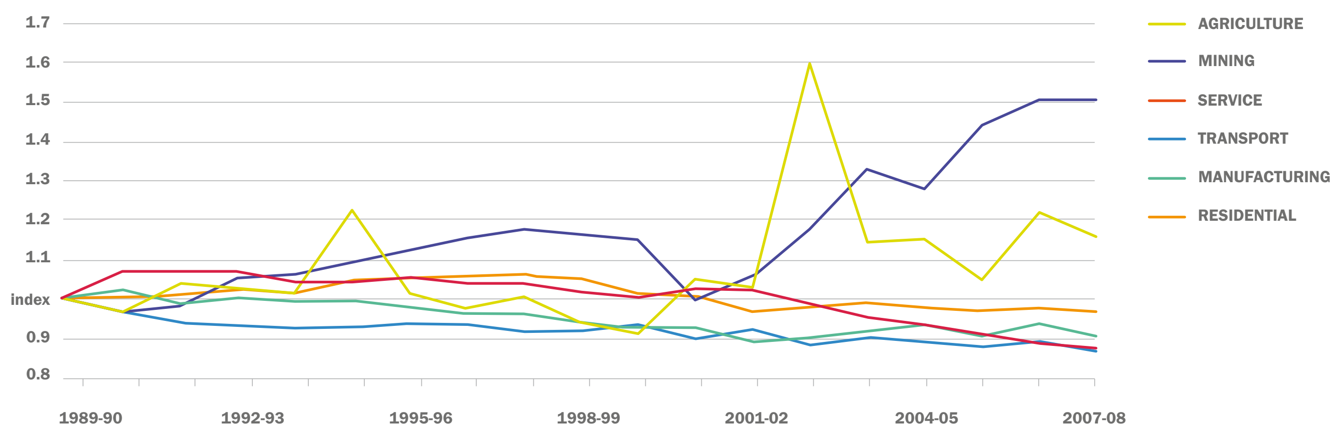
Energy Use in Australian Agriculture

In line with world trends, energy use is an increasingly important issue in Australian agriculture, with a focus on both energy intensity and energy sources.

From 1989-90 to 2007-08 Australian agriculture's annual average energy use increased by 3 per cent (Petchey 2010). Changes in agricultural energy use can be broken into the activity effect and aggregate intensity. The activity effect relates to the level of production (output in value added terms) in the system, which in cropping includes impacts on both yield and area cropped. While agricultural activity grew by 2.4 per cent between 1989-90 and 2007-08, periods of drought, such as 1994-95, 2002-03 and 2006-07, caused short-term decreases in agricultural activity. The intensity effect is the amount of energy input per unit of output, such as a dollar or a bale of cotton. The aggregate intensity is made up of structural effects and efficiency effects. Structural effects relate to the type of activity undertaken. The long-term trend of farmers shifting away from low energy intensive industries such as sheep to high-energy intensive industries such as cropping has been a major factor in the Australian agricultures growing energy use. The second part of aggregate intensity is energy efficiency, which is the level of output per unit of energy input. During short-term climate variation, such as periods of drought, planting and harvesting generally require similar amounts of energy use per hectare, but with reduced yields result in decreased energy efficiency. In irrigated crops such as cotton, where yield may remain constant, increased water pumping costs have a similar effect. Due to the dual impacts of decreased activity and decreased efficiency, reduced rainfall is seen as the main influence on agricultural energy intensity, which increased 0.8 per cent between 1989-90 and 2007-08 (Petchey 2010) and by 1.1 per cent per year between 2001-02 and 2009-2010 (Che and Pham 2012) (see Figure 1). Both of these years were drought years reducing agricultural output. Long-term projections from the present through to 2050 are for agricultural energy intensity to decrease by an annual average of 0.8 per cent (BREE 2014).

On farm agricultural energy is consumed in 2 major forms: refined products (89 per cent) and electricity (8 per cent) (BREE 2014, DIS 2015). This balance is expected to remain through to 2049-50 (BREE 2014). Energy consumption can further be broken down into 3 main activities: general electricity (pumping, lighting, appliances); fuel (machinery, vehicles and freight costs); and temperature control (heating, cooling and refrigeration) (CEFC 2016). These activities, however, vary depending on the type of agricultural activity. This paper will focus on irrigated cotton production in Australia.

FIGURE 1: Trends in composite energy intensity indicators in the Australian Economy *Image source: Petchey 2010*

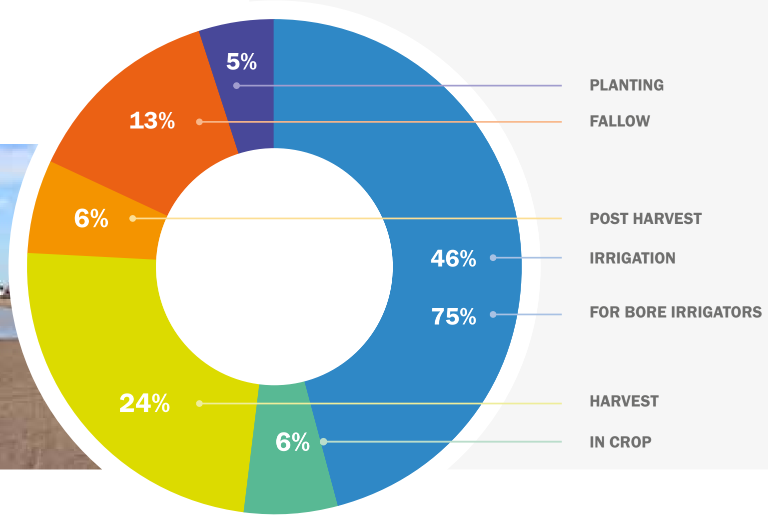


Note: These trends in energy intensity do not imply any weighing of energy consumption by sector.

Energy Use in Irrigated Cotton

Irrigated cotton is a broad acre cropping system producing premium quality food and fibre for domestic and export markets. Energy inputs are one of the fastest growing cost inputs to primary producers. This is particularly true for cotton, which is one of the most highly mechanised production systems in Australian agriculture. A report by Boyce (2016) found energy to be the second highest operating expense behind wages in irrigated cotton. In particular, the irrigated component is subject to high levels of direct energy consumption in the form of diesel and electricity with irrigation accounting for 46-80 per cent of direct energy consumption (see Figure 2) (Sandell, Hopf et al. 2014, BECA 2015, Foley, Sandell et al. 2015). Furthermore, in periods of high electricity prices, such as the four years to 2014, irrigators in New South Wales experienced total electricity cost increases of up to 300 per cent (Schulte 2014).

FIGURE 2: Energy consumption in cotton by farming practice *Source: Sandell, et al, 2013*



Foley (2015) found that irrigation accounted for around 4.2 per cent of total variable production costs, or $149 per hectare. However, a large variation exists within the sample, with application method and the total dynamic head (TDH) from ground and surface water being the key determinant. Research undertaken by Eyre, Alexandra et al. (2014) also identified the differences in energy use across variety of different irrigation systems with respect to TDH. As shown in Table 1, energy use can rise five-fold per mega litre under pressurised systems when compared with furrow irrigation.

Catchment-specific government financial incentives continue to address the challenge of increasing water scarcity through significant on-farm infrastructure investment including the adoption of new water efficient pressurised irrigation systems. However, while these incentives improve water use efficiency, a study by Maraseni et al (2010) finds that conversion to these systems will increase on farm energy intensity and carbon emissions. This provides additional incentive for the adoption of renewable energy sources in cotton farming.

The feasibility and development of renewable energy sources for cotton

A recent study of Australian cotton undertaken by Sandell et al (2014) found the application of alternative energy sources to be limited, due to high cost associated with some alternatives and limited data available of more promising and less mature technologies. Liquified Petroleum Gas (LPG) injection into pumping drive systems has a similar cost to diesel when expressed in per GJ of energy output. LPG has the added advantage of lower emissions than traditional diesel or grid powered energy sources. Biofuels and blended fuels at the time of the study were deemed uncompetitive on the basis that users were unable to claim the fuel excise rebate ($0.38/litre) on these fuel types. Cotton Gin Trash (CGT) is an emerging source of biomass fuel used to generate electrical or thermal energy. Industry research is underway to better understand potential applications of this resource and the merits of manufacturing biochar from CGT to compliment or substitute synthetic fertiliser use.

TABLE 1: Indicative 2014 irrigation grid electricity consumption for different systems and tdh *Source: Eyre, Aexandra et al. 2014*

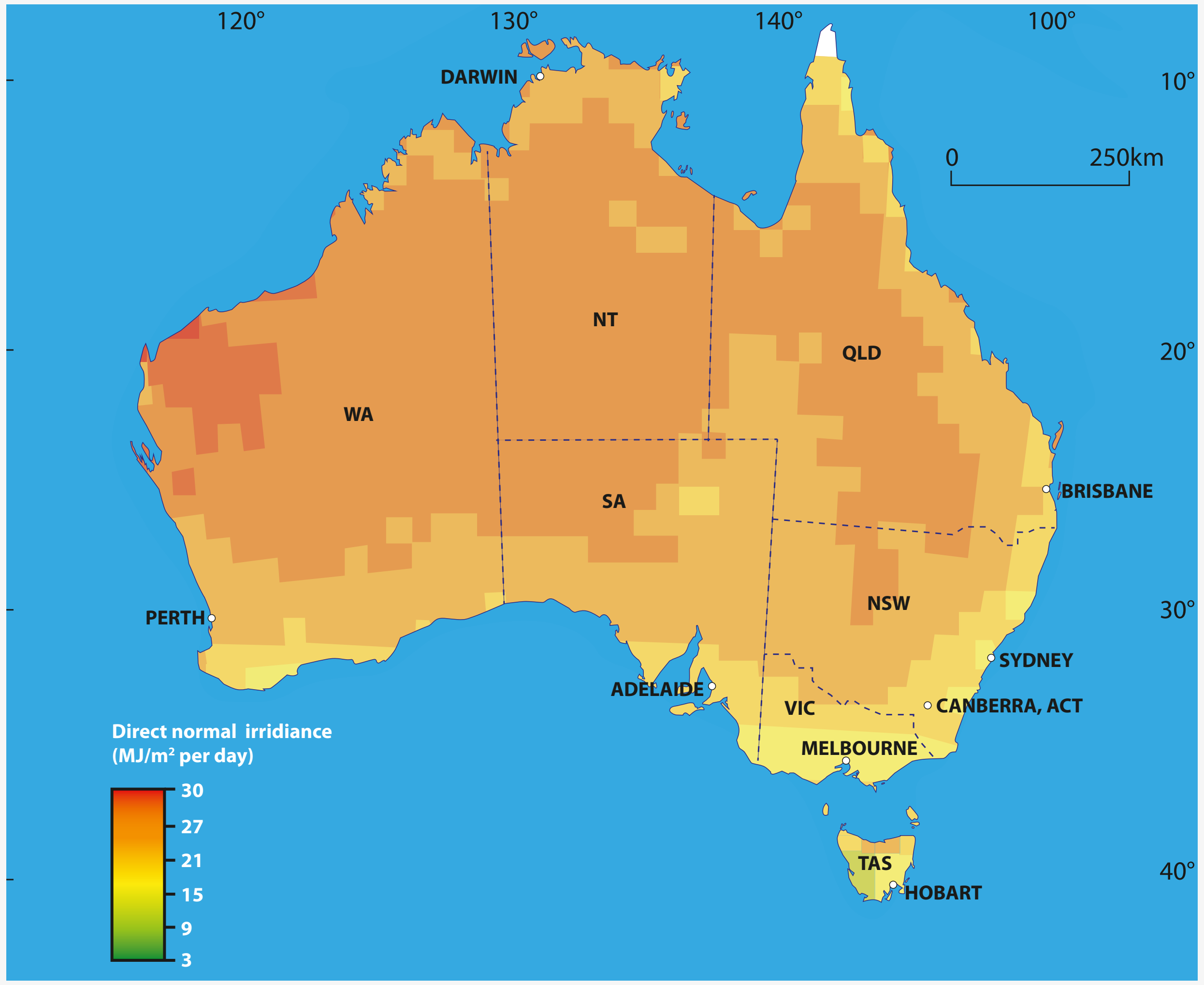
Irrigation System	Water Pumped (ML)	Total Head (m)	kWh/ML/mTDH	kWh/ML
Furrow (river)	600	10	4.542	45
Furrow (bore)	600	45	4.542	203
Pivot or Lateral move	600	40	4.542	203
Drip/jet spray	600	50	4.542	225

Cotton's agronomic requirement for high solar exposure means it is geographically well placed to take advantage of solar PV

The concept of Micro Hydro Power (MHP) is emerging in irrigation industries globally. The MHP systems, traditionally used in mountainous regions have been modified to accommodate low pressure systems. A model developed by researchers in Italy has identified calculations required to conduct MHP system feasibility of turbine size down to a 5kW system. The study by Zema, Nicotra et al. (2016) found feasibility increased proportional to water availability, and how this supply could match on-site energy demand. MHP technology is yet to be established in irrigated cotton production in Australia. Finally, with regards to wind as a potential fuel source; those commercially viable wind resources are situated in elevated areas along the Great Dividing Range or along the southern coastline (Geoscience Australia) placing it outside of the major cotton growing regions. However, cotton's agronomic requirement for high solar exposure (Pettigrew and Meredith 2013) means it is geographically well placed to take advantage of solar PV as an alternative energy source (Geoscience Australia 2014, BOM 2016).

Within cotton, the use of solar energy to date has largely been limited to offsetting the cost of domestic and workshop electricity, although hybrid solar/diesel/electric irrigation systems have now been installed at the time of writing this publication. However, certainty of government renewable energy policy, increased energy costs, and advances in solar technology provide a good opportunity for cotton growers to employ renewable energy pumping systems to both reduce on carbon emissions, as well as on farm costs.

FIGURE 3: Daily Direct Normal Irradiance (in MJ/m²) *Image source: Geoscience Australia 2014*



2 ENERGY POLICY SETTING

Australian Government Renewable Energy Policies

Secure, reliable and affordable energy supplies are fundamental to economic stability and development. The worsening global misalignment between energy demand and supply, with major consequences on energy prices, the threat of disruptive climate change and the erosion of energy security all pose major challenges for energy and environmental decision makers (IEA 2014). More efficient use of primary energy sources can help to mitigate the impact of these negative trends. Australia has formulated alternative energy policies in reducing dependence on fossil fuel and increasing domestic energy production by the application of renewable energy.

The Australian Government's carbon and energy policies have two main levers; the Renewable Energy Target (RET) and the Emissions Reduction Fund (ERF). The RET is an established policy instrument accessible to businesses and households, designed to reduce Australia's emissions growth in the electricity sector and encourage additional generation of renewable energy using financial incentives (Clean Energy Regulator 2016). The ERF operates alongside the RET, and is the centrepiece of the Australian Governments climate change policy to help achieve the emissions reduction target of five per cent below 2000 levels by 2020 (DOE 2015).

RENEWABLE ENERGY TARGET (RET)

Aim of the RET

Announced in 1997 and legislated in 2001, the objectives of the RET are to: encourage the additional generation of electricity from renewable sources; reduce greenhouse gas emissions in the electricity sector; and ensure that renewable energy sources are ecologically sustainable (Renewable Energy (Electricity) Act 2000).

History of the RET

The RET legislates a percentage of retail electricity, measured by gigawatt hours (GWh), is to be generated by renewable sources. Energy retailers achieve this target by purchasing renewable energy certificates created by renewable electricity generators, both large and small scale, and submitting them to the Clean Energy Regulator (CER). In 2001, the RET was 9,500GWh of additional renewable energy by 2010 above the 1997 baseline. In 2009 the RET was expanded to achieve at least 20 percent of renewable energy generation by 2020, with a legislated target of 45,000GWh above the 1997 baseline. From 2011, the RET has operated in two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES).

The LRET is designed to encourage new major renewable power generation, while the SRES is designed to encourage small-scale renewables, such as household and small business systems. The LRET was given a capped 2020 target of 41,000GWh, with the SRES given an uncapped, but notional 2020 target of 4,000GWh (Climate Change Authority 2014, Climate Council of Australia 2015). In line with these 2020 targets, the minister sets the yearly LRET and SRES targets (Clean Energy Regulator 2016). From late 2013, there existed a period of uncertainty regarding the future of the RET scheme that led to reduced investment in large-scale renewable energy generation, which decreased by 88 per cent in 2014 (McConnell 2015). The Warburton Report (Climate Change Authority 2014) noted that the RET was not the most cost efficient policy approach to reducing carbon emissions. In 2015, the RET legislation was amended to a capped LRET that would progressively rise to 33,00GWh by 2020, which would not be reviewed until 2020. In addition, the SRES remained unchanged with an uncapped target. Both schemes are due to finish in 2030 (DOE 2015, Wilson 2015). Together these amendments sought to provide renewed certainty for ongoing investment in renewable energy.

The small scale RET

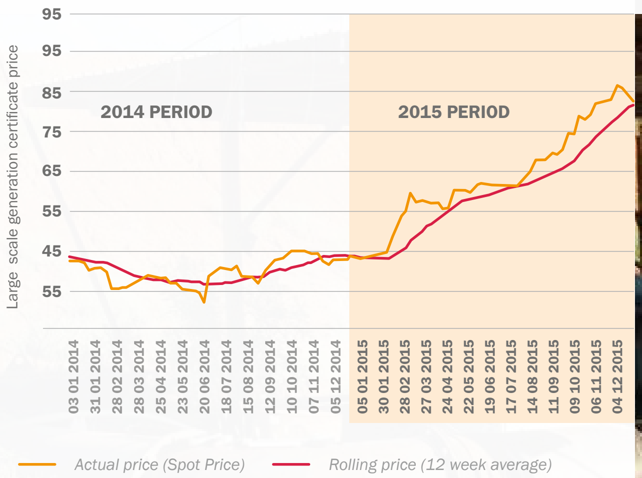
The small-scale Renewable Energy Scheme creates a financial incentive for owners to install eligible small-scale installations such as solar water heaters, air source heat pumps, solar panel systems, small-scale wind systems, or small-scale hydro systems. The main criteria distinguishing a small scale renewable plant from large scale is the size of the generation. In the case of solar, a system is considered small scale when capacity is no more than 100kW and it has a total annual electricity output less than 250MWh (Clean Energy Regulator 2015).

Eligible systems may be entitled to small-scale technology certificates (STCs), which RET liable entities have a legal obligation to buy and surrender to the Clean Energy Regulator on a quarterly basis (Clean Energy Regulator 2015). The number of STCs per system depends on its geographical location, installation date, and the amount of electricity it produces or displaces over its lifetime. STCs are paid upfront for the estimated energy generation over the life of the system. This is capped at 15 years; however, the current scheme ends in 2030, so new systems will have a progressively shorter system life. The market price for STCs is set in the STC clearinghouse, but capped at $40. Strong demand for STCs from 2015 resulted in an undersupply of STCs and a price of $40 (see Figure 4). SRES will scale out gradually, from 2017 or 2022 depending on the tech, as the last year of eligibility is 2030 (Climate Change Authority 2014).

FIGURE 4: STC secondary market spot price (GST inclusive) since 2011 (Clean Energy Regulator 2015)

Owners of wind generation systems with capacity between 10-100kW may choose to participate in either the SRES or the LRET (Clean Energy Regulator 2015); however, if nearby generation sites are owned by the same business, then they will be deemed a single system (Brazzale 2015). Energy requirements for irrigation pumps and bores range significantly so potential solar installations may fall into the small or large scale RET schemes; however, aggregation of multiple systems may push cotton farmers into the LRET. The LRET provides LGCs as they are created, rather than the upfront option of the SRES; however, at the end of 2015, the LGC market had a spot price almost double that of the STC market (see Figure 5).

FIGURE 5: Price fluctuation of LGCs from 2014-2015
Image source: Clean Energy Regulator 2015



The large scale RET

If the solar PV system has a capacity greater than 100kW, or total annual electricity output over 250MWh, the system will be classified as a power station and will need to be accredited as a power station under the LRET (Clean Energy Regulator 2015). A registered power station can create large-scale generation certificates (LGCs) based on actual generation. As with STCs, LGCs can only be generated through to the end of the scheme in 2030; however, unlike the STCs, LGCs are sold retrospectively once the energy has been generated (Climate Change Authority 2014). However, LGCs can be sold forward on delivery contracts out to four years providing some price certainty (Greenmarkets 2015). Most certificates are sold once generation can be measured and verified. When a large generation system is installed as a hybrid (i.e. grid or diesel fuel) a Large-scale generation certificate eligibility formula is used to calculate the amount of fossil fuel displaced and hence the eligible quantity of LGCs (Clean Energy Regulator 2015).

There is a relatively simple process to register as a power station using a consultant for approximately $500 (Greenmarkets 2015). This process can become complicated and process driven if the power station is grid connected. As an example, in the Namoi Valley (NSW), Essential Energy will allow grid connected solar system sizes up to 30-50% of transformer capacity depending what loads are attached. The transformer size may be anywhere from 100kVA to 1500kVA depending on the pump sizes. For example, for a grower with a 75kW pump and a transformer capacity of 200kVA, system sizes above 100kW will require additional Grid Protection Equipment, which could be up to $10,000 additional cost The regional specific service providers require an application to connect new generation. Connecting to the distribution network requires careful consideration of the proposed load capacity, i.e. what the current network can handle and any specific connection requirements, as well as your connection voltage (Essential Energy 2013, Wilson 2015).

EMISSIONS REDUCTION FUND

The Emissions Reduction Fund (ERF) is the Australian government's centrepiece to deliver emissions reduction as part of Australia's 2020 emissions target. The ERF is a voluntary scheme that provides incentives for a range of organisations and individuals to adopt new, low cost practices and technologies to reduce carbon emissions. Assessed projects will be credited with Australian Carbon Credit Units (ACCUs) for each tonne of carbon dioxide equivalent (CO_2e) emissions reduction achieved. The Clean Energy Regulator runs competitive reverse auctions to purchase ACCUs at the lowest available cost (DOE 2015). The Clean Energy Regulator releases auction guidelines prior to each auction, including, relevant dates and the minimum quantity of ACCUs. The third auction, held on 27-28 April 2016, had a minimum bid requirement of 2000 ACCUs and achieved an average price of $10.23 per ACCU (Clean Energy Regulator 2016).

Projects must adhere to approved project methods in order to be eligible for ACCUs. Two energy efficiency methods may be applicable to irrigated cotton growers, the 'Industrial Electricity and Fuel Efficiency' method and the 'Aggregated Small Energy Users' method. Both methods share a requirement that any measured reductions in emissions achieved from a 'business as usual' baseline will be eligible to generate ACCUs. This can be done in a number of ways set out in the method guidelines including upgrading equipment and changing behaviour to influence energy consumption. Energy efficiency abatement projects will be better suited to large scale industrial applications or an aggregation of farms, as farm scale projects will not likely achieve the ERF minimum ACCU bid thresholds. The cotton industry has published a number of fact sheets on ERF methods applicable to cotton growers available at: **www.cottoninfo.com.au/carbon-farming**

OTHER GOVERNMENT BODIES

Arena

The Australian Renewable Energy Agency (ARENA) was established in 2012 to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia (ARENA 2016). ARENA's role is to assist in the commercialisation of renewable energy technology by supporting projects, research and development. ARENA has $2.5 billion in funding out to 2022, with the intent to provide competitive renewable energy solutions that last through to 2030-40. In solar PV, ARENA achieves its objectives by focusing on generation capacity of 5MW or more (MacGinley and Morris 2015). A current priority for ARENA is reducing the gap in commercial competitiveness for large-scale solar PV. In June 2016, ARENA closed applications to its first large-scale solar competitive funding round. The program allocated $100 million in grants for up to 200MW of large-scale solar PV. Targeted projects are expected to be in the range of 5-50 MW and have a levelised cost of electricity (LCOE) of $135/MWh or less. This funding was open to proposals that included a cluster of smaller solar PV facilities with a single or even multiple points of grid connection (ARENA 2015). Similar funding rounds are expected to be held in the future. As of July 2016, ARENA had provided $586.5 million in support of 101 projects relating to solar PV research, development and commercialisation (ARENA 2016).

CEFC

While ARENA supports the commercialisation of new technology, the Clean Energy Finance Corporation (CEFC) provides debt finance to established clean energy technologies in order to address the lower level of private sector finance in the industry. By providing finance, the CEFC aims to encourage private sector confidence and finance into renewable energy, energy efficiency and low emissions projects and technologies. The CEFC has $2 billion in funding per year and focuses on the later stages of development when most projects have matured and offer a positive expected rate of return (CEFC 2016). Typically, the CEFC collaborates with the private sector to co-finance its projects. For solar PV, the CEFC provides funding for projects with a capacity of 10MW or more (MacGinley and Morris 2015). As of July 2015, the CEFC has been directed to no longer focus on wind and small-scale solar (Hepburn 2015). From 2015, the CEFC launched a large-scale solar debt program that compliments ARENAs large-scale solar competitive round programs. The CEFC allocated $250 million of finance to boost the construction of solar developments in Australia. Eligible projects will receive a minimum loan of $15 million, be 10MW or more and have a power purchase agreement (contract with a customer) in place. As of July 2016, the CEFC was providing finance for a third of the total 300MW of large-scale solar installed or under construction in Australia (CEFC 2016).

An emissions reductions policy mechanism is expected to result in wholesale electricity prices to be in the region of $100-$140/MWh by 2035; a 5 per cent per annum increase from $40/MWh in 2015.

3 ELECTRICITY MARKETS & PRICING

Distribution and Marketing

Australia's National Energy Market (NEM), accounts for 80 per cent of electricity transmissions, and serves five trading regions covering New South Wales and the Australian Capital Territory, Victoria, Queensland, South Australia, and Tasmania. Smaller separate markets exist in Western Australia, the Northern Territory, and around Mt Isa in Queensland. The five NEM trading regions are interconnected to ensure that wholesale prices are similar most of the time across the regions. Within each trading region, electricity supply is broken up into generation, high voltage transmission, lower voltage distribution, and retail. Bulk electricity is transported throughout the regions via extra high voltage lines operated by a single monopoly electricity transmission business, which in NSW is TransGrid. The majority of electricity is then delivered to end users through a local distribution network, operated by a Distribution Network Service Provider (DNSP), which are natural monopolies regulated by the relevant economic regulator. Each state has multiple DNSPs supplying electricity to a specific geographic area. NSW has three DNSPs, with Essential Energy servicing the majority of rural NSW. In each geographic area, multiple competing retailers provide billing and price risk management services to end-users (EEX 2014).

The NEM operates as a gross pool market, where all electricity delivered to the market is traded on five minute intervals, 24-hours a day, seven days a week. Energy retailers purchase electricity at wholesale prices, package it with costs associated with provision of network services, and sell it to customers. The National Electricity Rules stipulate a maximum wholesale spot price of $12,500 MWh and a minimum spot price of minus $1,000 MWh. The negative minimum spot price allows generators to pay to stay online when the cost of staying online is lower than shutting down their systems. For a renewable generator, staying online may cost less than what generators receive from support mechanisms such as the RET (EEX 2014). Electricity prices show a clear peak and off-peak pattern, which reflects changing demand due to the time of day and the season. The daily change in energy demand, and the impact on wholesale prices in NSW can be seen in Figure 6.

Trends in electricity pricing

Retail electricity prices have far outstripped inflation in recent years (see Figure 7) increasing 82 per cent from 2007-08 to 2013-14, compared with a 13 per cent increase in the consumer price index. This price increase is largely due to increased investment in transmission and distribution infrastructure to replace ageing infrastructure (BREE 2014).

Since 2011-2012, increased supply costs have been compounded by a downward trend in energy generation, which declined by 0.6 per cent in 2013-14, primarily driven by a 2 per cent decline in states connected to the NEM. This decline compares to a long-run upward trend of 0.9 per cent over the ten years to 2013-2014. This means the increased network costs are being recovered from a smaller quantity of electricity, resulting in significantly increased price per unit of electricity sold (DIS 2015). The short-run downward trend in generation can be attributed to increased energy efficiency, mild weather, and a reduction in industrial load (DIS 2015). In addition, the increased prevalence of off-grid and distributed generation, such as from rooftop installed solar PV, have been encouraged by government policy and rising electricity prices, further reducing demand from the grid (DIS 2015).

Electricity prices in the future

Modelling conducted by CSIRO researchers Brinsmead et al. (2014) identifies government policy as the key determinant of electricity pricing to 2035. An emissions reductions policy mechanism is expected to result in wholesale prices to be in the region of $100-$140/MWh by 2035; a 5 per cent per annum increase from $40/MWh in 2015. Under a 'no carbon price' or emissions policy scenario, wholesale electricity prices could be in the range of $40-$80 MWh based on increased generation from renewable sources under the RET pressuring price growth.

FIGURE 6: NSW demand and price for the period 28/06/2016 15:00 to 29/06/2016 14:45. *Image source: AEMO 2016*

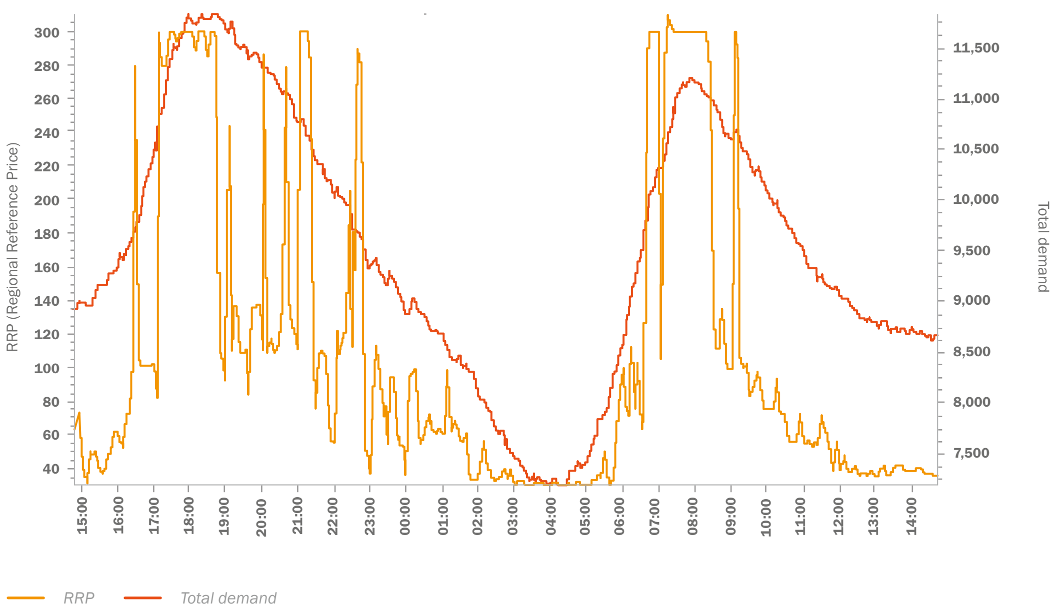
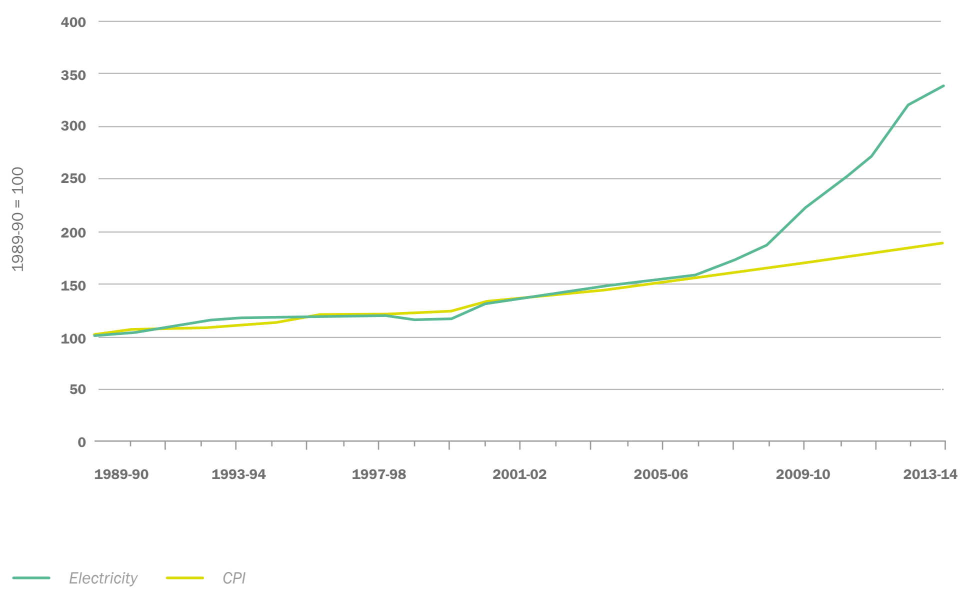


FIGURE 7: National Retail Electricity Price Index, 1989-90 to 213-14. *Image source: DIS 2015*



Electricity tariff structure

Australia currently runs a two-part electricity tariff structure, whereby end users pay a fixed connection charge as well as a variable consumption charge. This tariff structure cross-subsidises end users who draw electricity from the grid over peak periods. The Australian Government is committed to shift to cost-reflective tariffs and remove this cross subsidisation. Consumers would be charged according to the actual cost of delivering energy at the time of use, and the full value of permanent connection to a reliable energy supply. These changes would encourage end users to shift energy consumption away from peak times (DIS 2015). End-users that are unable to shift electricity use to off-peak periods, such as farmers relying on electricity for water pumping infrastructure during summer months, would face higher energy input costs. Having the option to shift to off-grid or distributed generation energy sources, such as solar PV, during peak periods would potentially reduce this input cost pressure.

Feed-in tariffs

Feed-in Tariffs (FIT) deliver a return (cents per kWh) for electricity fed into the grid, and are provided by some state governments. The New South Wales Solar Bonuses Scheme, in effect a feed-in tariff (FIT), was closed to new entrants in 2011 and will end in December 2016. The scheme provided a gross metered system, whereby all energy taken from the grid was purchased at retail prices, and all energy fed into the grid was given the FIT. New small-scale solar energy producers in NSW will have the option to use net metering, where they are only charged or credited for the excess energy that is drawn from or fed into the grid. Net metering requires a smart meter to track electricity inflows and outflows (DIRE 2016). At the request of the NSW Government, the Independent Pricing and Regulatory Tribunal provides ongoing recommendations for a 'fair and reasonable' FIT moving forward. IPART found that a 'fair and reasonable' FIT for solar PV in 2016-2017 is between 5.5 and 7.2 cents per kWh. The recommended FIT range takes into consideration the wholesale electricity price, avoided network losses and avoided market fees. Table 2 shows the electricity price and FIT for retailers in north-west NSW (additional fees and charges depend on the specific contract). The recommended FIT is lower than the retailer price of electricity due to fixed network costs, account administration, metering and billing (IPART 2016). This FIT is not mandated, with retailers instead encouraged to provide FIT prices consistent with IPART recommendations.

The Australian Energy Market Commission is being lobbied by consumer groups to change out-dated electricity pricing structures, based on large centralised power stations. This includes a proposed change to allow local generators feeding solar back into the grid to get a credit towards fixed network charges, recognising reduced overhead infrastructure usage (Vorrath 2015). Such changes would encourage shared energy and business-to-business trading, whereby domestic and small business solar systems trade surplus energy.

TABLE 2: RETAILERS AND TARIFF PAYABLE TO NEW SOLAR CUSTOMERS (C/KW) *Image source: AER 2016*

Retailer	Electricity Price (c/kWh) (Time of Use, Off-Peak and Peak)	Feed-in Tariff (c/kWh)
Urth Energy	17.5 and 27.5	10 to 20
Red Energy	17.47 and 28.36	5.0
AGL	18.58 and 33.35	5.1
Powerdirect	18.55 and 33.32	7.7
Origin Energy	16.15 and 27.05	6.0
Lumo Energy	16.28 and 27.28	5.0
Energy Australia	16.44 and 29.66	5.1
ERM Power	15.85 and 24.64	5.1
Drip/jet spray	17.32 and 28.71	8.0

Advances in Solar Technology

A technology's state of development is a key factor in its price, performance and uptake. Government policy, in Australia and around the world, has coupled with market drivers to encourage increased rates of research and development relating to solar technology. While solar energy is currently behind other forms of renewable energy, such as wind and hydro, in terms of technological development (see Figure 8); solar is expected to make greater gains in terms of cost and performance over the coming years (Geoscience Australia 2014).

Solar electricity generation is dominated by three main PV technologies, with varying levels of efficiency, price and system requirements (such as space). First generation crystalline silicon is fully commercial and the most widespread technology. First generation has increasingly high levels of conversion efficiency (at 20-25 per cent commercially or 40 per cent in laboratories). Second generation thin-film PV is an emerging technology that aims to improve on the cost of first generation PV cells, but with an associated reduction in efficiency to around 10 per cent. Third generation involves concentrating sunlight into a central receiver, which achieve higher levels of efficiency (20-40 per cent) but are in earlier stages of development and are generally suited to large-scale systems (Geoscience Australia 2014). Other solar PV technologies remain further behind in development, such as the recent Australian record for non-focused solar PV efficiency at 35 per cent (Parkinson 2016).

Solar installation costs

Over the life of a solar PV system, the majority of solar PV costs are borne in the system installation phase, however, these are rapidly decreasing with improved technology (Geoscience Australia 2014). In their 2014 report the International Energy Agency noted that the cost of PV modules (when measured against nameplate capacity in watts) had reduced by 80 per cent in six years, while the installed PV system had decreased by 66 per cent (IEA 2014). While Australia has been slightly behind the US in solar PV adoption, similar cost reductions have been observed, with a typical small-scale system price falling by more than 66 per cent between 2000 and 2013 (see Figure 9).

Over the life of the system, the other major cost comes from replacing the inverter, which converts direct current to alternating current power. The inverter generally needs to be replaced every ten years. Beyond this, there should be little to no other costs associated with the system over its useful life of 20-25 years. With a continued reduction in solar panel and installation costs, the balance of panel to inverter costs is expected to decrease over time (Geoscience Australia 2014).

FIGURE 8: Grubb curve for a range of renewable energy technologies (Geoscience Australia 2014), showing likely future price trends of different renewable technology

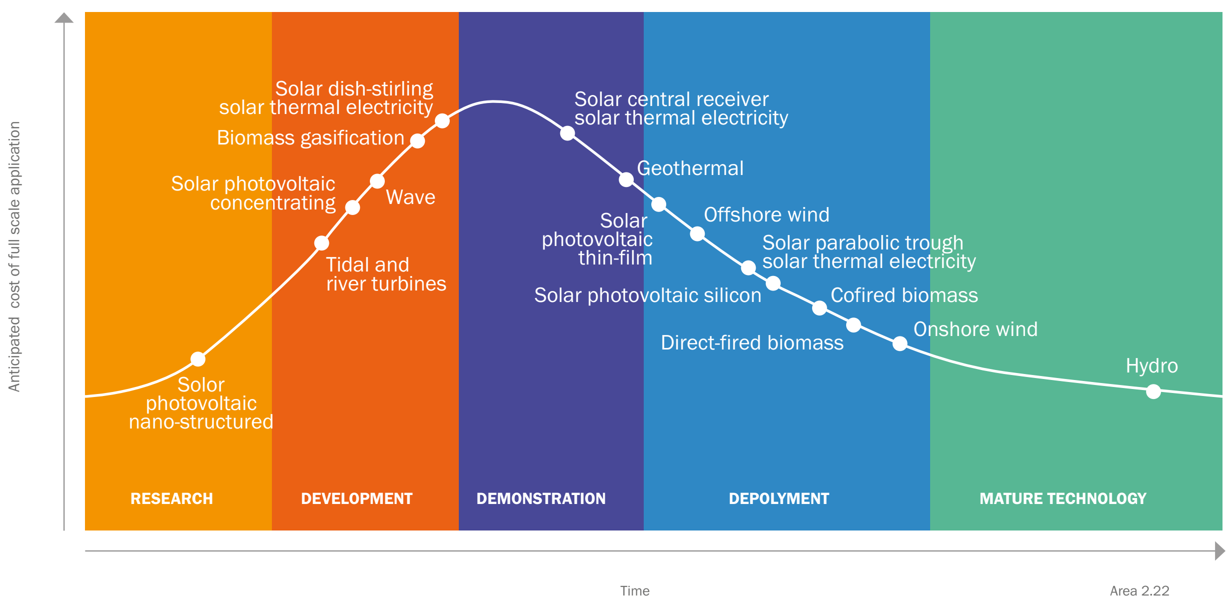
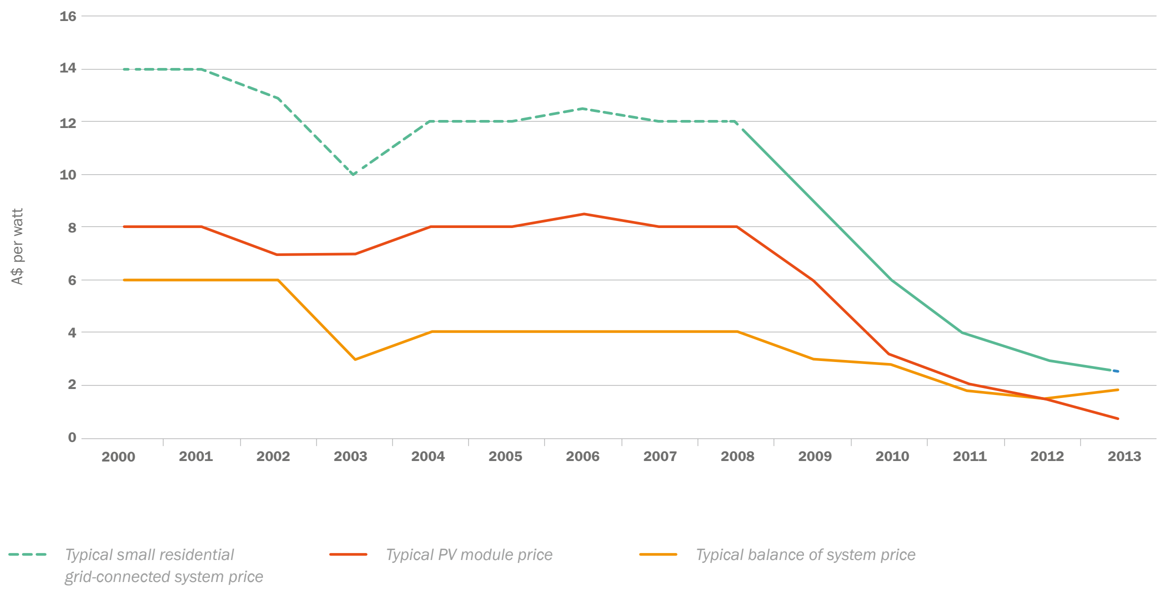


FIGURE 9: Trends in Australian PV systems costs, 2000-2013. *Source: Climate Change Authority 2014.*
Prices are prior to any SRES assistance, which would further reduce costs.



Assessing solar generation potential

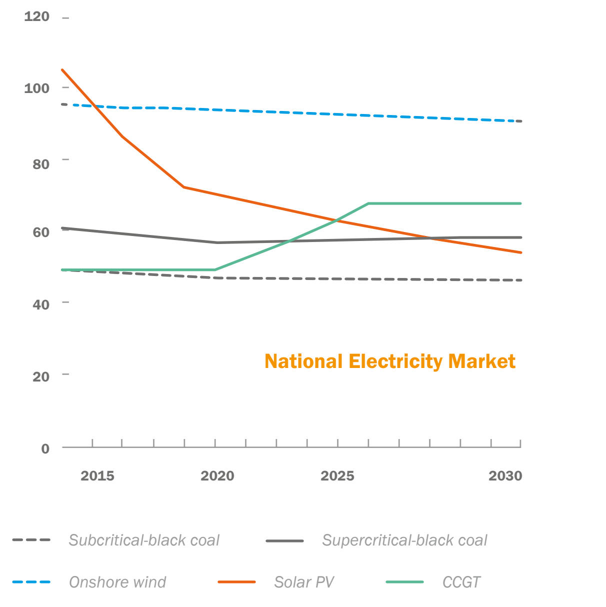
While upfront system costs employ nominal or nameplate capacity (the highest generation achievable under precise conditions at a single point in time), the actual output of solar PV is also dependent on the systems size and capacity factor (Clean Energy Council 2014). Capacity factor is impacted by periods of maintenance and other down time. Solar PV requires little to no maintenance; however, it is limited by season and weather (and therefore location) and also the time of day. A typical solar PV system that receives an average of 8 hours of full sun per day (summer only) has a capacity factor of 30 per cent in cotton areas. This compares to 30-40 per cent for a wind-farm and 30-55 per cent for hydro power year-round. When combined with nameplate capacity, the capacity factor gives the average production over a period of time. Taking into consideration varying system efficiency and capacity, the average daily production in NSW for a range of small-scale systems can be seen in Figure 10. Given varying initial and ongoing costs, and capacity factor associated with different energy generation systems, a combined measurement is required for comparison. Generally, the levelised cost of electricity (LCOE) is used for this purpose. LCOE considers capital costs, installation, finance, fuel costs and other ongoing costs such as maintenance, and is measured as a dollar value per actual generated electricity over the life of the system ($/MWh). LCOE also considers the capacity factor (the actual power generated over a given period of time).

In 2013-14, an average non-tracking solar PV system installed in NSW had an LCOE of A$224/MWh in 2013-14. In 2014, it was estimated that as a result of reducing capital costs, solar PV LCOE would drop to A$86/MWh by 2050 (Geoscience Australia 2014). However, a more recent assessment by McKinsey (2015) identified an even stronger downward trend. As a result, by 2025, Solar PV is predicted to have the lowest LCOE on the NEM outside of subcritical black coal (see Figure 11).

FIGURE 10: Average Daily Production for solar systems in NSW. *Source: Clean Energy Council 2014*

Location	10kW	20kW	50kW	100kW
Bourke	43.9kWh	87.8kWh	219.5kWh	439.0kWh
Broken Hill	44.9kWh	89.8kWh	224.5kWh	449.0kWh
Coffs Harbour	39.5kWh	79.0kWh	197.5kWh	395.0kWh
Dubbo	42.7kWh	85.4kWh	213.5kWh	427.0kWh
Lismore	40.1kWh	80.2kWh	200.5kWh	401.0kWh
Mildura (VIC)	43.2kWh	86.4kWh	216.0kWh	432.0kWh
Sydney	39.1kWh	78.2kWh	195.5kWh	391.0kWh
Tamworth	42.5kWh	85.0kWh	212.5kWh	425.0kWh
Wagga Wagga	41.9kWh	83.8kWh	209.5kWh	419.0kWh

FIGURE 11: Forecast LCOE for technologies on the NEM in US$ per MWh. *Source: McKinsey 2015*



A Bright Future for Solar Energy in Australia

Supportive government policies coupled with electricity market forces and rapidly advancing technology have all contributed to a dramatic increase in solar PV adoption (BREE 2014).

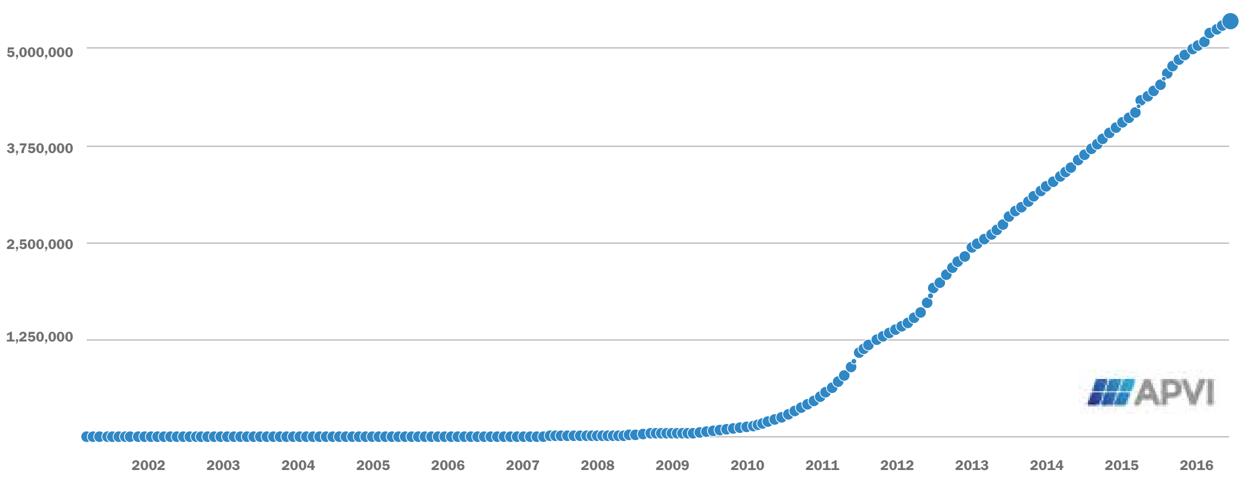
While black and brown coal currently dominate Australia's electricity production, with a 61 per cent share in 2013-2014, this has been declining consistently over the past decade. In the same period, natural gas marginally increased to 22 per cent of electricity generation. In contrast, renewable energy has experienced strong growth and rose to 15 per cent of electricity production in 2013-2014, dominated by hydro and wind energy sources. The Warburton Review (Climate Change Authority 2014) noted that 75 per cent of new large-scale renewable electricity generation supported by the RET was wind power. While solar PV accounted for only 2 per cent of total electricity production in 2013-2014, it accounted for approximately 60% of installed small-scale renewable systems, and 90 per cent of the year's generated STCs. Furthermore, over the ten years to 2013-14, solar PV sustained the highest average annual growth rate of 58 per cent, compared to 1 per cent across all energy types (Che and Pham 2012, DIIS 2015). Prior to the RET being split into the LRET and SRES, the uptake of small-scale solar PV was so far above expectations, that it led to a surplus of certificates on the market. When combined with reduced national energy consumption and uncertainty surrounding the future of the RET scheme, this surplus contributed to an 88 per cent reduction in investment in large-scale renewable energy generation in 2014 from which the industry is only just recovering (McConnell 2015, McKinsey Australia and New Zealand 2015, Edis 2016, Parkinson 2016, Parkinson 2016, Vorrath 2016).

Completed examples of large-scale solar generation during this period include AGL Energy's Nyngan solar power station, which at 102MW capacity is currently Australia's largest operating solar plant. It joins other large-scale projects in NSW, including the Broken Hill Solar Plant (53 MW) and Moree Solar Farm (56 MW) (Vorrath 2016). On a smaller scale, the 146kW Kamberra Winery power station in the ACT was constructed in partnership with retailer ActewAGL in 2013. The PV power station is leased to a third party with 100 per cent of the systems generation fed into the NEM. With the generated LGCs combined with the FIT negotiated with ActewAGL, Kamberra Winery represents a viable business model for the small end of the LRET (Parkinson 2012).

In contrast to these limited examples, small-scale renewables, led by solar PV systems, continued to grow steadily over the same period (McConnell 2015). This discrepancy between large and small-scale solar PV investment was due to a number of factors, including attractive state-based feed in tariffs and RET 'multiplier' credits for small-scale solar PV (Climate Change Authority 2014). Despite the expiration of some of these schemes resulting in a decrease in the number of system installations (IES 2014, Clean Energy Regulator 2016), an ongoing trend to larger commercial sized systems (10-100MWh) has resulted in a continued upward trend in Australian solar PV installation capacity (see Figure 12).

In the long term, national electricity generation is predicted to return to growth of up to 1.2 per cent annually. While coal and gas electricity generation are predicted to either remain constant or decrease as a percentage of the whole, renewable electricity is expected to experience strong growth to account for between 37-52 per cent of total production by 2030 (McKinsey Australia and New Zealand 2015, Blakers 2016). While the current investment pipeline for wind power is likely to dominate new generation out to 2020, beyond this point solar PV will constitute the majority of new large-scale generation capacity (DIIS 2015, McKinsey Australia and New Zealand 2015). Outside of investor confidence, the main limiting factors to large-scale solar PV generation are gradient and proximity to high-capacity transmission lines. This factors, however, do not impact stand alone and small – medium scale systems (Geoscience Australia 2014). As a result, small-scale solar is likely to become increasingly economically viable due to significantly reduced system and installation costs and associated LCOE. Even without the benefits of the SRES, net financial benefits would probably accrue from the installation of solar PV, but by providing an upfront payment, the scheme lowers initial expenses and shortens the payback period (Climate Change Authority 2014).

FIGURE 12: Australian PV installations since April 2001: total capacity (kW). *Image source: APVI 2016*



2016-05
Reported installed capacity (kW): 5,353,269
Estimated installed capacity (kW): 5,372,108

4 ASSOCIATED SOLAR TECHNOLOGY

Utilising 'excess' solar energy

Previous studies have highlighted the limited flexibility in the timing of water pumping applications, including dictated times of water pumping through water licensing requirements and also timing of irrigation practices to both maximise crop yield and minimise evaporative losses. Unless renewable energy generation matches the timings of irrigation energy demand, the economics become marginal at best (Clark and Vosper 1983, Vick, Clark et al. 2000, Vick, Neal et al. 2001, Gaskins, Amosson et al. 2007, Vick and Almas 2011, BECA 2015). In these instances, utilising surplus renewable energy was identified as a key area to improve project returns and payback time. While a grid connected system affords the option to be paid for energy fed into the network, low FITs may no longer provide the best financial option.

Battery Storage

Battery storage enables excess energy to be retained and used at a later time, and there are strong perceived benefits in incorporating battery storage with solar PV irrigation pumping systems (BECA 2015). As a result, energy supply and demand can be managed without the concern of intermittent generation (due to cloud or night), low FITs, high retail electricity prices, or pumping sites isolated from the electricity grid (Geoscience Australia 2014, BECA 2015). The cost of battery storage units has decreased rapidly in recent years. In the period 2010-2016 average lithium-ion battery costs dropped 65 per cent from $US1000/kWh in 2010, to approximately $US350/kWh in 2016. This trend is expected to continue with average costs of around $US120/kWh in 2030 (Macdonald-Smith 2016). For on grid systems, associated technology such as smart-metering and AGLs Solar Command app provide additional help in monitoring and managing energy consumption, and significantly reduce grid energy demand (DIIS 2015, Parkinson 2016).

Electric Vehicles

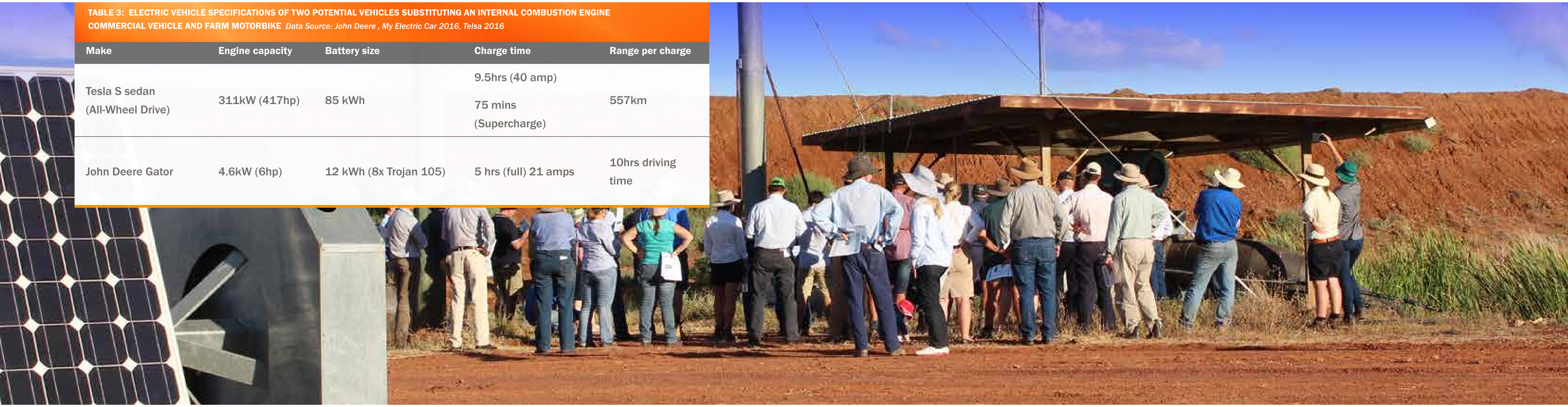
Another technology closely associated with battery storage is Electric Vehicles (EV). The technology development and viability of EVs is closely dependent on efficient battery storage, and as a result, the EV market is a strong driver in battery technology (Macdonald-Smith 2016). EV technology is improving rapidly, to the point that EVs show a better performance than internal combustion engine vehicles due to the usages of more efficient power trains and electric motors (Yong, Ramachandaramurthy et al. 2015). As a result, EVs provide an attractive and increasingly viable option to take advantage of high levels of solar PV energy production combined with battery storage (Hirth 2015). This is particularly relevant for Australian cotton farms, which are often located in relatively isolated inland regions. Individual landowners regularly travel 1,000 kilometres or more in one week between farming businesses, place of residence and the nearest commerce centre. In larger businesses, the kilometres travelled could be replicated by a number of employees, resulting in high fuel bills and increased carbon emissions from traditional combustion engines.

While electric tractors remain in the development stage, electric all-terrain vehicles (ATV's) and sedans are already commercially available (John Deere , My Electric Car 2016, Telsa 2016). Two currently available EVs are shown in Table 3.

While slow charge rates and sparse infrastructure presents particular challenges for EVs (Goldin, Erickson et al. 2013), EV infrastructure and support is expanding in Australia including Supercharger stations (Telsa 2016). While EVs currently come with a higher capital cost compared to a traditional internal combustion vehicle (Greaves, Backman et al. 2014), these prices are offset by large savings in fuel (My Electric Car 2016). Furthermore, these savings are enhanced when EVs are charged with solar PV generation (considering an opportunity cost of energy of 5.5-7.2 cents from FIT. As with solar PV technology, with ongoing technological development and penetration in the Australian car market, EVs will become an increasingly attractive option to include in a solar PV and battery system.

TABLE 3: ELECTRIC VEHICLE SPECIFICATIONS OF TWO POTENTIAL VEHICLES SUBSTITUTING AN INTERNAL COMBUSTION ENGINE COMMERCIAL VEHICLE AND FARM MOTORBIKE *Data Source: John Deere , My Electric Car 2016, Telsa 2016*

Make	Engine capacity	Battery size	Charge time	Range per charge
Tesla S sedan (All-Wheel Drive)	311kW (417hp)	85 kWh	9.5hrs (40 amp) 75 mins (Supercharge)	557km
John Deere Gator	4.6kW (6hp)	12 kWh (8x Trojan 105)	5 hrs (full) 21 amps	10hrs driving time



Conclusion

Energy consumption and efficiency is of increasing interest due to climate change and high prices of conventional energy sources. Together these issues are driving intertwined economic, environmental and socio-political imperatives to reduce energy consumption and seek alternative energy sources. At the same time, research is producing new technologies and practices that make these goals increasingly viable. Solar PV is one such technology that has advanced rapidly in recent years and is increasingly seen as a viable alternative energy resource. In Australia, solar energy uptake is being supported by government policy, such as the RET and incentivised by increasing retail electricity prices. Cotton farming has an opportunity to take advantage of solar PV and associated technologies as an alternative energy source in high energy practices such as irrigation.

Acknowledgements

This project has been supported by funding from the Australian Government. The authors would also like to thank George Revell for his timely contribution and editing to this document. Images courtesy Cottoninfo, Ruth Redfern, Janine Powell and Jon Welsh.

Proudly supported by

Australian Government
Cotton Research and Development Corporation

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