

GRID CONNECTED SOLAR

IRRIGATION CASE STUDIES

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Introduction

National environmental objectives have led to the development of government policies that create incentives for businesses to invest in renewable energy. These policies and increasingly affordable solar technology have aligned to deliver both economic benefits to farmers and co-benefits to the environment for grid connected solar installations.

This analysis aims to determine the economic feasibility of participating in both the Emission Reductions Fund (ERF) and Renewable Energy Target (RET) by installing solar energy production to assist in reducing electricity consumption for irrigation bores. Each case study is characterised by electricity consumption on different scales; one irrigator on a residential tariff and the other irrigator on an industrial demand tariff.

The background context on policy, energy and the cotton industry are reported in 'Solar energy: policy setting and applications to cotton production' (Powell and Welsh 2016). This report presents feasibility results and changes in environmental footprint (measured in carbon dioxide equivalents) for two case studies in the Upper and Lower Namoi Valleys of New South Wales.

The higher the proportion of solar electricity that is used (rather than fed back into the grid), the higher the project returns.



1 METHODOLOGY

Case studies were undertaken to consider the economic and environmental impact of installing grid connected solar to offset the electricity use of irrigation bore pumps used primarily for cotton production in the Namoi Valleys of NSW.

Optimal output is achieved by considering several factors that influence solar system design. These include investigation of all interacting physical (plant and soil type, irrigation system specifications, photovoltaic (PV) system sizing, site attributes), meteorological (solar radiation, air temperature, relative humidity, wind speed, precipitation) and managerial (irrigation scheduling) variables with the aim of achieving optimal output and reliability from the system (Maurya et al. 2015).

The bore site, electricity demand and pricing agreements are assessed for the case study farms to design and analyse a hypothetical solar installation.

FIGURE 1: Ground-mounted solar array beside an irrigation delivery channel



FIGURE 2: Solar array mounted over an irrigation delivery channel under a space-restricted scenario



1.1. Site location and assessment

The site location assessment considers the size of the bore and the location of the array. The system is most efficient when located as close as possible to the bore site. The location of the array will also determine the type of mounts used. Ground mounts (Figure 1) will generally be the most suitable mounting solution; however, where space is restricted on a cotton farm, the array can be built across the irrigation delivery channel supported by the banks of the channel and contributing to reduced evaporation from the channel (see Figure 2 as an example).

1.2. Electricity pricing and load assessment

Historical energy usage from the case study bores was sourced from the farmer so past and future electricity demands could be considered.

With the bores predominantly used to pump water for irrigated summer crops, the months from November to February have the highest electricity use, with little use from March to October. This demand pattern is complimentary with solar output patterns for the region, with the summer months having the highest output. It also results in generated solar power being underutilised for eight months of the year.

The broad acre production systems in the case study rely heavily on groundwater for irrigation. The nature of the irrigation design and crop water requirements result in the bores running 24 hours a day, often seven days a week during the peak irrigations months of summer. While 100 per cent of solar production can be used during the day, unless the array included battery systems, the pump would need to remain connected to the grid to operate 24 hours.

1.3. Reviews existing agreements with electricity retailers

The cost of electricity includes usage charges (based on the amount of electricity consumed), and additional fixed service and metering charges. The 'time-of use' electricity based charges (or tariffs) are split into peak and shoulder (7am to 10pm weekdays) and off-peak (all other times). The tariff consists of retail usage, environmental, network and market operator charges.

The variable cost of power offset by solar production has been calculated by averaging out the cost of electricity over these time-of-use intervals. Fixed line rental and metering charges are not considered within this analysis as they are unlikely to change with the installation of a solar array. If the solar installation included batteries, allowing for solar power to be utilised at nights (during 24 hour pumping), fixed costs may be minimised. Future analysis is planned that will consider batteries.

Within the model we assume that electricity prices increase by 5 per cent p.a. based on CSIRO report (Brinsmead et al. 2014) and the feed in tariff (FIT) does not increase over the life of the project. Whilst it appears that changes considered within this analysis would not affect the owner's contractual

obligations, anyone considering a solar installation should seek professional advice on how it may affect their existing electricity supply contract.

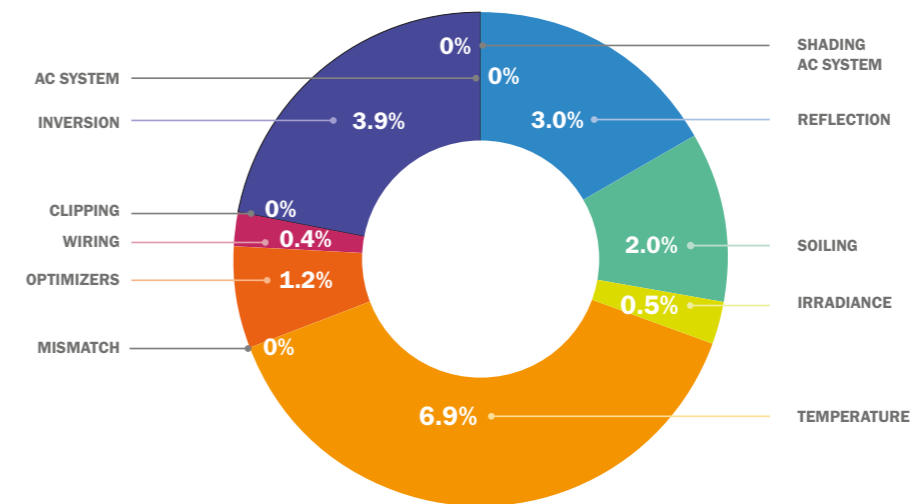
1.4. Solar generation assessment

A bankable modelling software 'HelioScope' was used to design a suitable array and produce solar output information. HelioScope has the ability to use customisable weather data. Weather data from the closest weather station was used as an input for each of the case studies.

A well designed and constructed solar system should perform to at least 80 per cent of capacity. Examples of the sources of solar system losses are expressed in Figure 3. Of particular interest is the 'temperature' loss. New panels are being designed that have improved performance in high temperatures such as those in the case study areas (up to 45 degrees Celsius). The solar module chosen for the analysis (Sunpower) has been selected due to high performing characteristics to suit the warm climate.

Within the model, the size of the solar installations has been kept below 100 kilowatt (kW). Solar systems above 100 kW need to be registered as commercial power stations, which may affect any existing electricity supply contracts.

FIGURE 3: An example of solar system losses (helioscope output)



1.5. Solar design

The maximum size of the solar array (without battery storage) is determined by matching daily energy demand to the peak insolation during the day. This ensures that while the bore pump is in operation, all solar being produced is used by the bore. With existing FITs nominal, the aim is to utilise the highest proportion of solar possible. When the irrigation bore is not in use, all electricity is fed into the grid.

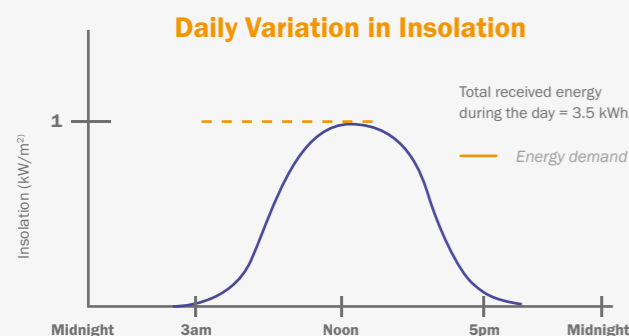
Steady energy demands of irrigation bores (that do peak on start up) are not consistent with the energy production patterns of solar. This mismatch is discussed in the report 'Solar energy: policy setting and applications to cotton production' (Powell and Welsh 2016).

The case study arrays were designed using well known quality brands, to ensure the components required minimum expense over the life of the project (25 years). The model assumes a 0.06 per cent annual degradation of solar capacity, so that after 25 years, the panels are at 80 per cent output compared to new.

Capital cost assumptions were made based on recent installations in NSW at Warren, Gunnedah and Moree. The 50 kW installation has an assumed cost of \$2.00 per watt and the 100 kW installation \$1.85 per watt. Advances in solar technology and cost reductions of more than 66 per cent were seen in Australia between 2008–2013 (Powell, Welsh et al. 2016). Given the constant movement in prices, it is strongly advised that those interested in installing solar investigate pricing by obtaining new quotes from reputable providers. The results within the analysis are very sensitive to the final installation cost, so any reductions (or increases) could change the payback period by years.

FIGURE 4: Solar demand and output

Image source: http://www.mpoweruk.com/solar_power.htm



The Government policies that provide Renewable Energy Certificates (RECs) as a subsidy for small scale solar is outlined in the report 'Solar energy: policy setting and applications to cotton production' (Powell and Welsh 2016). RECs were assumed to be paid upfront for 15 years of the estimated Megawatt hours (MWh) generated at a price of \$39 each. The policy expires in 2030, so newer schemes will have a progressively shorter life. I.e. the RET deeming period will be reduced from 15 years in 2015 to 14 years in 2016 and so on.

The number of RECs per system depends on geographical location, installation date, and the amount of electricity it produces or displaces over its lifetime. RECs for the case studies were estimated using the post code specific calculator from www.rec-registry.gov.au.

Some solar installers have an option where they take ownership of the RECs in return for an installation discount, in many cases the owner will make more money selling the RECs themselves.

Maintenance of the panels within the model includes costing for cleaning and insurance, increasing at a rate of 2 per cent p.a.

1.6. Avoided Emissions

The installation of solar technology on farm is an environmental consideration. By substituting traditional grid supplied energy with renewable energy, emissions are avoided. This can be substantial and is a clear environmental benefit. The avoided emissions were calculated using the total electricity offset due to the use of solar energy over the 25 year life of the project. Emissions factors have been calculated using data obtained from (Department of the Environment 2015) for NSW electricity and the (United States EPA 2014) for petroleum based fuels.

2 CASE STUDY: GUNNEDAH, 87 MWH PER YEAR



'KENSAL GREEN', GUNNEDAH

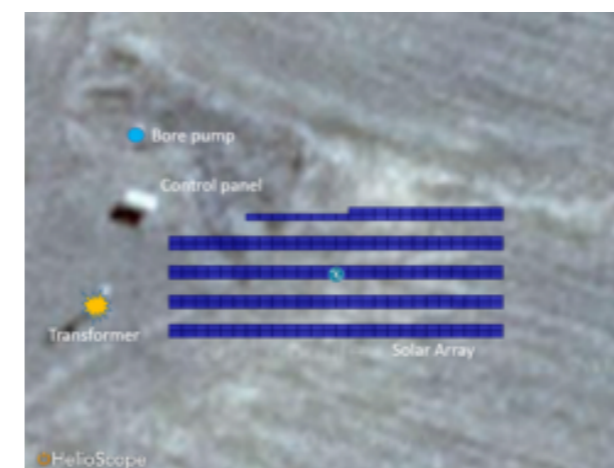
SCENARIO: Install 50 kW, grid connected solar system with net metering for an irrigation bore on the Mooki River at Gunnedah consumes approximately 87 MWh of electricity per year (77days).

2.1. Site Location & Assessment

Kensal Green was developed as an irrigated farming system in the 1970s. Development included several bore sites and access to river water, with a mix of diesel and electric pumps between the sites. In recent years, the case study bore has become one of the key water sources for irrigating the various crops on farm. The bore has an electric (grid connected), 50 kW pump. It is estimated in the future the bore will be used for approximately 77 days p.a. (87.4 MW hours).

There is room for an array of solar panels, adjacent to the bore, at the tail end of an irrigation paddock (see Figure 5). The space is currently utilised for dry-land farming, so the panels could be installed without space restriction allowing the array design to be optimised for shading and spacing combinations. Panels would need to be mounted on the ground, supported by driven or concreted posts in the heavy alluvial self-mulching grey cracking soils known as Vertosols (Powell and Scott 2011).

FIGURE 5: Bore location and solar array design (helioscope output)



2.2. Electricity pricing & load assessment

Current and future electricity demand

The months from November to January have the highest electricity use, with little use from February to October. This usage pattern is capped by ground water licencing agreements and assumes that, for the analysis period, irrigation water will only be used for the summer crop. The actual load on the pump has been calculated at 47kWh per pumping hour.

In the future, the farmer plans to allocate all irrigation water from the Water Access Licence to summer crops. The analysis was completed assuming an annual use of approximately 87 MW, which equates to approximately 77 days (of 24 hour) pumping through the growing season of November, December and January. At 87 MW per annum, the case study user falls into a "residential" tariff category. In New South Wales the consumption threshold between a residential and "industrial" customer is 160 MW of use per annum (Essential Energy 2016)

A review of retailer agreements with electricity retailers

Due to the lower level of annual use compared to some groundwater irrigators, a residential rate (rather than an industrial rate with large fixed demand charges and low wholesale price of electricity) has been negotiated with the electricity retailer.

Within this case study the variable costs were combined to give an average price of 21 c/kWh. The feed-in tariff (FIT) for electricity produced is 6 c/kWh.

2.3. Solar Generation Assessment

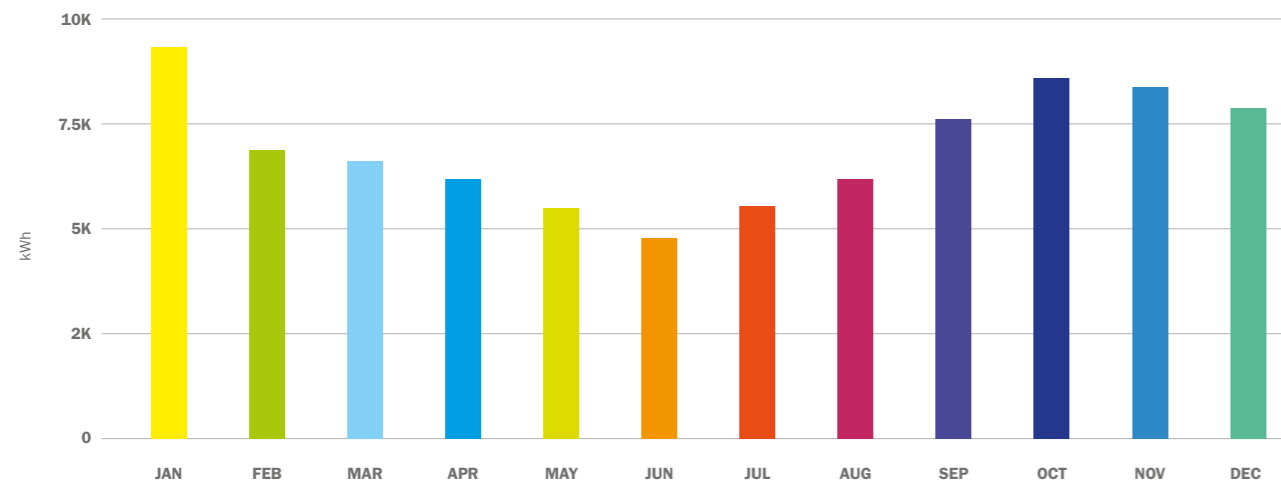
This analysis considers the installation of a 50kW, grid connected solar system with net metering. The solar size is

limited to 50kW in an attempt to match the pump capacity of approximately 50kW. Economies of scale can be achieved with larger systems; however, systems above 100kW need to be registered as commercial power stations, which may also affect the existing electricity supply contract. The economic impact of altering the size of the array to above or below the 50kW capacity of the pump is addressed in the sensitivity analysis.

Solar exposure data was downloaded from the 'Gunnedah Resources Centre' weather station (located within 5km of 'Kensal Green') on the Bureau of Meteorology's web site.

The HelioScope software modelled this data based on a 50kW system to give an annual 'energy to grid' of 83,741 kWh (229 kWh/day). This output (see Figure 6) varies throughout the year.

FIGURE 6: Solar production by calendar month for a 50 kW system on 'Kensal Green' (helioscope output)



2.4. Model Parameters

| | | | |
|----------------------------|----------------|-------------------------------------|----------|
| Type of system | Ground mounted | Assumed FIT inflation | 1.2% |
| System Capacity: | 50 kW | REC revenue | \$39 |
| System life: | 25 years | RECs generated | 1,036 |
| Install date: | 2015 | Total upfront Rec revenue | \$40,404 |
| Install cost: | \$100,000 | Retail electricity price | 21 c/kWh |
| Average annual cost # | \$3,000 | Assumed electricity price inflation | 5.0% |
| Daily system capacity * | 229 kW | Discount Rate | 5.8% |
| Annual generation (1st yr) | 83,741 | Pump size | 50 kW |
| Degradation rate of panels | 0.6% p.a | Days pumping | 77 days |
| Feed in Tariff (c/kWh) | 6 c/kWh | Electricity offset by solar (kWh) | 21,329 |
| Duration of FIT | 25 years | | |

Cleaning, maintenance, servicing & Insurance p.a

* DC rating (50) x Derate factor (.7) x peak sun hours a day (6) = 229

2.5. Results (base)

The base analysis results are a payback period of eight years, a 12 per cent internal rate of return (IRR) and a net present value (NPV) of \$39,556. The avoided CO₂e from production of 'green' energy is 546t of CO₂ over 25 years.

The solar installation offsets 24 per cent of the pumps annual electricity. As the solar array is matched to the pump size (in this case 50kW) the array provides the majority of the pumps energy requirements during peak day light hours (Helioscope works on 6 'peak sun' hours).

The pump is only used for 77 days of the year (throughout the summer) in this case study, resulting in 75 per cent of the energy produced being fed back into the grid. Whilst there is a feed in tariff of 6 c/kWh, the variable component of electricity charges at 21 c/kWh are 3.5 times greater than the FIT. With such a difference between the two 'uses', the higher the percentage of solar energy used to offset electricity costs, the better the project returns.

The cost of the installation affects the project's feasibility significantly. Affecting the net installation cost is RECs issued under the Australian Governments Small Scale Renewable Energy Scheme. For a summary of this policy see 'Solar energy: policy setting and applications to cotton production' (Powell and Welsh 2016). In this case study 1,036 RECs are generated and paid up front at a rate of \$39 each, which results in a \$40,000 (or 40 per cent) subsidy to the installation cost of the \$100,000 system.

The higher the percentage of solar energy used to offset electricity costs, the better the project returns.

2.6. Scenarios & Sensitivity Results

Changes to key inputs can affect project outcomes and influence future investment decisions. This section identifies potential changes in system size, rates of feed in tariff, power price inflation, pumping days, installation costs and potential electricity price increases and their effects on payback and IRR. Table 1 provides a summary of the outputs of these various scenarios.

SCENARIO A - Decrease system by 50 per cent to 25kW

By decreasing the system size, the solar installation offsets less of the electricity costs: 12 per cent of annual electricity usage rather than 24 per cent. There is also 50 per cent less energy feeding back into the system when the pump is not in use. The solar array being 50 per cent smaller will also produce half the RECs and therefore only half the upfront REC revenue. This all results in the IRR dropping from 12.08 per cent to 8.76 per cent, the payback period increasing from 8 to 11 and the avoided emissions over the life of the investment are reduced by 50 per cent to 273t CO₂.

SCENARIO B - Increase system by 50 per cent to 75kW

Increasing the solar installation by 50 per cent does not improve the investment, because the energy produced by the solar system is more than what the bore is using, therefore the increase in solar energy is fed into the grid rather than offsetting grid electricity use. Compared to the base case, the larger solar installation costs more but offsets the same amount of electricity; however, the larger system feeds 83 per cent of energy produced into the grid rather than 75 per cent in the base case. The solar array being 50 per cent larger will produce more RECs and therefore increase the upfront REC revenue. This all results in the IRR decreasing from 12.08 per cent to 10.18 per cent, the payback period increasing from 8 to 9 and the avoided emissions over the life of the investment remain at 546t CO₂. To make a larger solar system financially viable, energy produced from the solar array needs to be utilised in a way that returns more than 6c/kW.

SCENARIO C – 10 per cent reduction in gross installation cost

As the cost of installation is reduced the returns from the project increase. A 10 per cent decrease in gross installation cost results in a 15.01 per cent IRR (from 12.08 per cent) and reduces the payback period from 8 to 7 years. With the rapidly decreasing costs of solar technology, it is likely that these gains could be realised for investors.

SCENARIO D – A finance rate of 6 per cent

As an economic analysis, the cost to finance the project is not assessed in the base case. However, if a 6 per cent interest rate is assumed on the net installation cost of \$59,596 then the IRR remains positive, but drops to 4.47 per cent and the payback period increases to year 17.

SCENARIO E – Pump use increases by 20 per cent

In this scenario, the pump is used for 92.4 days rather than 77. This results in a higher proportion of solar energy produced being used to offset grid electricity costs rather than being fed into the grid (69 per cent fed in rather than 75 per cent). The increase results in a 14.17 per cent IRR and a 7 year payback period. Avoided emissions increase by 20 per cent to 655t over the life of the project.

SCENARIO F – Pump use decreases by 20 per cent

If the pump is utilised for 61.6 days rather than 77, less energy is used, so a higher proportion is fed back into the grid (80 per cent rather than 75 per cent). By decreasing the use of the pump, the IRR falls to 9.84 per cent (from 12.08 per cent) and the payback period increases to 10 years (from 8). The avoided emissions also drop by 20 per cent to 437t CO₂ over the life of the project.

| TABLE 1: Scenarios and sensitivity analysis on changes in key inputs for a solar generation plant at 'Kensal Green', Gunnedah NSW | | | | |
|---|---------------------------------------|----------------|-------------------------------|-------------------------------|
| Scenario | | Payback Period | Internal Rate of Return (IRR) | Avoided CO ₂ e (t) |
| A | Decrease system by 50% to 25kW | Year 11 | 9% | 273t |
| B | Increase system to 75kW | Year 9 | 10% | 546t |
| C | Reduce installation cost by 10% | Year 7 | 15% | 546t |
| D | Consider finance cost of 6% | Year 17 | 5% | 573t |
| E | Increase pump use by 20% | Year 7 | 14% | 655t |
| F | Decrease pump use by 20% | Year 10 | 10% | 437t |
| G | Increase FIT by 2c (to 8c) | Year 7 | 15% | 546t |
| H | Increase FIT by 6c (to 12c) | Year 5 | 20% | 546t |
| I | Electricity inflation 4% (base of 5%) | Year 9 | 11% | 546t |
| J | Electricity inflation 6% (base of 5%) | Year 8 | 13% | 546t |
| K | No RECs | Year 14 | 6% | 546t |
| L | No FIT's | Year 17 | 5% | 546t |
| M | Telsa Car & Gator | Year 5 | 21% | 828t |

FIGURE 7: Upper Namoi case study, scenario IRR and avoided emissions



SCENARIO G – Increase in FIT from 6c to 8c

An increase in the FIT by 30 per cent, increases the income from the 75 per cent of energy that is being fed into the grid. The increase in income from the FIT results in a 14.71 per cent IRR and a payback period of 7 years.

SCENARIO H – Increase in FIT from 6c to 12c

By analysing a double in the FIT, this scenario considers a possibility of private sale of energy. Whilst not currently an option, as the energy markets evolve and many smaller scale energy producers emerge, this may become an option in the future. Doubling income from the energy fed back into the grid results in a 20.33 per cent IRR and a payback period of 5 years.

SCENARIO I – Electricity prices increase at 4 per cent p.a

In the base scenario, electricity prices increase by 5 per cent p.a, in this scenario we assume a slower electricity price increase at 4 per cent p.a. This results in a lower value of the electricity offset in the future and a IRR of 10.97 per cent rather than 12.08 per cent and a payback period of 9 years.

SCENARIO J – Electricity prices increase at 6 per cent p.a
If the electricity price were to grow at a faster rate than the base case, the value of the electricity offset in the future is higher, resulting in a higher IRR of 13.19 per cent and a slightly quicker payback period (but still within the 8th year).

SCENARIO K – No Renewable Energy Certificates paid

The case study analysis was completed in 2015, assuming a 2015 solar installation. With RECs being paid up to 2030, the base scenario has an upfront payment of 15 years of RECs. For solar installations after 2015 the number of RECs decrease, i.e a 2016 installation would receive 14 years of RECs and a 2017 installation 13 years of RECs etc. As the REC income decreases, the net installation cost of the project increases, reducing the IRR and increasing the payback period of the investment. Here we consider a scenario with no REC payments; the project IRR remains positive at 5.91 per cent and the payback year increases to year 14. This indicates that as we draw closer to 2030 and the REC revenue is reduced or if this particular Government policy was withdrawn, this solar project remains a feasible investment.

SCENARIO L – No Feed in Tariff

Considering a scenario of no FIT, meaning the 75 per cent of solar energy that is produced generates no income. In this scenario, the avoided electricity costs are enough to keep the IRR positive at 4.58 per cent and the payback period at year 17, which is within the 25 year life of the project.



SCENARIO M – Electric Vehicles

One of the key ways to improve the feasibility of the solar investment is to utilise more power. The project parameters of 50kW installation combined with a maximum of 77 pumping days offsets approximately 24 per cent of power generation. 75 per cent of generated power is fed into grid at a rate equal to the cost of production (6c/kWh). Finding an alternative to utilise this large amount of energy may potentially change project returns, if other on-farm operating costs can be offset. As technology and costs of electric vehicles becomes more favourable, they provide a practical alternative for cotton farming businesses operating in isolated, sun-rich areas. Electric vehicles are discussed in the context of solar in the background report 'Solar energy: policy setting and applications to cotton production' (Powell and Welsh 2016). Information provided by electric vehicle maker Tesla

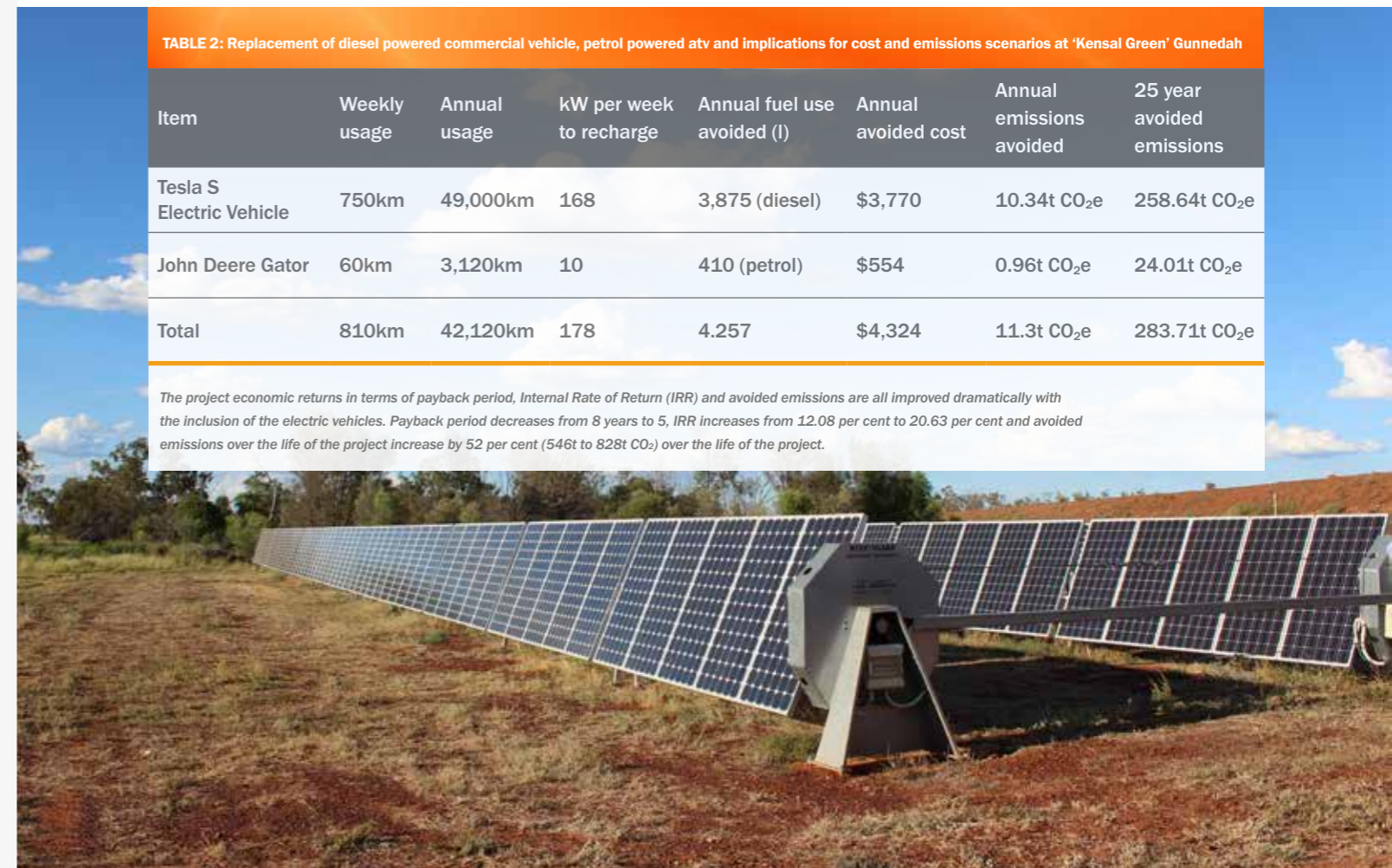
shows 84kWh to charge an electric car with a 500km range and John Deere shows 5kWh to charge an electric gator.

This scenario considers the current commercial vehicle used by the landowner travelling to and from his property to his residence is substituted with an electric vehicle. Secondly, a John Deere electric gator will replace a 500cc petrol driven 'All Terrain Vehicle' (ATV) used for general farm duties. For simplicity, the analysis assumes the current commercial vehicle used by the landowner (Isuzu diesel DMax) and the ATV (Yamaha petrol 500cc) can be replaced by electric powered versions at the same capital cost. Fuel cost calculations used in the analysis have removed GST and excise taxes (where applicable). These vehicles will consume and recharge electricity generated exclusively from installed solar power plant on farm. The breakdown of costs and emissions under this scenario are summarised in Table 2.

TABLE 2: Replacement of diesel powered commercial vehicle, petrol powered atv and implications for cost and emissions scenarios at 'Kensal Green' Gunnedah

| Item | Weekly usage | Annual usage | kW per week to recharge | Annual fuel use avoided (l) | Annual avoided cost | Annual emissions avoided | 25 year avoided emissions |
|--------------------------|--------------|-----------------|-------------------------|-----------------------------|---------------------|------------------------------|--------------------------------|
| Tesla S Electric Vehicle | 750km | 49,000km | 168 | 3,875 (diesel) | \$3,770 | 10.34t CO ₂ e | 258.64t CO ₂ e |
| John Deere Gator | 60km | 3,120km | 10 | 410 (petrol) | \$554 | 0.96t CO ₂ e | 24.01t CO ₂ e |
| Total | 810km | 42,120km | 178 | 4,257 | \$4,324 | 11.3t CO₂e | 283.71t CO₂e |

The project economic returns in terms of payback period, Internal Rate of Return (IRR) and avoided emissions are all improved dramatically with the inclusion of the electric vehicles. Payback period decreases from 8 years to 5, IRR increases from 12.08 per cent to 20.63 per cent and avoided emissions over the life of the project increase by 52 per cent (546t to 828t CO₂) over the life of the project.



3 CASE STUDY: WEE WAA, 595MWH PER YEAR



WEE WAA

SCENARIO: Install 100 kW, grid connected solar system with net metering for an irrigation bore NW of Wee Waa, consumes approximately 595 MWh of electricity per year (160 days).

3.1. Site Location & Assessment

Farm A was developed as an irrigated farming system in the 1970s. Development included several bore sites and access to river water, with a mix of diesel and electric pumps between the sites. In recent years, the case study bore has become one of the key water sources for irrigating the various crops on farm. The bore has an electric (grid connected), 155kW pump. It is estimated in the future the bore will be used for approximately 160 days a year (595 MW hours).

There is room for an array of solar panels, adjacent to the bore, at the tail end of an irrigation paddock (see Figure 8). The space currently has a channel used irregularly as farm overflow for irrigation water, so the panels would need to be mounted to sit over the channel and allow water to flow under them (see the example in Figure 2).

The array can be located close to the pump and as per Case study 1, concreted posts will be needed in the heavy vertosol soil.

FIGURE 8: Bore location, wee waa case study site



Retailer Summary

Peak tariff = 11.20c/kWh
 Off-peak Tariff = 9.47c/kWh
 Fixed Charges (approx.)= 11c/kWh
 Feed-in-Tariff for Solar = 6.0c/kWh

3.2. Electricity pricing & load assessment

Current and future electricity demand

Actual energy usage for the previous 14 months for the bore was sourced from the farmer in 2015. The months from October to January have the highest electricity use, with no use from April to August. This usage pattern indicates that, for the analysis period, irrigation water was only used for the summer crop. In 2014 the bore ran for 447 Megawatt (MW) hours, which equates to approximately 120 days (of 24 hour) pumping.

In the future, the farmer plans to allocate some irrigation water to winter crops as well as the key summer crops, the analysis was completed modelling an annual use of 595 MW, which equates to approximately 160 days (of 24 hour) pumping.

A review of retailer agreements with electricity retailers

Due to the significant annual energy use, a commercial rate (rather than the more expensive residential rate) has been negotiated with the electricity retailer. The cost of electricity includes usage charges (based on the amount of electricity consumed), demand charges (based on the maximum kVA demand at any point during the month) and additional fixed service and metering charges. Demand and fixed charges have not been considered within this analysis as they are unlikely to change with the installation of a solar array. With an annual usage of 595 MWhrs per annum, this case study falls into the “industrial” user category (>160 MWhrs per annum) with a different tariff structure than the previous case study.

Within this case study the variable costs were combined to give an average peak (11.20 c/kWh) and off-peak tariff (8.08 c/kWh), with an average of price of 9.47 c/kWh. The FIT for electricity produced is 6.0 c/kWh.

3.3. Solar Generation Assessment

This analysis considers the installation of a 100 kW, grid connected solar system with net metering. The solar size is limited to 100kW, to fit within network provider guidelines and keep in the Small-scale Renewable Energy Scheme.

Within the case study region the energy supplier, Essential Energy, limits grid connected solar systems to 30–50 per cent of transformer capacity (depending on the load that is attached).

If the project is over 100kW or has an annual electricity output of more than 250MWh, it falls under the ‘Large-scale Renewable Energy Target’ (LRET), meaning 15 years of RECs are not paid up front, but as they are created. Economies of scale can be achieved with larger systems; however, as a large scale power generator it would need to

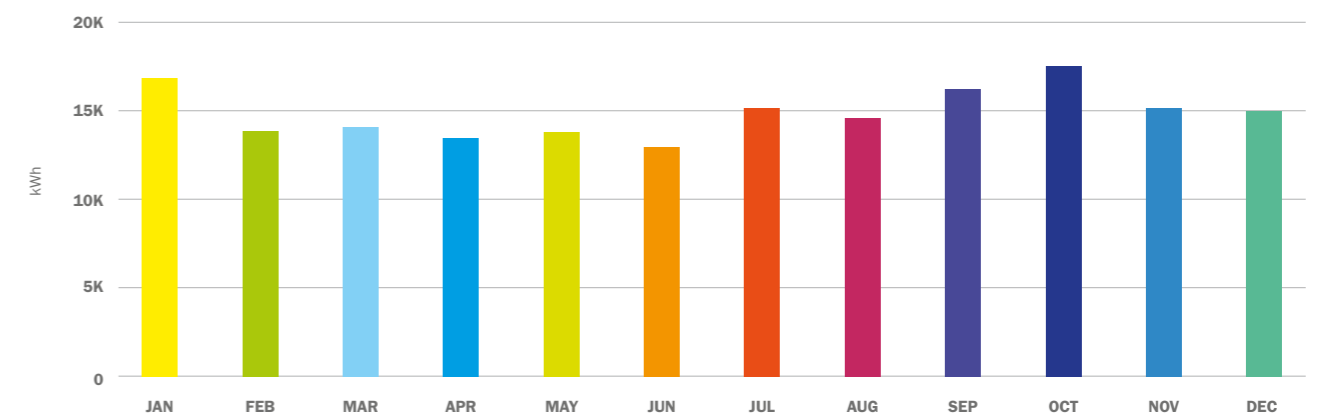
be considered what is involved in becoming a commercial power station and if it effects any existing electricity supply contract. Further information on the LRET can be found in Powell, Welsh et al. (2016). Given the above, a large-scale solar installation is discussed in Scenario N, assuming all variables remain constant except government payments.

A bankable modelling software ‘HelioScope’ was used to design a suitable array and produce solar output information. Solar exposure data was downloaded from the ‘Pendennis’ weather station (located on nearby Doreen Lane) on the Bureau of Meteorology’s web site.

The HelioScope software modelled this data based on a 99.8kW system to give an annual ‘energy to grid’ of 180,225 kWh (494 kWh/day).



FIGURE 9: Solar production, 99.8kW system for ‘Pendennis’



3.4. Model Parameters

| | | | |
|------------------------------|----------------|---------------------------------------|------------|
| • Type of system | Ground mounted | • Assumed FIT inflation | 1.20% |
| • System Capacity: | 100 kWh | • REC revenue | \$39 |
| • System life: | 25 years | • RECs generated | 2,304 |
| • Install date: | 2015 | • Total upfront Rec revenue | \$89,856 |
| • Install cost: | \$185,000 | • Retail electricity price | 9.47 c/kWh |
| • Average annual cost # | \$5,500 | • Assumed electricity price inflation | 5.00% |
| • Daily system capacity * | 494 kWh | • Discount Rate | 5.77% |
| • Annual generation (1st yr) | 180,225kWh | • Pump size | 155kW |
| • Degredation rate of panels | 0.60% p.a | • Days pumping | 160 days |
| • Feed in Tariff (c/kWh) | 6 c/kWh | • Electricity offset by solar (kWh) | 595,200 |
| • Duration of FIT | 25 years | | |

Cleaning, maintenance, servicing & insurance p.a

* DC rating (50) x Derate factor (.7) x peak sun hours a day (6) = 229

3.5. Results (base)

The base analysis results have a payback period of year 7 and a 15.2 per cent internal rate of return (IRR). If you consider discounted future values, the 25 year project has a net present value of \$98,026. The avoided CO₂e from production of 'green' energy is 2,022t over 25 years.

The solar installation would offset 13 per cent of the pumps annual electricity use. In this case study, the pump is used for 160 days of the year, resulting in 56 per cent of the energy produced being fed back into the grid. The feed in tariff of 6 c/kWh is just under the variable component of electricity charges at 9.47c/kWh.

In this case study 2304 RECs are generated and paid up front at a rate of \$39 each, this results in a \$89,856 (or 49 per cent) subsidy on the installation cost of the \$185,000 system. The cost of installing solar has been declining rapidly and is expected to continue in the foreseeable future (Powell and Welsh 2016).

3.6. Scenarios & Sensitivity Results

Changes to key inputs can affect project outcomes and influence future investment decisions. This section identifies potential changes in system size, rates of feed in tariff, power price inflation, pumping days, installation costs and potential electricity price increases and their effects on payback and Internal Rate of Return (IRR). Table 3 provides a summary of the outputs of these various scenarios.

SCENARIO A - Decrease system by 50 per cent to 50kW

By decreasing the system size, the solar installation is offsetting less of the electricity costs, 7 per cent of annual electricity usage rather than 13 per cent. There is also 50 per cent less energy feeding back into the system when the pump is not in use. The solar array being 50 per cent smaller will also produce half the RECs and therefore only half the upfront REC revenue. This all results in the internal rate of return dropping from 15.20 per cent to 8.87 per cent, the payback year increasing from 7 to 11 and the avoided emissions over the life of the investment are reduced by 50 per cent to 1,011t CO₂.

SCENARIO B - Increase system by 50 per cent to 150kW & LGCs

Increasing the solar installation over 100kW results in the array requiring registration as a power station and excludes it from RECs and opens up the projects to LGC's. LGCs are paid as they are produced (annually), rather than upfront.

LGC pricing assumptions were \$75 per MWh for the first five years and \$65 per MWh for years 6 to 25. Increasing the system to 150kW and changing to LGCs resulted in an improved return of 15.86 per cent IRR (from 15.2 per cent) and the project pay back in year 6 (rather than 7). With the solar system output closely matching the energy demands of the motor, the 150kW system offsets 20 per cent annual electricity use (rather than 13 per cent). The larger solar installation increases avoided emissions over the life of the investment from 2,022t to 3,032t of CO₂.

Participation in the LRET is analysed for the 100kW system in Scenario N.

SCENARIO C - 10 per cent reduction in gross installation cost

As the cost of installation is reduced the returns from the project increase. A 10 per cent decrease in gross installation cost results in a 19.41 per cent IRR (from 15.2 per cent) and reduces the payback period from 7 to 5 years. With the rapidly decreasing costs of solar technology, it is likely that this gains could be realised for investors.



TABLE 3: Scenarios and sensitivity analysis on changes in key inputs for a solar generation plant on the case study farm, Wee Waa NSW

| Scenario | Payback Period | Internal Rate of Return (IRR) | Avoided CO ₂ e (t) | |
|----------|---------------------------------------|-------------------------------|-------------------------------|--------|
| A | Decrease system by 50% to 50kW | Year 11 | 8.87% | 1,011t |
| B | Increase system to 150kW | Year 6 | 17.79% | 3,032t |
| C | Reduce installation cost by 10% | Year 5 | 19.41% | 2,022t |
| D | Consider finance cost of 6% | Year 12 | 7.86% | 2,022t |
| E | Increase pump use by 20% | Year 6 | 16.60% | 2,426t |
| F | Decrease pump use by 20% | Year 7 | 13.72% | 1,617t |
| G | Increase FIT by 2c (to 8c) | Year 5 | 17.89% | 2,022t |
| H | Increase FIT by 6c (to 12c) | Year 4 | 23.72% | 2,022t |
| I | Electricity inflation 4% (base of 5%) | Year 7 | 14.26% | 2,022t |
| J | Electricity inflation 6% (base of 5%) | Year 6 | 16.16% | 2,022t |
| K | No RECs | Year 13 | 6.49% | 2,022t |
| L | No FIT's | Year 12 | 7.78% | 2,022t |
| M | Telsa Car & John Deere Gator | Year 5 | 20.48% | 2,308t |
| N | LGC | Year 6 | 15.86% | 2,022t |

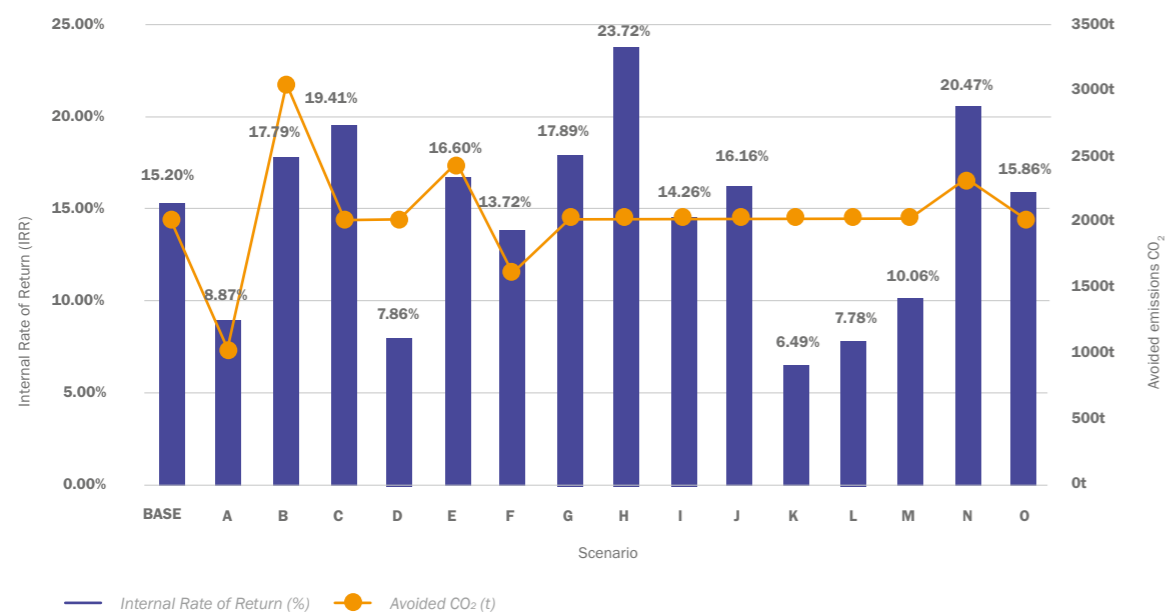
SCENARIO D – A finance rate of 6 per cent

As an economic analysis, the cost to finance the project is not assessed in the base case. However, if a 6 per cent interest rate is assumed on the net installation cost of \$89,856 then the Internal Rate of Return (IRR) remains positive, but drops to 7.86 per cent and the payback period increases to year 12.

SCENARIO E – Pump use increases by 20 per cent

In this scenario, the pump is used for 192 days rather than 160. This results in a higher proportion of the solar energy produced offsetting grid electricity costs rather than being fed into the grid (53 per cent rather than 44 per cent). The increase results in a 16.60 per cent IRR and a 6 year payback period. Avoided emissions increase by 20 per cent to 2,426t of CO₂ for the 25 year life of the project.

FIGURE 10: Lower Namoi case study, scenario Internal Rate of Return (IRR) and avoided emissions



SCENARIO F – Pump use decreases by 20 per cent

If the pump is utilised for 128 days rather than 160, 65 per cent of solar energy produced is fed back into the grid (rather than 56 per cent). By decreasing the use of the pump, the IRR falls to 13.72 per cent (from 15.20 per cent) and the payback period remains in year 7. Avoided emissions decrease 20 per cent to 1,617t of CO₂ over the life of the project.

SCENARIO G – Increase in FIT from 6c to 8c

An increase in the FIT by 30 per cent, increases the income from the 56 per cent of solar energy produced that is being fed into the grid. The increase in income from the FIT results in a 17.89 per cent IRR and a payback period of 5 years.

SCENARIO H – Increase in FIT from 6c to 12c

By considering a double in the FIT, this scenario considers a possibility of private sale of energy. Whilst not currently an option, as the energy markets evolve and many smaller scale energy producers emerge, this may become an option in the future. Doubling income from the energy fed back into the grid makes the FIT higher than the variable cost of grid energy and results in a 23.72 per cent IRR and a payback period of 4 years.

SCENARIO I – Electricity prices increase at 4 per cent p.a

In the base scenario, electricity prices increase by 5 per cent p.a, in this scenario we assume a slower electricity price increase at 4 per cent p.a. This results in a lower value of the electricity offset in the future and a IRR of 14.26 per cent rather than 15.20 per cent and a slightly slower payback period (but still within the 7th year).

SCENARIO J – Electricity prices increase at 6 per cent p.a

If the electricity price were to grow at a faster rate than the base case, the value of the electricity offset in the future is higher, resulting in a higher IRR of 16.16 per cent and a slightly quicker payback period of 6 years.

SCENARIO K – No Renewable Energy Certificates paid

The case study analysis was completed in 2015, assuming a 2015 solar installation. With RECs being paid up to 2030, the base scenario has an upfront payment of 15 years of RECs. For solar installations after 2015 the number of RECs decrease, i.e a 2016 installation would receive 14 years of RECs and a 2017 installation 13 years of RECs etc. As the REC income decreases, the net installation cost of the project increases, reducing the IRR and increasing the year's to pay back the investment. Here a scenario is considered with no REC payments; the project IRR remains positive at 6.47 per cent and the payback year increases to year 13. This indicates that as we draw closer to 2030 and the REC revenue is reduced or if this particular Government policy was withdrawn, this solar project remains a feasible investment.

SCENARIO L – No Feed in Tariff

Considering a scenario of no FIT means the 56 per cent of solar energy that is produced generates no income. In this scenario, the avoided electricity costs are enough to keep the IRR positive at 7.78 per cent and the payback period within the life of the project (year 12).

SCENARIO M – Electric Vehicles

This scenario uses the same vehicle and usage patterns as Case Study 1. Electric vehicles are one option to increase the use of the solar energy, in this case study they use 5 per cent of the solar energy produced and result in \$4,324 less being spend on fuel annually. This scenario results in a 20.47 per cent IRR, payback within year 5 and a 14 per cent increase (total of 2,308t) of avoided CO₂ over the life of the project. Given the location of the solar installation on the case study farm, charging electric vehicles would not be practical.

SCENARIO N – LGC

Solar installations between 10–100kW have the option of participating in either the Small scale renewable energy scheme or the Large scale renewable energy scheme. All installations over 100kW are considered large scale. Keeping all variables, the same as the base scenario, and changing the participation of the 100kW installation from the small to large scheme (using LGC assumptions as per Scenario B), the project returns improve marginally. Payback period improves to year 6 from year 7 and the IRR also improves to 15.86 per cent IRR from 15.2 per cent. The main difference between the schemes are that small scale RECs are paid upfront and large scale RECs are paid annually. Pricing assumptions within the analysis resulted in similar project returns, however for projects under 100kW there would be both pricing and policy risk associated by choosing to participate in the large scale scheme rather than the small.



Discussion

The project attributes that are key to the feasibility of a grid connected solar investment are the net cost of the installation and the benefits generated by the utilisation of the solar energy.

The net cost of the solar installation is dependent on the installation cost of the system and the upfront payment of RECs. The significant reduction in the cost of solar installations has meant that the RECs subsidise a significant proportion of the installation costs: 40 per cent and 49 per cent for case studies 1 and 2 respectively. Until recently, the case study solar investments were not economically feasible without the RECs; however, using current pricing, both case studies would be feasible without the RECs (as per scenario K).

Benefits generated by the use of the solar energy include FITs and avoided energy costs (such as grid electricity or fuels). Both case studies receive a 6c FIT, which is within IPARTS suggestion of 5.5 and 7.2 cents per kWh for a 'fair and reasonable' FIT (IPART 2016). The avoided electricity costs are those costs that would have been incurred without the solar installation. In the case studies these are the variable cost of electricity and with scenario M, the cost of fuel. The solar energy produced is split between these benefits (i.e. per cent used to offset electricity costs compared to 56 per cent feed back into the grid), which is particularly important when there is a considerable margin between the price of the different benefits. In case study 1, the avoided cost of electricity per kW is over three times the income received for the FIT (6c – 21c). In case study 2 it is 58 per cent higher (6c – 9.47c). If all other project variables were equal, the project with the highest margin would be the most feasible; however, there are other key differences between the case studies.

Case study 1 offsets 21,300 kW of grid electricity annually and case study 2 offsets 79,000 kW annually, representing 24 per cent and 13 per cent of the total electricity use. The pump in case study 2 is three times larger than the pump in case study 1 (but the solar installation is only twice the size). Despite the much larger amount of electricity offset by the pump in case study 2, proportionally it is less of the total electricity use

because the solar installation in Case study 2 was limited to 100kW for a 155kW pump and the installation for Case study 1 was 50kW for a 50kW pump.

Case study 1 and 2 have 12 per cent and 15.2 per cent IRR respectively. This large difference in returns comes down to the fact that the Case study 2 bore was used for 160 days which utilised 44 per cent of the solar produced (compared to 77 days and 25 per cent for case study 1). The higher the proportion of solar electricity that is used (rather than fed back into the grid), the higher the project returns. Where a pump is a secondary water source and usage is variable each year depending on weather and licence allocations, long term use needs to be considered carefully to assess the feasibility of a solar installation.

The installation of solar technology on farm is an environmental consideration. By substituting traditional grid supplied energy with renewable energy, emissions are avoided. This can be substantial and is a clear environmental benefit. In the base scenarios, avoided emissions over the 25-year life of the project were 546t and 2,022t for case studies 1 and 2 respectively. CO₂e valued at \$10/t, this equates to an environmental benefit of \$5,460 and \$20,220 respectively. Scenario analysis shows that this benefit could increase or decrease with changes to project inputs (scenarios A, B, E, F, M).

One of the scenarios (M) indicates improved project returns and increased avoided emissions with energy being used to charge electric vehicles. This scenario was analysed as an indication of the results when some of the solar energy can be utilised for a purpose in addition to irrigation. Depending on the location of a solar installation, charging electric vehicles may not be a practical solution. It should be noted that the addition of batteries (whilst not considered within this study due to the technology not being commercially available at the time of the analysis), would change the patterns in which the solar energy produced was used, thus changing the feasibility of the investment dramatically.

Conclusions

Current government renewable energy policy, increased energy costs, advances in solar technology and falling cost of solar installations have all aligned to create a good opportunity for cotton growers to employ renewable energy pumping systems that will reduce both on farm costs and carbon emissions.

The feasibility of an investment in solar will be highest when; solar energy produced can be utilised throughout the year and variable electricity costs are high. Until batteries are commercially available, or electric vehicles are a practical solution, realistic estimates of long term pump use are the key factor for those considering a grid connected solar installation.

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