Renewable energy in agriculture

A farmer’s guide to technology and feasibility
Contents

2. Foreword
3. About this guide
4. Overview
6. Solar Photovoltaics (PV)
14. Wind power
20. Solar hot water
24. Bioenergy
28. Ground source heat pumps
32. Financial assessment
40. Farm energy planning
42. Looking ahead
45. Bibliography
Renewable energy in agriculture

At NSW Farmers we believe that energy security has become a first order business risk for agriculture. Simply put, we must do everything we can to increase energy efficiency and to reduce exposure to projected increases in the cost of diesel, gas and electricity.

One way to reduce this exposure is to make some or all of our own energy.

Farmers are well placed to generate energy, having an abundance of land to install infrastructure and access to sunshine, wind and waste material, all of which are potential sources of cheap and reliable power. Further, the technology is maturing rapidly with falling prices and improved performance making return on investment more attractive each year.

Pretty well every farmer I speak to is curious about renewable energy and many of our members have found great success across the various technologies including solar, wind and bioenergy. An outstanding example is the Beveridge’s pig farm, near Young, where they generate all of their farm electricity from effluent and also sell excess power to the network.

Every farm presents different opportunities for energy generation. This guide sets out the key options and provides examples of what is possible with today’s technology. While it cannot take you all the way down the road to energy security, we hope that you find it to be a useful companion on a fascinating and rewarding journey.

Foreword

Fiona Simpson
President
NSW Farmers
About this guide

This guide has been produced by NSW Farmers with the assistance of the NSW Office of Environment and Heritage as part of a program to help farmers achieve faster uptake of renewable energy and increased energy security.

Intended as a general resource for farmers, it provides basic technical explanation and description of the most common types of enterprise-scale energy generation currently available in Australia.

Some of these technologies are more mature than others and some are more applicable for certain properties and farm types. They also vary widely in scale and cost, from small free-standing systems to major, grid connected infrastructure, potentially jointly owned and operated by communities.

Along with technology description, we discuss general design and financial considerations and provide some illustrative case studies.

The best solutions for on farm energy generation tend to be tailored to meet the needs of the farm rather than "off the shelf". Every farm will benefit from a customised design approach matching production strategy and other site-specific variables. While this guide highlights common issues and situations, we recommend seeking expert advice before locking in to a particular solution.
Renewable energy in agriculture

Recent advances in renewable energy technology have reduced costs, increased reliability and placed energy generation within the reach of most farms.

Increasingly, Australian farmers are switching from diesel, natural gas, LPG and electricity to renewable energy sources in core farming applications.

This is both as a hedge against future energy price increases and to mitigate the risk of electricity supply disruptions and power quality issues experienced at fringe-of-grid.

The degree of adoption of renewable energy varies widely across sectors. Adoption is highest in intensive, facility based sectors. An estimated 40 percent of dairy farms have already installed some form of renewable energy, such as heat pumps or solar thermal water heating, often with a booster (Clean Energy Finance Corporation 2014).

As a generalisation, large scale adoption of renewable technology (fully or largely replacing fossil-fuel based energy) is lowest for farms that have highly variable energy demand since this can impact favourable return on investment.

Small scale adoption is occurring across all sectors, with various solar technologies being most popular.

An important emerging area is the recycling of agricultural waste streams to produce heat and power. For example:

- **Biomass power generation**: Darling Downs Fresh Eggs is installing an anaerobic digester and generators to meet 100% of the company’s non-peak power requirements using chicken manure and other waste (Clean Energy Finance Corporation 2014).

- **Biogas heat generation**: The pork industry has been at the forefront of biogas capture and heat generation for some time, with farmers both generating energy and claiming credits for methane destruction.

Waste to energy schemes have the added benefit of reducing waste management cost and assisting farmers to meet environmental compliance standards.

![Figure 1: The energy management pyramid. The four steps towards energy management are (1) Energy analysis, (2) Energy conservation/time of use management, (3) Energy efficiency, and (4) Renewable energy. Energy analysis provides the foundation for effective investment in subsequent steps.](image-url)
Many farmers have already invested in solar PV, incentivised by feed-in tariff schemes such as the NSW Solar Bonus Scheme and benefits derived from Small-Scale Technology Certificates. While premium feed in tariffs are being wound back (ending in NSW in 2016), solar PV is still an economically viable option for many applications.

Lower cost and advances in battery storage technology is making off-grid power supply to farmers on the fringe of the electricity network increasingly attractive. This will continue to support the adoption of solar PV, with the pace of change in the solar PV market expected to accelerate in coming years (Energetics, 2014).

Investing in renewable technology – a strategic approach

Achieving good outcomes from investment in renewable technology depends on selecting the right technology, designed and specified to meet the specific nature and needs of your business.

A good starting point is to gain familiarity with the various technologies and the key factors that determine suitability for different properties.

The following chapters outline the most well-known and proven renewable energy technologies and their key design and cost considerations.

Before locking into a solution, it is important to clarify your broader farm energy management strategy.

NSW Farmers has delivered energy assessments on farms across NSW and across all sectors of agriculture. In our experience, analysis of a farm’s energy consumption profile, production system and site characteristics, quickly narrows down the kinds of renewable technologies that may be suitable. It also helps to clarify priorities for investment in energy savings.

In general, we recommend that you prioritise savings from general energy management and efficiency before investing significant capital in a renewable project.

Calculating optimal system size and assessing return on investment for your renewable project will be difficult if you have not first minimised energy wastage and established an accurate energy baseline for your property.

The energy management pyramid shown in Figure 1 indicates the place of renewable energy in a general farm energy management strategy.

Benefits of renewable energy technology

**Protection** from rising electricity, gas and diesel prices.

**Security of supply.** Electricity users in rural areas being the fringes of the network are often prone to high rates of brownouts, blackouts, or voltage spikes. Likewise, farmers in remote areas are the first to suffer from restrictions to diesel supply.

**Flexibility.** Renewable energy can supplement existing energy sources. There is often no need to become fully energy self sufficient. A farmer who can generate energy can make market based decisions as to when to buy (use) or sell (export) energy.

**Flow-on savings.** Installation of farm generation will typically be associated with energy efficiency measures such as automated control systems which help protect equipment, reduce maintenance costs and extend equipment life.

**Regional and community benefits.** Displacing a portion of your electricity demand can sometimes help stabilise local voltages and reduce the likelihood of your area experiencing outages from a tripped transformer. This can eventually help to lessen the need for costly network upgrades (which have significantly driven up electricity costs in recent years).

**Community energy projects.** NSW Farmers supports community energy initiatives where rural stakeholders collaborate to share the costs and benefits of renewable energy projects.

**Green credentials and product differentiation.** Incorporating renewable energy can help reduce environmental impacts from your farm and provide an enhanced marketing platform for many products. Differentiation through “carbon-neutral” or “sustainably grown” wines, eggs, dairy or other products can add value to a product through customer perception and increased demand.

**Capitalise on energy and carbon markets.** Surplus energy generated on farm can be sold directly to other users or into the energy market. Verifiable carbon abatements or other environmental credits can be claimed through government or privately-supported market exchanges.

**Improving the environmental sustainability of your property.** Minimising fossil fuel use can have multiple environmental benefits both on farm for the broader environment.

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**Section footnotes**

1. Recent decreases in the price of solar systems have in some cases made investing in solar more financially attractive than investing in energy efficiency first
During financial year 2010-11 solar PV overtook biogas and wood/bagasse, and became the third largest source of renewable energy for generation of electricity in Australia (after utility-scale hydro and wind). The amount of electricity generated from PV has continued to grow and has sustained an average year-on-year increase of 56.4% over the last 10 years. In 2013 solar PV generated around 1.5% of Australia’s electricity supply (BREE, 2014).

Photovoltaic systems have been in use for over fifty years and are a proven and stable technology. Solar photovoltaic systems now generate close to one percent of the planet’s total power needs, and in Germany they provide around seven percent of the yearly national electricity supply (Fraunhofer ISE, 2014).

Australia has immense potential for growth in photovoltaic power supply, with perhaps the largest opportunities existing in agriculture. Currently the great majority of PV systems in Australia are small domestic installations. This is in contrast to Europe where capacity is split into thirds across domestic, enterprise and utility installations.

Solar in agriculture

Solar photovoltaic (PV) applications are already widely adopted in intensive agriculture, and increasingly by broad acre farmers and pastoralists.

The most common applications are:

- **Facility based installations** to supply electricity for intensive animal and horticultural production. These are typically mounted on the roofs of sheds and are often integrated with general farm electricity supply

- **Diesel-solar hybrid power generation sets**: These can provide a cost-effective and reliable supplementary power supply in remote and regional areas.

- **Free standing small solar** where the cost to run power lines is high and the low maintenance nature of solar is highly beneficial. For example, for stock water pumping to replace diesel pumps or wind mills. These systems are best suited for transfer pumping to interim storage tanks.

- **Larger scale solar systems for irrigation**. Farmers with high but seasonal irrigation energy demand are candidates for projects to augment mains power supply enabling load shifting and sale of excess power.

Since the conversion of sunlight to electricity occurs without any moving parts, solar PV is a technology that requires little maintenance and is highly reliable.

One of the strengths of solar technology is its scalability. A solar system can be sized to power a single water trough pump in a remote corner of a paddock; an entire intensive animal or horticulture farming facility; theoretically, it can be sized to meet the needs of irrigation pumps moving millions of litres of water.

How solar PV works

A Solar PV system is typically comprised of two major components; the panels and an inverter.

Solar PV panels contain semiconductor devices (solar cells) made of materials such as silicon that use the photoelectric effect to generate electricity.
A farmer’s guide to technology and feasibility

Solar Photovoltaics (PV)

Figure 2: Australian electricity generation, by fuel type (2012–13) (BREE, 2014).

Figure 3: Simplified cross section view of a typical solar cell.

Figure 4: Typical grid-connected solar PV system (simplified).

Figure 5: Most farms make use of small or large pumps to meet their water needs. Solar systems can be arranged to provide power to pumps directly, or in tandem with other energy sources like diesel.
Energy from incident photons (in sunlight) is absorbed by the semiconductor by ‘knocking’ electrons loose from their atoms. These electrons are then ‘collected’ and, due to the composition of solar cells, can only flow in a single direction. Generally, multiple solar cells are connected in an array to generate a usable amount of direct current (DC) electricity. The generated DC electricity is fed to an inverter, which converts it into alternating current, at the right voltage (AC 230–240V in Australia), so that it can then be used by most appliances. Any excess electricity generated can also be exported to the main electricity grid. This setup, known as a ‘grid-connected’ system, is the most common, and will handle the use and export of power automatically.

Although users can continue to use electricity without adjusting any of their habits, shifting the use of equipment to times when the solar system is generating power may provide substantial savings to their energy bills.

Solar PV generators can be commissioned for varying purposes and may require different control systems and components. The relationship between generated solar power and its industrial application must be considered in an integrated way. Depending on your requirements, you may need additional components such as batteries for storage, or control systems to incorporate your electrical loads so that power levels match your solar generation.

### Design factors

Before commissioning a solar system a site assessment should be conducted to address the characteristics of your property and energy use. There are many variables to consider when establishing optimal size and configuration of system. Key design factors are discussed below.

#### Solar resource

The levels of solar irradiance change throughout the day and year. Mornings and afternoons have lower levels, and summer has higher levels than winter (seasonal variations in NSW can entail changes in PV power output of 50%). Solar radiation available will also vary for sites with different latitudes and different climates (e.g. a region highly prone to overcast or rainy days will have a reduced solar resource).

More detailed information of the specific solar resource available can be obtained through resources provided by the Bureau of Meteorology (BCM) or from propriety sources such as the Australian Solar Radiation Data Handbook from Exemplary Energy.

### Units of Power and Energy and Peak Sunshine Hours

- **kW (kilowatts)** is a unit of power.
- **kWh (kilowatt-hours)** is a unit of energy.

1 kWh is equal to the energy delivered by a generator supplying 1kW of power continuously for one hour (hence the term ‘kilowatt-hour’).

Solar radiation power is measured in kW/m², while solar radiation energy is measured in kWh/m².

1 kWh/m² is also known as 1 Peak Sunshine Hour (PSH).

You can use the Clean Energy Regulator’s (CER) ‘Postcode zones for solar panels’ list to determine the typical electricity-generating capacity of your location. Most postcodes in NSW fall under Zone 3, which means that a 1kW system will generate around 1,400 kWh of solar energy in a year.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Estimated yearly kWh generated / kWp installed</th>
<th>Average generation per day (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,622</td>
<td>4.44</td>
</tr>
<tr>
<td>2</td>
<td>1,536</td>
<td>4.21</td>
</tr>
<tr>
<td>3</td>
<td>1,382</td>
<td>3.78</td>
</tr>
<tr>
<td>4</td>
<td>1,185</td>
<td>3.24</td>
</tr>
</tbody>
</table>

Table 1: Clean Energy Regulator’s (CER) ‘Postcode zones for solar panels’

The optimal tilt of a system, to generate the most energy over the year, is equal to the latitude of the site. However, a steeper pitch may be used to increase the average solar generation in winter months, or a flatter tilt can be used if greater solar generation is desired during summer months.

The system output will also vary depending on the presence or absence of shading and ambient temperature. In some circumstances efficiency can be increased through the use of tracking systems (one- or two-axis), which can provide an increase of approximately 10-25 percent in efficiency. Tracking adds significant cost, however, and generally this outweighs the benefit of increased yield.

Panels and inverters should be placed as close as possible to each other, as running power long distances can be both dangerous and expensive, and can lead to transmission losses, which will downgrade the amount of usable power from the system.
Figure 6: If roof space is not available, solar panels can be installed on a ground mounted frame.

Figure 7: Solar radiation intensity through the day for summer and winter seasons (GSES, 2015).

Figure 8: a) A lower tilt – greater solar power generation in summer; b) A tilt equal to site’s latitude – greatest annual solar-power generation; c) A steeper tilt – greater power generation in winter (GSES, 2015).

Figure 9: A single-axis tracker will result in higher power output from a solar PV array in the early mornings and evenings. Cooler morning temperatures mean that the array’s morning output will be slightly higher than its evening output; a module’s power output reduces as it heats up (GSES, 2015).
Renewable energy in agriculture

Potential for network connection

In NSW and most Australian states, exported excess power generated from a new renewable energy system can be rewarded through feed-in-tariffs (IPART, 2013). However, the solar bonus scheme has been closed to new entrants, so in NSW the revenue offered per kWh of exported energy is reflective of the wholesale price of electricity, around 3 to 8 cents/kWh; depending on your location. For new renewable systems, every kWh that is generated can lead to 25-3.5 cents per kWh of savings if the energy is used on-site. Property owners considering a grid-connected solar PV system should ensure that the size and cost of their system and the expected savings meets their expectations.

Is significant power used during daylight hours and consistently through the year?

Solar systems generate electricity when the sun is shining on them, but do nothing when they are shaded or dark. Electricity can be expensive to store so any generated energy that exceeds a dwelling’s immediate needs is usually exported (fed back) to the local grid (for grid-connected systems). However, under current tariff rates for exported electricity (from zero to 8 cents per kWh), it makes more financial sense to use electricity generated by solar PV on site rather than exporting to the grid.

Figure 10: An indicative example showing that the payback time for a grid-connected system will rise quickly after a certain system size is reached. This is because past a certain point, larger systems will only serve to generate more electricity to export and will not offset the more expensive electricity which is consumed. This relationship will be different for farms using more/less power or at different times of the day.

Larger PV systems will generate more electricity but, as systems get larger, a greater portion of power will be exported instead of used to offset your own consumption. The effect of this is that the system will take longer to pay itself off. This dynamic is illustrated in Figure 10. These scenarios do not address benefits than can be achieved through load shifting on farms that have multiple sources of electricity demand. To maximise the benefit from a solar system, it is important to consider how solar power can be allocated across different electricity uses on farm to reduce network charges in high tariff periods.

Stand-Alone

In an off-grid (stand-alone) scenario, proper sizing of a PV system will not involve the dynamics of how much energy will be exported vs. used. Instead, it is pivotal to consider the size of the array and energy storage (e.g. batteries) in relation to:

- Average daily energy use.
- Days of autonomy required (i.e. How many consecutive days of little-to-no sunshine is expected, and what battery bank and PV system size can provide sufficient power through these days and allow solar PV array to replenish the batteries quickly once it is sunny again?).
- Large loads that need to be met.

Financially, it is usually better to size a stand-alone solar system to meet the typical ongoing energy needs of the property. A diesel generator can then be installed for backup power and to charge the batteries in an event where the batteries have been drained and there is little or no solar resource.

Types of solar panels

There are two main types of commercially available Solar PV technologies: crystalline silicon panels and thin film panels. Crystalline silicon panels currently hold the majority of the market and also represent the bulk of all installed capacity.

Within crystalline technologies there are two main variants: monocrystalline silicon cells and multicrystalline silicon cells. Monocrystalline solar cells are more efficient, but recent improvements in technology have meant that in many cases the performance difference between monocrystalline panels and multicrystalline panels is close to negligible.

There are various types of thin film panels, however; amorphous silicon panels are the most commonly available commercially. Thin film panels also tend to be cheaper than crystalline panels but are also less efficient, so they will require a larger area to achieve the same power output.

It is important to remember that not all panels with equal wattage ratings are made equally. The importance of solar panel selection lies in ensuring that the product is covered by strong warranties (industry standard is 80% of nominal power after 20 years) and that the panels have a significant and reputable presence in Australia.

The solar industry also categorises solar panels and their manufactures into tiers. Products from a tier 1 manufacturer are considered the best, while ‘tier 2’ or ‘tier 3’ products may indicate lower quality. However, interpretation of tiers may vary depending on suppliers (see Figure 14 for guidance provided by Pike Research).

The inverter – a critical component

Inverters convert the direct current (DC) electricity generated by solar panels into the Alternative Current (AC) electricity that most appliances and equipment require. Inverters also use electronics to optimise the output from the panels.

More advanced inverters can also be connected to multiple independent ‘strings’ of panels. This feature is useful if different strings will have some panels receiving shade or oriented in different directions.
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Solar Photovoltaics (PV)

Figure 11: An example comparing three grid connected solutions and the expected generated power that will be consumed, the generated power that will be exported and the simple payback rates of each system.

<table>
<thead>
<tr>
<th>3 kW System</th>
<th>5 kW System</th>
<th>7.5 kW System</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Cost: $4,800</td>
<td>System Cost: $8,000</td>
<td>System Cost: $12,000</td>
</tr>
<tr>
<td>Portion of power offset: 94%</td>
<td>Portion of power offset: 73%</td>
<td>Portion of power offset: 52%</td>
</tr>
<tr>
<td>Portion of power exported: 6%</td>
<td>Portion of power exported: 27%</td>
<td>Portion of power exported: 48%</td>
</tr>
<tr>
<td>Savings per day: $3.52</td>
<td>Savings per day: $4.76</td>
<td>Savings per day: $5.45</td>
</tr>
<tr>
<td>Savings per year: $1,286</td>
<td>Savings per year: $1,738</td>
<td>Savings per year: $1,988</td>
</tr>
<tr>
<td>Simple payback (years): 3.7</td>
<td>Simple payback (years): 4.6</td>
<td>Simple payback (years): 6</td>
</tr>
</tbody>
</table>

Figure 13: Residential solar PV system pricing trends since September 2012. Data points are the average $dollar per Watt for each system size (1.5kW–5kW until November 2013, then also including 10kW from December 2013). (Solar Choice, 2015).

Figure 14: Different tiers of solar panels
(SolarChoice; Pike Research, 2013)
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The electronics used by inverters can be sensitive to heat and other stresses so inverters should be installed out of the sun (shaded) with appropriate ventilation for cooling. Inverters are usually the first thing to fail in a solar PV system, so it is important to verify the warranty in case there is a problem or a component needs replacing. Standard industry inverter warranties will cover a range of faults up to 10 years. It is prudent to obtain reputable inverters that have a good presence in Australia.

**Pricing**

Since the energy source for solar PV is essentially free and abundant (sunlight), the only ongoing costs for this technology are maintenance and repair. A fixed-tilt solar PV system has no moving parts, and is designed to withstand regular wear and tear under normal weather conditions.

Looking at a PV System’s ultimate “per-watt” cost can help you to assess different proposals. Panels are rated for a certain number of watts per panel (typically between 160 and 275 watts for standard sized panels). The same goes with inverters, which can vary greatly in price and quality.

There are resources available online which aggregate and publish average prices for various PV systems in metropolitan areas (usually every month). These can serve to give an indication of the prices to expect, however, installing in rural or regional areas may incur additional costs due to transport and other factors.

In 2014 the average indexed price of PV systems of all sizes (inclusive of discounts from generated small technology certificates) was around 1.8 dollars per installed watt.\(^6\)

We recommend that you research pricing widely on the internet. It is important to compare quotes from different installers. There are services that will take your details and contact several installers so that you can compare the quotes that they will offer.

Examples of these services are:
- [www.solarchoice.net.au/solar-quote-comparison](http://www.solarchoice.net.au/solar-quote-comparison)

**Future innovation/technological maturity**

Although Solar PV has been around for decades and is an established technology, its components continue to evolve and improve.

The efficiency of solar cells has increased progressively over the years. Efficiencies attained at research labs for ‘mainstream’ crystalline silicon cells have improved from around 15 percent to over 25 percent over the last 30 years. Some of these improvements have transferred to commercial cells meaning solar modules today can achieve efficiencies in the range of 18–20 percent. Other types of solar cells have achieved even greater conversion efficiencies but these tend to be prohibitively expensive so their main use has remained in niche applications. Australia has been a leader in the development of the technology with breakthroughs in cell efficiency developed by research teams from the University of NSW (UNSW).

Future developments in solar will likely include a continued reduction in prices (which have fallen over 66 percent from 2010–2014) and moderate gains in performance efficiency, as technologies and manufacturing processes are refined. A major factor in solar PV system design is the price of energy storage. Battery technologies have continued to improve, and the cost of batteries continues to fall as production and design improve.

As battery storage becomes more affordable, the business case for solar PV will change, and it may become more cost effective to size solar systems with storage to cover additional loads of a property, rather than supplementing an existing electrical grid connection.

Existing solar PV systems can be upgraded with additional panels to generate additional power.

**More information**

Clean Energy Council guide to installing Solar PV for businesses in NSW:

Agricultural Innovators – Solar photovoltaic energy on farm:
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Figure 15: Solar PV cell efficiency records (National Renewable Energy Laboratory, 2015).

Figure 16: PV technology status and prospectus. © OECD/IEA 2010 Solar Photovoltaic Roadmap, IEA Publishing. Licence: (iea.org/t&c/termsandconditions/).

Section footnotes
2. The Clean Energy Regulator (CER) determined four broad zones, based on climate and solar radiation levels, within Australia. A Small Technology Certificate (STC) multiplier expressed as MWh/kW installed capacity is provided for each zone; this can be used as a general planning assumption. The ranges of postcodes and their corresponding zones can be found on the website (http://ret.cleanenergyregulator.gov.au/ArticleDocuments/205/RET-sgu-postcode-zones_0312.doc.aspx)


5. The tilt angle of solar panels varies depending on latitude. A tilt angle of 30.2 degrees is optimal for Sydney. Solar PV suppliers will model the most appropriate tilt angle for your project; however, often this is determined by the pitch of your roof.

6. For more info see: http://www.solarchoice.net.au/blog/what-is-a-tier-1-solar-panel-tier-2-or-3/
Renewable energy in agriculture

In recent years, however, a range of small to medium scale wind generators have come on the market that may be suitable for meeting some of your farms electricity needs. Being smaller and lower, farm-scale wind turbines can avoid the planning disputes sometimes associated with commercial wind farms. Wind energy is worth consideration by farmers in locations with predictably high wind.

Commercial scale wind farms

Commercial wind farms convert wind energy to electricity for supply to the national grid and can generate 1MW or more of electricity. This scale of generation is not generally practical for individual farms as the amount of power generated far exceeds the needs of the farm. There is, however, the possibility of leasing farm land to wind energy companies. Information on this subject is available in the NSW Farmers “Wind guide for host landowners.”

How wind power works

A typical farm-scale wind system consists of a turbine, a tower, a controller, a grid-connected inverter and a meter. The controller ensures that the turbine operates within safe limits and rectifies the varying frequency alternating current (AC) to direct current (DC) power. The DC power is then passed to the inverter, which converts it into AC power of the same voltage and frequency as electricity from the grid.

Typical farm scale turbines have a tower height of approximately 20 metres. Winds speeds generally increase with elevation, so maximising turbine hub height is important in developing a financially viable project.

Types of wind turbines

Wind turbines are mainly divided into vertical and horizontal axis designs. The common, three blade design that is often associated with large scale utility wind turbines is an example of a horizontal axis wind turbine. Horizontal-axis turbines are more efficient than vertical-axis, but can be more difficult to repair (since mechanical components are located in the nacelle at the top of the tower) and can also be more expensive.

On a vertical design, the “blades” of the windmill are attached in the parallel direction of the shaft, and mechanical components are often at the bottom of the shaft, making them more readily accessible. On these designs, the entire shaft sometimes turns with the blades, and drives the mechanics/power generation at the bottom of the design.
A good wind resource cannot be guaranteed for any given site, yet it is critical for the viability of a wind turbine. It is essential to first consider the characteristics of your farm and assess whether it’s suitable for a wind turbine. The financial case for small wind generators is not as attractive as comparable solar PV systems if the wind resource isn’t excellent.

Some turbines are designed to be mobile or demountable for easy relocation in response to seasonal wind patterns or the need for power generation at a specific site.

Wind resource

The first step is to establish the general strength and consistency of wind at your farm’s location. If your property does not have adequate wind speeds, consider solar or another type of renewable technology. Payback and investment with wind power is very dependant on wind availability, so strict calculations should be made before proceeding with project planning.

Design factors

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Figure 17: Monopole horizontal axis wind turbine and upwind turbine orientation (Stapleton, Milne, Riedy, Ross, & Memery, 2013) (left). Typical components of a domestic wind turbine (right).

Figure 18: 3-Bladed Horizontal Axis Wind Turbine (HAWT). Figure 19: Giromill Vertical Axis Wind Turbine (VAWT). Figure 20: Giromill/Darrieus Vertical Axis Wind Turbine (VAWT) with helical blades.

Source: (AUSTRALIAN WIND AND SOLAR, 2014)

Figure 21: A pickup vehicle is used to raise and lower a monopole tower. Collapsible towers may be placed around the property with ease and, in some cases, moved within a property to match changing wind conditions from season to season (Energy Matters, 2013)
Renewable energy in agriculture

Wind maps, with location information on historical levels of wind, are critical components in the wind power system design process. Wind resource maps for NSW are given in Figure 22 (below).

Map of NSW renewable energy projects. Green areas indicate highest wind resource (NSW Trade and Investment, 2014)
A wind turbine may be viable for your property if it’s located in a high wind resource area (orange areas on left map or bright green on right map). You may refine your assessment by obtaining information on the mean wind speed for your ‘region’ from the Bureau of Meteorology (BoM). An average wind speed of around 5 m/s or more is usually required at hub height for a suitable system. Remember however, that data obtained from the BoM is just a proxy, as on-site conditions will impact the particular wind speed at your location. In addition, wind speed measurements taken by the BoM are typically from a height of 10m, so extrapolation to turbine hub heights can be required. This can be done using the power law or log law equations (see workings overleaf).

If you are not in a high wind area it is unlikely that your site will be suitable for a wind turbine. However, certain ridges or specific locations can sometimes still have sufficient wind resource and may warrant investigation.

Once the average mean wind speed at hub height is known, it is necessary to determine the distribution of wind speeds (that is, how often any particular wind speed occurs). An approximation, such as the Weibull distribution can be used (Figure 25). However, this distribution must be redrawn for the particular mean wind speed of your property.

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Once the average mean wind speed at hub height is known, it is necessary to determine the distribution of wind speeds (that is, how often any particular wind speed occurs). An approximation, such as the Weibull distribution can be used (Figure 25). However, this distribution must be redrawn for the particular mean wind speed of your property.

Conduct a wind resource study (essential for large projects)

If you are considering a large project (installing 20kW or more), it is essential to undertake a technical and financial feasibility study to determine optimal system characteristics such as positioning, sizing and orientation of wind turbines; as well as expected performance, yield, financial savings and payback rates. A wind study for a farm scale wind turbine can cost between $3,000 and $15,000 per site with some companies offering credit to the property owner if the installation goes forward. These studies usually involve site visits, wind measurements, and can take anywhere from a week or two to several months.

Wind with other technologies

Wind and solar technologies can be complementary. Wind is often available at night or when clouds or rain are blocking the sun. Likewise, sunlight is often available on clear, calm days, when there is minimal wind. On a single-property scale, farmers are cautioned not to overcapitalise by installing more generation capacity than is necessary or financially sound.

Situations that justify the installation of a wind turbine and solar PV tend to be niche off-grid scenarios.

For example, a standalone (off grid) system design may be able to reduce its required battery bank capacity, if a wind turbine is available to top up batteries at times when the solar PV array isn’t producing energy (i.e. at night). The financial case of such decision has to be compared with the alternative, which is likely to be adding more solar panels and increasing the size of the battery bank. Generally, in most grid connected properties, there is little need to install a solar PV system AND a wind generator, unless there are space restrictions which prevent the expansion of solar PV, or if a wind turbine is expected to provide some substantial advantage by generating at night-time hours.
Calculating and extrapolating average wind speeds from measured data at different heights

There are two equations which permit you to estimate mean wind speed at different altitudes. These are shown below.

**Power law equation**

\[ v_2 = v_1 \times \left( \frac{h_2}{h_1} \right)^a \]

**Log law equation**

\[ v = v_{ref} \times \frac{\ln \left( \frac{h}{z_0} \right)}{\ln \left( \frac{h_{ref}}{z_0} \right)} \]

*where:*

- \( v_1 \) = Velocity at height \( h_1 \)
- \( v_2 \) = Velocity at height \( h_2 \)
- \( h_1 \) = Height 1 (lower height)
- \( h_2 \) = Height 1 (upper height)
- \( a \) = wind shear exponent

This method first requires one to calculate the wind shear exponent by using two known wind velocities from different heights:

\[ a = \frac{\log \left( \frac{v_2}{v_1} \right)}{\log \left( \frac{h_2}{h_1} \right)} \]

Calculated with \( a = 0.11978 \), \( z_0 = 0.055 \), \( h_2 \) (or \( h_{ref} \)) = 25 m, \( v_1 \) (or \( v_{ref} \)) = 7.689 m/s

<table>
<thead>
<tr>
<th>Roughness Length ((Z_0))(m)</th>
<th>Landscape Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0002</td>
<td>Water surface</td>
</tr>
<tr>
<td>0.0005</td>
<td>Inlet water</td>
</tr>
<tr>
<td>0.0024</td>
<td>Completely open terrain with a smooth surface, e.g. concrete runways in airports, mowed grass, etc.</td>
</tr>
<tr>
<td>0.03</td>
<td>Open agricultural area without fences and hedgerows and very scattered buildings. Only softly rounded hills</td>
</tr>
<tr>
<td>0.055</td>
<td>Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approximately 1250 metres</td>
</tr>
<tr>
<td>0.1</td>
<td>Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approximately 500 metres</td>
</tr>
<tr>
<td>0.2</td>
<td>Agricultural land with many houses, shrubs and plants, or 8 metre tall sheltering hedgerows with a distance of approximately 250 metres</td>
</tr>
<tr>
<td>0.4</td>
<td>Villages, small towns, agricultural land with many or tall sheltering hedgerows forests and very rough and uneven terrain</td>
</tr>
<tr>
<td>0.8</td>
<td>Larger cities with tall buildings</td>
</tr>
<tr>
<td>1.6</td>
<td>Very large cities with tall buildings and skyscrapers</td>
</tr>
</tbody>
</table>
Wind power

System size

Wind conditions may be hard to predict and vary significantly between times of the day and seasons. Therefore, it is preferable to size a system conservatively to meet your permanent minimum load or baseline consumption.

![Illustrative demand curve.](image)

**Power demand**

- **Peak**
- **Intermediate**
- **Base**

**Time of day**

You may calculate the expected energy (in kWh) that will be generated from a wind turbine by multiplying the wind speed by the number of hours of the year during which that wind speed is expected\(^8\), and then multiply that by the rated output of the wind turbine at that speed. This will give you the kWh generated during the year from that particular wind speed component. You must then repeat the process for other wind speeds and sum all the components to arrive at the total kWh expected from the turbine per year. This final total is usually multiplied by 90% to account for an expected 10% of losses due to any maintenance and repairs. This calculation exercise is illustrated by the following equation:

\[
\text{Generated Energy p.a.} = 0.9 \times \left( \sum_{\text{wind speed} \geq \text{cut-in speed}} \text{hours per annum \times \frac{\text{rated power}}{\text{wind speed}}} \right)
\]

This is simpler to understand and calculate using a spreadsheet. Alternatively, search for calculators available online, such as the REUK.co.uk version below:

![Yield calculator for prospective wind generators](image)

Figure 26: Yield calculator for prospective wind generators (REUK.co.uk – The Renewable Energy Website, 2014)

**Wind Watts vs. Solar Watts: How Capacity Factor Helps to Compare**

Both wind turbines and solar PV installations are rated by their rated power (in kW). This number represents the peak amount of power that the system can generate. However, these systems are intermittent and can generate less or no power when there is little sun or wind. “Capacity factor” is a unit of measurement used to represent the actual power that is generated. A capacity factor of 100% means that the generator operated at its rated power 100% of the time. Capacity factors vary between wind and solar technologies, and due to location specific attributes such as solar/wind resource. The average capacity factor for MW scale wind turbines is around 40%. However, capacity factors for farm-scale turbines of less than 100kW in size are usually between 15-20% (The Carbon Trust, 2008, p. 10). This compares to 15-25% for solar.

**Capital expenditure/ongoing costs**

Just like solar, wind power has a high up-front cost but a very low ongoing cost, as the fuel for the system (wind) is free. Wind turbines do have moving parts and therefore need to be maintained. Qualified technical experts for wind turbines may be difficult to find in your area so access to ongoing support should be given priority in decision making.

**Community and council considerations**

Despite their relatively small size, farm scale wind turbines will require local council permission, or other government design approval. Make sure to consult the appropriate local organisations when considering a wind turbine installation.

**More information**


**Section footnotes**

8 Data can be obtained by visiting [http://www.bom.gov.au/climate/data/](http://www.bom.gov.au/climate/data/) and prompting for weather and climate data for a location close to your farm. It may be useful to select a measurement station on/near an airport, as they can be more reliable. Note that accessing data for certain locations may incur some charges.

9 Expected number of hours per annum can be derived from the Weibull distribution for that specific mean speed.
Solar thermal technologies refer to the collection of solar energy for heating (thermal energy). There are a variety of technologies used to capture this thermal energy ranging from relatively low cost (solar hot water systems) to high cost (solar dishes and troughs). In this guide we will focus on solar hot water technology and ground coupled heat pumps. Solar hot water systems are widely deployed on Australian farms and can provide all or a large portion of the energy needed for water heating.

How solar hot water works

Solar hot water is a proven, mature technology. It involves the use of a collector made of materials that absorb heat from the sun very efficiently. Cold water travels through the collector, heating the water and returning it to the tank. Hot water floats to the top of the tank and colder water is taken from the bottom and returned to the solar collector. To assist with this circulation, some systems incorporate a small pump that is activated whenever the temperature difference between the water in the collectors and that in the tank is sufficient. When you use hot water, it is taken from the top of the tank where the water is hottest.

There are two main types of collectors: flat panels (which at first glance can be difficult to distinguish from solar PV panels) and evacuated tubes.

Solar hot water systems may provide all of the hot water needed on warm or sunny days, but may fall short on cooler or overcast days. For this reason, the solar technology often works in conjunction with an electric or gas “booster,” which provides additional heat in order to reach and maintain desired temperature points for stored water. The electricity or natural gas needed to heat water to 65° C (the temperature required in NSW) is much lower if the water has already been preheated by several degrees by a solar hot water system. Backup systems can also operate to fill in when there are extended periods without solar radiation, such as multiple consecutive rainy days.

Storage tanks are typically heavily insulated to minimise heat loss.

A key advantage of solar hot water over solar PV is the ability to store energy. Once converted from solar radiation, thermal energy (heat) can be stored in liquid form (i.e. oil or water), or as a gas (in other solar thermal systems).
A farmer’s guide to technology and feasibility

Solar hot water

**Flat plate**
- May be less expensive
- Operates most efficiently in the middle of the day
- More sensitive to frost causing damage to the collectors
- Heavier

**Evacuated Tube**
- Can be more expensive
- Can heat water to a higher temperature as they have a greater surface area exposed to the sun at any one time (approximately 40 per cent more efficient).
- Can be used in sub-zero and overcast conditions (can extract heat out of the air on humid days).
- Risk of overheating. As the water reaches its maximum temperature in the tank the pressure and temperate value automatically activate and release some hot water to allow for cold water to come back in, reducing the temperature build-up. To minimise the risk, the number of tubes must match the quantity of water to be heated.
- Lighter – some lightweight designs can be mounted on walls and even poles.
- Uses smaller roof area
- Less corrosive than flat systems.
- Are durable and broken tubes can be easily and cheaply replaced.

<table>
<thead>
<tr>
<th>Flat plate</th>
<th>Evacuated Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>May be less expensive</td>
<td>Can be more expensive</td>
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<tr>
<td></td>
<td>Are durable and broken tubes can be easily and cheaply replaced.</td>
</tr>
</tbody>
</table>

Table 2: Comparison of flat plate and evacuated tube hot water solar systems (Dairy Australia Ltd., 2013).

**Applications**

Solar hot water can be used to reduce the cost of energy involved in heating water for households. Solar hot water provides a key energy-efficiency solution for dairy farms and other operations that frequently need hot water for washing. Dairy farms require large volumes of very hot water (at around 80 °C) to wash equipment. Preheating water to 60-65 °C using solar hot water systems and then boosting the water to the final required temperature (using electricity or gas) is a great financial option for most dairy farms (Dairy Australia Ltd., 2013).

Because of the nature of insulated hot water storage, time of use for hot water isn’t very important. However, if there is a need for consistent large quantities of hot water when there is no solar radiation available (at night), the technology may not pay off as quickly.

**Design factors**

Before commissioning a solar hot water system consider some of the following steps and their impact on your budget and design.

**Identify space for mounting solar collectors**

The ideal position to maximise solar radiation collection in Australia is an unshaded, north facing roof. If there is not sufficient unshaded roof space available to install the solar collectors, a ground mounted system will need to be used. Ground mounting a system is more expensive, as the infrastructure for the panels/tubes needs to be constructed.

**Consult with qualified professionals**

Equipment dealers and professionals should be able to advise you as to which system will best meet your existing needs.
Renewable energy in agriculture

Check assumptions made to help size your system

Systems often come with ratings based on the number of bedrooms or occupants within a home. These ratings are based on residential averages and may not be applicable when looking at farm buildings, specific housing arrangements or intensive use of hot water in dairy farms. Be sure to discuss your individual needs with the equipment manufacturer or installer to ensure that you are looking at the right sized system.

If possible, tilt for winter

Unlike solar PV panels, solar hot water systems should be tilted at steeper angles. This is because savings can be maximised if the system works best during the times of the year when there is greater demand for hot water, and when it is hardest to heat water. This happens during winter. Therefore a steeper pitch on a solar hot water system will optimise its performance when the sun is lower in winter days. Tilting the system for winter will also help ensure that the system will not over boost temperatures during summer.

System size

To establish required system size:

- **Determine volume of total and daily hot water needs** – If the need for hot water is not consistent, determine your usage patterns and understand how you use hot water.

- **Determine when hot water is needed** – This is part of the needs analysis process, but it is important to understand how water is used. If usage patterns can shift depending on the availability of solar thermal energy, you may be able to size your system differently to maximise return on investment.

- **Calculate water storage needs** – Water storage is an important component of the solar thermal system. Without sufficient storage, you’ll be using the backup electric or natural gas boost system, and you may not be able to take advantage of all the benefits of the solar thermal collectors. Ensure that the system design incorporates enough water storage so that energy from the solar collectors is being used for the intended purpose of heating this water. All new tanks should come well insulated to help maintain optimal pressure for an extended period so that water does not cool significantly while sitting in the tank.

More information


Immersun: [http://www.immersun.co.uk/](http://www.immersun.co.uk/)

STCs and solar hot water

Under the current renewable energy target (RET), eligible solar hot water systems are entitled for small technology credits (STCs). To find out if the system is eligible, speak to the system installer for a quote. Typically, the simplest solution is to have the installer claim the STCs, and give you the credit as a discount off the purchase price of the system. This saves the customer from going through the process of collecting and selling their available STCs.
Solar hot water system or Solar PV?

Given recent price drops in the cost of Solar PV (around 60% drop from 2010 to 2013) it is worth considering a Solar PV powered electric water heater as an alternative to a solar hot water system.

Solar hot water systems can transform incident solar energy into heat in water with an efficiency of 40-60% (APRICUS AUSTRALIA, 2014). Solar PV systems, on the other hand, are currently at most 20% efficient at transforming solar energy into useful heat via an electric heater in a tank. This means that for most farms undergoing a full upgrade of their water heating system a solar-hot water system is the better option.

However, there are cases where a PV system may be cheaper. For example, if solar PV is being installed anyway, and a storage tank with an electric heater is already available, then installing additional Solar PV capacity is possibly cheaper than adding a solar hot water system. This is because the cost of a new tank (or a tank retrofit) will be avoided and the solar PV system can be used to meet other energy requirements. The savings from this option can be further maximised by installing devices that automatically turn on an electric water heater when there is excess solar generation available.

Remember that each case will require an individual assessment of the site and its requirements to determine the most appropriate system. Upgrading the whole system at one time minimises installation costs and can ensure that all components are warranted to work together over a longer period.
Bioenergy is a complex field, involving many different technologies to produce different forms of energy. The main technologies feasible at farm scale are:

- Combustion technologies that convert solid biomass through direct burning to release energy in the form of heat which can be used to generate electricity and process steam.
- Biogas technologies that produce methane by anaerobic digestion of animal and crop waste.
- Biofuel technologies that produce ethanol and biodiesel using chemical conversion processes.

Advantages of bioenergy solutions may include:

- the ability to store feedstock in bulk for conversion to energy when needed
- the reduction or removal of waste disposal costs
- cost-effective management of smell, pests and other environmental impacts of waste.
- an alternative use for crops (allocating crops to energy when food commodity prices are less favourable).

Waste to energy

Every farm produces organic by products that potentially can be recycled into energy.

Key challenges facing organic waste to energy projects in other sectors are variability in volume and quality of crop and animal based waste, costs of aggregating waste and the large capital investment typically required for processing plants.

Australia’s sugar industry has used bagasse, the fibrous residue left over after extraction of cane juice, to meet its electricity and heat requirements for over 100 years, and in recent years has supplied ethanol refineries with feedstock. Bagasse is economical as an energy source, however, because the sugar industry is structured on a cooperative basis and shares aggregation and processing infrastructure for the waste material.

The greater cobenefits of recycling animal waste to compared to plant waste tends to make animal bioenergy projects more prospective than crop waste projects. The past decade has seen successful methane capture projects in piggeries (NSW Farmers, 2014) and dairies (Dairy Australia Ltd., 2013) and there is growing interest in the potential of chicken waste as an energy source (McGahan, Barker, Poad, & Wiedemann, 2013).

Complex financial and sustainability questions may arise, also, around the allocation of waste to energy. For example: chicken waste may fetch a better price as manure in some years than as an energy feed stock; crop or agroforestry waste may be better returned as biomass to soil rather than burned for energy.

The challenges facing waste to energy projects are steadily being overcome by significant collaborative research programs, including Rural Industry Research and Development Corporation (RIRDC) and Dairy Australia research on biomass and biogas, and CSIRO and NSW Department of Primary Industry research into biochar.
Areas for future development and demonstration include collaborative models where intensive producers share the capital costs of processing plants and aggregation of waste, and commit to supply the volumes of waste needed to achieve return on capital.

Precinct models are the most prospective in this regard. For example, poultry farmers could co-locate sheds around waste to energy infrastructure, reducing both aggregation costs and the costs of distributing the resulting energy within the precinct. The aim of such models would be for farmers to collectively generate all the energy needed to run their operations.

Biofuels

Biofuel is the general term for liquid fuel products derived from organic sources. The two most common types of biofuel are bioethanol, which replaces traditional petrol or gasoline, and biodiesel which replaces traditional diesel fuel. In addition, there is increasing demand for sophisticated aviation biofuels, with both Qantas and Virgin airlines undertaking research into the feasibility of feedstock and biorefinery projects. Biofuels can be produced both from organic waste and from crops produced specifically for fuel or energy production. The specifications and chemistry of biofuel products can be exactly the same or better that fossil fuel derived fuels. The challenge in commercialising the biofuel industry is the relatively high cost of production.

Biodiesel

A wide variety of fats and oils can be used for biodiesel including soy, canola and waste cooking oil. Presently, however, the majority of Australia’s biodiesel is produced from recycled cooking oil.

Australia’s total annual biodiesel production appears have stalled at 175 ML sourced from relatively small commercial recycling plants. For example, Biodiesel Industries Australia, in Maitland, recycles used vegetable oil and produces 9ML per annum (Geoscience Australia and BREE, 2014).

Present national production is much lower than installed capacity which the Biofuels Association of Australia reported to be 500 ML in 2012.

Farm scale biodiesel

While technology is available for farmers to implement biodiesel plants on their properties or as local cooperatives there is currently no compelling economic case for such investment.

Sharp increases in diesel prices in the period 2001 to 2005 from less than $1 per litre to close to $1.40 created interest in small farm-scale biodiesel plants. This interest waned, however, partly because petroleum prices did not climb as sharply as anticipated but also because farmers discovered the effort and cost of growing fuel crops and processing the bio diesel did not warrant the return.

In addition to the capital and operating costs of biofuel technology farmers must consider the relative cost of petroleum diesel and the opportunity cost of crops used as feed stock, both of which vary from season to season. Lower canola prices and sustained increases in petroleum diesel...
Renewable energy in agriculture

prices may stimulate renewed interest in the technology. The generation of biofuel from algae may ultimately provide new pathways to diesel self sufficiency with research projects providing encouraging outcomes. Costs of production are still too high to be commercial, however. (NAABB, 2014)

Examples of waste to energy generation:

- Animal effluent fed into aerobic digester producing methane
- Chicken waste as feedstock for a pyrolysis plant creating both electricity and biochar (for use as soil conditioner)
- Woody weeds, straw or other cellulosic refuse directly burned or put through pyrolysis to create electricity and biochar

How waste to energy works

There are four main types of conversion processes associated with energy from biomass:\n- Anaerobic digestion, pyrolysis, gasification and direct combustion.

Anaerobic digestion (AD)

Anaerobic digestion (AD) is the microbial conversion of biomass into a methane rich gas (biogas) in the absence of oxygen. The fuel gas can then be used for power generation using a gas engine, heating (e.g. combustion in a gas-fired boiler) or chemical transformation (i.e. use biogas as raw material for chemical processes). Processes that treat low solid content wastes (usually <15% dry solids composition) are commonly known as ‘Wet AD’; and those that are designed to treat higher solid content waste (usually 15-40% dry solids) are referred to as ‘Dry AD’.

Pyrolysis

Pyrolysis is the thermal degradation of biomass to produce bio-oil, syngas and charcoal at medium temperatures (350–800°C) in the absence of oxygen. The ratio of char-to-liquid-to-gas is affected by the speed and temperature of the pyrolysis reaction. Slow pyrolysis favours the production of bio-char, while fast pyrolysis maximises the production of bio-oil.

Biochar is a solid form of biomass and is a material similar to coal or charcoal. It can be used as an amendment to help increase soil fertility or for other uses, including direct combustion.

In Australia, the majority of bioethanol is produced by commercial refineries of which there are three, all located on the east coast. The largest of these is the Manildra Group refinery in Nowra NSW which has an annual production capacity of 180 ML (Geoscience Australia and BREE, 2014). These refineries meet demand for mandated ethanol for inclusion in e10 petrol. Currently, the feed stock for these refineries comes largely from the sugar industry.

Gasification

Gasification is a similar process to pyrolysis with minimal or no oxygen at a medium to high temperature but focused on the production of the gaseous products rather than the char output. The resultant gas, often called syngas, is largely made up of carbon monoxide, hydrogen and carbon dioxide but with a variety of tars and other contaminants which may need to be removed depending on application.

Biogas

Utilising biogas involves the controlled collection of gases released during the decomposition of organic matter to use for burning, which runs an engine, powers a turbine, or directly creates heat;

Biogas processing and collection can happen on a small or large scale, and is accompanied by varying degrees of

Section footnotes

10 Few farms produce high volume waste streams that are suitable for biodiesel production.
11 Biomass energy refers to any energy derived from an organic waste source. This includes any sort of material including woody weeds, animal effluent, crop by-products or grasses grown for the express purpose of fuel utilisation.
Design Considerations

The design of a bioenergy solution requires significant expert input at selection stage and then in relation to subsequent design and installation.

- Feasibility studies are essential that addresses
- Alternative uses of feedstock (what is the best and most sustainable use of the feedstock)
- Value of the feedstock (if purchased from off farm, or if sold instead of used for energy)
- Cost of aggregation
- Feedstock chemistry and consistency (this is critical to system performance)
- Capital and operational costs of the plant itself
- Co-benefits (for example, reducing waste disposal costs)

As noted above, a primary consideration is locking in a sufficiently consistent supply of feedstock to warrant investment in the technology. Related to this is deciding whether energy generation is in fact the most sustainable or profitable end use of the biomass. In many cases, grain waste and other agricultural by-products are better returned to the soil to help retain moisture or other vital soil components like phosphorus or nitrogen. Likewise, allocating land and water to production of energy crops raises complex sustainability questions at a local and global level.

More information

- Piggery case study http://www.aginnovators.org.au/initiatives/energy/case-studies/power-pig-poo

Figure 30: An anaerobic biodigestion facility installed on the Beveridge piggery near Young, NSW.

Farms that produce animal effluent with high methane content such as piggeries and dairies should give serious consideration to capturing methane for conversion to electricity. Poultry farms also generate waste that has significant energy content. Various technologies may be viable in this case including biodigestion and pyrolysis.
Ground source heat pumps can be highly effective as a source of night time heat in combination with Solar PV during the day: For example, to eliminate the need for LPG in heating animal production facilities.

Heat exchange technology is commonplace in today’s world. Examples of heat exchangers are traditional air conditioning systems which use air as their temperature source (these are known as air-source heat pumps or ‘ASHPs’). The technology is similar when applied to (GSHPs) but, as their name implies, the main difference between a GSHP and an ASHP is their source of a temperature differential.

By using stable ground temperatures at a depth of just a few metres, GSHPs avoid the large temperature swings that reduce the efficiency of traditional systems, while also minimising exposure to outdoor ‘pollutants’ such as salt, dust, pollen, etc. GSHPs can provide high efficiency heating and cooling to farm houses and buildings. Essentially, anything that requires heating, cooling or hot water can benefit from a GSHP.

Ground source temperature regulation solutions for agricultural facilities are relatively new in Australia but are well established in the Northern Hemisphere.

GSHPs are often referred to as geothermal heat pumps or ground coupled heat pumps. The term GSHP is typically used in Australia and elsewhere to avoid confusion with ‘geothermal’ power plants that generate electricity from ‘hot rocks’ or other unique geological features.

The name ground source heat exchange can be confusing, as this technology is used to provide cooling as well as heating.

GSHPs are a well established technology internationally and are common in many parts of North America and Northern Europe. However, despite the first local installations occurring in the early 1990s, they are not yet widely adopted in Australia.
Ground source heat pump

How it works

Across Australia, ground temperatures are a function of average ambient air temperature and range from 10-12°C in the colder south to 32-34°C in the tropical north. The main population areas from Perth across to Melbourne and north to Brisbane range from 16-22°C.

In a similar way that a traditional air source heat pump (ASHP) exchanges heat with the outdoor air, a GSHP exchanges heat with the ground. As pumping rock and soil through a heat pump is not a very sensible option, a GSHP attaches itself to the ground via a network of pipes called a Ground Heat Exchanger (GHX).

The GHX can be thought of as an onsite thermal battery. It provides both heating and cooling capacity and enables a dwelling to store the heat rejected from it during summer so that a portion of it can be recovered and used to heat that same building in winter.

The GHX can be either vertical or horizontal and in some cases can use a water body such as a farm dam or a harbour. The system can even use groundwater pumped by a bore in what is called an ‘open loop.’

The slow transfer of energy (both into and out of the ground) means that ground temperatures remain relatively constant regardless of air temperatures during any particular season.

Ground source heat pumps take advantage of this consistent thermal mass to make heating or cooling more efficient, and can provide all or a portion of the required conditioning needed for a designated space. Although a GSHP system does not require a backup system to provide a buildings heating and cooling needs, sometimes a hybrid system is installed which may integrate the GSHP with more conventional heat sources or heat rejection systems.

The most common systems are either “open” or “closed loop,” and are a series of connected polyethylene (PE) pipes with fluid that runs through an underground trench or in a borehole. Systems can either be horizontal, with pipes running horizontally through trenches, generally one to two metres below the surface, or vertical, where boreholes are drilled up to 100 metres deep.

Horizontal systems are typically less expensive as they don’t require drilling equipment. Vertical systems may cost more to install but require a smaller land footprint. The type and depth of ground is important when assessing suitability for a Ground source heat system, as it can be difficult to dig horizontal systems without sufficient soil depth.

Heat pump efficiency is measured in “Coefficient of performance,” (COP) which is a metric that defines the amount of energy used to generate or transfer a unit of heat. COP ratings on heat pumps are defined at a particular temperature,
Renewable energy in agriculture

and this efficiency declines as temperatures become more extreme – i.e., colder temperatures that need to be heated or hotter temperatures that need to be cooled.

Applications

Ground source heating is ideal for farm houses and other buildings that need to be heated or cooled. This includes poultry sheds, greenhouses that require temperature regulation, and other cool storage areas. These systems are especially attractive when constructing a new building, as system design can be incorporated into the general design process. However, retrofit is possible and in some instances, existing equipment may be incorporated into a final ‘hybrid’ design.

Heat pumps use electricity to run the heat exchange process, and can be installed in conjunction with other forms of renewable energy, such as solar PV or wind.

While these systems use electricity, they are much more efficient than conventional electrical heating or air conditioning units. The key to this is the use of those constant ground temperatures discussed earlier, rather than being reliant on outdoor air temperatures that can range from -10 to 50°C depending on location, direct sunlight and wind chill.

Much in the same way that solar thermal uses latent solar radiation to “pre-heat” a fluid, in Ground source heating, the latent heat in the ground is used to “pre-heat” a fluid, getting it closer to the optimal temperature to run a heating or cooling system. The GSHP is then used to provide temperature set points. In heating mode, the ‘passive’ element of circulating water through the GHX typically provides 70-80 percent of the heat delivered into the building. The GSHP is the mechanical or active element of the heating cycle and will provide the balance as required by a thermostat or building control system. By providing up to 80% of heating requirements through passive water circulation, this process uses significantly less energy than a conventional system.

Design considerations

Ground source heat pumps will be used primarily for heating or air conditioning. The following steps are important to ensure that you are installing the proper sized system:

• Is GSHP the right system?: Because of the higher up-front cost of a Ground source heating system, the technology makes the most financial sense the more often it is used. For example, if the space only needs to be heated or cooled for a few weeks each year, it may not be the most cost effective solution. A primary residence in an area with variable temperatures, or a space that needs to maintain consistent temperatures throughout all seasons are best suited for this technology.

• Determine heating and cooling loads for the building: There are a number of software heat load modelling programs that you can use to determine the proper sized system, but these can be difficult to navigate if you don’t have much experience with HVAC systems. Make sure that the dealer/manufacturer is using a method for sizing your system, as opposed to simply giving you whatever is available. It may make sense to shop around, compare quotes, and have multiple sources examine your proposed system.

Figure 33: Example horizontal ground heat exchanger being installed in a pit (before filling in) (GeoExchange, 2014)
• **Select and calculate the Ground Heat Exchanger:**
  Selection of an appropriate GHX is key and is dependent on soil type, geology, available land area and land uses. The presence of water bodies such as dams and even aquifers should also be taken into consideration. It is usually a fairly simple selection for any given site. The GHX calculation requires experienced industry professionals and industry specific software that considers all elements of system design from the building loads to the ground conditions, local climate and the GSHPs to be installed.

### More information

- [www.igshpa.okstate.edu](http://www.igshpa.okstate.edu)

<table>
<thead>
<tr>
<th>Benefits of GSHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reduce electrical use and costs by up to 60%;</td>
</tr>
<tr>
<td>• Reduce LPG costs by up to 80%;</td>
</tr>
<tr>
<td>• Reduce peak electrical requirements (eg cooling during heat waves or heating during cold snaps) by up to 40%;</td>
</tr>
<tr>
<td>• Reduced maintenance and long system life;</td>
</tr>
<tr>
<td>• The combination of onsite renewable power and GSHPs future proofs buildings against future energy increases in both electricity and gas;</td>
</tr>
<tr>
<td>• Removal of LPG improves air quality in production sheds;</td>
</tr>
<tr>
<td>• Removal of LPG removes reliance on the gas provider for regular deliveries;</td>
</tr>
<tr>
<td>• Heat transfer possible between separate buildings on the same site, especially where they may have slightly different heating/cooling requirements.</td>
</tr>
</tbody>
</table>
Financial assessment

Capital expenditure/ongoing costs

In general, renewable energy generation technologies have a high up-front cost, but very low ongoing operating costs. Technologies like wind, solar, Ground source heating/cooling all use free energy inputs to generate power. Waste to energy systems require a more complex planning and delivery process for inputs, but these inputs are often readily available on site, and cost little to nothing to produce.

The Renewable Energy Target (RET) and Small Technology Credits (STCs)
The federal Renewable Energy Target (RET) refers to the legislative framework to incentivise the production of renewable energy in Australia. It does so by requiring energy companies and other entities to acquire and periodically surrender a number of Renewable Energy Certificates (RECs). This requirement means that RECs have a market value and can be sold and/or traded.

Each RECs represents 1 MWh of renewable energy generated. There are two types of RECs:

‘Small-scale Technology Certificates’ (STCs), and
‘Large-scale Generation Certificates’ (LGCs)

As of the writing of this guide, renewable energy generators such as solar PV systems of less than 100 kW, wind turbines under 10 kW and solar hot water systems were eligible to generate STCs as part of the RET. These can be claimed upon the installation of the system and typically deemed for the expected energy that the system will generate in the next 15 years.

It is common and sound for customers to sign over the STCs generated from their new renewable energy system over to the business who conducted the installation. This allows the installer to offer a discounted price for the system and cover this shortfall by selling the generated STCs. Customers can check whether the level of discount offered is in line with the revenue that will be generated by the forfeited certificates.

This can be done by estimating the expected energy (in MWh) that the system will generate over 15 years and multiplying this figure by current prices of STCs. These can be accessed online through websites such as:

- greenenergytrading.com.au/incentives/small-scale-technology-certificates
- greenmarkets.com.au/resources/stc-market-prices

In November 2014, the weighted average price of commercial PV system across capital cities in Australia was approximately $1.46/W (Solar Choice, 2014). Discounts offered via forfeiture of STCs for these systems amounted to approximately $0.65/W on the system price. This means the RET permitted discounting to a level of about 31% off the sticker price.

The process of selling or trading certificates is complex and involves risk and is therefore best left for agents (like solar installers) who have aggregated large numbers of certificates and are familiar with the market and framework.
Feed in Tariffs

Feed in tariffs are payments for energy supplied by renewable energy generators such as solar PV and wind turbines.

Historically, state and federal governments in Australia have employed various levels of reward for renewable energy generated by small private parties (see ‘NSW Solar Bonus Scheme’). In many cases this meant that it was preferable to install systems to generate and export as much energy as possible.

However, government policy changes and reduction in overall electricity demand have meant that most feed-in-tariff schemes have been reduced, or are no longer available to new system owners.

As of February 2015, most states have no government mandated regulation to ensure feed in tariffs are offered for generated renewable power. This has switched the financial game around, as it is now best to size a system to maximise the amount of energy from it that is self-consumed (resulting in savings of power since electricity does not have to be bought from the grid).

Nonetheless, even though it is not required by regulation, most electricity retailers wish to remain competitive and therefore continue to offer some level of feed-in tariffs. It is important to shop around for a good retailer that will reward generated power appropriately.

### Net vs Gross Feed-in-tariffs

**Net feed in tariff**

A net feed-in tariff pays you only for the surplus energy that you feed back into the grid. This type of scheme operates virtually everywhere in Australia now. The power that is not exported to the grid is used by the home, thereby reducing the electricity of the home or business in question through avoided purchase of power from the grid in the first place.

**Gross feed in tariff**

A gross feed in tariff pays you for every kilowatt hour of electricity your solar cells produce, regardless of how much energy you consume. Generally speaking, gross feed-in tariffs are not offered through electricity retailers these days. The vast majority of feed-in arrangements are net feed-in arrangements.
Renewable energy in agriculture

<table>
<thead>
<tr>
<th>Retailer</th>
<th>Feed in tariff (cents per kWh, excluding GST)</th>
<th>Net/Gross Metered</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGL</td>
<td>8.0</td>
<td>Net</td>
</tr>
<tr>
<td>Diamond Energy</td>
<td>8.0</td>
<td>Net</td>
</tr>
<tr>
<td>Powerdirect</td>
<td>7.8</td>
<td>Net</td>
</tr>
<tr>
<td>Origin</td>
<td>6.0</td>
<td>Net</td>
</tr>
<tr>
<td>Lumo Energy</td>
<td>5.5</td>
<td>Net</td>
</tr>
<tr>
<td>Energy Australia</td>
<td>5.1</td>
<td>Net</td>
</tr>
<tr>
<td>ERM Business Energy</td>
<td>5.1</td>
<td>Net</td>
</tr>
<tr>
<td>Red</td>
<td>5.0</td>
<td>Net</td>
</tr>
<tr>
<td>Commander Power &amp; Gas</td>
<td>0.0</td>
<td>Net</td>
</tr>
<tr>
<td>Momentum Energy</td>
<td>0.0</td>
<td>Net</td>
</tr>
<tr>
<td>Powershop</td>
<td>6.4</td>
<td>Net</td>
</tr>
</tbody>
</table>

*Table 4: Feed in tariffs available to small business customers in NSW (Australian Energy Regulator, 2015)*

**NSW Solar Bonus Scheme**

In January 2010, the NSW Solar Bonus Scheme was introduced; it entailed a 60c gross feed-in-tariff. This meant that customers under the scheme would receive 60 cents for every kWh of energy generated by an eligible system. This resulted in a tremendous uptake in solar PV.

![Number of Systems Connected/Applied for Connection in NSW during Open Applications Term of the Solar Bonus Scheme](image)

The solar bonus scheme was reduced to 20c per kWh on 27 October 2010 (for new applicants) and was subsequently closed to new entrants on 1 July 2011. It will be completely phased out by December 31 2016.

*Figure 34: Number of Systems Connected/Applied for Connection in NSW during Open Applications Term of the Solar Bonus Scheme (New South Wales Auditor-General, 2011) (DTIRIS, May 2011 and DNSPs, 30 June 2011)*
Financing options for renewable energy systems

Because of the high initial cost of renewable energy, finding the money to fund the investment may require external capital. The usual avenues for investment (your local bank or the equipment installer) will usually offer financing options, and it is important to shop around, as interest rates for financing can add significantly to the lifetime cost of your project.

Documentation and evidence of project payback is often useful and sometimes required in securing project financing. Some lending institutions offer specific “clean-energy” finance packages at lower rates.

Speak with a lending professional to understand the requirements for obtaining a loan for a renewable energy project.

The NSW Office of Environment and Heritage has published an “Energy Efficiency and Renewables Finance Guide,”13 which provides extensive detail on the main financing options available for renewable and energy efficiency projects.

These are:

**Bank Loans**
- Self funded
- Commercial loan
- Energy efficiency loan

**Lease Agreements**
- Operating lease
- Capital lease

**Others**
- Environmental upgrade agreements (EUA)
- Utility on-bill financing
- Energy services agreement (ESA)
- Purchasing power agreement (PPA)

A description, and the advantages and disadvantages of these financing methods are introduced in Table 5 (overleaf).

Power purchasing agreements (PPA)

Power purchasing agreements (PPAs, sometimes referred to as ‘solar leases’) are a recent development in Australia but have been highly successful in the US and Europe. These arrangements are similar to a lease agreement, in that a company will install a solar system on the customer’s property (typically at little or no up-front cost to the customer) but retain ownership of the system. The customer will then agree to buy the power generated by the system for a contracted rate. This rate is lower than typical retail rates and therefore, provides immediate savings to the customer’s electricity bills.

The contractual length of these agreements is 20 years or more and an option to purchase the system before or at the end of the term is typically part of the contract.

It is easier to think of a PPA as an agreement to buy power from a renewable source than an agreement to have a solar system installed (Solar Choice, 2013).

PPAs can offer several advantages over other financing options. For example, energy savings are incurred immediately and the duty and costs involved in maintaining and ensuring operation of the system is kept with a third party and not the consumer. However, PPAs can be hard to obtain for smaller installations and can entail arrangements which limit the flexibility and utility of the system for the customer.

More information on solar PPAs and their suitability for particular cases is available here: [http://www.solarchoice.net.au/blog/is-a-solar-leasing-program-right-for-you/](http://www.solarchoice.net.au/blog/is-a-solar-leasing-program-right-for-you/)

Financial appraisal methods to compare solutions and offers

We recommend that all farmers analyse financial suitability before commissioning renewable technology on their farm. There are three key appraisal methods that help convey and compare the financial effectiveness of an investment on a system.

These are:
- Simple Payback method
- Internal Rate of Return
- Net Present Value
## Renewable energy in agriculture

<table>
<thead>
<tr>
<th>Financing Type</th>
<th>Financing Option</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
|                | Self funded               | Energy efficiency or renewables project is financed with own funds from capital budget | No external obligations to financiers  
Business owns and can depreciate the equipment                                                                                         | Must meet the company’s minimum acceptable rate of return on capital (also referred to as the project hurdle rate)  
Less capital available for investment in core business activities  
Business carries all finance and performance risks                                                                                     |
|                | Commercial loan           | A lender provides capital to a borrower, to be repaid by a certain date, typically at a predetermined interest rate that moves in line with changes in a reference lending rate  
Customer makes regular repayments to lender to cover interest costs. Capital repayments can be bundled with interest payments, or can occur at the end of the loan | No or reduced up-front cost. Interest and depreciation of energy efficient equipment are tax deductible.                             | Customer bears the economic and technical risk if the equipment becomes unusable  
Customer could be required to provide security, such as a lien on property or other assets, or guarantees from parent companies, another financier or owners  
Loan is on the balance sheet                                                                                                              |
|                | Energy efficiency loan    | A loan available only for energy efficiency and renewables projects          | No or reduced up-front cost. Interest and depreciation of new equipment is tax deductible In addition, these loans are specifically designed for energy efficiency and renewable energy projects, so generally have lower interest rates and longer finance periods | Customer bears the economic and technical risk if the equipment becomes unusable  
Customer could be required to provide security, such as a lien on property or other assets, or guarantees from parent companies, another financier or owners  
Loan is on the balance sheet  
Few financiers offer this type of loan product                                                                                           |
|                | Operating lease           | The equipment is owned by the financier and the customer obtains the sole right to use it.  
The customer pays regular lease payments to financier and pays all maintenance costs.  
At the end of the lease, the customer has the option of returning the equipment, making an offer to buy it, or continuing to lease it | No or reduced up-front cost. Limited collateral required (other than the asset)  
Leasing costs are tax deductible  
Fixed lease payments  
Lease obligation is off – balance sheet  
Financier bears ‘residual value risk’ (i.e. risk that the equipment has no value at the end of the lease). Particularly suitable where equipment has perceived high obsolescence or is required for a short period | Customer bears the risk of the equipment becoming unusable during the lease  
Customer cannot depreciate the asset  
More suitable for capital intensive projects and where costs are mainly for physical assets  
Less suitable for less expensive equipment, such as lighting, or when a large portion of costs are for installation and associated services.  
Less suitable when equipment is difficult to remove or reuse                                                                                   |
|                | Capital lease             | Same as operating lease, except that at the end of the lease, equipment ownership transfers to the customer on payment of an agreed amount | No or reduced up-front cost  
Fixed lease payments  
Customer depreciates the equipment  
Interest component of repayments are tax deductible                                                                                      | The lease obligation appears on the balance sheet  
Customer bears the economic risk of the equipment becoming unusable, including the ‘residual risk’  
As for operating lease, more suitable for capital intensive projects and where costs are predominantly for physical assets |
<table>
<thead>
<tr>
<th>Financing Type</th>
<th>Financing Option</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Upgrade Agreement (EUA)</strong></td>
<td></td>
<td>A loan for the environmental upgrade of a building which is repaid through a local council environmental upgrade charge</td>
<td>No or reduced up-front cost Loan tied to the property leads to lower risk for the financier, so better rates and extended terms are offered. Lower risk for financier, so better rates and extended terms offered Interest component of payments are tax deductible Fixed EUA repayments Provides a mechanism for transparent pass-through of repayments to tenants</td>
<td>At present only available for commercial and industrial buildings in limited council areas: City of Sydney, North Sydney, Parramatta, Newcastle, Lake Macquarie, and City of Melbourne Perceived to be complex Consequently, deals below $250,000 are not preferable for some financiers. The loan can be considered on the balance sheet, subject to the specific circumstances of a business</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td><strong>Utility on-bill financing</strong></td>
<td>Energy retailer installs equipment. This is repaid through a ‘repayment’ charge on energy bills. Once all payments are made, title for the equipment transfers to the customer</td>
<td>No or reduced up-front cost Interest component of repayments are tax deductible Payment via utility bill reduces risk of default, therefore lowering financing costs Typically have guaranteed savings Typically arranged through a provider who can identify and implement energy saving opportunities</td>
<td>Generally ties customer to the energy retailer for the financing term, regardless of whether the retailer offers competitive energy rates Risk of energy being cut if customer defaults on the debt repayment If energy savings are not guaranteed, customer bears technical risks Repayment liability is on the balance sheet</td>
</tr>
<tr>
<td><strong>Energy services agreement (ESA)</strong></td>
<td></td>
<td>An ESA provider designs, constructs, owns and operates equipment. Customer pays fees to cover operation and maintenance costs, including energy costs, and to repay capital and implementation cost. The fees are indexed to CPI, labour rates, and to the price of energy. Customer can typically purchase equipment at end of ESA. An ESA provides the end-to-end delivery of energy efficiency and renewable energy projects. Finance can be arranged using any of the finance options above, or can be provided by the ESA provider</td>
<td>No or reduced up-front cost An ESA is off balance sheet Payments are tax deductible (operating expense) Implementation and operating risks are transferred to the ESA provider The ESA provider is incentivised to maximise energy savings; they guarantee savings or the customer only pays for the output of the equipment</td>
<td>Can be higher cost than using other finance options in isolation, due to transfer of risks to an ESA provider ESA suppliers will generally not undertake projects that do not require significant on-going maintenance The ESA market in Australia is at an early stage of maturity; it is a limited source of financing for non-governmental organisations ESAs are typically only available for large projects</td>
</tr>
</tbody>
</table>

*Table 5: Advantages and disadvantages of energy efficiency and renewables finance options (OEH; Energetics, 2014)*
SPB – Simple Payback

For an investment that generates revenue or savings, the simple payback rate equates to the number of years (or months) that it will take to recoup the original investment amount. The simple payback method generally makes no adjustment to discount the value of money/capital in the future or additional financial inputs like inflation or escalating energy costs. It is merely calculated as follows:

\[
\text{Simple Payback Rate (in years)} = \frac{\text{Investment (capital expenditure)}}{\text{Annual savings from investment}}
\]

Example:
A 10kW solar PV system cost $15,000 AUD to fully install and will enable yearly savings of $4,000 AUD. The simple payback rate for this system is:

\[
\text{Simple Payback Rate (in years)} = \frac{15,000}{4,000} = 3.75 \text{ years}
\]

SPB is used profusely to market renewable energy systems and has the advantage of being easy to calculate. However, it has many disadvantages including, among others:

- Lacking account of discounting of future cash flows,
- Inability to differentiate between projects with similar payback rates but dissimilar returns
- Future savings (after payback is met) are not quantified or compared.

NPV – Net Present Value

Another way of appraising the financial value of a renewable energy generation project is by inspecting its Net Present Value. This value represents the sum of all outflows (costs) and inflows (savings and revenue) from an investment in a figure that takes into account the time value of money, that is: the concept that money in the future is ‘discounted’ (worth less) than an equal amount of money today.

Discounting is due to a variety of factors that can be pertinent to a given investor such as inflation, or the interest that is forfeited by not placing the principal sum in a competing investment. The equation that derives the Net Present Value of an investment is given by summing the discounted value of each yearly cash flow. For instance, for our previous example of a $15,000 solar PV system, assuming a discount rate of 7%, a life of the system of 20 years, and constant savings of $4,000 per year, we have:

\[
\begin{align*}
\text{NPV} &= \sum_{t=0}^{20} \frac{C_t}{(1 + r)^t} \\
\text{where:} & \\
N &= \text{the total number of years pertinent to the investment} \\
C_t &= \text{the cash flow (savings or cost) during the year } t \\
r &= \text{the discount rate}
\end{align*}
\]

This can also be expressed in equation form as follows:

\[
\text{NPV} = \sum_{t=0}^{N} \frac{C_t}{(1 + r)^t}
\]

Where:

- \(N\) is the total number of years pertinent to the investment
- \(C_t\) is the cash flow (savings or cost) during the year \(t\)
- \(r\) is the discount rate

This calculation can also be automatically calculated using a spreadsheet program like Microsoft Excel and its inbuilt NPV function.\(^1\)

Net Present Value is considered a strong appraisal metric as it takes into account the time value of money, as well as the lifetime and scale of an investment. Consider, for example, two project opportunities with the following outcomes:

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required initial outlay</td>
<td>$8,000</td>
</tr>
<tr>
<td>Lifetime of investment</td>
<td>5 years</td>
</tr>
<tr>
<td>Savings generated per year</td>
<td>$5,000</td>
</tr>
</tbody>
</table>

On paper it seems that Project 1 is a better option, and appraising this project using simple payback method would support this:

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple payback rate</td>
<td>1.6 years</td>
</tr>
</tbody>
</table>

However, even though the second project requires a larger outlay it has a better NPV outcome if the discount rate is less than 8%.

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV after 10 years (7% discount rate)</td>
<td>$12,501</td>
</tr>
</tbody>
</table>

This indicates that over the length of the investments, the second project has a higher net value to invest into today. This, of course, is a manufactured example, but it showcases the utility of the NPV method for financial appraisal.

IRR – Internal Rate of Return

The internal rate of return (IRR) is the discount rate that makes the Net Present Value of an investment equal to zero. This value is useful to compare against alternative investments or the cost of borrowing. For example, an internal rate of return of 6% is insufficient if borrowing costs are 8%.
Calculating internal rate of return is done iteratively by trial and error. Using the NPV formula as before:

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1 + r)^n}$$

One must repeat the calculation (preferably with the help of a spreadsheet) until the selected discount rate ($r$) makes the final net present value equal to zero. For our examples below these are:

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal rate of return (IRR)</td>
<td>55.66%</td>
</tr>
</tbody>
</table>

Using the IRR is beneficial in comparing your energy generation investment against a more traditional financial investment opportunity, as it gives a comparable figure to a bank savings account, stock or bond. However, IRR doesn’t generally calculate risk factors, labour costs, or the reliability of the technology.

**Understanding of future needs (expansion, etc)**

A major component of energy planning and assessing the viability of on farm energy technologies revolves around future planning for the farm. When possible, plans for expansion or contraction of the existing business model should be factored into the equation when considering energy investments.

**Incorporating renewable design**

New infrastructure often provides a perfect opportunity to incorporate on-site energy generation into the existing farming operation, and may reduce overall costs, or increase technology efficacy. For example, if a farm is planning to add sheds, the shed roof orientation and slope can be designed with the intention of including a solar thermal or solar PV system. This will provide an optimal location and orientation for the solar collectors. Other options, like ground source heating systems are much more cost effective when constructed along with a new structure, as costs for a conventional HVAC system can be avoided. Drilling and planning loop fields is also more practical during an existing foundation construction process.

Another example is the use of Solar PV in new shading structures such as those for cattle at feedlots (see Figure 35).

**Preparing quotations and evaluating suppliers**

The marketplace for on-farm energy generation technologies is constantly evolving and changing. Currently, there are many local and regional solar PV installers, but fewer companies able to design and install other types of technology (like waste to energy or Ground source heating).

As with any major investment, it is recommended that you research the technology, understand the market, and compare quotes from potential installers.

**Solar Installers**

There are certain certifications and indicators that may help to assess whether a solar PV installer and their products are reputable. These include:

- Solar panels have a good warranty (industry standard is 80% of nominal power after 20 years)
- Inverter has a good warranty – preferred industry standard is 10 years
- Installation warranty (5 to 10 years)
- Products are Tier 1 or Tier 2.
- The installer and their products are accredited by the Clean Energy Council (CEC)
- The products have a presence in Australia
- The installer is experienced and reputable

While these criteria do not necessarily guarantee the quality of the installation, they are a basic step that you should look for as a potential customer.

**Section footnotes**

12 The RET legislation is currently under review, and the change or elimination of the RET could result in a change to, or elimination of, these STCs. We recommend that you conduct your own investigation and speak to installers about the incentives that are currently available to help fund these types of projects.


14 Be aware that Excel’s NPV function incorrectly discounts the first cash flow (at year 0) so some steps are needed to correct the outcome (see tvmcalcs.com/blog/comments/the_npv_function_doesnt_calculate_net_present_value)

15 IRR can also be calculated using the inbuilt ‘IRR’ function available in Excel.
As mentioned in the overview, we recommend that you address on farm energy management and efficiency before investing significant capital in renewable energy.

You will find it difficult to select the best technology and calculate return on investment accurately if you don’t first minimise energy wastage and establish the true energy baseline of your property.

Farm energy planning should not be seen as a complex or daunting process. NSW Farmers has developed a suite of tools and information materials to help producers better understand the process of farm energy planning and achieving energy efficiency gains. These may be accessed at: www.aginnovators.org.au/initiatives/energy.

In addition, professional energy assessors and planners can visit your property and provide advice for a modest cost.

The key steps in implementing an effective farm energy plan are:

**Step 1** – Conduct an energy audit to establish baselines and patterns of use

**Step 2** – Improve energy purchasing (i.e. negotiate better rates or shift equipment to off-peak times)

**Step 3** – Implement conservation strategies (e.g. reduce idling, ensure power is off when not required) and, where possible, identify and invest in energy efficiency opportunities

**Step 4** – With consideration to the updated energy baseline and costs (after efficiency and lowering of rates strategies have been implemented), investigate on-farm sources of renewable energy

Following these steps will help determine the right system size for a renewable energy generator. Any cost-of-power reductions, ‘quick-win’ opportunities and/or energy efficiency investments that are implemented before step four should be taken into account. This is critically important when considering investment in electricity generation as current tariff frameworks in Australia can make it counterproductive to invest in farm generation capacity in excess of actual needs, or out of step with use patterns.

**Step 1: Establish farm energy baseline**

There are several levels of detail and accuracy involved in energy analysis. As a rule of thumb, the larger the energy bill, the more detail may be warranted. Medium or large scale farming operations should consider hiring an independent energy consultant to conduct an energy audit and provide advice and suggestions for increasing operational energy efficiency. There are three energy audit levels available in Australia, as defined by the Australian Energy Audits Standard AS/NZ 3598:2000. A typical level one audit in a regional location can be delivered for between $500 – 1000 dollars.

We recommend that farmers commission at least a Level 1 Energy Audit or equivalent. This involves producing a basic inventory of energy using equipment and processes and documenting major energy uses. These audits can be conducted over a single day at relatively low cost. Many farms, such as intensive production facilities, will benefit from more comprehensive audits which include detailed analysis of usage patterns and opportunities for savings.
**Step 2: Improve energy purchasing**

**Find better rates**

After identifying baseline energy use, review rates for electricity, gas, and other energy sources.

Farms using more than 160 MWh or $50,000 of electricity per year are likely to be in a position to negotiate special contracts. Retailers are looking to minimise their risk so, so providing them with certainty and additional information on predicted electricity use will generally enable then to offer a lower rate.

Farmers using less than 160 MWh per year should ensure they are in the most economical tariff (see below) and have obtained all available discounts. Discounts can be obtained by joining a buying group or, in some instances, by simply asking the retailer. Don’t assume that the current retailer will automatically offer the deals they are offering to bring in new customers.

Sourcing liquid and gas fuels at good rates can involve more complexity, but it may pay to talk to several suppliers and negotiate prices.

**Switch to Off-peak**

An important consideration around energy use is time-of-use tariffs (TOU) and load shifting. Many electricity contracts include different rates for power used at different times. Typically, contracts include “peak,” “off peak” and “shoulder” rates. Peak and shoulder rates are higher than off-peak rates, so customers can save money by shifting electricity use from peak and shoulder times to off-peak times. However, when employing renewable energy sources (such as solar or wind), there are added layers of complexity. Peak electricity rates generally occur during the day (7am-10pm), when there is available sunshine that can generate power from a PV system. This may impact design considerations around a solar PV system, as well as payback/system investment.

**Figure 36: Time intervals for peak, off peak and shoulder power rates (Ausgrid).**

**Step 3: Invest in energy efficiency**

Programs such as the NSW Farmers’ Energy Innovation Program and the Energy Efficiency for Small Business Program (EESBP) determined that most farmers are capable of reducing their energy use by at least 10% by implementing energy efficiency measures. In many cases, however, farmers can achieve savings far in excess of this figure.

Energy efficiency measures are often the simplest and least expensive ways to reduce existing energy expenditure. Skipping the first steps of the efficiency process will make it difficult to outline accurate return on investment scenarios, which are often essential in securing capital for this type of financial investment.

**Different Levels of Energy Audits**

- A Level 1 Audit will provide an overview of energy use and help establish initial benchmarks. It will also provide some guidance on possible energy saving opportunities, but these savings are rough and generally only accurate to within ±40%

- A Level 2 Audit will identify the particular energy sources being used and the amount of energy used for specific purposes. It will also provide recommendations on measures to reduce energy and its cost with a general accuracy of around ±20%

- A Level 3 Audit will involve a more detailed and comprehensive energy assessment which may cover a whole building or focus on a specific area or process. Level 3 audits utilise data logging for specific equipment to generate detailed energy use profiles over single days as well as over prolonged periods (months or even years). The recommendations from a level 3 audit are much more accurate and refined, and will therefore typically express costs estimates with a +10% margin of error and savings estimates with a -10% margin.

A Level 3 Audit will require more time and effort and incur a much higher cost than a Level 2 or Level 1 Audit.
Step 4: Selecting a suitable renewable technology

As addressed in previous sections of this guide, there are differences between each of the main-farm energy generation technologies, including different advantages, disadvantages, capital expenditure and investment return potential for each. Erecting a wind generator in a property with little wind resource is unsound; much like installing a biogas plant using anaerobic digestion may be unsuitable for a farm with little or poor quality waste generated through the year. The technology must fit the farm.

Energy efficiency measures are often the simplest and least expensive ways to reduce existing energy expenditure

When it comes to energy, the term “efficiency” can be confusing and is at times deliberately misused by vendors of equipment.

In the case of generation technologies, vendors typically calculate and present efficiency data in the terms that are most favourable to their particular technology.

The conversion rate of input energy to work done is an important comparison tool, but is not always relevant to return on investment, or cost efficiency.

For example, Solar PV cells are around 18-20% efficient in converting sunlight directly to electricity, but this efficiency rating is usually irrelevant since, unless there are space restrictions, a system can be expanded in order to obtain the required peak power.

Typical pump engines and generators powered by diesel are more efficient at converting the energy source, extracting up to 35-40% of the fuel’s energy (the rest of it is wasted as heat).

However, once installed the solar system’s fuel source is free: the diesel is not. Comparing cost efficiency in this case involves comparing the capital cost of the solar system with the avoided cost of diesel, maintenance and time.

Radiant versus heat pump heating is another example. In engineering terms electric heaters are 100% efficient, as they transform the entirety of their input energy into heat (the desired end form of energy). That sounds good until you realise that a heat pump-based air-conditioning system can be 300-400% efficient because it leverages the temperature differential between the indoor and outdoor environment. A modern reverse cycle unit can provide three to four times more heating than an equivalent resistive electric heater for the unit of electricity.
Looking ahead

Solar has proven to be a preferred entry point to renewable energy for many farmers, due to its flexibility, simplicity and relatively low entry cost. Because of its scalability, falling prices and innovation in battery technology, we can expect to see ongoing growth in solar on farm.

Moving forward, we hope to see farms adopting an integrated suite of complementary renewable energy technologies. We also hope to see increased community investment in local generation projects and, related to this, load shifting, with renewable power distributed between users on a diurnal and seasonal basis.

Particularly in relation to bioenergy, renewable projects must be functionally related to production strategy and will have implications for general infrastructure, operational procedure and resource allocation. For example: a poultry farm, dairy or piggery that invests in an energy plant must commit its waste stream to that capital asset. Likewise, a farmer wishing to produce biodiesel must carefully consider the pros and cons of allocating land and biomass to fuel feed stock.

Farmers who embrace renewable energy start to think differently about their businesses and also about collaborative models for financing and operating shared facilities. For example, intensive animal production facilities grouped in precincts around a shared waste to energy plants; biodiesel plants owned and operated by grain cooperatives.

While it is relatively easy to replace a small proportion of conventional energy with renewable energy, moving towards energy independence demands a fresh perspective within farm businesses and across regional communities.

There is an element of “back to the future” in this since, decades ago, and before the national energy grid was established, most regional centres operated their own local power stations and networks.

Where to go for more advice

NSW Farmers information papers covering renewable energy and other aspects of farm energy productivity are available by contacted the members centre on 1300 794 000 or online at http://aginnovators.org.au/initiatives/energy

Other important sources of information are:

The NSW Office of Environment and Heritage

The Clean Energy Council

The Alternative Technology Association
http://www.ata.org.au
Renewable energy in agriculture

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