AUSTRALIAN MEAT PROCESSOR CORPORATION

Extension guide: Renewable Energy and Energy Storage Technologies Applicable to Red Meat Processing Manufacturing businesses

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PV electricity

Figure 1: Grid connected solar PV - typical upfront system component cost

INTRODUCTION

This extension guide provides information on the renewable energy, low emission and energy storage technologies that could be suitable for use at Australian red meat processing sites. It has been developed to assist site owners and managers determine which technologies could be suitable for their sites and develop business cases for the installation of such technologies.

Five technology classes are considered; renewable electricity generators, electricity storage, renewable heat supply, heat storage and low emissions technologies.

The guide contains three sections:

1. A compendium that considers all major generation and storage technologies currently available, with recommendations on the situations in which they are most effective. This compendium is intended as a screening tool to help you determine which technologies are worth investigating for your specific site.

2. Ten factsheets on the most attractive technologies currently available. These factsheets are intended to assist with more detailed investigations of the technologies of interest to your site. They provide guidance on how to develop business cases for the implementation of each technology, including constructing cost-benefit analysis.

3. A report on the main technical and practical barriers to the installation of the technologies included in the factsheets. These barriers include space requirements, resource requirements, planning and network restrictions, requirements to match renewable energy output with site demand, and maintenance issues. This report is intended to further assist you with determining the suitability of these technologies to your sites.

For further information relating to this extension guide, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

Compendium

EXECUTIVE SUMMARY

This report considers renewable energy, low emission and energy storage technologies, and how they can best be applied to Australian meat processing sites.

Five technology classes are considered; renewable electricity generators, electricity storage, renewable heat supply, heat storage and low emissions technologies. All major generation and storage technologies are covered, with recommendations on the situations in which they are most effective.

This document is intended as a screening tool to inform detailed business case analysis. In some classes the best technology is not obvious and will only be determined by modelling the energy source, the collection technology and the interaction with the plant. The following recommendations summarise this first screening of technologies.

ELECTRICITY GENERATION

Solar PV is currently the most attractive renewable electricity generating technology. Module prices have fallen sharply in the last five years, with less than $2 per watt capacity available in every capital city. Output is predictable and reliable and can be modelled before installation using many established tools and data sources. There is a widely established installation, service and sales industry in Australia selling a wide range of products from China, Germany and Japan, among others. Solar PV is cost-competitive with grid supplied electricity in some areas of Australia.

The closest competitor to solar PV is wind, which is more site limited than solar, requiring high wind areas such as on the coast and on inland ridges. Planning restrictions in some states and objections from locals also make installation difficult.

ELECTRICITY STORAGE

Battery technologies are the standout electricity storage technology, suitable in both size and response times. Of the many battery chemistries and formats available, Sodium-Sulphur, ZEBRA, Zinc-Bromine and Vanadium-Redox flow batteries and lead-acid batteries should be investigated first. Their technical performance is similar, with the ultimate system cost likely to be determined by availability in Australia, maintenance regimes and turnaround efficiencies.

HEAT SUPPLY

Anaerobic digestion of wet abattoir waste to produce biogas is an attractive option for meat processing sites, as a low-complexity way to provide heat while treating an existing waste stream. The biogas produced could be used to fire a modified gas boiler or burnt through an engine to provide combined heat and electricity. Pyrolysis or gasification may also be competitive, but in general work better with drier, more cellulosic wastes.

A comparison of anaerobic digestion and pyrolysis/gasification will hinge on whether there are other waste streams available, such as animal bedding and be impacted by the value of carbon farming credits which could be generated from pyrolysis/gasification.

A very simple solar thermal system which uses evacuated tube collectors may also be attractive for augmenting fossil fuel-powered boilers. In this scenario, solar energy would raise the water temperature from ambient to 70°C to reduce the load on the boiler.

HEAT STORAGE

This is an emerging area, driven in part by interest in solar thermal systems used for grid electricity supply. Two integrated heat capture and storage systems are worth comparing; linear solar collectors with molten salt storage and heliostat arrays with massive solid storage. Both these combinations can provide process steam and store solar heat for long periods.

LOW EMISSIONS TECHNOLOGIES

Cogeneration should be considered in areas with reliable gas supply and heat requirements on site. Trigeneration should be considered where there is a flat electricity load profile and large cooling requirement. The analysis of both of these technologies should consider future gas prices.

Heat pumps are best used as a booster for hot water systems or space heating, particularly in areas without reticulated gas.

CONTEXT

This document outlines the renewable energy technologies and associated energy storage systems that could reduce energy costs and the use of fossil fuels on meat processing facilities.

AMPC members operate sites which cover a wide range of sizes and use different processing methods, including some which operate almost continuously and other small, regional sites with infrequent operation and variable species processing. This leads to different operating profiles, energy using processes and energy use proportions.

To overcome these differences, information on technologies will be presented with consideration for where the technology is best used and where other technology might be more appropriate.

According to data collected under the project ‘AM12-5066 Domestic Processors Energy Efficiency Program’ and reported in ‘The *Energy Consumption Guide for Small to Medium Red Meat Processing Facilities’,* small to medium sized red meat processing sites use significant amounts of energy across a number of distinct processes. These sites use both electricity and natural gas or LPG, with thermal processes accounting for more than half the energy used on site and closer to 75% for sites which conduct rendering as well. The report findings showed that that not all sites are the same in terms of total energy consumption and the intensity of consumption (i.e. energy consumed per unit of output), differing in the degree to which value-add processes are incorporated, head per day are processed and whether rendering occurs on-site.

Large sites differ in scale and profile, but not in type. Where the smaller sites were found to use natural gas and LPG to drive thermal processes, larger sites could use coal in place of gas to fire large boilers. These sites also have flatter demand profiles, working around the clock in shifts. But the energy consuming processes are broadly the same; all sites use electricity for refrigeration, lighting, air conditioning and specialist equipment such as conveyors. Fossil fuels, such as coal, natural gas and LPG are used to power thermal processes, particularly rendering and sterilizing. So site energy use can be grouped as electric or thermal; the technologies that can generate or store these energy types will be analysed.

This document considers renewable energy use and storage in five categories; renewable electricity, renewable heat, electricity storage, heat storage, and low emissions technologies. Consideration has been made for when each is best used, which processes are most applicable to different meat processing facilities and the environmental conditions which are favourable for their use.

Recommendations have been put forward on how these technologies could be used without compromising the supply of energy to the site. If a technology requires back up or integration with existing technology to guarantee safety, reliability or accurate control, this has been noted.

RENEWABLE ENERGY GENERATION AND STORAGE TECHNOLOGIES

The suite of renewable energy technologies has expanded markedly in the last five years, with technologies that were previously at the research and development stage now being successfully demonstrated at scale. This growth in technologies has led to increased specialisation, where some technologies are only applicable at certain scales and with favourable climate and geography. The short summary below considers the whole suite of renewable energy technologies and energy storage technologies, eliminating those which are not suitable for the meat processing sector. Those which are considered suitable will be explored in much more detail in the following section.

Table 1: Renewable energy generation and storage technologies currently available

Technology option	Energy type	Description	Good / *Bad* site characteristics
Solar PV	Electricity	Photovoltaic solar converts sunlight to electricity through the use of semiconductors, using the photoelectric effect. There are many combinations of materials used to achieve this, including the typical silicon cells, organic solar and compound systems which use multiple compounds to capture a broader spectrum of light. Efficiencies range from less than 10% for organic solar to approximately 24% for silicon based cells (typical rooftop solar) to over 40% for multi-junction crystalline cells. Organic solar and high-efficiency units account for less than 20% of global installed solar capacity; silicon cells have had greater than 80% market share since 2010 and this is expected to continue until 2017 and beyond. This is a commercial, fully-mature renewable electricity generating technology. Over 100GW installed worldwide.[1] **This report will only consider silicon PV as it is the most mature, reliable and well known technology.**	**Good fit:** High insolation areas,[2] typically northern/inland Australia High electricity costs ***Poor fit:*** *Rainy/cloudy areas* *Poor roof/available space*
Solar hot water (low temperature collectors)	Thermal	Solar hot water is available in both flat-panel and evacuated tube configurations. All systems use sunlight to heat water for domestic use. Flat-panels are generally lower cost, while evacuated tubes perform better in cold climates. Solar hot water systems could preheat water entering a fuel fired boiler and thus reduce the demand for fuel, however they are not capable of producing hot water at temperatures suitable for sterilisation. This technology is only beneficial for heating water from ambient temperature to 70°C and slightly above. This would be of little value on plants which have waste hot water from the rendering process, but represents very good value on plants that do not. Solar hot water is a mainstream technology now, producing hot water for domestic use. **Solar hot water is discussed later in the context of plants which require water heating to 70°C only.**	**Good fit:** High insolation areas High thermal fuel costs ***Poor fit:*** *Rainy/cloudy areas* *Poor roof/available space*
High temperature solar thermal collectors	Thermal	High-temperature solar collectors use mirrors to focus sunlight onto a collector, making them capable of higher temperatures than domestic hot water systems. These systems collect solar energy across a wide area, heating a working fluid to temperatures where steam turbines can be employed to generate electricity, generally in the 300°C to 400°C range, making them suitable for generating steam for	**Good fit:** High insolation areas High thermal fuel costs Sites with large hot water or steam loads

[1] http://www.epia.org/fileadmin/user_upload/Publications/GMO_2013_-_Final_PDF.pdf
[2] Insolation is a measure of the solar energy received per unit area. Typically expressed as kWh/m2/day. Higher values indicate better solar resources and are associated with hot and dry areas of Australia.

Technology option	Energy type	Description	Good / *Bad* site characteristics
		sterilization and cleaning tasks. The collection technologies include linear systems such as Fresnel lenses and parabolic trough collectors, dish systems and those which use heliostat arrays to focus sunlight onto central receivers. Most high-temperature solar thermal systems can be considered mature, with some specific types still being demonstrated in first-of-type installations. Installed capacity of solar thermal worldwide is of similar magnitude to solar PV, but in fewer, larger installations.[3] High temperature solar thermal systems will not be considered as electricity supply options for meat processing sites as at the small scale required they are very unlikely to be cost effective. **The collection technology will be considered to supply heat independent of the storage technology.**	***Poor fit:*** *Rainy/cloudy areas* *Lack of available space*
Very-high temperature solar thermal collectors	Electricity	These systems use large heliostat arrays to focus sunlight onto a central receiver. These systems achieve the largest ratio of solar collection to receiver and so achieve the highest temperatures, in excess of 700°C in some instances. Heliostat solar thermal towers are appropriate for large scale power generation (up to 100 MW and well beyond with planned designs). These systems are too large for meat processing facilities; systems of a more suitable size would be prohibitively expensive. **High temperature solar thermal collectors are not discussed in more detail in this report.**	**Good fit:** Sites with good insolation and very large land availability ***Poor fit:*** *Inappropriate for most sites. Grid-scale electricity production only.*
Wind turbines	Electricity	Wind turbines use wind energy to create mechanical energy, which in turn generates electricity. There are both horizontal and vertical axis turbines available, but the vast majority of units in operation are horizontal axis units. Horizontal access wind turbines can be considered a mature technology, with over 282 GW of capacity installed worldwide.[4] Wind turbines have limited application in the meat processing industry. The economics of wind power strongly favour large (over 2 MW) turbines in windy locations. The turbines typically sit on towers the order of 100m high. This said, some meat processing facilities in remote areas may have a use for a small (less than 1 MW) wind turbine. **Small wind turbines will be covered in more detail below.**	**Good fit:** Coastal/inland ridge sites with consistent, high wind ***Poor fit:*** *Ineffective in urban areas and unlikely to be permitted in built up areas.* *Only cost effective if sized to about 80% of the baseload.*
Geothermal	Electricity	Geothermal energy systems use heat produced by the Earth's core to provide space heating and electricity generation. The systems employed can be broadly divided into two categories; naturally occurring hot aquifers such as those that occur in areas of high volcanism, like Iceland, and engineered geothermal systems which use the heat of radioactive decay captured in large, underground granite bodies. Geothermal power based on hot fluid associated with active	**Good fit:** Sites require homogenous, sub-surface granite bodies, insulated by coal or other later deposits, or areas with deep hot aquifers.

[3] http://www.renewableenergyworld.com/rea/news/article/2011/06/the-rise-of-concentrating-solar-thermal-power
[4] http://www.gwec.net/wp-content/uploads/2012/06/Annual_report_2012_LowRes.pdf

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Technology option	Energy type	Description	Good / *Bad* site characteristics
		volcanism is not applicable to Australia. Other geothermal power generations systems such as enhanced geothermal and hot sedimentary aquifers systems have potential application in Australia. However they are at the pre-commercial stage and rely on the availability of suitable geothermal resources. While the temperatures being achieved by enhanced geothermal systems are appropriate for sterilizing and rendering, the cost of accessing these resources is prohibitive. In most cases two holes will be required to access the heat reservoir, and current drilling technology costs about $5 million per hole. This scale is considered beyond the scope of most meat processing facilities. **Geothermal energy for electricity production is not discussed in more detail in this report.** Geothermal energy for use as heat is applicable in very few places in Australia. While a good option where available there will be few plants where this is a cost effective approach. However, geothermal energy supplying heat will be considered in the compendium	***Poor fit:*** *Grid scale electricity production only*
Marine technologies – wave and tidal	Electricity	Wave power uses the motion of the waves to generate electricity; tidal power uses the daily cycle of the tides. While both of these families of technology have been successfully demonstrated at scale they are too limited in geographic scope to be of broad application on meat processing sites. **Marine technologies will not be discussed further.**	**Good fit:** Marine – regular onshore waves with rocky floor Tidal – long narrow inlets with high tidal range ***Poor fit:*** *Sites with small demand. Must be on the coast. Requires good marine power resource*
Anaerobic digestion	Thermal	Wet organic waste is heated to less than 40°C where naturally occurring bacteria digest remaining organic material in a low-oxygen environment. Methane is released by the bacteria as a by-product of this process. This methane is captured in the digester, creating biogas, a mixture which is fully saturated and includes trace amounts of gases apart from methane. This is a commercial renewable energy technology, widely used in the sewage treatment and meat processing industries for the production of biogas from waste streams. Technology options range from low-tech covered anaerobic lagoons (CALs) to high-tech in-vessel anaerobic digesters (IVADs) This biogas can then be burnt through an engine to produce electricity or burnt through a boiler to produce heat. While the system captures gas and reduces odour for most of the time, during clean out and maintenance odour can escape. This has been a problem for urban sewage treatment systems. **Biogas systems will be considered both as an energy source for thermal loads and as a fuel in cogeneration.**	**Good fit:** Best for sites with high chemical oxygen demand/biological oxygen demand in the waste water High electricity and thermal energy costs Large heat requirement Site is liable for emission of methane from the waste water treatment plant (i.e. under the Carbon Pricing Mechanism) ***Poor fit:*** *Some technologies are limited in their application due to available land space*

Technology option	Energy type	Description	Good / *Bad* site characteristics
			(i.e. CALs)
Dry biomass combustion	Thermal	Organic matter can be burnt directly in a boiler to provide process heat. Sources of biomass can include paunch waste, sludge, wood chip and saw dust, hay and stubble. In some cases these biomass streams may be used in existing coal boilers, while others will require modification. This process is commonly used in the sugar cane and forestry industries which generate waste as part of their manufacturing processes. There are a few examples of biomass-fired boilers at abattoirs, however fuel processing and preparation (in particular lowering the moisture content to an acceptable level) are technical challenges preventing broad-scale uptake of this energy source. **Dry biomass combustion will not be considered further in this report.**	**Good fit:** Viable on sites with significant amounts of paunch waste, sludge, animal bedding or other dry waste streams. Can be used to augment coal use in existing boilers ***Poor fit:*** *Moisture content in biomass is above 25-30%* *Biomass is not processed and therefore not homogeneous* *Long-term supply of sufficient biomass is not available*
Pyrolysis and gasification	Thermal	Pyrolysis and gasification convert solid biomass into liquid or gaseous fuels. Fuels containing volatile organic compounds are heated in the absence of oxygen, creating synthetic gases which can be burnt much like natural gas. This gas is often used as the heat source for the pyrolysis reaction. The material left is very high in carbon and can be used as a soil conditioning agent. Gasification is focused on creating a syngas for later combustion, while pyrolysis aims to create charcoal from biomass. Torrefaction can be considered a type of pyrolysis where lower temperatures are used, resulting in a higher energy content final product, called biocoal. This is an evolving field in Australia with a few demonstration projects underway, principally focused on biochar production from the removal of woody weeds. **These processes are an alternate to anaerobic digestion and are applicable to the meat processing industry.**	**Good fit:** Technically viable as a mechanism to process abattoir solid wastes, particular DAF sludge and paunch waste[5] ***Poor fit:*** *Pyrolysis is not suitable for electricity production but for creating biochar for soil conditioning and biocoal for transport and later combustion*
Cogeneration/ Trigeneration	Electricity	Cogeneration captures a number of specific generation technologies that share a common theme; a fuel is burnt in an engine to produce electricity, with waste heat from combustion captured and used to drive thermal processes. In industrial settings this heat is used as process heat, in commercial buildings this heat can be used for space heating or less commonly, space cooling. Cogeneration is a mature technology, applied in sewage	**Good fit:** Best used on sites with flat demand profiles and large heat/cooling loads

[5] *Pilot testing pyrolysis systems and reviews of solid waste use on boilers,* AMPC document for project A.ENV.0111

Technology option	Energy type	Description	Good / *Bad* site characteristics
		treatment plants, for district heating in colder climates, commercial buildings and abattoirs. When linked with a biogas digester the waste heat can be used to heat the digestion process, improving the conversion of organic material to biogas. **Cogeneration fuelled by biogas will be considered in this report.**	***Poor fit:*** *Natural gas price rises could impact economics* *Requires relatively large heat load to be viable, since cogeneration system typically produce twice as much heat as electricity.*
Air source heat pump	Thermal	Air source heat pumps use electricity to transfer heat from one point to another. They can be considered a renewable energy source which have a parasitic electric load; a typical system with a coefficient of performance (COP) of 4 uses one unit of electricity to move 4 units of heat. These systems are becoming increasingly efficient, driven particularly by advances in DC motor technology. They are popular for space heating in cold climates, and as hot water boosters in areas where natural gas is not available. **Air source heat pumps are discussed later in this report.**	**Good fit:** Ideal for hot-water heating in absence of natural gas network Good for offices with climatic variation, particularly small areas/plant operator rooms ***Poor fit:*** *Large spaces or high temperature process heating applications*
Ground source heat pumps	Thermal	Ground source heat pumps are also considered a class of geothermal energy. While they still use electricity to drive the heat pump, the use of the ground as a source or sink of heat in a refrigeration cycle can significantly reduce the electricity demand of a refrigerator or heat pump. Ground temperature is more stable than air temperature and even in cold regions the ground temperature can be 15 to 20°C above air temperature. This gives the pump access to more heat so the cycle runs more efficiently. These systems are being used in residential and commercial settings, particularly in north America and Europe. Ground source heat pumps may have application in meat processing for refrigeration and space conditioning. However, it is not a renewable energy technology that links well to energy storage. **Ground source heat pumps will be considered with air source heat pumps.**	**Good fit:** Space/water heating in cold climates, generally below 10°C Refrigeration/space cooling in hot climates above 30°C ***Poor fit:*** *Climates where ambient temperature is generally above zero*
Batteries	Electricity storage	Batteries store electricity as chemical energy in such a way that it can be recovered later. There are many different chemical combinations possible for electricity storage, with the most common being lead-acid, lithium ion and nickel-metal-hydrides. Flow-batteries, where the reaction agents are stored in separate tanks until required for electricity production, are becoming available at smaller sizes with some units available now for residential solar-power support. Flow batteries and similar sodium-sulphur batteries have been used in many grid-support applications. They can be considered mature in	**Good fit:** Best for maximizing the value of on-site renewable electricity production.

Technology option	Energy type	Description	Good / *Bad* site characteristics
		most applications, but with some specific applications still gathering operation experience. The technology and economics of battery storage are changing rapidly and batteries are close to being viable options for electricity storage. **Batteries will be covered in more details in this report.**	***Poor fit:*** *Economics currently unfavourable for peak shaving*
Pumped hydro storage	Electricity storage	Conventional pumped hydro uses two water reservoirs, separated vertically. When renewable energy is being generated, water is pumped from the lower reservoir to the upper reservoir. During times when renewable energy is not available, the water flow is reversed to generate electricity. There is over 90 GW of pumped storage in operation worldwide, which is about 3% of global generation capacity. Pumped storage is the most widespread energy storage system in use on power networks. In NSW, Australia, an example of pumped hydro is the 1,690 MW pump facility at Tumut 3 Power Station in the Snowy Mountains returns water to Talbingo Reservoir.[6] The deployment of pumped hydro is constrained by finding suitable sites. **The economics of pumped hydro are severely influenced by geography and scale, and the technology will not be considered further in this report.**	**Good fit:** Requires two reservoirs separated by at least 50m head. ***Poor fit:*** *Only suitable for grid electricity storage and very long project lifetime*
Compressed air energy storage (CAES)	Electricity storage	CAES seeks to store energy in the form of compressed air. The energy is recovered by feeding the compressed air into the compressor stage of a gas turbine generator which has the effect of increasing the efficiency of the gas turbine generator. Electricity generated from renewable sources can be used to compress the air prior to storage, generally in underground mines or caverns created inside salt rocks. The first commercial CAES was a 290 MW unit built in Hundorf, Germany in 1978. The second commercial CAES was a 110 MW unit built in McIntosh, Alabama in 1991. The construction cost $US65M (about $US591/kW). The third commercial CAES, the largest ever, is a 2,700 MW plant that is planned for construction in Norton, Ohio. This 9-unit plant will compress air to 1,500 psi in an existing limestone mine about 670 m underground. **The economics of CAES are severely constrained by geography and scale, and CAES will not be considered further in this report.**	**Good fit:** Excellent for very large energy storage in grid support application ***Poor fit:*** *Severely limited by geology and requires significant scale to be viable* *Grid support only*
Flywheels	Electricity storage	Most modern flywheel energy storage systems consist of a large rotating cylinder that is supported on a stator by magnetically levitated bearings that eliminate bearing wear and increase system life. To maintain efficiency, the flywheel system is operated in a low vacuum environment to reduce drag. The flywheel is connected to a motor/generator mounted onto the stator. Some of the key features of flywheels are little maintenance, long life (20 years or tens of thousands of cycles) and environmentally inert material. Flywheels can bridge the gap between short term ride-through and long term storage with excellent cyclic and load	**Good fit:** Cost effective storage for uninterrupted power supply applications. Short duration power delivery, long storage times

[6] See http://electricitystorage.org/tech/photo_pumpedhydro1.htm and http://www.snowyhydro.com.au/LevelThree.asp?pageID=247&parentID=66&grandParentID=4

Technology option	Energy type	Description	Good / *Bad* site characteristics
		following characteristics. Small 2 kW to 6 kW systems are in service today, often supporting telecommunications facilities. Larger quantities of energy (e.g. above 1 MWh) can be stored using a collection of flywheels. The Denham Wind Farm and Energy Storage System in Western Australia, uses two 4 tonne flywheels for energy storage. **Flywheels may provide cost effective electricity storage for meat processing sites and will be discussed further in this report.**	***Poor fit:*** *Inappropriate for load shifting*
Superconducting magnetic energy storage (SMES)	Electricity storage	SMES systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature (the state below which the coil loses its resistance to the flow of electricity). The stored energy can be released for use by discharging the coil. SMES systems are highly efficient; the round-trip efficiency is greater than 95%.[7] A 30 MJ (8.3 kWh) SMES system has been built to damp power oscillations on the Western U.S. Power System, particularly on the Pacific AC Intertie that is used to transmit power from the Northwest to southern California.[8] **SMES systems are best suited to very high power, short duration applications and are not suitable for meat processing sites. They will not be discussed further in this report.**	**Good fit:** Best for frequency control and grid support. Particularly at end-of-line locations ***Poor fit:*** *Unable to store enough energy for load shifting on sites* *High cost*
Electrochemical capacitors (EC) or Supercapacitors	Electricity storage	A capacitor stores energy using a static charge rather than a chemical reaction. The charge is stored in polarized layers between a conducting electrolyte and a conducting electrode.[9] They are characterised by their quick charging and discharging capability. As a storage option for renewable energy, electrochemical capacitors can store and stabilise the power output of a wind or photovoltaic installation. As they absorb power quickly and just as quickly discharge it when required, electrochemical capacitors are suited to different uses and applications than comparatively slower reacting batteries. They have a low storage capacity, and are best suited to applications of short duration, such as providing a boost in times of high demand, or acting as a bridging system for uninterrupted power supply. In some cases they have been teamed in a 1:3 ratio with slower, cheaper lead-acid batteries for faster cycling, grid support batteries. **Electrochemical capacitors in hybrid systems are available at attractive prices and will be considered in this report.**	**Good fit:** Fast response, great for sites with specific power quality requirements ***Poor fit:*** *Value diminished if fast response times are not required*
Molten salt storage	Thermal storage	Molten salt thermal storage uses a mixture of salts with low melting temperatures (130°C and above) to store sensible heat for reuse later. The hot salt is then used to create steam	**Good fit:** Best for sites with large heat loads, particularly

[7] "Large-Scale Energy Storage Systems ", Cheung et al, Imperial College London: ISE2, 2002/2003.

[8] "30-MJ superconducting magnetic energy storage system for electric utility transmission stabilization", Rogers et al, Proceedings of the IEEE, v71, n9, 2005

[9] NESSCAP, Ultracapacitor 'Product Overview', http://www.nesscap.com/products_overview.htm

Technology option	**Energy type**	**Description**	**Good / *Bad* site characteristics**
		which then drives a typical steam turbine. Molten salt thermal stores are typically linked to large scale solar thermal power plants operating at temperatures well above the heating requirements in meat processing plants. Considerable research is being directed towards the commercialisation of molten salt storage systems, often linked to solar power towers. Molten salt storage is normally associated with grid-scale solar thermal; however there are no significant technical reasons that would make this system non-financially viable at site-scale. **These systems will be discussed in more detail in this report.**	rendering ***Poor fit:*** *Needs significant heat loads to be effective*
Graphite/concrete block storage	Thermal storage	This technology exploits the low emissivity and high heat capacity of high-purity graphite or concrete blocks, storing solar energy as sensible heat. This is a relatively new technology with one company developing the technology in Australia. This was the recipient of an Advanced Energy Storage Technology grant in 2009 with a proof of concept project in Cooma, and a scale demonstration project at Lake Cargelligo in NSW. In this project heliostat arrays were used to reflect sunlight onto a central block of graphite which stored thermal energy during the day for use at night. This technology has been demonstrated to deliver electricity, but is most promising for meat processing sites as an option to supply process steam. **This technology will be considered further as a source of process steam.**	**Good fit:** Best for sites with large heat loads, particularly rendering ***Poor fit:*** *Needs significant heat loads to be effective*
Phase change (ice) energy storage	Thermal	These systems store energy as ice to offset air conditioning loads. They exploit the heat of fusion of water (latent heat) to store a large amount of cooling capacity which can reduce refrigeration cycle loads later. Typically this system is used to store energy when electricity is cheap and offset electricity use during peak hours later. For example, businesses exposed to variations in electricity price can use cheap off-peak electricity to freeze water during the night and then use this thermal capacity (coolth) to reduce the refrigeration load when electricity is more expensive. This can also be linked to solar PV as a way of shifting the generation peak to match the price or demand peak. **This system will be discussed further.**	**Good fit:** Suitable for shifting generation peak to match refrigeration peaks ***Poor fit:*** *Can only offset refrigeration loads (HVAC or refrigeration)*

MEAT PROCESSING AND ENERGY USE

THE PROCESS

There are many processes involved in meat processing and a broad range of outputs, both commercial and waste. The basic operation of a fully integrated red meat processing facility that includes rendering and value-add processing is shown in Figure 2.

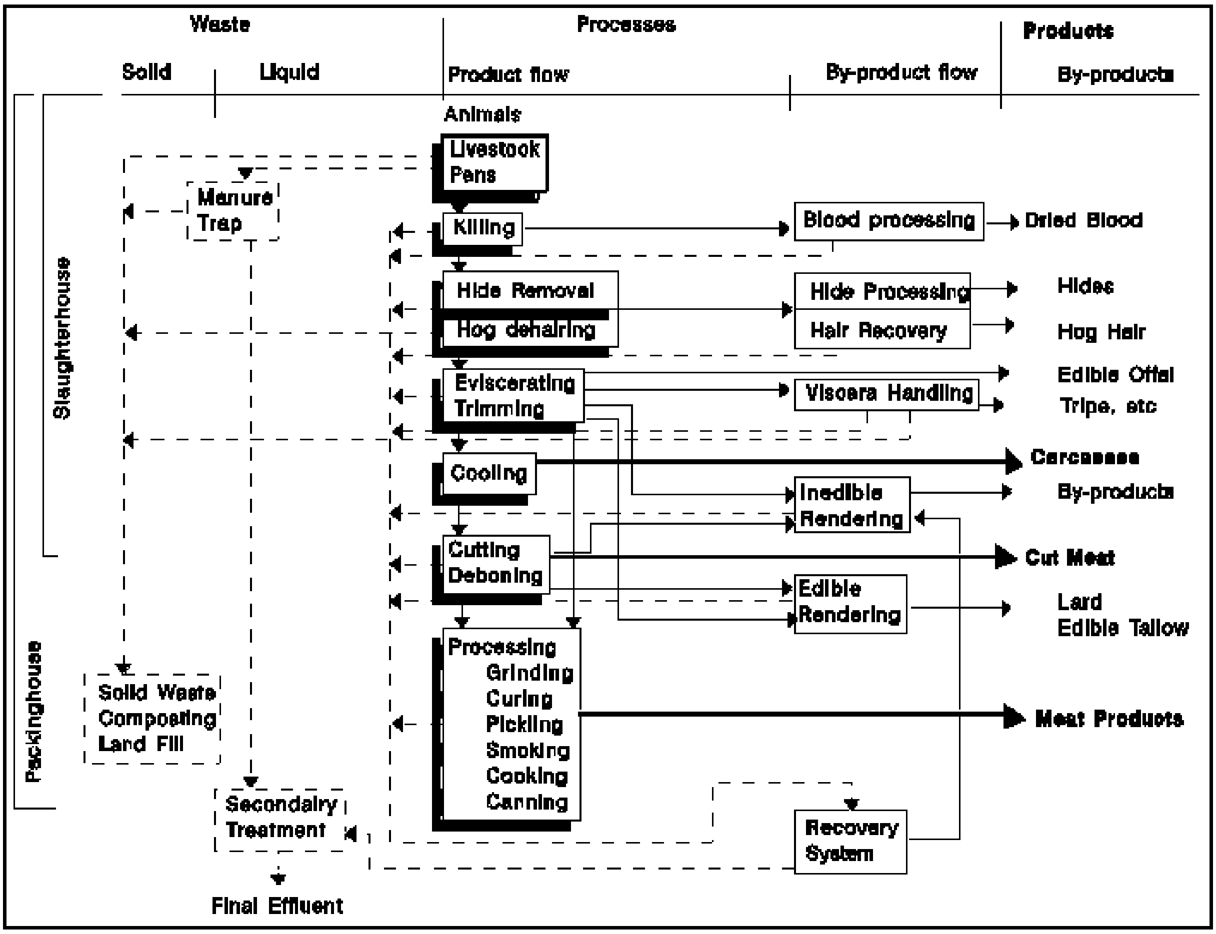

Figure 2: Flow diagram of red meat processing (Source: www.fao.org)

The waste streams highlighted in Figure 2 are rich in organic matter and are therefore candidates for various waste-to-energy options. These waste streams include:

- Wash-down water which contains manure, blood and other animal products
- Solid organic waste originating from the slaughter floor, rendering plant or tannery facilities. This may include paunch, sludge, viscera, blood, fat, oil, grease hide, hog hair, hooves and spoiled feed.

ENERGY USE

The major energy consuming activities at processing plants are refrigeration and the production of steam and hot water for rendering and sterilization. Less significant amounts of energy are used for lighting, ventilation, motors and pumps.

There is large variation across meat processing sites in the proportion of site-wide energy use consumed by each equipment type due to the different ages and sizes of processing plants, variations in the refrigerated product mix, whether rendering is conducted at the site or the installation of value added meat processing facilities.

Energy use can be considered in two classes; electrical and thermal. Electrical energy is used primarily in electric motors, in refrigeration, pumping and conveyors, and as such does not have very stringent power quality requirements. In general this is supplied by the grid but could include diesel generators and other remote area power supply options.

Thermal energy is used to heat water for sterilization and rendering and to a lesser extent space heating. This thermal energy can be supplied by coal, natural gas or LPG. Thermal loads are defined by temperature and heat rate and in some cases specifically require steam.

Figure 3 below shows firstly the energy end-use breakdown for a population of small to medium sized meat processing sites, taken from the 'Energy Consumption Guide for Small to Medium Red Meat Processing Facilities' (AM12-5066 Domestic Processors Energy Efficiency Program). This energy use is then grouped by energy type, either thermal or electrical (right side of Figure 2). In both cases the energy storage and renewable energy technologies which can offset this energy use are noted. As an example, refrigeration uses electricity, which can be supplied by solar PV, and stored using flow batteries.

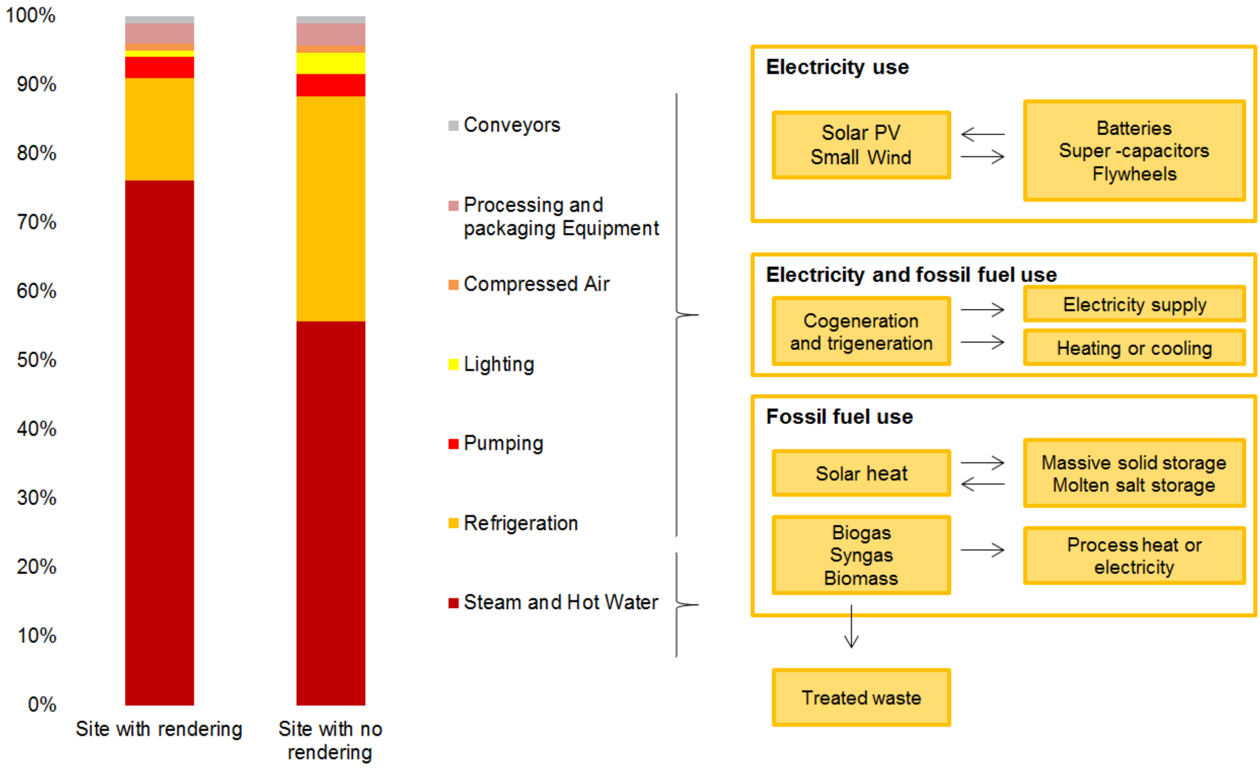

Figure 3: Energy use proportions by end use, plus the possible renewable energy sources and energy storage options that could power them

RENEWABLE ENERGY OPTIONS

This report considers the technology available to meet both electrical and thermal demands with renewable energy.

The most attractive electricity generating technologies available today are solar PV and wind. These systems are cost-competitive with grid electricity in a number of locations in Australia, with solar PV generally more appropriate for most areas. Newer technologies such as geothermal and marine which are technically feasible in a number of areas are not cost competitive to provide electricity, except in some specific locations and at grid scale.

Part of the problem with local electricity production is the conversion from thermal or mechanical energy into electricity. Typical systems achieve in the order of 25% efficiency; for every 100kWh of solar or wind energy captured about 25kWh of electricity is produced. But if the conversion process can be avoided and the energy used directly, as it is in a solar hot water system, closer to 80% of the energy captured is used.

This gives direct use of renewables a significant advantage. More of the energy source is available for use and the system cost is reduced as it need not include electricity generation and regulation equipment, like alternators and inverters.

Steam and hot water could be powered with bio-energy, be it biogas, pyrolysis or direct combustion of cellulosic waste, solar thermal systems or heat-pumps.

This makes for technically simpler systems, but the economics are not greatly affected. While thermal systems achieve higher rates of utilization of available energy, the energy use they are offsetting is often provided by lower cost fossil fuels.

Meat processing sites looking to reduce their energy purchases in the most cost effective manner should consider both thermal and electrical systems. This analysis should consider current and future costs of energy, the location of the plant and its operating profile and the impact of government policy, particularly on the value of renewable energy certificates and the cost of emitting greenhouse gasses.

THE IMPACT OF STORAGE

When using renewable energy generation, coupled with energy storage, the goal is to capture more than is required at the time of generation so the excess energy can be used later when the source is no longer available. In the example of a solar PV system, that means generating enough electricity during the day to exceed the daytime site load. This excess charges a battery for use once the sun goes down.

Consider the illustrative site profile in Figure 4, taken from the ‘Energy Consumption Guide for Small to Medium Red Meat Processing Facilities’ (AM12-5066 Domestic Processors Energy Efficiency Program). This represents a site with daytime operation only. Energy use rises in the morning as the shift commences

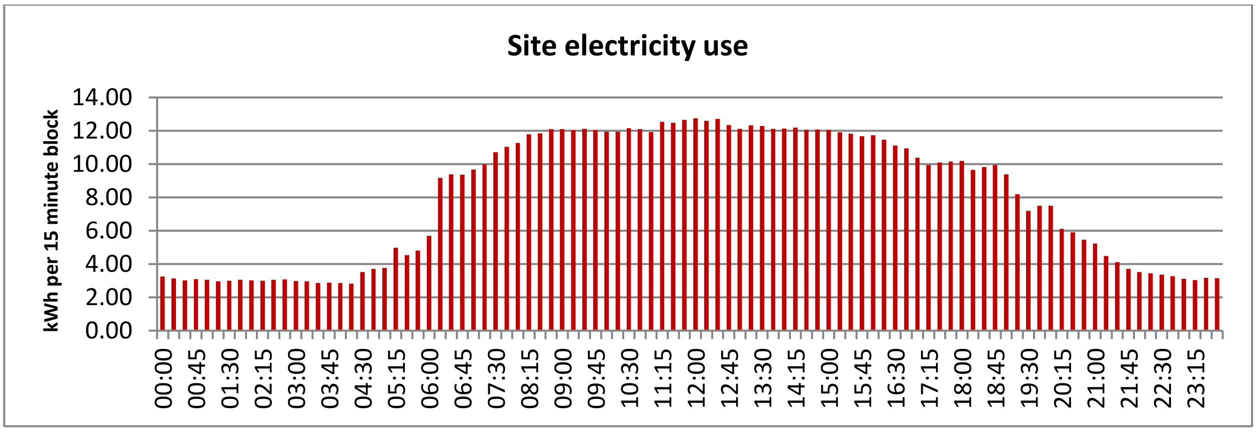

Figure 4: Illustrative site profile. Peak demand is about 50kW, four times the 15 minute energy use

If solar PV were installed at this site it would generate between about 7am and 5pm. A very simple solar profile can be modelled and laid over this profile to see the impact it has. In Figure 5 below, an illustrative 80kW system is considered, which generates zero kW at 7am and 5pm, with a peak at midday and a straight line profile between those points.

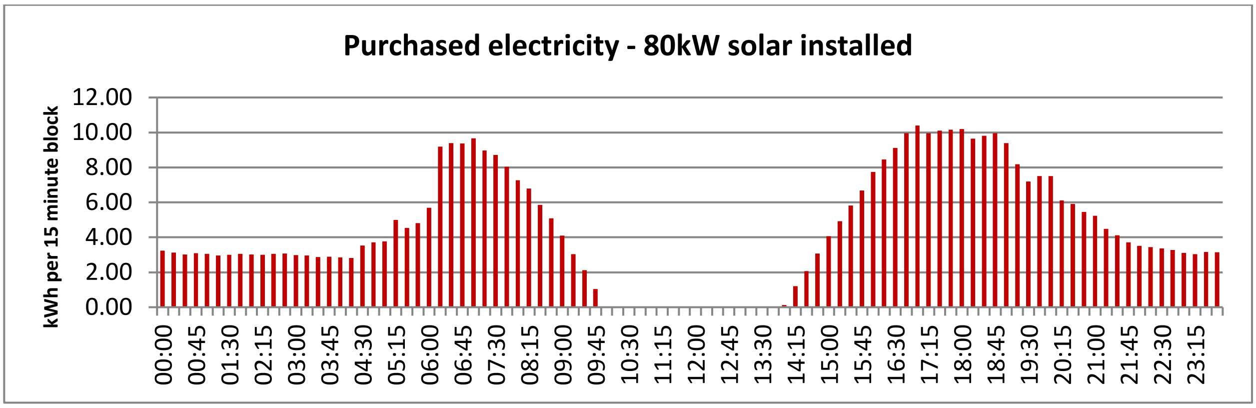

Figure 5 Purchased electricity profile, with illustrative solar profile deducted

The solar PV system in this scenario saves 341kWh of purchased electricity each day. Further, much of this reduction is during peak hours when electricity costs are higher. A full business case for a site application would consider this extra value.

As this system is sized larger than the maximum site demand there is excess generation, which could be sent to the grid. But, in some jurisdictions, the amount paid for excess solar generation is less than the amount paid for grid electricity. It is better value to use this electricity on site. This is where batteries add value.

If a 64kWh battery were added to this site, the excess electricity generated between 10am and 2pm could be stored for later use. This situation is modelled in Figure 6 below.

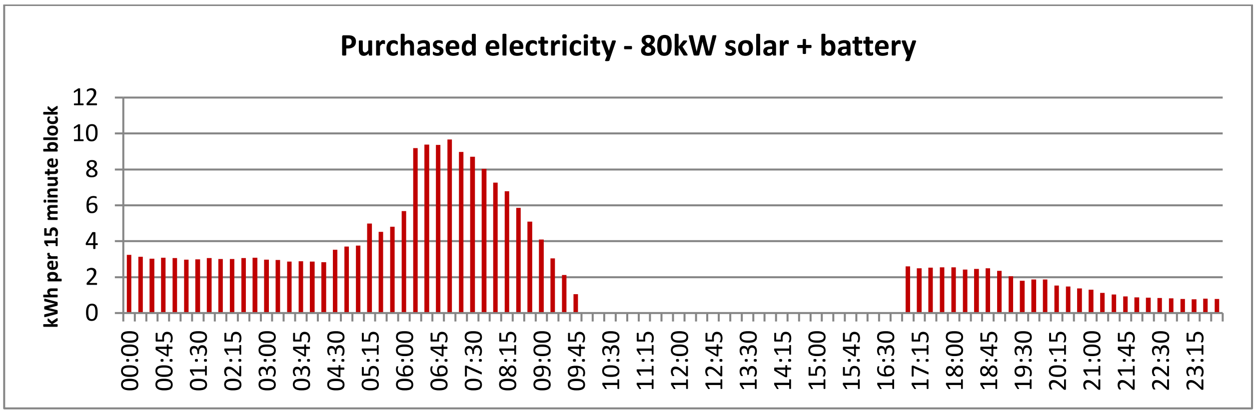

Figure 6 Purchased grid electricity with the addition of 80kW solar and a 64kWh battery

Adding a battery to this system saves an additional 59kWh each day, noting that this is modelled assuming 100% turnaround efficiency and no losses during storage. A more realistic figure would be closer to 50kWh saved.

So the value of solar PV, or any renewable energy source, is the amount of energy which does not need to be purchased while the energy source is available. The value of storage is the value of purchased energy offset when the energy source diminishes, less the losses associated with storage.

These same principles can be applied to any renewable energy or storage technology. When used at the time of capture, their value is the direct offset of fossil fuel use. When stored there will be some energy lost, but the value comes from being able to use the renewable-generated energy when the source is no longer available or at times when the cost of offsetting energy purchases rises.

RENEWABLE ENERGY GENERATION AND STORAGE TECHNOLOGIES APPLICABLE TO THE RED MEAT PROCESSING INDUSTRY

Renewable energy sources contribute about 12% of world primary energy supply; mostly biofuels (10%) and hydro (2%). The worldwide use of renewables to supply electricity is closer to 20%; about 15% as hydro and the rest as biomass, solar and wind.[10]

Many renewable energy technologies provide an intermittent supply of energy, depending on when the energy source is available; for example, solar technologies only generate energy when the sun is available, and wind technologies when wind is blowing at the right speed. These technologies benefit from being combined with storage systems that enable some of the generated energy to be stored for use at times when the renewable energy source is unavailable.

The following compendium offers a starting point to consider the many differing renewable energy and energy storage technologies available, with guidance on the most suitable applications. This information is designed to act as a screening tool for the available technologies and to inform technology selection for more detailed feasibility studies.

As a companion to this guide, ten factsheets have been prepared which go into more detail on ten of the most promising technologies. These cover solar PV, wind, anaerobic digestion, batteries, heat pumps, graphite solar thermal storage, cogeneration/trigeneration, evacuated tube solar thermal collectors, geothermal for thermal energy and biomass boilers. They include more detail on the technology and guidance on how to prepare a business case for each.

RENEWABLE ELECTRICITY GENERATION TECHNOLOGIES

Renewable electricity generation is one of the most credible paths to reducing the greenhouse gas emissions associated with electricity generation and so have benefited from increased investment and development in the last decade. As a result there are many different ways of generating electricity using renewable sources and the solutions available are evolving constantly. The various systems exploit different aspects of the available energy sources and so are better suited to different applications.

The technologies included in this review were chosen as those most likely to be applicable to meat processing sites, in both scale and geographic location.

SOLAR ELECTRICITY SYSTEMS

Solar energy systems use the heat and electromagnetic energy in sunlight to generate electricity. There are two major groups of solar energy technologies: photovoltaic (PV) and solar thermal. PV principally uses the electromagnetic energy in sunlight to produce electricity, while solar thermal uses the heat of the sun.

SOLAR PV

Solar photovoltaic (PV) uses semiconductors to convert solar energy into electricity. Unit efficiency in terms of electricity generated compared to solar energy received varies from around 10% to over 40%, with around 24% most typical for residential-sized installations[11]. The market for solar PV has grown rapidly in recent years, supported by subsidies in Germany and Spain, which have increased manufacturing capacity and lowered unit prices.

Solar PV is the most suitable electricity generating technology for sites in the meat processing industry. Both wind and cogeneration will also be competitive in some circumstances, but for the sake of storage recommendations later in the document it is assumed the electricity source will be solar PV.

Figure 7: California Valley Solar Ranch - 250MW capacity

[10] http://www.iea.org/publications/freepublications/publication/KeyWorld2013_FINAL_WEB.pdf
11 The National Renewable Energy Lab in the US maintains a chart of record solar efficiencies over time, which can be found at http://www.nrel.gov/ncpv/images/efficiency_chart.jpg (Very large image)

Type	**Source:** Solar **Storage or generation:** Generation **Heat or electricity:** Electricity
Applicability to the meat processing industry	Highly applicable. Solar PV is a known product with reliable and predictable electricity output. There is a well-established service and installation industry throughout Australia. It could be used as a direct electricity source at meat processing facilities. The solar PV arrays would need to be installed on available roof and/or ground space. As a rule of thumb, $10m^2$ of space is required per kW installed. In general, the economics of solar are most favourable when used to offset purchasing grid electricity, particularly in places of high electricity prices. Output is highest in the northern parts of Australia, in areas of low rainfall and infrequent cloud cover. The Australian Bureau of Meteorology (BOM) measures and records insolation across Australia. This data can be accessed through the BOM website: http://www.bom.gov.au/jsp/awap/solar/index.jsp
Current status	Market accumulation. This is a mature technology with very widespread use.
Size, scalability and efficiency	Typical residential-sized panels start at 180W and can be linked together to provide almost unlimited power; there will be a 20MW solar PV power station in Australia in the next year,[12] with 100MW and much larger stations planned.
Current and projected costs	Installed system prices in Australia, particularly larger sizes, have trended down for a number of years, with every capital city delivering capacity at less than $2/watt.[13] It is expected this downward trend will continue, with increased focus on 'soft costs' of solar in recent months, in parallel with decreasing unit costs.
Country of development and manufacture	Major manufacturing centres include China, Germany, Japan and the US. Development continues in most major economies, with Australia's University of New South Wales a well-regarded research centre.
Drivers for uptake	Cheaper unit prices and government policy (such as the Carbon Pricing mechanism and the Renewable Energy Target) and fiscal support measures (such as capital grant schemes and Renewable Energy Certificates) have been significant drivers for uptake.
Forecast status: 5-10 years	Increasing global capacity, with a trend towards larger systems.
Social and environmental costs and benefits	Previously solar PV has been used as a remote area power supply, reducing installation costs by removing the need for lengthy electricity supply wires. With decreasing costs PV represents a simple, low-maintenance electricity supply option for households and businesses.

12 http://www.environment.act.gov.au/energy/solar_auction
13 http://www.businessspectator.com.au/article/2013/9/10/solar-energy/solar-pv-price-check-september?utm_source=exact&utm_medium=email&utm_content=415080&utm_campaign=cs_daily&modapt=

SOLAR THERMAL SYSTEMS

These systems use solar energy as heat to provide process heat or generate electricity. They are the front-runner for grid-scale solar energy as the technology mirrors many of the components in a conventional power station and they benefit strongly from economies of scale. Further, as they capture solar energy as heat they are useful for creating dispatchable electricity.

These systems can also capture and store heat to be used later as process heat. The following entries consider solar thermal technology in this capacity; not as a grid scale power station, but as a cost-effective alternative to fossil-fuels used to generate process heat at meat processing facilities.

EVACUATED TUBES AND FLAT PANEL SOLAR COLLECTORS

Solar hot water systems used to heat water for residential premises are one of the most widely used renewable energy systems in the world. They have provided a cost-effective alternative for heating water in Australia for over 20 years. The systems are simple and reliable, some with no moving parts. There is a well-developed manufacturing, service and installation industry in Australia.

As these systems do not concentrate solar energy, unlike the two collectors below, their maximum temperature is capped at about 70°C.

Evacuated tubes are considered better for colder climates than flat panel collectors. Each tube has a vacuum around the heat collector and acts as an insulator. This reduces energy lost to the environment during cold weather. This is not a feature of flat panel collectors.

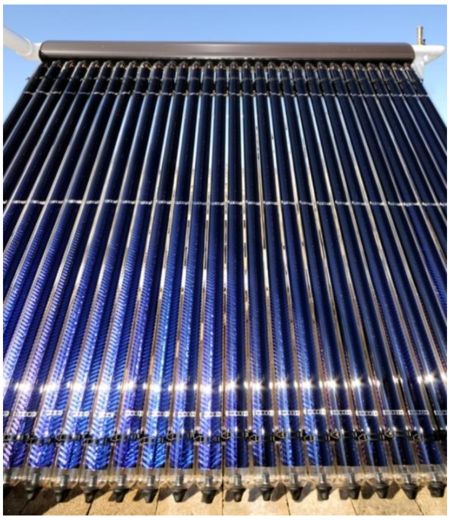

Figure 8: A typical residential evacuated tube array, sized for a family of 4

Type	**Source:** Solar **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	High Solar thermal systems developed for residential use are low-cost, simple systems which can heat water from ambient to 70°C and above. While this may not be hot enough for sterilization or rendering operations consider that raising the temperature of water requires significant energy and any energy which is essentially free reduces site costs. If a site requires water at temperatures above 70°C, this technology can still assist in raising the temperature from ambient at about 20°C to 70°C, with the remainder provided by fossil fuels as before. Mirroring residential systems, this could be applied in conjunction with an instant gas water heater. The collector heats water during the day which is stored in a tank. When hot water for rendering or sterilizing is required the water flows from the tank through the gas heater, which checks the temperature. The water is heated further if required.
Current status	Fully mature and widely deployed technology.
Size, scalability and efficiency	Completely scalable. Tubes and panels both come in standard sizes (approximately metre-squared multiples) which can be linked together to increase the heating capacity. Efficiencies up to 80% are possible with modern evacuated tube collectors and closer to 70% for flat panel collectors.[14]

[14] http://bit.ly/1fOduWG

Current and projected costs	Using residential prices as an indicator, evacuated tube collectors retail for about $300/m^2, possibly less for a large order, or about $6,000 for 20m^2 of collectors, the minimum size for a typical industrial application. While costs will continue falling as manufacturing processes improve, it is not likely they will fall far. This is a mature technology and there are few advances which have not been attempted.
Country of development and manufacture	Worldwide.
Drivers for uptake	Simple, cost-effective water heating for residential premises. As this is a widely manufactured technology, module prices are cheap and represent an option with low technological risk for red meat processing plants to use to heat water.
Forecast status: 5-10 years	Continued use, growth steady.
Social and environmental costs and benefits	Evacuated tube collectors are principally glass and copper, meaning environmentally low impact materials are used throughout.

LINEAR FRESNEL COLLECTORS

Thin strips of mirror are arranged in parallel to reflect sunlight onto a central receiving pipe containing a working fluid. The heated working fluid is run through a heat exchanger to heat water, oil or molten salts to either store the thermal energy or capture it for immediate use on site. The mirrors are moved independently to always focus the sun on the collector. Thin, flat mirrors lower the production cost with respect to a parabolic trough, which is discussed below.

Figure 9: Liddell linear Fresnell array which supplies 10MW of steam to Liddell powerstation

Type	**Source:** Solar **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	Applicable as a relatively low-cost generator of thermal energy for use in sterilization and rendering. This technology is usually used as an electricity generating technology where turbine sizes and efficiency dictate that larger systems are more cost effective. However, using the collector as a stand-alone thermal system, rather than electric generation, reduces the cost significantly and removes the need for larger systems. As a stand-alone thermal system, the collector would be connected to a heat storage system, such as molten salt, hot water or hot oil, which could be used to reduce natural gas use in rendering and sterilizing operations. Used in a system comparable to a residential instant hot water system, water for sterilizing would exchange heat with the storage system and raise the temperature as high as possible. This heated water then passes through a gas water heater that can raise the temperature further if needed. In this way the system has backup in case of low solar energy, and the solar energy can reduce gas use as much as possible. Using Sydney solar estimates, approximately 30m^2 of solar thermal collectors could heat one tonne of water to 100°C every day.
Current status	Market demonstration in Australia, market accumulation in Spain and the US.
Size, scalability and efficiency	Completely scalable. Turbine size presents a lower limit for cost effective electricity production. Collector efficiency approaches 90%, depending on the materials used.
Current and projected costs	Most indicative system costs include generation technology in the price, creating a significant distortion when considering use as a thermal collector only. Most system costs include the electricity generating component, which significantly inflate the overall price. Considered without this equipment, studies from Germany suggest the size of the installation has a great impact on price (larger systems are cheaper) with a collector of around 20m^2 likely to cost about $16,000.[15]
Country of development and manufacture	Developed in a number of countries, deployed in Spain, the US and at small scale in Australia.
Drivers for uptake	Fresnel arrays have been developed in response to the costs of manufacturing parabolic lenses. They require more complex control than a parabolic mirror.
Forecast status: 5-10 years	Increased application, particularly in large-scale electricity production.
Social and environmental costs and benefits	Solar thermal technologies largely require steel, which is abundant and low environmental impact material.

[15] http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/themen_0108_engl_internetx.pdf

PARABOLIC TROUGH

Parabolic trough collectors are the second of the linear solar thermal collectors and comparable to the linear Fresnell technology described above. The systems use the same fundamental principles to capture heat and create electricity, but employ slightly different collector designs in an effort to reduce manufacturing costs. Parabolic troughs are the most common type of collector currently used in grid-scale solar thermal power plants.

These collectors use a mirror curved in the profile of a parabola, with a central collecting pipe along the focal point of the mirror. The trough is tilted towards the sun, depending on the sun angle due to the time of year, and all sunlight that hits the mirror is reflected onto the central receiver. This concentrates the sunlight and allows higher temperatures. A working fluid, such as water or oil is heated in the receiver, to temperatures above 200°C. In electricity generating stations this is used to create steam and drive a turbine.

Figure 10: Mirrors at the Solar Energy Generating Systems plant in California, currently the largest solar thermal plant in the world at 350MW

Type	**Source:** Solar **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	Applicable as a relatively low-cost generator of thermal energy for use in sterilization and rendering. This technology is typically used as an electricity generating technology where turbine sizes and efficiency dictate that larger systems are more cost effective. However, using the collector as a stand-alone thermal system, rather than electric generation, reduces the cost significantly and removes the need for larger systems. As a stand-alone thermal system, the collector would be connected to a heat storage system, such as molten salt, hot water or hot oil, which could be used to reduce natural gas use in rendering and sterilizing operations. Used in a system comparable to a residential instant hot water system, water for sterilizing would exchange heat with the storage system and raise the temperature as high as possible. This heated water then passes through a gas water heater that can raise the temperature further if needed. In this way the system has backup in case of low solar energy, and the solar energy can reduce gas use as much as possible. Using Sydney solar estimates, approximately 30m^2 of solar thermal collectors could heat one tonne of water to 100°C every day.
Current status	Market demonstration in Australia, market accumulation in Spain and the US. Commercial scale plants have been operating since at least 2007.
Size, scalability and efficiency	Completely scalable. Turbine size presents a lower limit for cost effective electricity production. Collector efficiency approaches 90%, depending on the materials used.
Current and projected costs	Most indicative system costs include generation technology in the price, creating a significant distortion when considering use as a thermal collector only. Most system costs include the electricity generating component, which significantly inflate the overall price. Considered without this equipment, studies from Germany suggest the

	size of the installation has a great impact on price (larger systems are cheaper) with a collector of around 20m^2 likely to cost about $16,000.[16]
Country of development and manufacture	Developed and deployed worldwide. The vast majority of grid-scale installations are in Spain, typically in the 50-100MW range, with the two largest in the US.
Drivers for uptake	Concentrating solar thermal attempts to concentrate solar energy to temperatures where conventional electricity generation is possible. Parabolic trough collectors are a simple and effective means to this end.
Forecast status: 5-10 years	Increased application, particularly in large-scale electricity production.
Social and environmental costs and benefits	Solar thermal technologies largely require steel, which is abundant and low environmental impact material.

[16] http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/themen_0108_engl_internetx.pdf

GEOTHERMAL HEAT

The geothermal resources in Australia are generally poor. Australia is a large and old continent with little active vulcanic activity and very stable plate tectonics. However, there are places in Australia where magmatic intrusions bring heat closer to the surface and provide visible hydrothermal activity, such as Hepburn Springs and the Otway Ranges region in Victoria.

Much of the capital cost associated with geothermal energy is used in drilling holes. The subsurface temperature increases by about a 3°C per 100m, with higher temperatures achieved in some places. The geothermal power industry uses a rule of thumb of about $1 million per kilometre of hole drilled. Combining these estimates, a 500 meter deep hole can be expected to cost $500,000 and access heat 15°C warmer than the surface temperature.

Maps of this resource are complex and expensive to produce. A portion of Victoria Tourism's geothermal resource map, released in 2007 is reproduced in Figure 11 below and can still be found at the below reference.[17]

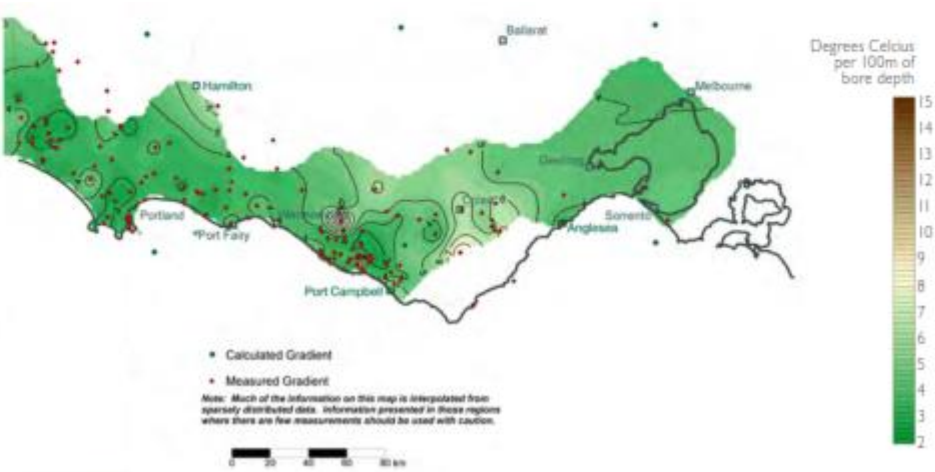

Figure 11: Geothermal resource map created by Tourism Victoria

Geoscience Australia have also mapped the geothermal resource, but as this was intended for the power industry, it maps the resource at a level far deeper with much higher temperatures than red meat processing sites would require. This can be found at the below reference.[18]

Type	**Source:** Geothermal **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	Applicable as a generator of thermal energy for use in sterilization and rendering. The geothermal resource varies greatly across Australia and can be hard to determine without direct measurement. There may be sites in Australia that are viable sources of process heat for red meat processing businesses, but assessing these opportunities depends greatly on the information available. Drilling holes to test the resource directly could eliminate any cost savings derived from a future project. This heat source has been used in a plant in Warrnambool, Victoria, in a hybrid geothermal/cogeneration system.[19]
Current status	Early demonstration in Australia, limited by geography

[17] http://www.tourism.vic.gov.au/images/stories/Documents/StrategiesandPlans/Geothermal-natural-spa-tourism.pdf

[18] http://www.ga.gov.au/image_cache/GA10036.pdf

[19]http://www.ampc.com.au/site/assets/media/Factsheets/Climate-Change-Environment-Water-Waste-Energy-Sustainability/11-AMPC-MLA-Cogen-Geothermal-Midfield-Group.pdf

Size, scalability and efficiency	Scale depends on the geothermal resource present, which is related to the hole depth. The power industry works towards resource temperatures in excess of about 140°C, which occurs in less than 1% of sites across Australia, measured at 4km. They also assume a resource life in the order of 25 years; extracting heat from granite eventually results in a depletion of the resource. In a hydrothermal project these rules are less rigid. Theoretically any energy obtained in this way will offset fuel use and reduce costs, but in practise this will need to be balanced against the cost of drilling the hole. This can be estimated against your fuel costs by determining the heating value of your fuel, the cost of drilling and the energy returned per metre depth.
Current and projected costs	Geothermal energy system costs in Australia are driven substantially by the cost of drilling a hole. The rigs for this work are slightly different to those used in oil exploration and as such supply has been limited in Australia, with major projects experiencing significant delays.[20] Costs are in the order of $100,000 per 100m of hole, with pumping and pipe additional costs.
Country of development and manufacture	Hydrothermal energy has been used traditionally in Japan, Iceland and New Zealand for hundreds of years in some places. The technology to use these resources for electricity rely on many of the same technologies used in thermal electricity production and have been developed internationally.
Drivers for uptake	In Australia the drivers for exploiting the geothermal resource have been the promise of low-carbon, 'baseload' electricity supply. The geothermal resource at 4km below ground in Australia is outstanding and worthy of investigation. About 10 projects have been initiated during the last 5 years, with none producing grid electricity yet. Their main barrier has been the location of the resource and the distance to electricity users.
Forecast status: 5-10 years	Increased application, particularly in large-scale electricity production. There should be a pilot plant in Australia in the next 5-years.
Social and environmental costs and benefits	Geothermal can provide zero-emissions heat or electricity in the right context.

[20] http://www.energybusinessnews.com.au/energy/geothermal/habanero-geothermal-is-go/

WIND SYSTEMS

WIND TURBINES

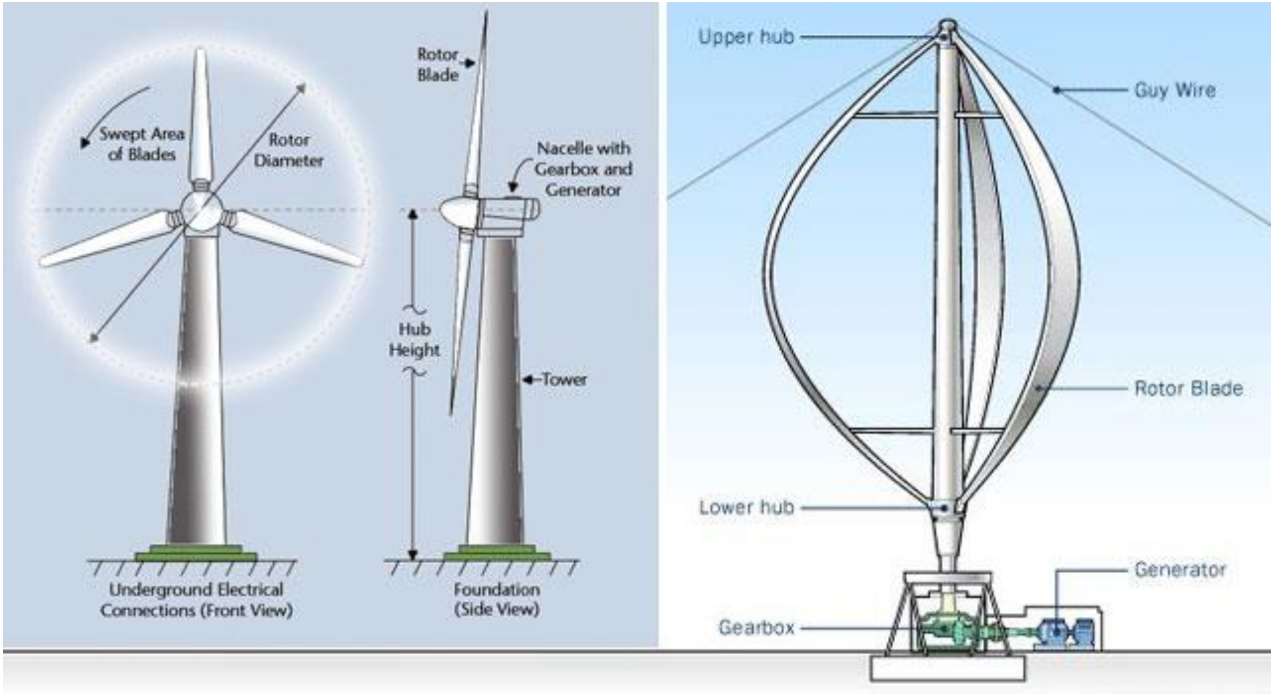

Figure 12: Comparison of horizontal and vertical axis turbines

Wind turbines convert the kinetic energy of wind into rotational mechanical energy, which in the past has been used to pump water and more recently generate electricity.

The power available from a typical horizontal axis wind turbine (HAWT) is proportional to the cube of the swept area, so there is a strong incentive to make larger turbines. Thus development in this field is focused on materials and manufacturing techniques which increase the blade length and increase maximum power output. Similarly, wind speed is more constant at higher altitudes so turbines are mounted on tall towers. A typical grid scale wind turbine (2MW) sits on a tower about 60m tall, supporting a turbine with 40m long blades. They are usually located where the wind is strongest and most reliable, such as coastlines, ridgelines and land positioned in the trade winds, such as the Eyre Peninsula in South Australia.

Installed capacity worldwide has increased every year since 1996, with over 240,000MW installed at the end of 2012.[21]

Vertical axis wind turbines (VAWT) have been developed in recent years which are intended for developed areas to address the concern that HAWTs are noisy and can be built closer to the ground. The forces acting on the blades of VAWTs are more complex than those acting on HAWTs, leading to blade distortion and ultimately failure. They also have poor start-up torque and some designs require a motor to start the turbine moving, significantly reducing their performance.

VAWTs make an attempt to reduce the noise of HAWTs and the requirement for constant, directional wind. The result is a turbine that can operate in changing wind conditions but at vastly reduced efficiency and higher cost. There are very few applications where VAWTs are a better or commercially viable choice.[22]

In general, wind turbines are a poor choice for site electricity supply, benefiting strongly from scale. Small turbines installed at sites with anything less than optimal wind resource have been found to perform very poorly. Trials in the UK across 21 urban sites in Warwick reported average capacity factors below 1%, rising to 4% if maintenance and turbine failure periods are removed.[23] This study also identified a large disparity between the modelled and actual output of a turbine. When the output was modelled using the standard wind resource maps available from the weather bureau they were found to overestimate the actual output by a factor of 15. This is due in large part to the effects of turbulence from

[21] http://gwec.net/wp-content/uploads/2012/06/GWEC_-_Global_Wind_Statistics_2011.pdf
[22] http://news.nationalgeographic.com/news/energy/2012/08/120820-helix-wind-collapse/
[23] http://www.warwickwindtrials.org.uk/resources/Warwick+Wind+Trials+Final+Report+.pdf

nearby objects, which can be overcome by using taller mounting masts. In all cases taller hub heights lead to better wind resource and aiming for mast heights twice as high as the obstacles in the area is a good rule of thumb.

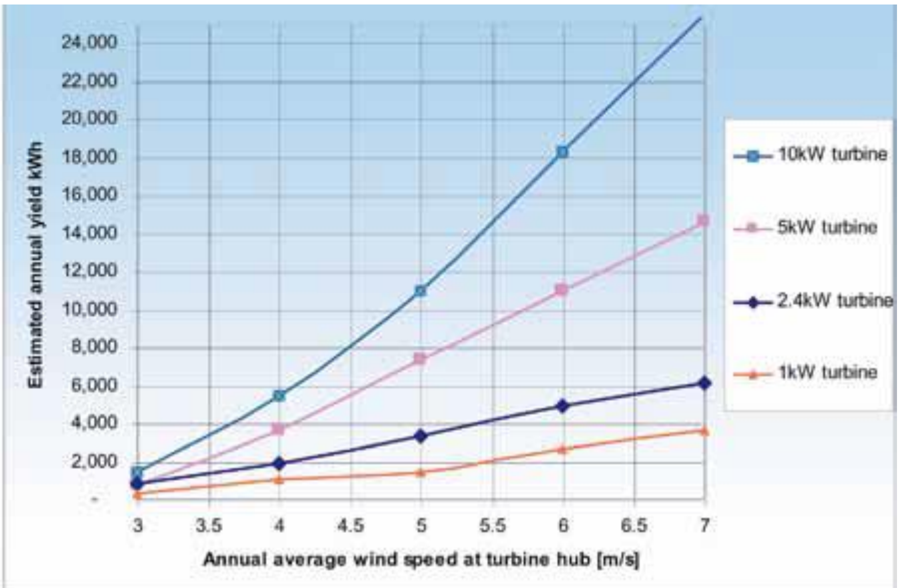

Figure 13: The effect of wind speed on output[24]

Wind speed can be estimated using the Australian wind resource map[25] or through higher resolution state maps like that produced in NSW.[26] Note that these maps record wind speed at about 60m from the ground and that at heights less than this the wind resource will be significantly reduced. As a rule of thumb, average wind speed decreases by 10% for every halving of hub height; wind speed of 6m/s at 60m translates to about 5.4m/s at 30m and 4.8m/s at 15m. As shown in Figure 13 above, a 10% decrease in wind speed will have a significant impact on annual generation. Due to this acute sensitivity to wind speed and the impact of local conditions, most authorities recommend installing an anemometer to measure the wind in your proposed location, for at least a year.

In scoping for a wind project, upland or coastal regions, or wind farms in your area indicate a viable wind resource. Commercial developers in Australia generally look for wind resources that average 7m/s at hub height. Footnote number 25 below suggests these sites are mostly found in South and Western Australia with good proximity to south-west facing coastline, and on elevated regions along the Great Dividing Range on the east coast.

It is also worth considering the project development time for a wind project, which can be impacted by Development Approvals and local objections. A typical wind project might take two-years from inception to electricity where an equivalent solar project can be generating in eight-weeks and less.

Type	**Source:** Wind **Storage or generation:** Generation **Heat or electricity:** Electricity
Applicability to the meat processing industry	Low in general – but very high in the right conditions. In favourable conditions wind can provide power at about half the cost of solar, but these conditions are rare in industrial sites. The economics of wind turbines favour large turbines in reliable wind areas. These sites are typically on the coast or inland ridge lines, which are not likely to match well with meat processing sites. However, there may be some suitable locations. Very favourable conditions are required for wind to be attractive as site energy supply; a site with constant, prevailing wind, such as that on-shore around Esperance or the Eyre Peninsula, with the site either positioned on a ridge or exposed, flat piece of land, would be suitable. There may be regional sites with paddocks that can provide the ‘fetch’ required for a clean air flow, but wind is very unlikely to be suitable in forested or built up areas, as

[24] http://www.environment.nsw.gov.au/resources/climatechange/0449SWCG.pdf
[25] www.renewablessa.sa.gov.au/files/121219-windresourcemappingaustralia.pdf
[26] http://www.energy.nsw.gov.au/sustainable/renewable/wind/sustain_renew_wind_atlas_poster.pdf

	these obstacles create turbulence.
Current status	Mature technology, in market accumulation.
Size, scalability and efficiency	Typical grid turbines are 2MW and larger. The performance of wind turbines is proportional to their radius and so small turbines (<100kW) do not perform well. More recently developed turbines may be applicable in less than ideal wind resources and at smaller scales; however this is unlikely to be the most cost-effective form of electricity generation at the majority of red meat processing facilities in Australia. A fully-costed comparison of wind and solar, with consideration for the site characteristics, is required to find the best value solution.
Current and projected costs	If installed in a location with favourable wind speeds and grid connection costs, wind power can be cost competitive with grid power and new wind power can offer cheaper electricity than new coal-fired power plant.[27] There is significant effort being directed at lowering wind energy costs and these are expected to continue falling. 100kW turbines retail for about $17,000 Australian dollars. This is very similar to capacity costs for solar and so the climate (wind and insolation in particular) will have a large impact on the final choice.
Country of development and manufacture	Major development centres include China, Denmark and Japan.
Drivers for uptake	Wind power has recently become a mature and reliable electricity generating technology whose uptake has been driven by government incentives for clean energy.
Forecast status: 5-10 years	Increasing deployment in windy areas and new resources will be exploited with new technology. Some new turbines are now being sold with integrated storage and this trend is likely to continue.
Social and environmental costs and benefits	Some groups oppose the loss of visual amenity associated with wind turbines and fringe groups complain of health effects from living near wind turbines, despite there being no solid evidence for this position.[28] In use wind turbines offer relatively cheap, emissions free electricity, with increasing confidence and predictability of generation.

[27] http://www.asce.org/cemagazine/Article.aspx?id=23622328066#.UoVrC-I7nKc
[28] http://tobacco.health.usyd.edu.au/assets/pdfs/publications/WindHealthReviews.pdf

WASTE-TO ENERGY SYSTEMS

Waste-to-energy systems use organic matter to create. These can be used by either direct combustion, as in a biomass fired boiler, or converted using anaerobic digestion, pyrolysis or gasification. Traditionally some of the wet waste streams are treated anaerobically in a bio-digester, creating biogas which contains methane that is a useful renewable energy source. The waste streams from the meat processing industry lend themselves to this type of treatment as the bacteria present in the stomachs of animals is suitable for anaerobic digestion and may only need to be heated to encourage efficient conversion. Some of the dry wastes can also be used in this system and benefit from mechanical maceration before being incorporated into the biogas digester.

These systems have been successfully deployed in anaerobic sewage treatment plants and in a number of piggeries and similarly intensive animal raising and processing sites. In such applications biogas is typically captured in the digester, then 'scrubbed' to remove impurities such as sulphur dioxide, and the 'cleaned' methane gas is then burnt through a specifically designed bio-methane-fired engine, which produces electricity and/or heat for use on the site. Waste heat captured in the engine jacket water is circulated around the digester to raise the temperature and improve the processing time. Biogas used in this way can be considered a mature technology.

The solid waste left over from the digestion process is high in available minerals and can be used as a fertiliser in some situations.

More recently systems have been developed which can process dry waste to create heat, leaving a biochar suitable for improving the organic content of soil. These systems use pyrolysis to remove the volatile compounds from organic matter, creating a synthetic gas, which is burnt to drive the process. The biochar produced by this process may be useful in Carbon Farming Initiative projects, if a suitable methodology is developed for the red meat processing sector. These methods are currently under development and their development can be monitored through footnote number 29 below.

ANAEROBIC DIGESTION

Wet organic waste is heated to less than 40°C where naturally occurring bacteria digest remaining organic material in a low-oxygen environment. Methane is released by the bacteria as a by-product of this process. This methane is captured in the digester, creating biogas, a mixture which is fully saturated and includes trace amounts of gases apart from methane.

There are two broad classes of digester; Covered Anaerobic Lagoons (CALs) and In-Vessel Anaerobic Digestion (IVAD). CALs are simpler and can often be installed as a retrofit to an existing lagoon. IVAD systems use an engineered tank as the digestion vessel, often with integrated pipes for heating the mixture. Both of these systems can also be enhanced by mechanical stirrers driven by electric motors.

Figure 14: A covered anaerobic digester. This cover expands and can buffer gas delivery

Type	**Source:** Biological material **Storage or generation:** Generation **Heat or electricity:** Heat or electricity
Applicability to the meat processing industry	This technology is highly applicable to the meat industry as it works most effectively with high-nutrient, organic-waste streams such as those found at abattoirs.
Current status	Anaerobic digestion to produce biogas is a mature technology used throughout the world for processing organic waste, for sewage treatment and residential gas production in India and China. Feed in tariffs for power from anaerobic digestion in Germany assisted in the development

[29] http://www.daff.gov.au/climatechange/cfi/biochar/list-of-successful-biochar-projects

	of the technology.
Size, scalability and efficiency	Residential biogas digesters are common in China and India and very large industrial systems are common on sewage treatment plants across the world. Conversion efficiency is increased by heating the waste.
Current and projected costs	Creating biogas can be achieved at very low cost, with little required beyond a containment vessel. The cost of biogas digesters is unlikely to fall further, as this is a simple and mature technology. Development continues on the engines which produce electricity and the costs of these are expected to decrease slightly in future years.
Country of development and manufacture	Worldwide.
Drivers for uptake	Commercial and industrial application of biogas technology is driven by regulation governing the emission of methane from waste water treatment (i.e. the Carbon Pricing Mechanism), desires to reduce waste management costs and utilise waste streams for value recovery such as energy and nutrients for fertiliser.
Forecast status: 5-10 years	Biogas use will always be limited by the availability of waste streams. These will continue to be exploited in coming years.
Social and environmental costs and benefits	Energy from waste systems offer significant social and environmental benefits, reducing landfill, producing electricity and usable thermal energy and producing useful compost.

GASIFICATION

Gasification converts solid organic material (biomass) into a gaseous fuel, called syngas, that is rich in carbon monoxide, hydrogen and carbon dioxide. The biomass containing volatile organic compounds is heated in a oxygen-controlled environment. The advantage of gasification is that the syngas can be burnt at much higher temperatures than the combustion of the original biomass and therefore generate electricity at a higher efficiency.

Type	**Source:** Biomass **Storage or generation:** Generation **Heat or electricity:** Heat or electricity
Applicability to the meat processing industry	Broadly applicable to the meat industry but better suited to drier waste streams than typical abattoir waste, and those which are mostly cellulosic (i.e. paunch waste), rather than protein containing (i.e. fats, oils and greases). Theoretically any organic material can be gasified, but industry publications suggest moisture content below 30% be considered as a minimum; above this anaerobic digestion might be more suitable. Syngas from gasification could be used in a gas turbine power generator with a waste heat boiler used to raise steam for rendering and sterilisation. This could also be attractive in situations where a local wood waste stream is available. Examples include wood waste from timber mills, bedding from large-scale chicken sheds or bagasse from sugar mill operations.
Current status	The gasification of coal and other fossil fuels is a long used and very well understood technology. Application to biomass is still emerging.
Size, scalability and	Biomass gasification is still an emerging technology. Some large scale plants that use wood

efficiency	waste have been deployed. Smaller units that fit into a shipping container for transport to site are also available. In all cases, the upper limit of capacity is determined by fuel availability and logistics.
Current and projected costs	The costs of production are coming down as systems are tested. The attractiveness of this technology is strongly linked to the value and availability of suitable waste streams, the cost of fuel preparation equipment (such as paunch and DAF sludge drying equipment) and the presence of financial support mechanisms such as the Carbon Pricing Mechanism.
Country of development and manufacture	Developed worldwide, with many local applications.
Drivers for uptake	Technology improvements to reduce cost. Government policies to favour carbon free energy.
Forecast status: 5-10 years	Applications which produce carbon for soil conditioning will become increasingly common, driven by incentives in carbon mitigation policies.
Social and environmental costs and benefits	This is a simple system able to organic waste into a useful soil conditioner.

PYROLYSIS

Pyrolysis converts biomass into a stable high-carbon final product, by heating the material in an oxygen-free environment. Typically the heating process creates a syngas, some of which can be used to heat the pyrolysis reactor. The material left is very high in carbon and can be used as a soil conditioning agent.

Aspects of the pyrolysis and gasification processes are similar, but their intent is different. Gasification aims to create a gas for later combustion, while pyrolysis aims to create carbon rich bio-char along with the syngas.

Figure 15 Container mounted pyrolysis machine for processing woody weeds in Victoria

Type	**Source:** Biomass **Storage or generation:** Generation **Heat or electricity:** Heat or electricity
Applicability to the meat processing	Broadly applicable to the meat industry but better suited to biochar production from woody

industry	biomass. If applied to a meat processing site this would use the drier waste streams from plant operations. Applied, pyrolysis would supply fuel for power generation and process heat for sterilization or rendering, leaving a carbon-rich waste material which could be used as a soil conditioner. This could also be attractive in situations where a local wood waste stream is available. Examples include wood waste from timber mills, bedding from large-scale chicken sheds or bagasse from sugar mill operations.
Current status	Pyrolysis has been used to make charcoal and coke for centuries, at scales ranging from domestic (to produce clean solid fuel for cooking) through to large industrial scale (coke ovens in steel making). Industrial pyrolysis of biomass to produce biochar for soil conditioning and carbon sequestration is currently under development.
Size, scalability and efficiency	Current pilot plants are at small scale, able to fit into a shipping container for transport to site. The upper limit is determined by fuel availability and transport.
Current and projected costs	The costs of production are coming down as systems are tested. The attractiveness of this technology is strongly linked to a carbon price and the value of soil carbon.
Country of development and manufacture	Developed worldwide, with many local applications. Traditionally used in Europe as a way of producing charcoal for cooking.
Drivers for uptake	In Australia development of this technology has been driven by the Carbon Farming Initiative as a way of improving soil carbon.
Forecast status: 5-10 years	Applications which produce carbon for soil conditioning will become increasingly common, driven by incentives in carbon mitigation policies.
Social and environmental costs and benefits	This is a simple system able to convert woody weeds such as willow and poplar into a useful soil conditioner.

BIOMASS DIRECT COMBUSTION

Some agriculture wastes, such as farm stubble, animal bedding and forestry wastes, can be combusted in boilers to produce steam for process heat. Of the wastes available through red meat processing activities, dewatered paunch waste is the most promising and has been examined in great detail in work previously commissioned for the AMPC.[30] This work found that up to 30% of boiler fuel needs could be met with dewatered paunch waste, with no major ill-effects. However, this was tested in a boiler designed for burning sawdust; augmenting coal boilers with dewatered paunch waste may not deliver a satisfactory result. Large scale trials of co-firing coal power station boilers with wood chips and other forestry waste have found that particle size and moisture content need to be tightly controlled to achieve the correct burn time within the boiler.

The value of biomass projects are strongly correlated with the cost of the fuel. While using on-site waste such as paunch waste might be cost effective, purchasing forestry wastes and shipping them to site is likely to be less attractive. The fuel cost, future prices and the impact of changes in shipping costs should all be considered carefully before committing to a biomass project.

[30] http://www.ampc.com.au/site/assets/media/Climate-Change/On-site-Energy-Generation-Research/Use-of-paunch-waste-as-a-boiler-fuel.pdf

Type	**Source:** Biomass **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	Broadly applicable to the meat industry but strongly dependent on available waste streams or fuels. The most favourable projects would be those that use existing waste streams which currently have a disposal cost and can be burnt using existing technologies. An example would be to dewatered paunch waste and burn it in an existing coal or saw dust boiler.
Current status	Burning biofuels for heat is the oldest renewable energy technology in use and still contributes a significant amount of primary energy across the world. Despite this, technologies which are designed to efficiently burn biofuels continue to be developed. As recently the 1990s, novel ways of combusting biomass for cooking have been invented, with the rocket stove design delivering significant improvements in conversion efficiency.[31] Concerns about greenhouse gas emissions related to climate change have driven innovation in boiler design and control, with units designed for specific waste types continually under development.
Size, scalability and efficiency	Augmenting existing boilers with biomass can occur at very low levels of biomass and effectively offset fossil fuel use. The upper limit of biomass projects is determined by the fuel availability and rate, with projects up to 200MW electricity generation proposed to use existing black coal boilers in NSW. Unit efficiency is governed by boiler design, fuel burn and moisture content, with 80% plausible.
Current and projected costs	Biomass can be an extremely cost effective source of heat, particularly if existing waste streams are used. Costs or biomass fuels are likely to increase as competition for them increases as demand for low carbon sources of energy rise.
Country of development and manufacture	Developed worldwide, with many local applications.
Drivers for uptake	Low emissions heat and power, to reduce greenhouse gas emissions and reduce waste disposal.
Forecast status: 5-10 years	This technology will be more widely deployed and waste streams utilised.
Social and environmental costs and benefits	Low emissions energy and waste disposal.

[31] http://www.ashden.org/winners/aprovecho

LOW EMISSIONS TECHNOLOGIES

Cogeneration, trigeneration and heat pumps are not strictly renewable energy technologies because they are, in part, run using fossil-fuel derived energy sources, however each could be fuelled by renewable energy sources. Both trigeneration and cogeneration benefit from bringing the combustion to create electricity on site, allowing access to the surplus heat associated with heat-to-electricity conversion.

Heat pumps use electricity to access ambient heat, delivering heat far more efficiently than using electricity alone.

These technologies are included for their potential to reduce energy use and greenhouse gas emissions.

COGENERATION AND TRIGENERATION

Cogeneration captures a number of specific generation technologies that share a common theme; a fuel is burnt in an engine to produce electricity, with waste heat from combustion captured and used to drive thermal processes. In industrial settings this heat is used as process heat, in commercial buildings this heat can be used for space heating or less commonly, space cooling.

Trigeneration extends this concept to use heat to drive a cooling process. The cooling part of the plant will be supplied using an absorption refrigeration cycle, like the ammonia-water absorption system used in “Three-Way” camping fridges, or “thermal wheel” systems, which exploit the cooling effects of evaporation.

The economics of trigeneration systems are most attractive on sites which require constant cooling loads, and some need for low-grade heating. Hospitals and data centres are typical examples, but there are obvious parallels for the meat processing sector. Electricity can be provided on-site by the generator, waste heat can run an absorption chiller to reduce the refrigeration load, and the low-grade heat remaining can heat water to reduce boiler use.

When linked with a in-vessel anaerobic digestion unit, the waste heat can be used to heat the digestion process, therefore improving the conversion of organic material to biogas.

Figure 16: Biogas engine as part of a trigeneration system at a large sewage treatment plant

Type	**Source:** Fuel from renewable or non-renewable sources e.g. biogas or natural gas **Storage or generation:** Generation **Heat or electricity:** Electricity, heat and cooling
Applicability to the meat processing industry	Highly applicable. Many projects have demonstrated how useful biogas cogeneration can be to utilise meat processing and animal industry waste streams to produce electricity and provide process heat. A complete system for meat processing sites could be assembled as follows: waste streams are collected in a large concrete tank where they undergo anaerobic digestion to

	produce methane/biogas. This gas is collected and used to fuel an engine, which drives a generator and produces electricity. Combustion heat, captured in the engine jacket water is used to heat the digester and speed the anaerobic digestion process. Gas supply can be buffered in the tank using expanding bladders or floating lids, which allows the generator to meet the plant electricity load. The hot water from the engine will not be hot enough for rendering or sterilization, but could be heated further using biogas in an instant gas heater.
Current status	Cogeneration is a mature technology, applied in sewage treatment plants, commercial buildings and abattoirs. It is used increasingly in public spaces to provide electricity and district heating, particularly in cold areas such as Europe.
Size, scalability and efficiency	System cost is driven by the motor which produces electricity, grid connection costs, and maintenance costs. Very small systems are possible (~10kW) but the motor efficiency would make the economics of such a project unfeasible. Typical meat industry projects are in the 300kW to 500kW range, while sewage treatment plant projects can be up to 10MW.
Current and projected costs	As a rule of thumb, a cogeneration system costs $1 million per MW of electricity generation.
Country of development and manufacture	Worldwide.
Drivers for uptake	The availability of low cost fuel gas coupled with a consistent demand for heat or cooling.
Forecast status: 5-10 years	Increasing penetration in the animal sector in particular, with estimates suggesting less than 10% of the available resource is currently being exploited.[32]
Social and environmental costs and benefits	Systems that utilize waste streams for energy production reduce waste and create low-emissions electricity. Cogeneration systems allow use of the heat produced in thermal electricity production.

HEAT PUMPS

Many businesses will already be familiar with heat pumps employed as air conditioners, but technology that uses the vapour-compression cycle to access environmental heat for process heat is becoming more common.

While not considered a renewable energy technology, heat pumps use electricity to transfer thermal energy from ambient sources such as air or earth, to the built environment for uses such as space heating or cooling, or heating water. System performance is measured in terms of the coefficient of performance (COP), which is the relationship between electricity used and heat supplied. High-performing systems available on the market now have COPs as high as 6; conceptually this means for one unit of electricity spent, six units of thermal energy are utilised for heating or cooling purposes. These systems work very well when the ambient temperature is high and so would provide very efficient process heat in warmer areas in northern Australia.

Heat can be applied to space heating or water heating. Heat pump hot water systems are common to augment solar heating in cold areas of Australia without extensive natural gas networks, such as Tasmania.

Environmental heat can be collected from two sources; either the air or the ground. Air-source heat-pumps are the most common application and are familiar to many as standard air conditioning systems. They collect heat from (or reject to) the air and so their performance is significantly influenced by the ambient air temperature.

To smooth these fluctuations the external heat exchanger can be contained in the ground, either as buried copper pipes or embedded in engineered concrete blocks. Ground temperature is much more stable than air temperature and offers an advantage in both hot and cold climates. Taking the hot climate example, air temperature might vary from 20°C to 40°C, while the ground temperature a few metres below the surface might only vary from 18°C to 22°C. This allows a refrigeration cycle to reject heat to a much lower temperature than the ambient temperature, improving the

[32] http://porkcrc.com.au/wp-content/uploads/2013/08/BEA-27-June-2013-Tait-Biogas-Pig-Industry.pdf

system performance. The reverse applies in cold climates, where a ground temperature of 10°C can be a significant improvement over the air temperature.

Type	**Source:** Electricity, to access environmental heat **Storage or generation:** Generation **Heat or electricity:** Heat
Applicability to the meat processing industry	Moderately applicable. Heat pumps can provide reliable hot water and space heating. Modern systems are becoming increasingly efficient, making it worthwhile to revisit the economics even if they have been considered in the past. These systems would be most applicable in warm areas to heat water to temperatures below 100°C. They are simple, reliable systems. Ground source heat pumps are good for supplying heat in cool areas and cool in hot areas. Putting the heat exchanger in the ground increases the capital cost so the benefits are best realised in areas of more extreme climate.
Current Status	Heat pumps are fully mature technology, widely applied around the world. Traditionally applied to space heating and cooling they are seeing increasing use as hot water boosters. Ground source heat pumps are a more recent development and are being applied in space heating, particularly in cold climates.
Size, Scalability and efficiency	Based on the vapour-compression refrigerator cycle heat pumps can be scaled to provide heat at almost any scale. Current installations exist from as low as 1kW electric, through to 1MW and greater systems. Efficiency or coefficient of performance ranges from less than 3 to above 6.
Current and Projected Costs	Equipment costs have been broadly stable for a number of years, but their effective value has improved as unit performance increases. This is likely to continue in coming years.
Country of Development and Manufacture	Worldwide.
Drivers for uptake	Principally driven by a desire for simple, reliable and cheap water heating in areas which do not have natural gas. Ground source heat pumps for heating have been developed to overcome the performance disadvantage of very cold climates.
Forecast Status: 5-10 years	Increasing penetration at residential and industrial scale
Social and Environmental costs and benefits	Simple, reliable hot water boosting which can use electricity far more effectively than resistance heaters.

STORAGE TECHNOLOGIES

Due to the intermittent nature of many renewable energy sources, the capacity to store energy assists in increasing the amount of overall energy use that can be supplied by renewable sources.

Storage systems can either store heat or electricity. Electricity is generally transformed into another form of energy such as potential energy, kinetic energy or chemical energy. Heat is usually stored as heat, and is not transformed.

The information provided on storage technologies has mainly been sourced from the International Energy Agency (IEA)[33],[34], Electric Power Research Institute (EPRI)[35] and the Electric Storage Association (ESA),[36] except where indicated otherwise.

ELECTRICITY STORAGE ON MEAT PROCESSING SITES

For the purposes of this analysis, we will assume the electricity being supplied for storage is supplied by solar PV panels, generating for about eight hours a day, and requiring storage for up to 16 hours, albeit at reduced load. The most valuable use of solar power is displacing grid-purchased electricity, rather than selling excess into the market, and so the system will be considered from the perspective of maximizing onsite renewables use.

The solar array would be sized to deliver about twice the average day-time load. The plant would run directly from panels during the day, and then supplied from the batteries once solar generation decreases. Back-up would be provided by normal grid power. The value of extra storage diminishes in line with the odds that it will be required; as an example, storage for one hour is very high value because it would be needed every day when the sun goes down. Ten hours storage has slightly lower value because the plant may not require that much energy overnight. Twenty-four hours and beyond has even less value because there is an opportunity to recharge the battery between uses. To accurately determine the most cost effective battery size requires the insolation of the site (the amount of sun), a long-run load profile for electricity use and the price of electricity throughout the day. Models of different storage sizes can then determine how much electricity is purchased from the grid and different sizes can be compared.

ELECTRICITY STORAGE SYSTEMS

Electricity storage systems come in several forms including chemically reactive batteries, systems that convert electricity into potential energy (pumped hydro, compressed air energy storage) or kinetic energy (flywheel). Three applications for electricity storage systems are recognised:

- **Power Quality Maintenance**: applied for seconds or less, as needed, to assure continuity of quality power. These systems are designed to stabilize system voltage.
- **Bridging Power**: used for seconds to minutes to assure continuity of service when switching from one source of energy generation to another.
- **Energy Management**: to decouple the timing of generation and consumption of electric energy. A typical application is load levelling, which involves the charging of storage when energy cost is low and utilization as needed. This also enables energy consumers to use renewable energy over greater periods of time.

This section focuses on the use of storage systems for energy management. This is an important distinction as electricity storage technologies are highly size and use dependent. There are two separate characteristics to consider; the amount of time storage is required and the speed of response. The most appropriate technology in a given application will consider both of these characteristics.

BATTERIES

Chemical batteries are widely used in renewable energy supply systems. Typically, batteries consist of sets of electrodes in an electrolyte and are characterized by the nature of the electrodes and the electrolyte. The range of the most relevant battery types are described in Table 2 below.

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[33] IEA Energy Technology Perspectives 2008, International Energy Agency, 2008

[34] “Prospects for Large-Scale Energy Storage in Decarbonised Power Grids”, International Energy Agency, 2009

[35] “Energy Storage: Enabling grid-ready solutions”, The Electric Power Research Institute, 2010

[36] See http://www.electricitystorage.org. The Electricity Storage Association (ESA) is a trade association established to foster development and commercialization of energy storage technologies. ESA members represent Electric utilities, Electricity Supply Companies (ESCOs), Independent Power Producers and technology developers involved with advanced batteries, flywheels, CAES, pumped hydro, supercapacitors and component suppliers, such as power conversion systems

Sizes of these batteries tend to be reported in maximum power and delivery time. All of the batteries considered below are capable of discharging over hours, the consensus time period for energy management applications.

Table 2: Battery types

Type	Description	Status
Lead-acid	A commercially mature battery type. Lead-acid batteries are low cost and popular, and have been used in automotive and small power storage applications for many years. The use of lead-acid batteries for energy management has been very limited due to their short cycle life particularly if they are allowed to be fully discharged. Lead-acid batteries have been used in a few commercial and large-scale energy management applications. The largest one is a 40 MWh system in Chino, California, built in 1988.	These batteries have reached their full commercial potential.
Lithium-ion	The cathode in these batteries is metal oxide containing lithium ($LiCoO_2$, $LiMO_2$, etc.) and the anode is made of graphite. The electrolyte is made up of lithium salts (such as $LiPF_6$) dissolved in organic carbonates. Lithium-ion batteries have a high energy density (300 - 400 kWh/m3) and long cycle life (3,000 cycles at 80% depth of discharge). Li-ion batteries have typically been used in mobile applications due to their excellent energy density.	Currently several companies are working to reduce the manufacturing cost of lithium-ion batteries to capture large energy markets. The high cost comes from the special packaging required and internal overcharge protection circuits.
Metal-air	The anodes in these batteries are commonly available metals with high energy density like aluminium or zinc. The cathodes or air electrodes are often made of a porous carbon structure or a metal mesh covered with catalysts. The batteries work by transferring oxygen from the air as OH^- through a conductor such as KOH to the metal anode where the metal is oxidised. The oxidation releases energy. These are the most compact and, potentially, the least expensive batteries available. They are also environmentally benign. Electrical recharging of these batteries is however very difficult and inefficient.	While the high energy density and low cost of metal-air batteries may make them ideal for many primary battery applications, the problems with recharging limit use. Development effort is focused on this issue. **These batteries do not recharge and so will not be considered further.**
Sodium sulphur cells	A sodium sulphur (NaS) battery consists of molten sulphur at the positive electrode and molten sodium at the negative electrode as active materials separated by an alumina ceramic electrolyte. The electrolyte allows only the positive sodium ions to pass through it. The sodium ions combine with the sulphur to form sodium polysulfides. As with ZEBRA batteries the temperature must be kept near 300°C to keep the electrolyte liquid. These batteries are an effective means of stabilising renewable energy output. NaS batteries have been demonstrated at over 190 sites in Japan totalling more than 270 MW with stored energy suitable for 6 hours daily peak shaving. The largest NaS installation is a 34 MW, 245 MWh unit for wind stabilization in Northern Japan. U.S. utilities have deployed 9 MW for peak shaving, backup power, firming wind capacity and other applications and project development is in-progress for an equal amount.	The application of these batteries for peak shaving, backup power, and firming wind capacity will develop further with the global push to renewable energies.
Sodium Nickel Chloride battery (ZEBRA)	Very similar in operation to a sodium-sulphur battery, these use liquid sodium salt as an electrolyte. As a result the internal temperatures need to be kept above 300°C, which is usually managed by the battery electronics. This particular molten salt chemistry was developed to address some of the technical issues of sodium-sulphur batteries.	Market demonstration – General Electric have recently built a factory to manufacture these batteries. There are a few demonstration battery banks in operation.

Type	Description	Status
Vanadium Redox Batteries	Vanadium Redox Batteries store energy using vanadium redox couples. During the charge/ discharge cycles, H^+ ions are exchanged between the two electrolyte tanks through a membrane. Vanadium Redox Batteries are an example of a flow battery. The key feature is the use of liquid electrolytes to store the energy. The stored electricity is released as the electrolyte is pumped though an electrolytic cell. The electrolyte is stored in tanks and the size of these tanks is not linked to the size of the cells. Therefore, the power and energy ratings of Vanadium Redox Batteries are independent of each other. Vanadium Redox Batteries were pioneered by the University of New South Wales in the early 1980's and the technology is currently licensed to Sumitomo Electric Industries	Vanadium Redox Batteries storage of up to 500kW, 10 hrs (5MWh) have been installed in Japan.
Zinc-Bromide	Zinc-Bromide batteries are another example of flow batteries. In each cell of a ZnBr battery, two different electrolytes flow past carbon-plastic composite electrodes in two compartments separated by a microporous polyolefin membrane. This chemistry is being explored at both residential and grid support scales. The net efficiency of this battery is about 75%.	ZnBr batteries are used in integrated energy storage systems.
PolySulfide Bromide battery (PSB)	These are regenerative fuel cells involving a reversible electrochemical reaction between two salt-solution electrolytes: sodium bromide and sodium polysulfide	Early deployment. There have been no successful demonstration projects as yet.

PERFORMANCE COMPARISONS

The characteristics of the various electricity storage technologies are compared in Figures 8 and 9.

Figure 17 compares electricity storage systems in terms of their capacity to deliver an amount of power and the time frame that they can deliver the power. For use at meat processing facilities, the most appropriate technologies are for discharge times measured in hours, and power ratings between 100kW and 1MW, typically the various batteries.

In Figure 18, efficiency is a measure of the amount of energy extracted from the storage system is compared to the amount of energy stored. The lifetime at 80% depth of discharge indicates how many charge-discharge cycles a storage system can provide when each cycles discharges 80% of the energy stored. One of the key messages here is the role that maintenance plays is determining lifetime system costs. Lead-acid batteries in particular have acceptable turnaround efficiency but are degraded rapidly if regularly 'deep discharged'. So while the technology is applicable on meat processing sites, due to its cost, size and power delivery characteristics, the maintenance costs could be significant if the system is not sized appropriately. A detailed analysis should consider these factors before proceeding to a project.

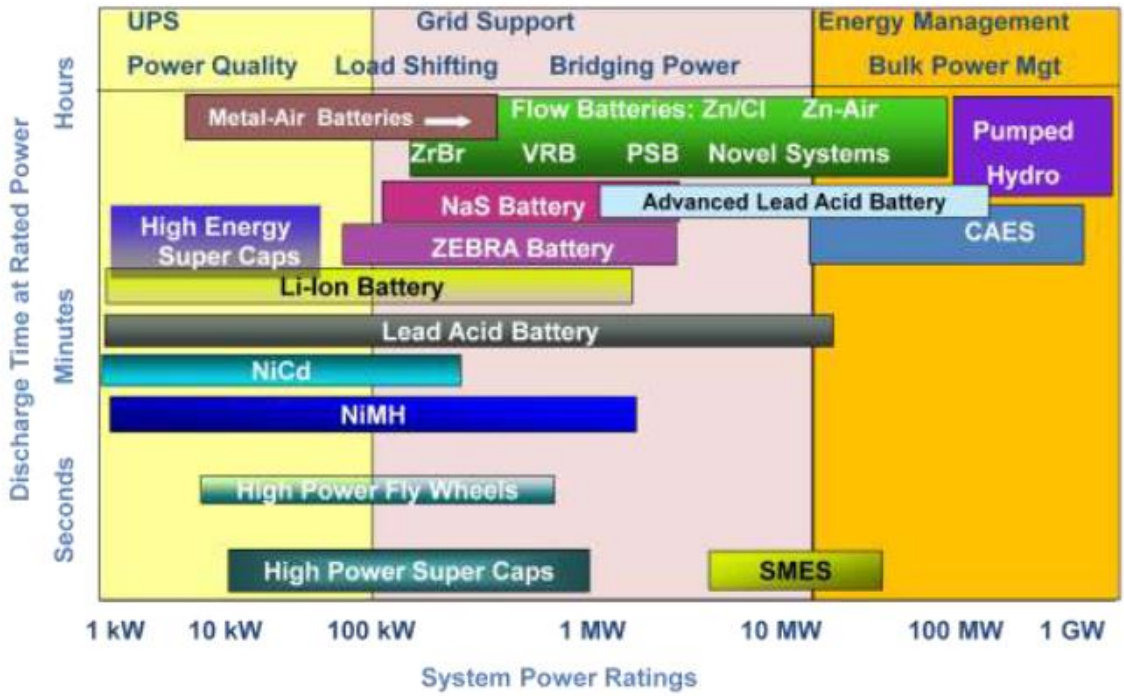

Figure 17: Summary of discharge times and output of electricity storage technologies[37]

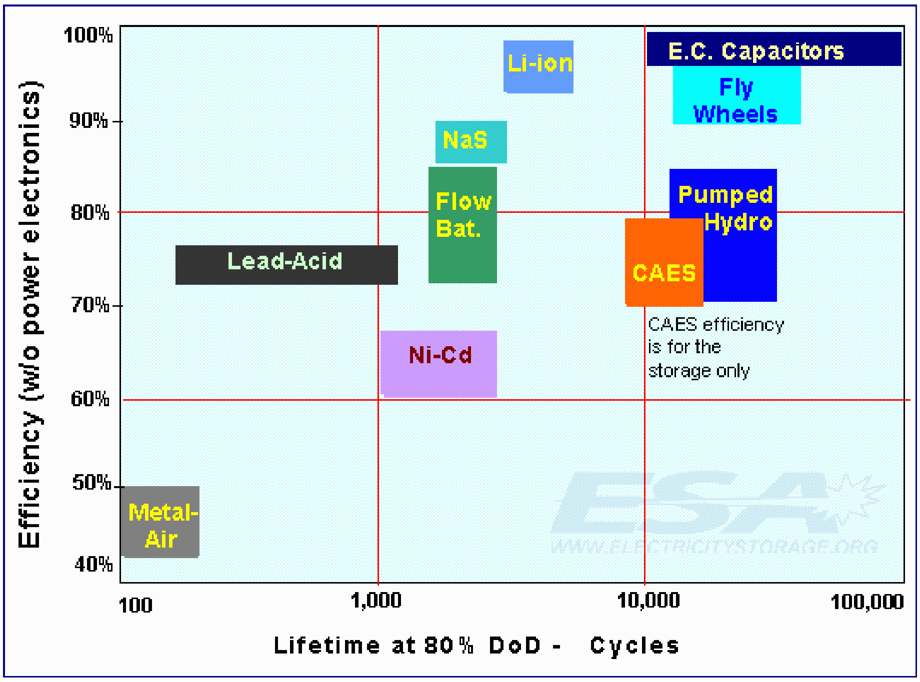

Figure 18: Efficiency and power rating of electricity storage systems[38]

[37] From the Electricity Storage Association, based on 2011 data http://www.electricitystorage.org/technology/tech_archive/technology_comparisons

[38] From the Electricity Storage Association, based on 2011 data http://www.electricitystorage.org/technology/tech_archive/technology_comparisons

LEAD-ACID BATTERY

Lead-acid batteries have been used in cars, trucks and portable equipment for a number of years and are one of the most common battery chemistries in use today.

As shown in Figure 18 , lead-acid batteries perform poorly in deep-discharge situations; they are unsuitable for use in situations where the battery is discharged below 80%, which would be a frequent occurrence in a cost-minimizing application, such as that suggested for meat processing sites. They should still be considered in detailed business casa analysis as their low cost makes it feasible to install considerably greater capacity, reducing the incidence of deep discharge.

They are presented here for completeness, but when maintenance and replacement lifetime are taken into account, lead-acid batteries are unlikely to represent a cost-effective option for meat processing sites.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing industry	Medium applicability. Lead-acid batteries are cheap and well known. They can provide cheap storage for situations where they are required to provide power for short periods and to sit idle for long periods; hence their widespread use for starting automotive engines. They are generally unsuitable for load-shifting applications, due to their slow response time, high maintenance requirements and degradation due to deep discharge use. They may appear attractive in a cost-comparison with other technologies, but will be largely driven by assumptions about maintenance and replacement costs.
Current Status	Mature technology. Lead-acid batteries have been the most commonly used battery for cars and trucks for a number of years. More recently they have been used in “off-grid” households supporting solar panels, but this is mostly due to few alternatives being available.
Size, Scalability and efficiency	Available from AAA battery size through to load-shifting grid support batteries. Can be scaled by adding units in parallel to supply more current. Turn-around efficiency is near 75%, making it one of the least efficient batteries available.
Current and Projected Costs	This is a fully mature technology and costs are unlikely to change much in future. Effort is being put into power electronics which overcome some of the battery’s deep-discharge problems, which may raise costs slightly, while greatly improving reliability.
Country of Development and Manufacture	Worldwide.
Drivers for uptake	Cheap storage capacity, the incumbent technology in many cases.
Forecast Status: 5-10 years	Declining share in grid support applications as flow batteries and other competitors become cheaper and more readily available.
Social and Environmental costs and benefits	Strong concerns have been raised about the use of lead in these batteries and care must be taken when disposing of them.

LITHIUM-ION BATTERY

Lithium-ion batteries are a mature and widely deployed battery technology. They are rechargeable, have good energy density and deep-discharge characteristics, making them an excellent option for mobile applications. Lithium-ion batteries are the number one choice for mobile phones, laptops, cordless power tools and electric vehicles.

It is their energy density that makes them most attractive for mobile applications, which is less important with load-leveling, stationary applications. However, since there are so many lithium-ion batteries in operation, and so many manufactured each year, there is significant manufacturing capacity available which lowers prices. They are increasingly being used in stationary applications and could be attractive in an AMPC context.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing industry	High applicability. Lithium-ion batteries are widely used and technically very well understood. They are increasingly being used in grid-support roles, with 5-10MW battery banks in operation in Germany and England[39]. These experiences and the availability of smaller batteries around the 100kW mark make them a definite candidate for consideration.
Current Status	Mature technology, very widely used.
Size, Scalability and efficiency	Available from mobile phone battery size through to load-shifting grid support batteries. Can be scaled by adding units in parallel to supply more current. The charge-discharge (turn-around) efficiency is above 90%, making it one of the most efficient batteries available.
Current and Projected Costs	This is a fully mature technology and costs are unlikely to change much in future. As development has traditionally been focused on mobile applications there may be scope to reduce costs at large-scale in future.
Country of Development and Manufacture	Worldwide.
Drivers for uptake	High-efficiency and energy-density have made lithium-ion batteries the number one choice for mobile applications.
Forecast Status: 5-10 years	Increasing use in large installations; continued use in mobile applications.
Social and Environmental costs and benefits	Some lithium-ion batteries have caught fire in the past, raising safety concerns. The smoke emitted can be irritating. They contain no heavy metals and so are not considered hazardous waste.

[39] http://reneweconomy.com.au/2013/the-battery-storage-system-that-could-close-down-coal-power-38259

SODIUM SULPHUR BATTERY

The sodium-sulphur battery is a molten salt battery constructed from liquid sodium and sulphur. It has a high turnaround efficiency and is constructed from inexpensive materials, but because the battery must be maintained at temperatures in excess of 300°C it is only applicable to stationary applications.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing industry	High applicability. The fast response, high efficiency and inexpensive material construction make this battery ideal site-based energy management. This is the most technically applicable technology to this application.
Current Status	Market accumulation. Several, large (10MW range) installations have been operating in excess of 5-years now.
Size, Scalability and efficiency	There is only one manufacturer at the moment, and their smallest unit is 50kW. These can be connected to provide higher power into the MW range.
Current and Projected Costs	Current costs are mostly driven by a lack of competition in production. The materials are inexpensive and abundant, the reasonably straight-forward. Costs will fall, possibly rapidly, should production capacity and uptake increase. This seems plausible as both California and Germany have introduced incentives for battery storage, which brought down international prices of solar PV in the last 5-years.
Country of Development and Manufacture	Japan. The current sole manufacturer is NGK in Japan.
Drivers for uptake	Inexpensive materials, grid support.
Forecast Status: 5-10 years	These will continue to be deployed, particularly in grid-support roles. Likely applications include wind farm storage and ride-through for solar sites. Ride-through is the power supplied when PV solar output drops due to cloud cover. The need to cycle these batteries frequently to maintain operating temperature make them well suited to this application.
Social and Environmental costs and benefits	Constructed from abundant and environmentally benign materials.

SODIUM NICKEL CHLORIDE BATTERY (ZEBRA)

The ZEBRA battery was developed based on the same theory and chemical families as the sodium-sulphur battery, but with electrolytes that are liquid at slightly lower temperatures.

General Electric is manufacturing these batteries under the Durathon name.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing	High applicability. The fast response, high efficiency and inexpensive material construction make this battery ideal site-based energy management. This is the most technically

industry	applicable technology to this application.
Current Status	Market accumulation.
Size, Scalability and efficiency	General Electric are the major manufacturer of this battery, with units available in from 20kWh to 6MWh, and maximum power from 10kW to 1MW.
Current and Projected Costs	Current costs are mostly driven by a lack of competition in production. The materials are inexpensive and abundant, the manufacturing reasonably straight-forward. Costs will fall, possibly rapidly, should production capacity and uptake increase. This seems plausible as both California and Germany have introduced incentives for battery storage, which brought down international prices of solar PV in the last 5-years.
Country of Development and Manufacture	General Electric is manufacturing the Durathon/Sodium-nickel chloride battery in the US.
Drivers for uptake	Inexpensive materials, grid support.
Forecast Status: 5-10 years	These will continue to be deployed, particularly in grid-support roles. Likely applications include wind farm storage and ride-through for solar sites. Ride-through is the power supplied when PV solar output drops due to cloud cover. The need to cycle these batteries frequently to maintain operating temperature make them well suited to this application.
Social and Environmental costs and benefits	Constructed from abundant and environmentally benign materials.

FLOW BATTERIES

For the purposes of this review, the flow batteries should be considered together. There are a few different chemistry compositions available, but these do not impact the user experience and for a technology assessment they are essentially interchangeable. Making business case decisions on which flow battery to use will be determined by availability, technical support and cost.

Unlike the batteries above, which are formed by grouping cells together, flow batteries employ a central reaction vessel and up to two separate tanks, which contain the reaction components of the battery. When current is required, the reaction components are circulated through the central receiver, which contains a membrane to keep the components separate and control the reaction.

All flow batteries are rechargeable and have flexible voltage and current configurations. Energy storage is governed by the size of the tanks, so very large systems are possible with little extra marginal cost. They are more complex than traditional batteries, requiring pumps and sensors which impact the system efficiency.

There are three main types commercially available at the moment; vanadium redox (VR), zinc-bromine (ZBr) and polysulfide-bromide (PSB). In the categories that they differ these designations are used below.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing industry	High applicability. The flow batteries are those best suited to this scale application, working best in the 100kW to 1MW range and above, with discharge times in hours.
Current Status	Market accumulation. Several, large (3MW range) installations have been operating in

	excess of 5-years now. PSB is the least commercially mature, VR the most widely demonstrated.
Size, Scalability and efficiency	Power and energy ratings can be determined independently in flow batteries. Currently they are used in the 1-10MW and above range, and designed for discharge times of about 10 hours.
Current and Projected Costs	There have been few demonstrations of this technology so costs are volatile. Industry estimates put the costs of the flow batteries roughly level, so the project cost would be driven by supplier costs and would need to be quoted for accuracy. Flow batteries are just now becoming a mass manufactured technology. Many analysts have compared the battery storage market to the solar market ten years ago[40]; the benefits and applications of the technology are obvious but there is little manufacturing capacity in place. As with solar, the price is inversely proportional to the amount of manufacturing capacity available, so as capacity comes on line the price will fall. Again as with solar, battery storage has recently become the target of incentive schemes in the major markets of California and Germany. The expectation is that these schemes will drive demand, which will bring manufacturing capacity on line and lower prices. RedFlow offer a 3kW constant/5kW peak, 8kWh unit, which is their standard module, for $8,000 US. ZBB's Australian headquarters is in Kardinya, WA and were unable to provide a firm price at the time of writing.
Country of Development and Manufacture	Flow batteries have been developed worldwide with major contributions from UNSW in Australia, NASA and the other technical universities in the US, Japan, Germany and China. Only ZBr batteries currently have manufacturing and sales representation in Australia, with two companies supported to develop commercial offerings through the federal Advanced Energy Storage Technology program. RedFlow developed both 5kW and 100kW models[41] while ZBB developed a 100kW battery for load shifting[42].
Drivers for uptake	Inexpensive materials, grid support.
Forecast Status: 5-10 years	These will continue to be deployed, particularly in grid-support roles. Likely applications include wind farm storage and ride-through for solar sites.
Social and Environmental costs and benefits	Constructed from abundant and environmentally benign materials.

NON-BATTERY ELECTRICITY STORAGE

Of the non-battery electricity storage systems available at the moment, the most applicable to meat processing operations is flywheel storage. The others, compressed-air energy storage, superconducting magnetic energy storage and pumped hydro all benefit strongly from economies of scale and are only applicable in 10MW and much greater capacities. An assessment of flywheel electricity storage follows.

FLYWHEEL STORAGE

Flywheel electricity storage units convert electrical energy into mechanical through the use of a spinning cylinder. Energy stored is proportional to the square of the angular velocity; so much effort is being applied to making the cylinder spin faster. This requires sophisticated materials for the flywheel so that it does not break apart at the very high speeds achieved. To maintain this energy once the cylinder is spinning flywheel storage systems use magnetic levitation bearings to minimize friction losses and operate within a vacuum.

[40] http://www.greentechmedia.com/articles/read/three-factors-driving-the-marriage-of-solar-and-energy-storage
[41] http://www.ret.gov.au/energy/Documents/clean-energy-program/acre/studies/Redflow-public-report.pdf
[42] http://www.ret.gov.au/energy/Documents/clean-energy-program/acre/studies/ZBB-public-information-report.pdf

Flywheels have traditionally been considered most appropriate for power-quality applications and uninterrupted power supplies (UPS) in telecommunications and data applications; they can deliver high power very quickly, but are unable to supply loads for very long periods. Recent development has focused on addressing this aspect and longer duration/higher energy installations have been completed.

Type	**Source:** Electricity **Storage or generation:** Storage **Heat or electricity:** Electricity
Applicability to the meat processing industry	Low These systems are best suited to high-power/short duration applications, with discharge times measured in minutes rather hours. For this reason they are being applied in situations where the cost of interruption is very high. Examples include telecommunications and data centres, where flywheels can cover the minutes of outage between losing grid power and diesel generators starting.
Current Status	Market accumulation. There are a number of sizable installations worldwide, but this is still an emerging technology.
Size, Scalability and efficiency	Flywheels typically deliver less than 1MW and as little as 2kW. This is usually for short durations, in the order of 15 minutes. The system can be scaled up by using a number of smaller units, much like using multiple batteries to increase the power or energy of the system.
Current and Projected Costs	Current costs are currently “at least twice that of lead-acid batteries”[43]. This will fall in coming years as manufacturing capacity increases and the market becomes more familiar with the product.
Country of Development and Manufacture	These are mostly used in aerospace and telecommunications and so development has been led by NASA and the large manufacturing centres.
Drivers for uptake	The high-power/low maintenance characteristics of flywheels make them excellent candidates for situations where the supply is needed infrequently.
Forecast Status: 5-10 years	Increasing use, particularly as worldwide data requirements grow and more server farms are built.
Social and Environmental costs and benefits	Environmentally benign components used throughout.

43 http://www.electricitystorage.org/technology/tech_archive/flywheels

THERMAL STORAGE SYSTEMS

Storage of thermal energy can be achieved by raising the temperature of a material (sensible heat storage) or causing a material to undergo a phase change (latent heat storage). Latent heat storage materials do not change temperature, but undergo a phase change. An example of latent heat is ice melting to become water; the temperature remains unchanged during the transition, but as more ice becomes water the internal energy of the fluid rises.

Thermal energy can also be used to cause a material to be absorbed into a liquid or adsorbed onto a solid.[44] Finally, thermal energy can be used to drive a chemical reaction; the energy is stored in the reaction products and can be recovered by reversing the reaction. These two processes can be considered thermo-chemical storage. At this stage there are no thermo-chemical storage technologies near commercial demonstration and which are applicable to meat processing operations, hence they are not considered further.

Some of the main uses for thermal storage are levelling the output of solar thermal power plants and improving the energy performance of buildings.[45] Sufficient energy storage can make a solar thermal power plant a dispatchable energy source.

This section considers thermal storage suitable to meat processing site. Most attention is given to those technologies which can reduce fossil fuel use by direct use of solar thermal energy; these systems are most cost-effective and efficient as they do not require turbines to convert the heat into electricity.

HEAT STORAGE

Developments in thermal storage have mainly been focused on electricity applications; it is easier to store heat than electricity using technologies and principles that have been applied to many different industries.

Meat processing facilities can benefit from the development of these technologies by considering the use of heat storage and collection technologies developed for electricity generation. Some of the options discussed are novel uses of new technology and so technically risky; however, there may be additional funds available from state and federal agencies to assist in such projects, particularly where these projects use Australian technologies.

MOLTEN SALT STORAGE

In this system, molten salts are stored in two tanks; one hot, the other cold. Salts on the way to the hot tank for storage are heated through a heat exchanger. When it is necessary to recover the thermal energy, salts pass back through the same exchanger transferring the heat to oil which reaches temperatures of just under 400°C. Thermal units (made of high heat capacity materials) store heat from a solar collector, which allows the linked power plants to produce electricity when direct solar energy is not available. The heat storage medium can be molten salt (eg Na_2NO_3, K_2NO_3) operating between 290°C and 390°C.

The most advanced and widely demonstrated thermal storage technology is the two-tank sensible heat system using molten salt as the storage medium.[46] The two-tank indirect system is being deployed in the Andasol solar thermal power plant in southern Spain, and is planned for Abengoa Solar's 280 MW Solana plant in Arizona. This concept was successfully demonstrated in a commercial trough plant (13.8 MWe[47] SEGS I plant; 120 MWht storage capacity) and a demonstration tower plant (10 MWe Solar Two; 105 MWht storage capacity).[48]

In an indirect system the salt is heated by (or heats) a second fluid that passes through the solar collector or the generator. In a direct system, molten salts are used for both the thermal transfer and storage. This means direct storage and higher temperatures are possible and costly heat exchangers can be eliminated. It is also possible to use only one tank and rely on thermal gradients to keep hot and cold material from mixing.

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[44] For example, Hardorn in 'Advanced Storage Concepts for Active Solar Energy' gives an example of sorption storage system involving a tank containing water (evaporator), and another tank containing a hygroscopic salt (reactor). The water will evaporate to the salt that absorbs the water. The absorption of water vapour has the effect of reducing the vapour pressure of water, and cause the liquid water to boil. This will remove heat from the environment. The process is reversed by heating the salt solution in the reactor. Energy storage by absorption and adsorption is more applicable to building heating and cooling rather than utility scale power generation. [Ref: http://www.solarthermalworld.org/files/Hadorn_storage.pdf?download/. Accessed 22 November 2010.]

[45] This is clearly demonstrated in the distribution of tasks of the IEA Solar Heating and Cooling Programme.

[46] "CSP thermal storage: Increasing the options", CSP Today, 12 March 2010

[47] The 'e' in MWe refers to electrical so MWe means electrical power. MWt refers to thermal power. Similar terminology is used for stored energy (MWhe and MWht)

[48] "Two-tank molten salt storage for parabolic trough solar power plants", Ulf Herrmann et al, doi:10.1016/S0360-5442(03)00193-2

Type	**Source:** Solar **Storage or generation:** Storage **Heat or electricity:** Heat
Applicability to the meat processing industry	Medium. Molten salt storage has been successfully demonstrated as an effective thermal storage medium, however, these projects have been linked to electricity generation. There may be more cost effective methods of storing heat on meat processing sites.
Current Status	Molten salt storage has been demonstrated at the pre-commercial stage. The SEGS I plant and Solar Two both included demonstrations of thermal storage. The thermal storage unit for Andasol 1 has a storage capacity of 1,010 MWh thermal, which is enough to run the plant for 7.5 hrs of full load operation.[49] Enel operate a 5MW CSP plant (Archimede) that uses molten salts for heat transfer and storage, and is integrated to an existing combined-cycle gas power plant.[50]
Size, Scalability and efficiency	Up to 1 GWh. In principle, the molten salt systems can be any size as the technologies involved are straightforward. Alternative storage systems are not so well understood as to allow for forecasts
Current and Projected Costs	Costs for just the storage component of the large solar power plants are hard to judge as they are fully integrated with the energy capture and electricity generation components. As the system components are simple and use technology established in other fields the costs of the thermal storage component of these systems is not likely to fall far. They are individually designed systems using standard components and so will benefit little from manufacturing scale.
Country of Development and Manufacture	Internationally, Spain (Andasol), USA (Abengoa, NREL), Germany (PCM at DLR), Europe (SolarPACES).
Drivers for uptake	Inexpensive materials, grid support.
Forecast Status: 5-10 years	These will continue to be deployed, particularly in combination with solar thermal.
Social and Environmental costs and benefits	The fluids used in molten salt– storage systems introduce some hazards. The salts are nitrates which act as fertilizers and can affect waterways. They are also strong oxidising agents and introduce risks of explosions if in contact with hydrocarbons.

MASSIVE SOLID THERMAL STORAGE

These systems store solar energy in graphite or concrete blocks as sensible heat storage. Sunlight is reflected onto the block from an array of mirrors causing it to heat. When electricity or steam is required, water is pumped into pipes inside the block where it is heated to steam temperatures. This steam can then be used to generate electricity or supply process steam. This system, if appropriately sized, can deliver energy generated from solar sources 24 hours a day.

[49] "Andasol: The World's Largest Solar Thermal Power Plant Project Development in Andalucia (Spain)". Solar Millennium. See http://www.solarmillennium.de/upload/Download/Technologie/eng/Andasol1-3engl.pdf.

[50] "The world's first molten salt concentrating solar power plant", Guardian Environment Network, 22 July, 2010

There have been major demonstrations of this technology in Australia, supported through the federal Advanced Energy Storage Technology program. The storage medium is graphite. This project culminated in a 1MW demonstration project at Lake Cargelligo in NSW. In this system, custom designed software controls heliostats which follow the path of the sun and direct its rays onto the receiver. Once the intensity of the sun's rays reduces to an inefficient level the entry point to the receiver is closed and sealed.

Graphite is being used as a heat storage medium because of its low emissivity and high specific heat. These characteristics enable systems that can store a large amount of energy per unit mass and hold it for long periods with little loss. In this system solar energy is stored by reflecting sunlight to a central block of graphite where it is absorbed. When steam or hot water is required, water is pumped through the block where it is heated. This system has been demonstrated for electricity production and has potential in process heat applications.

There is currently just one manufacturer of graphite thermal storage so much of the information below is based on this system.[51]

The German Aerospace Centre (DLR) has developed a thermal energy system for parabolic trough plants that uses concrete as the thermal energy storage medium. The heating medium can either heat or be heated by the concrete block, depending upon the relative temperatures. The system operates to temperatures of up to 400°C. DLR has successfully tested a 20m^3 concrete test module and another test facility, currently going into operation in Spain, will test direct steam generation.

Type	**Source:** Solar **Storage or generation:** Storage **Heat or electricity:** Heat
Applicability to the meat processing industry	Potentially high, but would be somewhat experimental. The ability to store large amounts of heat and generate steam on demand makes this a very attractive technology. However, as this application would likely be a first-of-type there is substantial technical risk.
Current Status	Market demonstration. Pilot demonstration was conducted at Cooma in NSW, followed by scale demonstration at Lake Cargelligo in NSW. Both of these projects were supported by grants from the federal Advanced Energy Storage Technology program
Size, Scalability and efficiency	Size: 3MWh (thermal)/module ~1MWh electricity per module Efficiency: Very high efficiency heat collector ~90%
Current and Projected Costs	$800,000 per 3MWh (thermal) module. This includes the block, tower and mirrors. Cost-competitive to supply steam at current natural gas prices.
Country of Development and Manufacture	Various. Graphite Energy is an Australian company developing a thermal storage system based on graphite blocks.
Drivers for uptake	Enables dispatchable solar energy and steam supply. Storing solar energy directly as heat is extremely effective.
Forecast Status: 5-10 years	Commercial deployment in less than 10 locations. Some international projects to generate electricity (Cypress and China) are under way, manufacturing facility being constructed in China.
Social and Environmental costs and benefits	Materials manufacture fairly inert, recycles windmill towers in some cases.

[51] http://www.ret.gov.au/energy/Documents/clean-energy-program/acre/studies/AEST-Final-Report-Lloyd.pdf

Factsheets

THE BUSINESS CASE FOR SOLAR PHOTOVOLTAICS

TECHNOLOGY OVERVIEW

Solar photovoltaic (PV) technology uses semiconductors to convert solar energy into electricity. Unit efficiency in terms of electricity generated compared to solar energy received varies from around 10% to over 40%, with around 17% most typical for non-military applications.[52] The global market for solar PV has grown rapidly in recent years, supported by subsidies in Germany and Spain, which have increased manufacturing capacity and lowered unit prices.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

Solar PV could be an attractive investment option, especially if:

- the variable electricity charge at the site is greater than 20 cents per kWh (this factor is based on current capital costs for Solar PV, the higher the electricity charge, the more favourable the project economics become); and
- the site has either a large roof surface facing north with unimpeded direct sunlight or large areas of unused land close to where the electricity needed.

HOW TO DEVELOP YOUR BUSINESS CASE

The actions to take when developing a business case for an on-site solar PV generation project include:

- Determine the electricity load profile at your facility
- Identify suitable buildings or areas for the PV panels
- Calculate the electricity generation potential from your PV system
- Estimate electricity savings and the capital investment required
- Approach the market for a quote for supply and/or installation of the equipment

DETERMINE THE ELECTRICITY LOAD PROFILE

Request your half-hourly interval meter data from your eelctrcity retailer to determine your load profile. You should aim to scale your system to meet daytime base load requirement (see figure 1).

Over sizing your PV solar installation can decrease the profitability of the project substantially, due to the difference between the cost of grid electricity and the amount paid for exported electricity.[53]

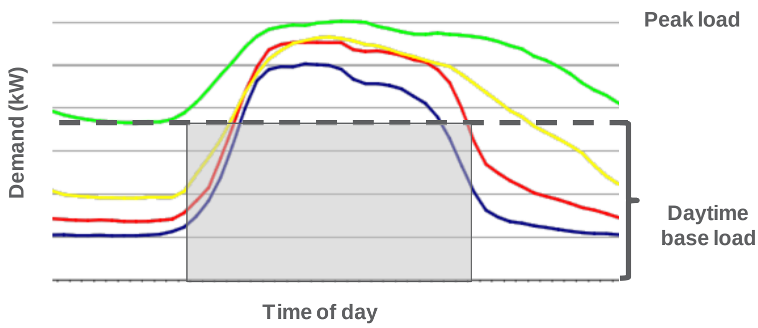


Figure 1: Illustrative seasonal load profiles

It is not recommended to include solar PV as part of a peak load and demand charge reduction strategy. Although in some instances it may be effective in reducing your peak demand, a single cloudy day could result in your peak demand returning to the pre-solar PV profile. This could result in the same demand charges as before.

IDENTIFY SUITABLE BUILDINGS OR AREAS FOR THE PV PANELS

52 The National Renewable Energy Lab in the US maintains a chart of record solar efficiencies over time, which can be found at http://www.nrel.gov/ncpv/images/efficiency_chart.jpg (Very large image)

53 For a full list of feed-in-tariffs across Australia visit www.energymatters.com.au/government-rebates/feedintariff.php#fit-table

Assess whether you have a large enough north facing roof surface with unimpeded direct sunlight or unused land close to where you need electricity. As a rule of thumb, you will need 10m^2 north facing roof/ground space per kilowatt of solar PV capacity installed.

CALCULATE THE ELECTRICITY GENERATION POTENTIAL FROM YOUR PV SYSTEM

Use the Clean Energy Regulator's (CER) "Postcode zones for solar panels" list to determine the typical electricity generating capacity at your location (i.e. MWh of electricity per kWp installed capacity). As an example, a typical flat panel array in NSW generates approximately 1.4 MWh of electricity per kWp installed capacity. Output is seasonal; summer and winter insolation in NSW often varies by 50% or more depending on the location.[54]

The system output will also vary depending on orientation and tilt angle[55] of the solar panels, 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% in efficiency. However, tracking adds significant cost and generally this outweighs the benefit of increased yield.

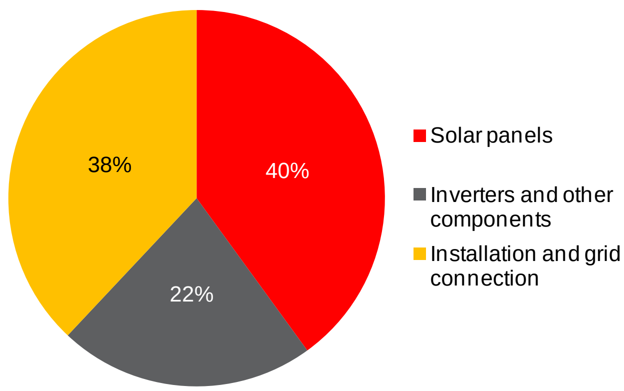
ESTIMATE SAVINGS, INVESTMENT REQUIRED AND FUNDING SOURCES

In addition to electricity savings,[56] also consider revenue from certificates under the Renewable Energy Target (RET) Scheme as a co-funding source. You can determine whether your project qualifies under the RET Scheme for Small-scale Technology Certificates (STCs) by referring to the CER website.[57] Many solar PV retailers will purchase future certificates (for an amount determined by the value of the certificates and the amount of energy the solar PV system will generate) upon selling the system (this is known as 'deeming') and reduce the sale price by the corresponding amount.

At present the upfront cost of a roof-mounted grid-connected solar array is approximately $2 per watt[58], once STCs are deducted. This does not change much irrespective of whether you are installing a 5kW or 100kW PV system.[59] As system size increases, economies of scale apply. However, a reduction in capital costs associated with equipment is offset by increased upfront cost associated with planning, grid connection, network studies and project management fees for larger projects. The intersection of these factors, in addition to load requirements and space, will influence the optimal project size.

Most PV panels have a warranted life of 25 years, and inverters typically closer to 10-years, but warranties vary depending on the manufacturer. Solar panel costs continue to fall, although at a slower pace than in recent years. Generally, solar panels constitute less than half the cost of a system as illustrated in Figure 2. Other variables to consider when costing your system include whether the system is grid connected, roof mounted or ground mounted, and whether storage capacity is required and how much.

The costs of an off-grid solar PV system tends to be higher due to additional auxiliary equipment such as energy storage systems, as shown in Figure 3. If security of supply is critical, back-up diesel generators may also be required for periods when the solar system does not generate electricity.



PV electricity

Figure 19: Grid connected solar PV - typical upfront

Ground mounted systems are often about 10% more expensive than roof mounted systems due to the requirement for additional civil engineering works such as concrete footing and piles.

[54] Go to the Australian Solar Energy Information System (ASEIS) http://www.ga.gov.au/solarmapping/?accept_agreement=on to see the variance in average solar radiation (MJ / day) for your area.
[55] The tilt angle of solar panels varies depending on latitude. Solar PV suppliers will model the most appropriate tilt angle for your project however, this is often set by the roof pitch.
[56] It is not recommended to include potential changes in demand charges in the payback calculation.
[57] http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Small-scale-Renewable-Energy-Scheme--SRES-/about-sres.
[58] http://www.businessspectator.com.au/article/2013/11/14/solar-energy/solar-pv-price-check-%E2%80%93-november.
[59] For example, the average price per kW for a 5kW system in Sydney, excluding government incentives, is approximately $2,300. STCs typically accounted for a discount of about **$680 per kW** for the Zone 3 cities such as Sydney. Retrieved on 1 October 2013 from: http://www.solarchoice.net.au/blog/solar-pv-price-index-september-2013/ ; Also see other system price estimates at http://www.solarchoice.net.au/blog/30kw-commercial-solar-power-installations-and-solar-farms-price-output-returns/ and https://www.standardsolar.com.au/new-solar-systems/100kw-solar-system.

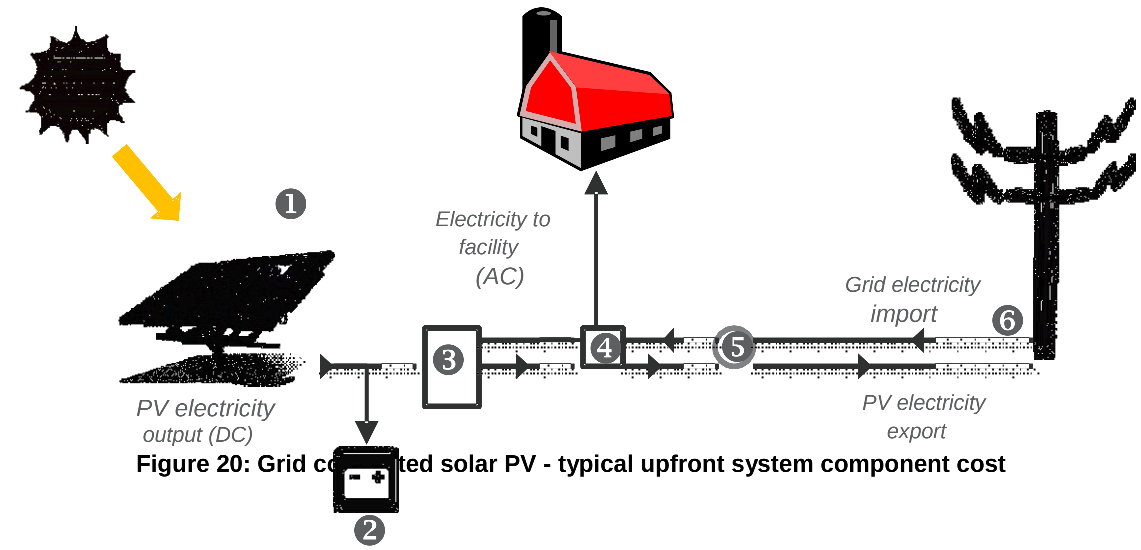


Figure 20: Grid co[...]ted solar PV - typical upfront system component cost

❶ Solar PV Panels ❷ Batteries and charge regulator ❸ Inverter ❹ Abattoir ❺ Meter ❻ Electricity Grid

Figure 3: Schematic of a grid connected PV system with battery storage

APPROACH THE MARKET FOR A QUOTE

Once you have determined the viability of your project, you should approach the market to quote for the supply and installation of the equipment. The installation and wiring of solar panels must be undertaken by a licensed electrical contractor (or the holder of a qualified supervisor certificate). If the solar installation needs to be connected to the electricity distribution network, contact your network provider to determine connection requirements. Generally the installer can install the panels and inverter, but the network provider is required for the connection to the grid.

If you wish to claim any State or Federal Government rebates, including STCs for the installation of solar panels, you should ensure the installer you use is accredited by the Clean Energy Council (CEC). A list of accredited installers is available on the CEC website (www.cleanenergycouncil.org.au). Every installation carried out by an accredited installer is required to meet the Australian Standards for installation[60] and products. The Clean Energy Council has compiled a list of approved products - including solar PV modules (panels) and grid-connect inverters - that meet these standards that can be accessed at www.solaraccreditation.com.au/approvedproducts.

EXAMPLE COST-BENEFIT ANALYSIS

Following is a simple example CBA based on high-level assumptions about site energy use. More detailed energy use data will better inform your decision, particularly when considering the proportion of electricity which is used during the day. Best-practice would be to use a model based on usage data, which compares potential generation with use, and determines the most appropriate size by maximising on-site energy use.

A more simplistic determination can be made based on the assumptions listed in Table 1. The average daytime electrical load for each season can be calculated using the formula below, with the results presented in the last column of the table.

The consumption figure should be taken from your electricity bills or be provided by your electricity retailer. The percentage of daytime use is typical for commercial installations and will change extensively for businesses which operate continuously, which could lead to daytime electricity use closer to 50% or 60% of total electricity use. The daytime hours estimate could be shaped to reflect seasonal variance, using data from the Bureau of Meteorology, but assuming 12-hours year round is satisfactory. The difference between summer and winter day-length decreases further north in Australia.

$$Daytime\ electrical\ load\ (kW) =$$

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[60] AS4777 Grid-connections of energy systems via inverters, AS/NZS 3000 Electrical wiring rules, AS1768 Lightning protection, AS/NZS 1170.2 Wind loads and AS/NZS 5033 Installation of photovoltaic (PV) arrays

(Electricity consumption (kWh) x percentage energy use in daytime) / daytime hours / days in season

Table 3: Key assumptions

Season	Consumption (kWh)	% of electricity use in daytime	Daytime hours (6 am and 6 pm)	Days	Daytime electrical load (kW)
Summer	165,600	80%	12	92	120
Autumn	136,500	80%	12	91	100
Winter	150,150	80%	12	91	110
Spring	163,800	80%	12	91	120
Total	**616,050**			**365**	

Based on the seasonable variability of the load at the example site detailed in Table 1, a 100kW solar PV system is recommended (i.e. 80% of the spring daytime load). This is a very conservative estimate that ensures onsite use is maximised, but larger systems could be favourable given more detailed calculations.

You will need to assess whether there is enough space to install this system.

$$Suitable\ space\ required\ (m^2) = 100kW \times 10\ m^2\ per\ kW\ = 1000\ m^2$$

Then calculate the electricity generation potential from your PV system, assuming the site is located in 'Zone 3'[61] with an electricity generating potential of 1.4 MWh per kW capacity (see Clean Energy Regulator postal code list).

$$Electricity\ generation\ potential\ (MWh) = 1.4\ MWh\ x\ 100 = 140\ MWh$$

Assuming the price paid for electricity is \$0.25/kWh, the annual energy savings of \$35,000 are anticipated (i.e. 140MWh x \$250/MWh). At an STC value of **\$680 per kW** or \$68,000 for this system, the payback period is reduced by two years. The value of STCs is typically discounted at the point of sale.

A preliminary assessment of the financial viability of a standard grid connected roof mounted solar PV installation is presented Table 2. These calculations do not account for future energy price increases and assumes no financing costs. It is further assumed that 100% of the energy is used to displace facility electricity use. A potential reduction in peak demand changes are not included, for reasons stated in the previous section.

Table 4: Illustrative simple payback

PV system capacity	Upfront cost (\$)	Upfront cost / W installed	Annual electricity production (MWh)	Simple payback on standard installation without incentive	Payback with existing incentives (i.e. STCs)
100kW	\$220,000	\$2.20	140	6.3 years	4.3 years

FURTHER INFORMATION

This fact sheet is number 1 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

[61] Refer Clean Energy Regulator website for more information http://ret.cleanenergyregulator.gov.au/Forms-and-Publications/Publications/calculations_stc

THE BUSINESS CASE FOR WIND TURBINES

TECHNOLOGY OVERVIEW

Wind turbines convert the kinetic energy generated by the wind into rotational mechanical energy to generate electricity.

The power available from a typical horizontal axis wind turbine (HAWT) is proportional to the cube of the swept area, so there is a strong incentive to make larger turbines. Thus development in this field is focused on materials and manufacturing techniques which increase the blade length and increase maximum power output. Similarly, wind speed is more constant at higher altitudes so turbines are mounted on tall towers. A typical grid scale wind turbine (2MW output) sits on a tower about 60m tall, supporting a turbine with 40m long blades. They are usually sited where the wind is strongest and most reliable, such as coastlines, ridgelines and land positioned in the roaring 40's, such as the Eyre Peninsula in South Australia.

Wind is an intermittent source of power and therefore is most commonly integrated with other base-load power generating systems.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

When it comes to wind turbines, bigger is generally better in terms of reliability and power output. However, small-scale (less than 600kW rated turbines) wind turbines can be a viable option for meat processing facilities that:

- use a significant amount of electrical energy,
- are located in windy areas (e.g. coastal or upland area), and
- are not surrounded by populated areas or areas with planning restrictions.

Assessing the potential for a wind turbine project at your facility is complex, especially due to the influence of topography on the quality of wind resource and wind characteristics. This fact sheet will provide high level guidance to conduct a preliminary assessment of the potential for wind power on your site.

HOW TO DEVELOP YOUR BUSINESS CASE

The actions to take when developing a business case for an on-site wind turbine include:

- Determine your site base load
- Identify the physical space available and regulatory constraints
- Determine the available wind resource and characteristics
- Estimate savings and cost (i.e. financial viability)
- Determine the planning constraints

DETERMINE SITE BASE LOAD

Request 12 months of half-hourly metering data from your electricity retailer. Determine the power demand or load requirement for a typical winter and summers day by dividing the kWh consumption data by the hours. Then assess the permanent minimum load that your operations require (i.e. the base-load in kW - see figure 1).

The load shape for winter and summer months are likely to be different depending on the nature of your operations. It is common practice to size any onsite generation to approximately 80% of base-load, taking into account future growth in electricity demand.

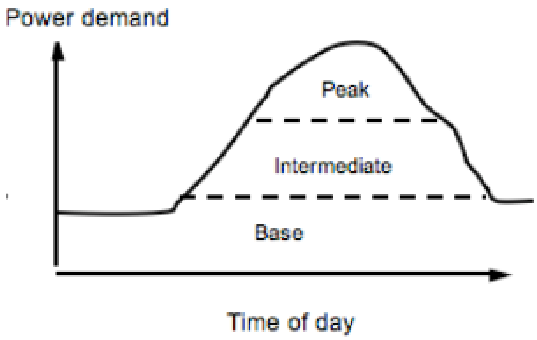


Figure 21: Illustrative demand curve

PHYSICAL SPACE AVAILABLE AND REGULATORY CONSTRAINTS

A wind turbine must be located where it will be exposed to the longest possible "fetch" (i.e. the distance over which the wind flows uninterrupted). Rough surfaces such as nearby forests or buildings can disturb the windflow, whilst hills and ridges can amplify the windflow. However, small-scale turbines are frequently located near buildings, trees and other potential obstructions. This requires careful planning to avoid a turbulent wind resource, which reduces the efficiency of the rotor and therefore the output of the turbine.

Space constraints may make a few smaller units more viable than one larger unit. However, as a rule of thumb, turbines should not be placed closer to obstructions than five times the diameter of the rotor to avoid significant loss of power.[62]

Site selection may be impacted by planning regulations; there are currently laws in NSW and Victoria which limit how close to residences new wind turbines can be placed. There could also be restrictions governed by local councils and planning authorities. Check with your authorities, both state and local before committing funds as these laws are changing frequently.

Other considerations include nearby natural habitats, important plant or animal species that may be impacted, landscape impacts and preferences of nearby communities. In addition, a buffer from major infrastructure such as public roads may be required.

WIND RESOURCE AND CHARACTERISTICS

Spatial and temporal variation of wind resource and characteristics are a major challenge when planning a wind project. The choice of method to assess the wind conditions depends on the certainty to which generation must be known.

As a preliminary assessment of whether your site is in a "windy location", you can refer to the Australian Wind Atlas, shown in Figure 2, for an indication of whether your site is located in a high wind speed zone. Sites located in the blue areas are less favourable for wind power systems. If you are in the orange to red areas, you could get an indication of the mean wind speed for your "region" from the Bureau of Meteorology's (BOM's) website. The BOM website publishes mean wind speed data taken at 9 am and 3 pm daily. Start by selecting a location close to your site. Using airport measurement stations typically provides more reliable results as these areas are open, generally unobstructed and the data collected is often higher quality because of its intended end use (health and safety regarding aircraft movements and weather forecasting).[63] This is just a proxy as on-site conditions will impact wind speed but does provide a guide to the local wind resource. To convert wind speeds provided by BOM in km/h to m/s, divide it by 3.6 (1 m/s = 3.6 km/h).

The BOM measurements are typically taken at 10m above the ground. To adjust the wind speed to take account of the likely height of your turbine hub is complicated. It depends on a range of factors such as the roughness of the surrounding terrain and the time of day.

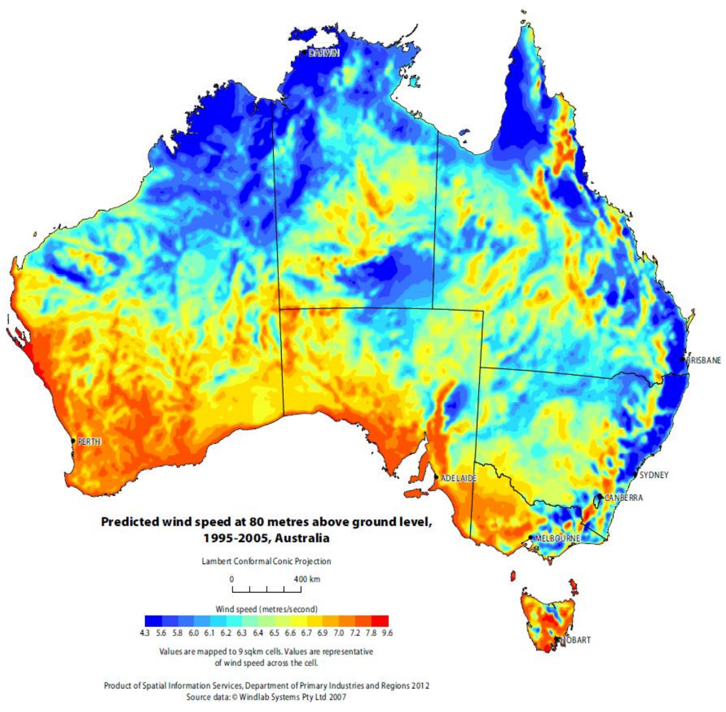


Figure 2: Australian wind atlas. A higher resolution version is available at http://www.renewablessa.sa.gov.au/files/121219-windresourcemappingaustralia.pdf

62 McKay, David (2008), Sustainable energy – without the hot air, Version 3.5.2., page 265 Accessed at http://www.inference.phy.cam.ac.uk/sustainable/book/tex/sewtha.pdf
63 Select the monthly statistic dataset for "Weather & Climate" available at http://www.BOM.gov.au/climate/data/index.shtml?bookmark=200

However, as a rule of thumb, wind speed increases by around 10% every time the height of the hub is doubled.[64]

Outlined below are two methods for assessing the wind resource at your site before engaging suppliers in more detailed investigation; the Easy Way and the Hard Way. The Easy Way is best applied to small scale projects, where the cost of detailed investigation may erode the benefits too much to proceed. The Hard Way is for larger projects, where the scale of investment warrants detailed estimation of the costs and benefits.

The Easy Way

Once you have determined your baseload electricity requirement, it is possible to select a turbine and estimate its output based on its capacity factor. Capacity factor is a measure of the actual output of a turbine against its potential output. For example, a 10kW turbine could theoretically output 87,600kWh per year. That is 10kW x 24 hours a day x 365 days a year. The capacity factor indicates what proportion of the theoretical maximum was achieved.

For turbines with a rated power of less than 10kW the capacity factor is typically between 10% and 15%. This could increase for larger units of 100kW to between 15% and 20% and for large turbines in commercial wind farms, capacity factors reach 30-40%. The basic “ballpark yield”, allowing for the 10% loss factor, could be calculated as follows:

$$\text{"Ballpark" Net Annual Electricity Generation } (kWh) = (\text{turbine rated power } (kW)\ x\ 365\ days\ x\ 24\ hours\ x\ \ capacity\ factor)\ x\ 90\%)$$

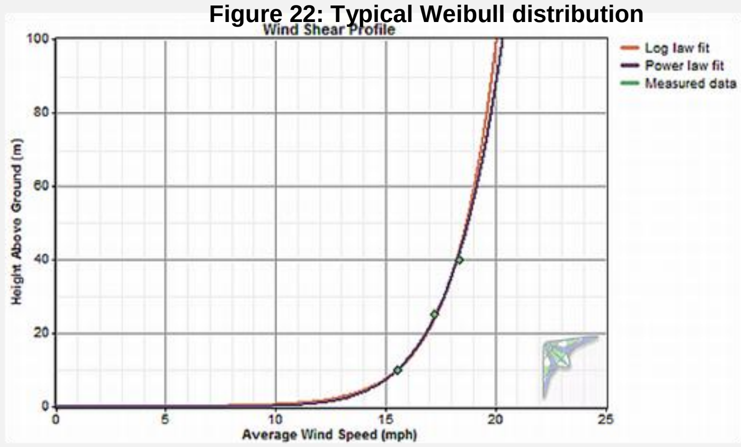
This estimate is enough to start investigating the costs and benefits. If greater certainty is required, use the Hard Way below to more accurately determine your wind resource.

The Hard Way

If you are in a windy location, your next step would be to determine the yield potential of the area (i.e. likely kWh of electricity to be generated by the wind turbine). This is a factor of the turbine’s power output at different wind speeds and the frequency that the wind blows at the different speeds. You will have the mean wind speed from the BOM website for your area. However, without detailed wind data the frequency distribution of the wind at different speeds is unknown. For a preliminary assessment, you could assume a Weibull distribution of wind speeds across the 8,760 hours available in a year. This is typical for sites with a good wind resource as illustrated in figure 3. This illustrated example has a mean wind speed measured at hub height of 4.8 m/s.

If the wind resource in your area and specific site looks attractive, you may want to invest in wind monitoring. Wind vanes and a wide range of anemometers are available on the market of varying quality. This is not straightforward as wind is seasonal and may vary significantly over short distances. For a big project you should consider engaging specialist data providers to conduct a feasibility study. They will be able to assist you in determining the wind resource, optimal turbine location, inter-annual variability and ultimately the business case for investing in a wind turbine. The cost of this service could be anywhere between $5,000 and $15,000 per site.

Figure 22: Typical Weibull distribution



To determine the likely power output from your project, start by selecting a turbine, or a number of turbines, with a rated power, or cumulative rated power, close to the base load requirements of your site. You can always adjust the size of the turbine(s) in later calculations. However, the power output from two turbines with the same rated power can vary significantly. Therefore, the type of turbine you select will determine power output of your project at different wind speeds, as reflected by the unique power curves[65] of different turbines (See figure 4).

64 McKay, David (2008), Sustainable energy – without the hot air, Version 3.5.2., page 266 Accessed at http://www.inference.phy.cam.ac.uk/sustainable/book/tex/sewtha.pdf

65 The power curves provides an indication of the likely power output at different wind speeds having taken account of the hub height, the rotor blade diameter, turbine efficiency factor and likely capacity factor.

Wind turbines are usually designed to start generating power at windspeeds of 3 to 4 m/s, also referred to as the cut in speed. Since small turbines are mounted at relatively low heights, the mean hub height wind speeds may be close to their cut in speeds. The implication is that, for long periods of time, a small turbine may not operate at all. Even if it does spin, it may not generate much electricity. In calculating the yield potential, only "useful" wind resource between the cut in and cut out speeds must be considered (See figure 4 – i.e. wind resource at stable speed between 4 m/s and 25 m/s in the example).

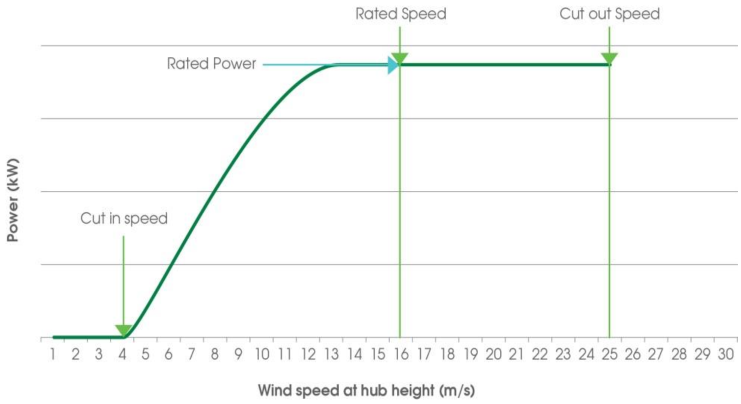


Figure 23: Illustrative wind turbine power curve

By applying the power curve of a selected turbine to the Weibull distribution of wind speeds, an approximate electricity yield can be calculated (see worked example section below). This yield is usually adjusted downwards by 10% to allow for maintenance (availability), electrical losses and other disruptions (loss factor) to output.

ESTIMATE SAVINGS, INVESTMENT REQUIRED AND FUNDING SOURCES

The wind resrouce assessment can be used to determine the potential electricity savings from a project. It is recommended that the electricity cost savings calculation be based on the variable ***electricity charge only***. Although the project may result in a reduction in peak demand changes, it is not recommended that you include this in your financial evaluation. A single calm day could result in your peak demand returning to the pre-wind project profile. This will result in the same demand charges as before.

In addition to electricity savings, also consider other revenue created by Government support programs, such as revenue from certificates under the Renewable Energy Target (RET) Scheme. You can determine whether your project qualifies under the RET Scheme for Small-scale Technology Certificates (STCs) and Large-scale Generation Certificates (LGCs) by referring to the Clean Energy Regulators website.[66] Wind systems less than 10kW are eligible for STCs and those greater the 10kW are considered large scale and qualify for LGCs. Both certificates act as revenue support for a project and typically trade in the range of $30-$40 each.[67]

Guidelines for the high level financial viability assessment for a wind turbine project as shown in Table 2. If the high level business case looks attractive, approach the market for quotations before developing a detailed business case.

Table 5: Planning assumptions for small scale turbines (<100kW capacity)

Upfront cost	Life of the system	Annual maintenance cost
Cost are highly variable but average around $5000/kW, including equipment, permits and installation cost.	25 years	$60/kW of installed capacity

EXAMPLE COST-BENEFIT ANALYSIS

A meat processing facility has a base load of 500 kW, taking account of seasonable variation in electricity use. The facility is located in an area with a Weibull distribution of wind speeds typical of a good site as illustrated in Table 3 (Column A and B). The facility manager has sourced the power curve for a wind turbine with a rated power of 500kW (Column C). The electricity production (column D) for each "wind speed bin" can be derived by applying the following formula:

$$\begin{aligned} & Electrcity\ generated\ per\ bin\ (kWh) \\ & = Duration\ of\ wind\ at\ bin\ speed\ as\ a\ percentage\ of\ the\ total\ hours\ in\ a\ year\ x\ wind\ power\ at\ bin\ speed \\ & = (Column\ B\ x\ 356\ days\ x\ 24\ hours)\ x\ Column\ C) \end{aligned}$$

66 http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Small-scale-Renewable-Energy-Scheme--SRES-/about-sres
67 Each MWh of output = 1 LGC or 1 STC depending on the installed capacity (system size)

Table 6: Illustrative application of power curve data to a good wind site

Assumed		ABC Wind turbine 15kW	Calculated	
Wind speed bins (m/s)	Wind distribution (Weibull distribution - hours pa)	Turbine Power Curve (kW)	Turbine electricity production (kWh)	
A	B	C	= (B x 356days x 24 hrs) x C	
0	0.00%	-	-	
1	5.27%	-	-	
2	11.00%	-	-	
3	15.20%	-	-	
4	16.85%	-	-	
5	15.89%	63	88,157	Wind resource range
6	13.07%	127	145,023	
7	9.48%	197	163,320	
8	6.10%	267	142,495	
9	3.50%	337	103,221	
10	1.79%	400	62,721	
11	0.82%	450	32,324	
12	0.33%	477	13,779	
13	0.12%	493	5,186	
14	0.04%	500	1,752	
15	0.01%	500	438	
16	0.00%	500	0	
17	0.00%	500	0	
18	0.00%	500	0	
19	0.00%	500	0	
20	0.00%	500	0	
21	0.00%	500	0	
22	0.00%	500	0	
23	0.00%	500	0	
24	0.00%	500	0	
25	0.00%	500	0	
Total excluding losses			758,416	
Less 10% losses due to maintenance			75,842	
Net Annual Electricity Generation (kWh)			682,574	

Sum the electricity produced at each bin speed to derive an estimate of the electricity this turbine will generate, namely 758,416kWh per annum. The 682,574 kWh net annual electricity generation represents a capacity factor of 15.6% (i.e. 682,574 kWh / (500kW x 365 x 24). Assuming a variable electricity charge of $250/MWh, this represents annual savings of:

$$= 683\ MWh\ x\ \$250/MWh \cong \$170{,}500 \text{ per annum}$$

Assuming the project qualifies for LGCs which have recently been trading at ~$36/ MWh, the annual revenue from government incentives could be in the region of $24,500 per annum, reducing total annual electricity cost by approximately $195,000.

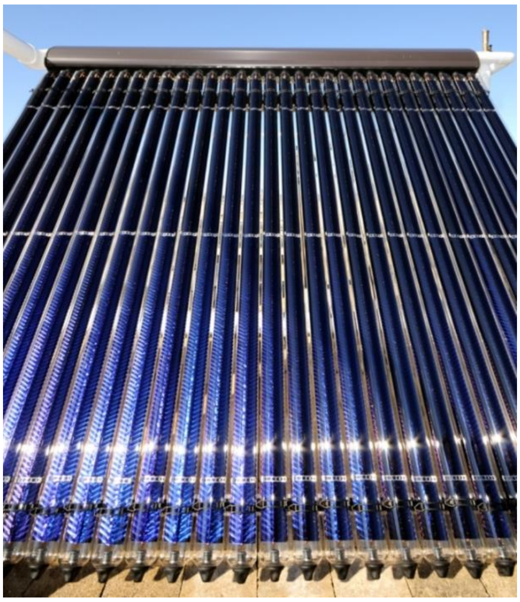
$$= 683\ MWh\ x\ \$36/MWh \cong \$24{,}500$$

At an upfront cost of approximately 500kW x $5000 = $2,500,000 the simple payback on this project will be 13 years. This calculation does not account for future energy price increases and assumes no financing costs. It is further assumed that 100% of the energy is used to displace facility energy use.

FURTHER INFORMATION

This fact sheet is number 2 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

THE BUSINESS CASE FOR EVACUATED SOLAR THERMAL TUBES



TECHNOLOGY OVERVIEW

Evacuated solar thermal tubes are one of the most widely used renewable energy systems in the world. They have provided a cost-effective alternative for heating water for domestic applications in Australia for over 20 years. The systems are simple and reliable, some with no moving parts. There is a well-developed manufacturing, service and installation industry in Australia.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

Solar thermal systems can heat water from ambient to around 70°C. If a site requires water at 130°C for rendering, this technology can be used to raise the temperature of water from ambient to 70°C, with the remainder provided by other heating sources such as an instant gas water heater. The collector heats water during the day which is stored in a tank. When hot water for rendering or sterilizing is required the water flows from the tank through the gas heater, which checks the temperature. The water is heated further if required.

These systems are most suitable for:

- Areas with high insolation (i.e. high amount of solar energy received per unit area)
- Colder climates – compared to flat panel collectors which are less efficient
- Sites with high or increasing heating energy costs
- Sites with large hot water or steam loads

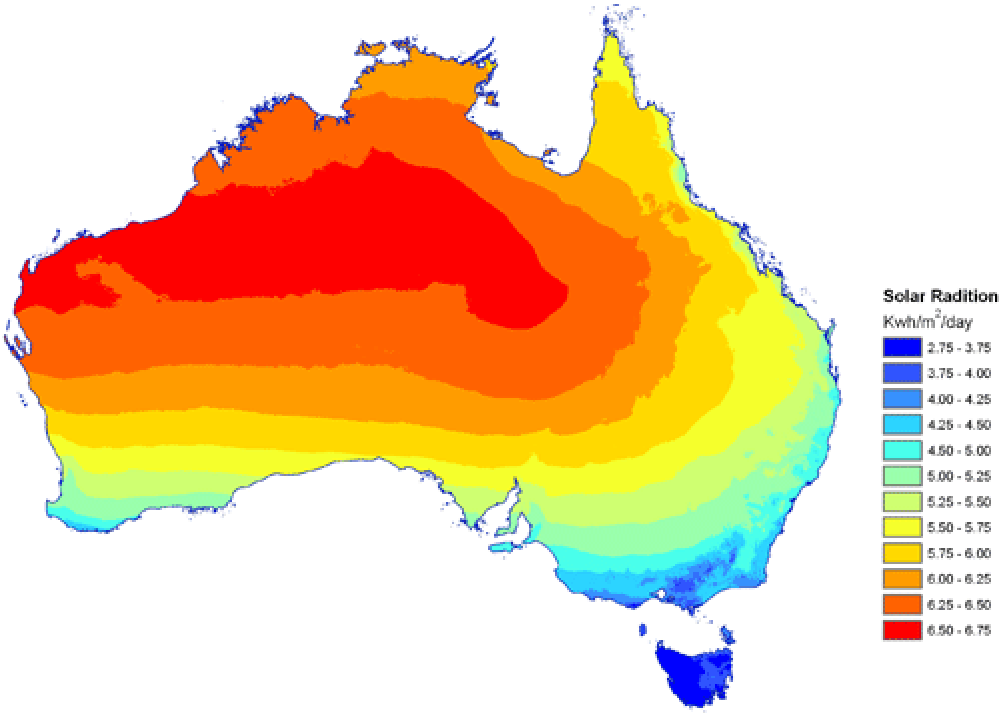
HOW TO DEVELOP YOUR BUSINESS CASE

The steps to consider when developing a business case for an evacuated tube system include:

- Determine the amount of sun received at the site (insolation)
- Identify suitable buildings or areas for the tubes
- Calculate the energy saving of the tubes
- Estimated savings and the investment required
- Approach the market for a quote

DETERMINE YOUR INSOLATION

Insolation is the amount of solar energy received per unit area. It varies around Australia and is generally presented as a map, like the one below. These values are often normalised to equivalent midday insolation received per day, to make the comparison between areas easier. Higher values indicate more favourable solar conditions.



Australian mean annual solor radiation levels (data and map supplied by CRES, ANU)

IDENTIFY SUITABLE BUILDINGS OR AREAS FOR THE EVACUATED TUBES

Assess whether you have a large enough north facing roof surface or unused land with good, direct sunlight. Based on an insolation of 5kWh/m^2/day, each square metre of evacuated tubes can heat a tonne of water about 4°C.

CALCULATE THE ENERGY SAVINGS OF THE TUBES

Collection efficiency of evacuated tubes approaches 80% for most units. This can be used with the insolation data above to estimate the energy saved throughout a year. These data are averaged over a year, so to calculate the energy collected, find the insolation of your site, multiply by the number of days per year, the area of tubes proposed and the efficiency. This will be covered in more detail below.

ESTIMATE SAVINGS, INVESTMENT REQUIRED AND FUNDING SOURCES

Typical systems retail at about $400/m^2 of collector, with discounts possible for large purchases.

The cost to install a solar hot water system can be significantly reduced through generous government rebates. You could be eligible to receive Small-scale Technology Certificates (STCs). An STC is a measure of renewable energy which can be traded for money or a discount on the purchase price.

A new solar hot water system is eligible if:

- it is a new system and is listed on the register of solar water heaters on the website of the Clean Energy Regulator (http://ret.cleanenergyregulator.gov.au/Hot-Water-Systems/eligible-swhs)
- small-scale technology certificates are created within 12 months of installation. If you choose to go through an agent they will create the certificates on your behalf.

Agents registered with the Clean Energy Regulator will offer you a financial benefit for your small-scale technology certificates, such as a discount off the invoice, in exchange for the right to create and sell certificates.

You can determine the number of certificates your system is eligible for by using the solar water heater calculator on the website of the Clean Energy Regulator (https://www.rec-registry.gov.au/swhCalculatorInit.shtml).

Alternatively, you can ask your registered agent about the number of certificates your system is eligible for, and the price they are offering for each small-scale technology certificate. The financial benefit is usually based on the small-scale technology certificate price at the time of the offer, as this fluctuates depending on supply or demand.

The Clean Energy Council publishes the small-scale technology spot price on its website; however different traders may offer different prices depending on the buyer. You may wish to conduct an internet search for 'STC price' or 'REC price' to find other traders and prices.

EXAMPLE COST-BENEFIT ANALYSIS

An abattoir in northern NSW wants to reduce their fuel costs for water heating. They are currently using natural gas which is provided at $8/GJ. Their current boiler has an efficiency of about 90% and consumes 5,000GJ of gas annually, which provides 4,500GJ of heat to water annually and an annual gas bill of $40,000.

They have a large warehouse with good northerly solar access. They want to deliver about 90% of their load with solar thermal tubes, so they are determining what area of tubes can deliver this load.

Annual Gas GJ	At 80% collector efficiency	Daily Requirement GJ	Conversion to kWh	Area required at 5kWh/m^2 (m^2)	Cost at $400/$m^2$	Simple Payback
4,500	5,625	15.4	4281	856	$342,400	8.5 years

A method to calculate the energy savings for solar hot water systems in Australia is covered in great detail in Australian Standard AS4234 and summarised well by the Green Building Council of Australia. The pdf of this method can be found at the link below.[68]

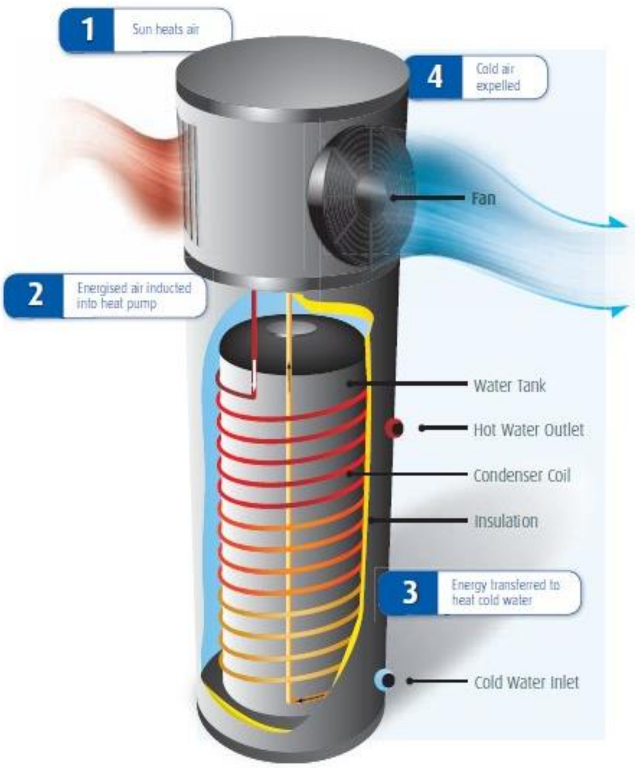
FURTHER INFORMATION

This fact sheet is number 3 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

68 http://www.gbca.org.au/uploads/221/1757/Green%20Star%20-%20Solat%20Hot%20Water%20and%20Heat%20Pump%20Booster%20Energy%20Calculation%20Methodology.pdf

THE BUSINESS CASE FOR HEAT PUMPS

TECHNOLOGY OVERVIEW



Heat pumps use electricity to move heat between two places. The most common of these use the vapour-compression cycle, or refrigeration cycle, and is commonly applied in domestic refrigerators and air conditioners and more recently modern reverse-cycle air conditioners which can both heat and cool. While refrigerators can be considered heat pumps they will not be included in this fact sheet.

Heat pump performance can be compared using the Coefficient of Performance (COP) which is a measure of the heat moved per unit electricity consumed. So a heat pump which moves four MJ of heat per MJ of electricity has a COP of 4. Higher COPs indicate more efficient units.

Heat pumps have improved markedly in recent years, driven by the widespread use of electrically-commutated motors, often described as “inverter technology”, “DC” or “brushless motors”. These motors are as much as 70% more efficient than the motors previously used in air conditioners. As each heat pump system typically has three motors which use 70% or greater of the system energy use, improving the motor efficiency makes a significant change to overall system performance. Where older, and poor performing heat pumps have COPs around 3 and even less, modern heat pumps achieve COPs as high as 6. The energyrating.gov.au website, run by the Federal Government, rates the efficiency of heat pumps available on the Australian market, providing values for both heating and cooling, and for operation in cold climates.

Figure 24 Schematic of a typical heat pump water heater[69]

[69] Taken from here https://www.solarmarket.com.au/solar_hot_water/choosing_a_system/

AIR SOURCE OR GROUND SOURCE?

The performance of a heat pump is driven by the temperature of both the ‘hot place’ and the ‘cold place’. In a heating application the hot place is that being heated, and the cold place is the source of heat, typically the ambient air. As the ambient temperature changes, the amount of energy available per cycle of working fluid changes and so does the system performance. Consider Figure 2[70], which shows the performance curve of a heat pump hot water heater. This illustrates how both the ambient and tank temperature alter system performance, with the most efficient arrangement being a combination of low tank temperature and high ambient temperature.

This relationship means that when a heat pump is most needed, during extreme heat or cold, the ambient conditions are sub-optimal. One way to address this is by using the ground as the external heat source/sink. The ground temperature fluctuates far less than ambient temperature, and is generally cooler in hot climates and warmer in cold climates.

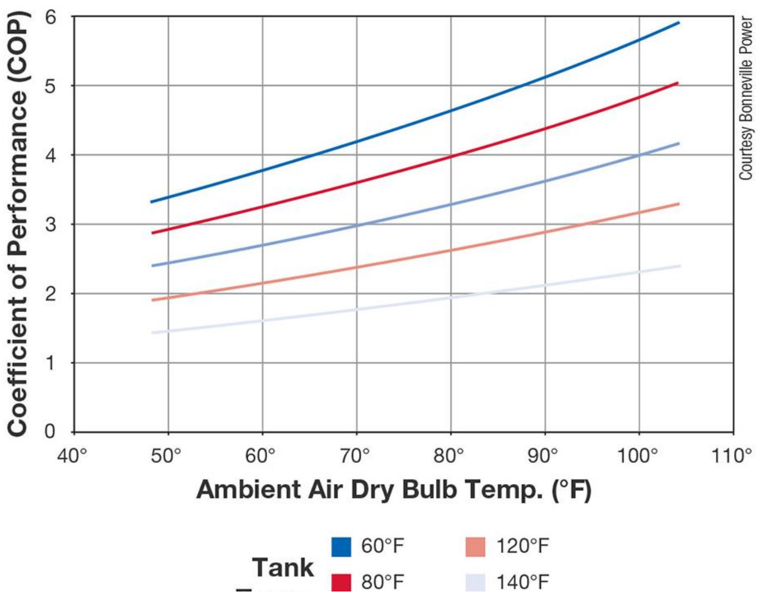


Figure 25: An example COP vs ambient air temperature for a heat pump hot water system

Figure 3 shows a plot of soil and air temperature for a cold northern hemisphere site, so winter is December to February. In this scenario the heat pump would be used during winter for heating. The green bars represent the difference between air and soil temperature, with positive results indicating the soil is warmer. So in this situation any time where the green bar is positive a ground source system would be more efficient. This can become even more acute where time of day is considered; typically ground temperatures are fairly stable overnight, while air temperatures are lowest in the morning before the sun starts heating the air.

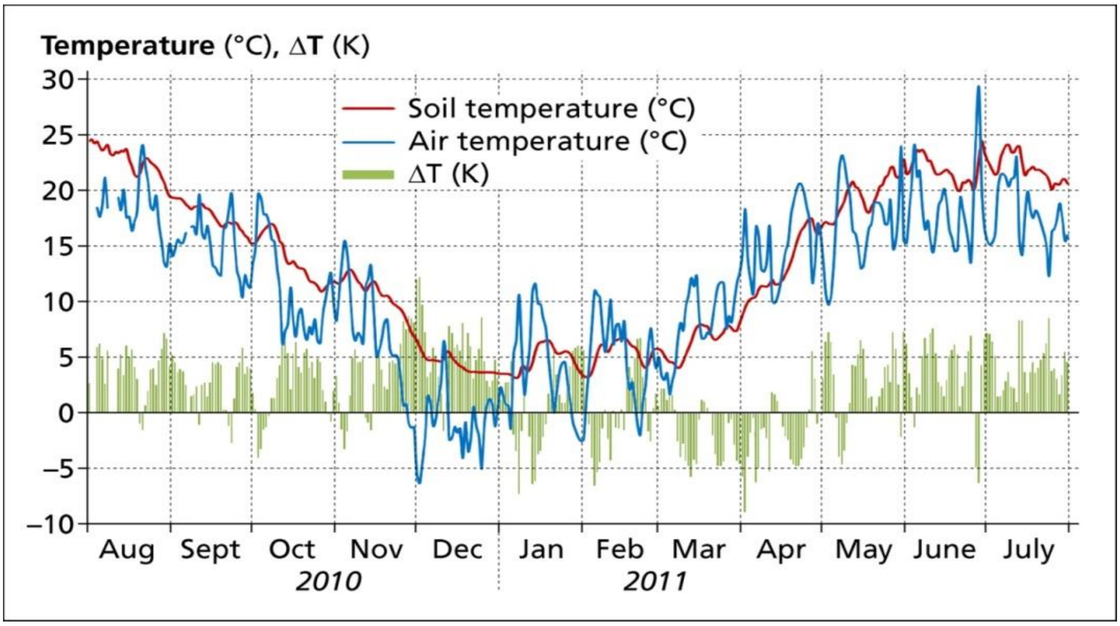


Figure 26: Daily mean values of air temperature (2 m above ground) and subterranean (2 m below ground) temperatures in Oberhausen, Germany, and their difference for the period 08/2010 – 07/2011 (source: H. Püllen, pers. comm.)[71]

70 Taken from http://www.homepower.com/sites/default/files/articles/ajax/docs/3_HP156_pg58_Gocze-2.jpg
71 Wilhelm Kuttler (2012). Climate Change on the Urban Scale – Effects and Counter-Measures in Central Europe, Human and Social Dimensions of Climate Change, Prof. Netra Chhetri (Ed.), ISBN: 978-953-51-0847-4, InTech, DOI: 10.5772/50867. Available from:

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

Heat pumps are most suitable in hotter climates in order to maintain worker comfort, although they may be replaced by water chillers in larger facilities.

Heat pumps are beneficial in cooler climates for heating water, particularly in the absence of natural gas. A short comparison of natural gas and heat pump heating will be provided later.

Ground source heat pumps could be worthwhile in hot climates with stable ground temperature.

HOW TO DEVELOP YOUR BUSINESS CASE

The business case requires a relatively simple comparison of improved efficiency against capital costs. Websites like energyrating.gov.au offer a good starting point to consider the efficiency and capital cost of different heat pumps. This site has the energy efficiency rating, purchase cost and coefficient of performance for each system and includes a calculator to determine your energy costs. Once this desktop analysis has been performed you can then approach the market for quotes, or seek a more detailed feasibility study.

When seeking quotes be sure to ask about the installation cost and any limitations on the system. Most modern heat pumps are split systems, which use an evaporator and condenser in different locations, joined by refrigeration pipes and electrical control. Each half consists of a heat exchange coil and a fan and requires about a metre of clear space to allow airflow through the coil.

The Green Building Council of Australia also have an excellent guide on calculating savings from heat pumps.[72]

FUNDING SOURCES

The cost to install a heat pump hot water system can be reduced by utilising Government incentive schemes (if available). You could be eligible to receive Small-scale Technology Certificates (STCs). An STC is a measure of renewable energy which can be traded for money or a discount on the purchase price.

A new heat pump hot water system is eligible if:

- it is a new system and is listed on the register of solar water heaters on the website of the Clean Energy Regulator (http://ret.cleanenergyregulator.gov.au/Hot-Water-Systems/eligible-swhs)
- small-scale technology certificates are created within 12 months of installation. If you choose to go through an agent they will create the certificates on your behalf.

Agents registered with the Clean Energy Regulator will offer you a financial benefit for your small-scale technology certificates, such as a discount off the invoice, in exchange for the right to create and sell certificates.

You can determine the number of certificates your system is eligible for by using the solar water heater calculator on the website of the Clean Energy Regulator (https://www.rec-registry.gov.au/swhCalculatorInit.shtml).

Alternatively, you can ask your registered agent about the number of certificates your system is eligible for, and the price they are offering for each small-scale technology certificate. The financial benefit is usually based on the small-scale technology certificate price at the time of the offer, as this fluctuates depending on supply or demand.

The Clean Energy Council publishes the small-scale technology spot price on its website; however different traders may offer different prices depending on the buyer. You may wish to conduct an internet search for 'STC price' or 'REC price' to find other traders and prices.

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http://www.intechopen.com/books/human-and-social-dimensions-of-climate-change/climate-change-on-the-urban-scale-effects-and-counter-measures-in-central-europe

72 The full methodology is available here in pdf http://www.gbca.org.au/uploads/221/1757/Green%20Star%20-%20Solat%20Hot%20Water%20and%20Heat%20Pump%20Booster%20Energy%20Calculation%20Methodology.pdf

EXAMPLE COST-BENEFIT ANALYSES

REPLACING A SPACE COOLING HEAT PUMP

The control room air conditioner at an abattoir needs to be replaced. The old unit had a COP of 3 and is known to consume 20,000kWh per year. Assuming a flat performance curve (for simplicity) it is determined that the cooling requirement is 60,000kWh per year.

Two new units are being considered to replace the old unit. These units will deliver the same amount of cooling; however one has a higher capital cost and efficiency, and hence a lower annual electricity cost, than the other.

The efficiency, annual electricity consumption, annual electricity cost, and capital cost of the two units is illustrated in the table below. The price paid for electricity is assumed to be $0.25/kWh.

Unit	COP	Electricity required to deliver 60MWh of cooling (kWh)	Annual electricity cost (at 25c/kWh)	Capital cost ($)
Unit A	5.1	11,764	$2,941	$750
Unit B	5.5	10,909	$2,727	$950

Based on these values, a preliminary assessment of the financial impact of selecting Unit B, which is more efficient, though has a higher up-front cost, is shown in the table below.

Annual electricity saving (kWh)	Annual electricity cost saving ($)	Additional capital cost	Payback of purchasing Unit B rather than Unit A
855	$214	$200	0.9

This calculation shows that the extra up-front cost of Unit B will be repaid within one year of purchasing the unit due to the lower electricity costs with this more efficient unit.

HEAT PUMP HOT WATER BOOSTER

A rural abattoir has to replace an electric resistance hot water heater. A 5m^2 array of solar evacuated tubes was installed the year before and until now boosting had been provided by the electric hot water heater. The electric unit consumed 75,000MJ per year, or 20,833kWh of electricity.

Site engineers are considering replacing the electric unit with either a gas boosted or heat pump boosted system.

The efficiencies, annual energy requirements and costs, and capital costs of these two systems are shown in the tables below.

Instant Gas

Efficiency	Gas required to deliver 75GJ of heat (MJ)	Annual gas cost (at $9/GJ)	Capital cost ($)	Total for five-years
85%	88,235	$794	$700	$4,670

Heat Pump

COP	Electricity required to deliver 20.8MWh of heat (kWh)	Annual electricity cost (at 25c/kWh)	Capital cost ($)	Total for five-years
5.2	4,006	$1,002	$1,000	$6,010

As can be seen, the instant gas unit has both a lower up-front capital cost and lower annual energy cost. Therefore in this scenario the instant gas hot water heater represents a better investment. However, this comparison is highly dependent on the input fuel cost. At gas prices of about $12 and above the heat pump becomes more attractive.

The heat pump is eligible for Small-scale Technology Certificates (STCs), tradable certificates that offer an incentive for heat pumps and solar hot water heaters. Many retailers will deem STCs at the time of sale, reducing the sale price or they can be claimed after purchase. In this case the system is eligible for 26 STCs[73], which are trading at $20. This lowers the price of the heat pump system by $520, thus making it a more attractive investment compared to the instant gas heater.

GROUND SOURCE COOLING

A northern Australia abattoir finds that their air conditioner struggles during hot days, causing discomfort in the workplace. Site engineers plan to replace the existing system and are considering a ground source heat pump. The outgoing air conditioner was metered separately and delivered 60,000kWh of cooling each year. The new system will be sized to deliver 80,000kWh each year.

The site engineers find a local installer who can supply a heat pump system with either ground source or air source. Ground source comes with additional capital expenditure, but improved system performance.

The supplier has a data set comparing ambient and underground temperatures for the last 12-months, measured daily at midday. They also supply the performance curve for the heat pump system, showing COP against condenser temperature.

The following table provides a simplified comparison of the two systems using these data. This comparison assumes that maintenance costs are the same and that the installation of the ground source system costs an extra $5,000.

Month	Cool delivery (kWh)	Air temp (°C)	Air source COP	Air source electricity use	Ground temp at 5m (°C)	Group source COP	Ground source electricity use (kWh)	Energy saving from ground source (kWh)	Energy cost saving (at 25c/kWh)
January	10,000	35	2.8	3,571	17	4	2,500	1,071	$268
February	10,000	34	3	3,333	17	4	2,500	833	$208
March	6,800	27	3.2	2,125	16	4.2	1,619	506	$126
April	6,800	25	3.4	2,000	16	4.2	1,619	381	$95
May	6,800	24	3.45	1,971	16	4.2	1,619	352	$88
June	3,000	22	3.6	833	15	4.3	697	136	$34
July	3,000	21	3.8	790	14.5	4.4	681	108	$27
August	3,000	22	3.6	833	14	4.5	666	167	$42
September	6,800	24	3.45	1,971	15	4.3	1,581	390	$97
October	6,800	25	3.4	2,000	16	4.2	1,619	381	$95
November	6,800	27	3.2	2,125	16.5	4.1	1,658	467	$117
December	10,000	32	3.25	3,077	17	4	2,500	577	$144

The total annual savings of installing the ground source heat pump rather than the air source heat pump is $1,342. Considering the ground source heat pump would cost an extra $5,000 to install, this results in a simple payback period of 3.7 years.

As both of these systems are heat pumps they are eligible for the same number of STCs. This will lower the price of each by the same amount and thus does not impact the comparison.

FURTHER INFORMATION

This fact sheet is number 4 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

[73] STC allocations around Australia are available here http://ret.cleanenergyregulator.gov.au/Hot-Water-Systems/Incentives-for-your-Solar-Water-Heater/Heat-Pump/incentives-hot-water-heat-pump

THE BUSINESS CASE FOR METHANE CAPTURE & REUSE

TECHNOLOGY OVERVIEW

Anaerobic digestion is the breakdown of organic matter using naturally occurring bacteria in the absence of oxygen. The by-products produced from this process include a composite gas, referred to as 'biogas', and nutrient-rich solid residue, referred to as digestate.

The biogas is comprised of predominantly methane (CH_4), in addition to carbon dioxide (CO_2) and small traces of naturally occurring gases. The methane, can then be used for power generation, heating or chemical transformation.

Methane capture and reuse is a commercial renewable energy technology, widely used in the sewage treatment and meat processing industries for the production of biogas from waste streams.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

This technology is highly applicable to the meat processing industry as it works most effectively with organic waste streams such as those found at abattoirs.

The feasibility of methane capture and reuse is site specific and influenced by a range of factors, including:

- The cost of existing thermal fuel(s) used at the site (i.e. gas, coal, oil).
- The organic loading of the wastewater stream (which determines the methane generation potential from the anerobic digestion process).
- Potential to reduce current waste storage, treatment and transport cost.
- Revenue from existing waste management strategies (such as Tallow production) compared to the revenue generated by or cost savings associated with methane capture and reuse, or sale of the digestate[74].
- Labour cost differential between existing and new waste management strategies.
- Non-economic benefits (i.e. odour control).
- Potential to benefit from carbon offsets. Methane has a global worming potential of 25[75] times that of carbon dioxide. Combustion transforms methane into heat and carbon dioxide.
- For some sites using biogas could be as simple as covering the existing anaerobic lagoon and using the captured gas to heat boiler water. In others though anaerobic digestion will require complex piping, a new digester and staff who can operate the system in a safe and effective manner.

74 This is the material remaining after the anaerobic digestion of a biodegradable feedstock. The solids left after digestion can be used as a soil conditioner, fertiliser or even as bedding for farm animals.

75 http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

DEVELOPING THE BUSINESS CASE

The main factors to consider when developing a business case for a methane capture and reuse project include:

- Assess the waste resource quality and quantity
- Determine the suitability of the site
- Compare the onsite energy demand with the biogas generation and utilisation potential of the anaerobic digestion system
- Estimate potential savings and cost
- Evaluation funding options

ASSESS THE WASTE RESOURCE

The anaerobic digester should be scaled to use the feedstock available from the site or nearby (i.e. from third parties). Without a continuous supply (e.g. daily or weekly) of the specific type of feedstock for which a facility is designed, the investment in an anaerobic digester may not be justified as it will be operating only part time.

The waste stream can be modelled based on the head processed per day or week, and using industry standard factors for the waste and type of waste per head for different species. Determining the methane generation potential from abattoir waste can be complex as waste streams are non-homogeneous. The methane production potential influenced by various factors including the composition of the waste stream (i.e. relative portions of fats, oil, greases, cellulosic material, nutrients) and the volume of waste.

DETERMINE THE SUITABILITY OF THE SITE

A methane capture and reuse facility requires space for the production, storage, movement, handling and utilisation of biogas. Physical space constraints, as well as safety and environmental requirements should be considered. Planning guidelines for methane capture and reuse projects are evolving. A good starting point for methane capture and reuse projects is Pork Australia's Code of Practice for On-farm Biogas Production and Use (Piggeries).[76] A Biogas handling and reuse manual is under development and will be available from AMPC by mid-2014.

There are two main types of anaerobic systems; covered anaerobic lagoons (CALs) and in-vessel digesters (IVADs). In a CAL, biogas accumulates under an impermeable cover and is piped for processing. In IVADs, the digestion process can be more controlled, meaning the mixing rate, temperature and bacterial mix can be modified to enhance the process. A CAL is generally cheaper to construct, but requires more space and consideration for clean out of solids every few years due to build-up of sediment.

COMPARE THE ONSITE ENERGY DEMAND WITH THE BIOGAS GENERATION AND UTILISATION POTENTIAL OF THE ANAEROBIC DIGESTION SYSTEM

Anaerobic digestion facilities are most economically attractive when the captured methane is used to displace incumbent fuel sources such as natural gas, LPG or electricity. Electricity generation from methane, as part of a cogeneration system, is a secondary consideration due to the relatively high cost associated with grid connection and operation and maintenance of such systems. However, cogeneration may be feasible in the event of a large supply of biomass, potentially requiring off-site sources as part of a 'community-scale' project to ensure a constant supply of feedstock to justify the infrastructure investment required.[77] Generation of electricity alone without heat recovery is generally not economically viable due to current capital costs outweighing current electricity prices.

ESTIMATE POTENTIAL SAVINGS AND PROJECT COST

76 http://porkcrc.com.au/wp-content/uploads/2013/07/BIOGAS-2011_1013.423-FINAL-REPORT-CONSULTATION.pdf

77 See the AMPC factsheet "Cogeneration and trigeneration"

Anaerobic digestion of manure and abattoir waste should be considered as part of an integrated waste and energy strategy, as it can assist in meeting any environmental consent requirements, and reduce the cost of waste disposal and energy.

The cost of feedstock, if unused, is generally negative (i.e. avoided cost of storage, treatment and transport). However, other uses for the waste (e.g. Tallow) will be impacted and should be factored into your cost estimate as an 'opportunity cost'. Also assess the impact the methane capture and reuse project may have on business process and cost, such as manure management.

Also consider the commercial value of by-products from the anaerobic digestion process, such as bio-solids that can be used or sold as compost.

Consider the savings achieved by displacing existing fossil fuel energy sources (i.e. displaced gas and / or electricity sourced from the grid). Electricity consumption and the demand profile of the site can be reduced which would result in a reduction in demand charges at the site.

Project Economics Considerations

Project costs vary significantly depending on a range of variables such as the technology of choice, the scale of the project, and the installation method.

METHANE CAPTURE SYSTEM

This can range from a simple and low-cost cover for an existing anaerobic lagoon, to a fully engineered above-ground tank with integrated heating.

PIPING

Incorporating biogas production into your business may change the way in which wastes are collected and where they are stored. To automate these processes, new piping and collection system (drains, screens etc) may be required. Remember that some of this piping will have positive cost effects through reduced operator journeys or process time, but others could have large cost impacts.

BIOGAS UTILISATION

The end use of the biogas will have a significant impact on the project cost. If being used to augment natural gas or LPG use in a boiler, no additional changes may be required other than an upgrade of the burners on each boiler.

If the gas is to be used to generate electricity, a combustion engine will be required. This will increase the upfront and operating costs associated with the project.

WASTE HANDLING EQUIPMENT

Generating biogas may require a large change of process and waste handling equipment. The anaerobic digestion system will require periodic cleaning to remove sediments. Waste collection before digestion might require maceration pumps or centrifuges to concentrate wet waste.

FUEL COSTS

Biogas use and cogeneration could generate significant energy savings. Direct use of biogas for heating can offset coal, natural gas or LPG use, and any associated costs of a price on greenhouse gas emissions.

Using a biogas-fired engine to provide electricity means the electricity is valued at your normal delivered rate (i.e. in c/kWh). Similarly, the waste heat generated by the biogas-fired engine can be used for other hearting applications across the site.

GREENHOUSE GAS EMISSIONS TRADING

Methane capture and reuse systems result in reduced emissions associated with fossil fuel use, as well as reduced emissions associated with the release of methane into the atmosphere from waste water treatment systems. This may create revenue through generation of carbon credits under the Carbon Farming Initiative (CFI). Note: an approved CFI methodology would need to be applied in order to generate credits.

WASTE DISPOSAL

Onsite treatment of abattoir waste may reduce shipping, processing and waste acceptance fees. Anaerobic treatment of solid waste will reduce the mass of the waste, and process it to a level where different handling is required. There could also be savings realised by on-selling the processed waste as fertiliser.

PROCESS CHANGES

Simplifying the waste collection system could remove labour from the abattoir process with a positive impact on the cost-per-head. Conversely though, using more of the animal waste onsite may require retraining wastewater treatment plant operators in new procedures, which could have safety implications.

Financial Incentives

Some bioenergy projects may qualify for Renewable Energy Certificates under the Renewable Energy Target (RET). Engage with your energy supplier to assess what support they can provide through the RET.

Investigate co-funding sources such as carbon credits under the Carbon Farming Initiative (CFI). A number of methane destruction methodologies have been approved, providing a potentially new source of revenue from methane capture and reuse projects. A list of approved CFI methodologies is published on the Department of the Environment's website.[78]

FURTHER INFORMATION

This fact sheet is number 5 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

78 http://www.climatechange.gov.au/reducing-carbon/carbon-farming-initiative/methodologies/methodology-determinations

TECHNOLOGY OVERVIEW

In cogeneration (cogen) systems (also referred to as combined heat and power systems), a fuel is burnt in an engine to produce electricity, with waste heat from combustion captured and used to drive thermal processes. In industrial settings, this heat is used as process heat, while in commercial buildings this heat can be used for space heating or cooling.

Trigeneration (trigen) extends this concept by using the heat to also drive a cooling process. The cooling part of the plant will be supplied using an absorption refrigeration cycle, like the ammonia-water absorption system used in "three-way" camping fridges, or "thermal wheel" systems, which exploit the cooling effects of evaporation.

When linked with an in-vessel anaerobic digester[79], the waste heat can be used to heat the digestion process, which improves the operation of the digester.

An example theoretical integrated energy from waste system for meat processing sites could be assembled as follows: waste streams are collected in a large concrete tank where they undergo anaerobic digestion to produce methane/biogas. This gas is collected and used to fuel an engine, which drives a generator and produces electricity. Combustion heat, captured in the engine jacket water, is used to heat the digester and speed the anaerobic digestion process. Gas supply can be buffered in the tank using expanding bladders or floating lids, which allows the generator to meet the plant electricity load. The hot water from the engine will not be hot enough for rendering or sterilization, but could be heated further using biogas in an instant gas heater.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

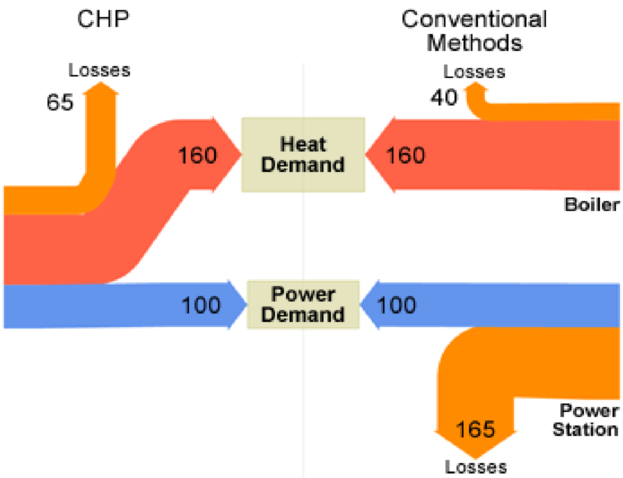

Figure 27 Energy flow diagram comparing conventional methods and cogeneration (CHP)[2]

As a rule of thumb, conventional cogen systems convert incoming energy (fuel) into one third electricity and two thirds heat. Therefore, the key determinant of the economic feasibility of a cogen project is whether a sufficient heat load exists at the site, or near the site (i.e. in the form of a district/community heating scheme). If a use for the waste heat does not exist, the heat generated by the cogen system would not be utilised and the project could be economically unviable.

As shown in Figure 1,[80] generating electricity via a cogen enables waste heat usually vented to atmosphere to be collected and used for process heating applications such as rendering and sterilising.

Similarly, the economics of trigen systems are most attractive when a constant cooling load exists, in addition to some need for low-grade heating. Electricity can be provided on-site by the generator and the waste heat can be utilised by an absorption chiller to reduce the refrigeration load, as well as heat water to reduce boiler use.

HOW TO DEVELOP YOUR BUSINESS CASE

The main factors to consider when developing a business case for a cogen or trigen system include:

79 See the AMPC Factsheet "The Business Case for Methane Capture and Reuse"
80 Diagram from http://chp.decc.gov.uk/cms/chp-benefits/?phpMyAdmin=ff232c1d3b302ac6e951f554eeeaefdf

- Electricity use and demand profile at the site
- Generator fuel – i.e. biogas, natural gas, LPG or fuel oil
- Energy savings – electricity cost and pricing profile, boiler fuel reductions
- Future prices of generator fuel
- Revenue generated through financial support mechanisms such as a carbon pricing scheme
- Heating and cooling loads at the site.

ELECTRICITY USE AND DEMAND PROFILE

Maximum economic value for any onsite generation of electricity is realised through onsite use (to offset more expensive grid-sourced electricity), rather than electricity export. The first step is to determine how much electricity is used on site and when the usage occurs.

Half-hourly interval metered data, obtainable from your electricity supplier, can be used to determine the site's load profile and consumption. The generator should be scaled to provide no more than the maximum power required by the site (see figure 2).

Over-sizing the cogen/trigen system can decrease the profitability of the project because it is rarely economic to export the generated power. This is due to the current low price of power purchase agreements on offer from energy suppliers.

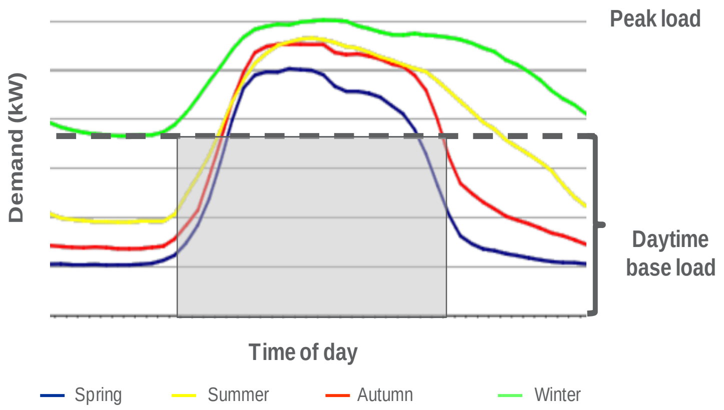

Figure 2: Illustrative seasonal load profiles

FUEL AVAILABILITY

The economics of cogen/trigen systems is most favourable when the generator runs constantly. Consider whether you have a stable supply of fuel to meet this demand. Sites connected to a gas grid are unlikely to experience a fuel supply problem, sites who rely upon biogas captured from the onsite wastewater treatment facility may experience fuel supplies problems if the wastewater system ceases to produce biogas.

ENERGY SAVINGS

Energy savings in cogen/trigen projects can be found across multiple sources; including electricity, heating and refrigeration loads, as outlined in the cost benefit analysis below.

FUTURE PRICE OF FUEL AND CARBON CREDIT PRICES

Gas prices are forecast to rise in the coming years, driven by export competition on the global market. This could have a significant impact on the economics of a cogen/trigen project. Similarly, markets for carbon credits change over time and changes to the values of these credits impact upon the economic viability of a project.

HEATING AND COOLING LOADS

A site's heating load can be estimated using thermal modelling techniques, or by determining the capacity of the existing hot water heater(s) or boiler(s), their efficiency, and their period of operation.

A site's cooling load can be estimated using thermal modelling techniques, or by determining the cooling capacity of the existing refrigeration plant, their efficiency, and their period of operation.

FINANCIAL INCENTIVES

A coge/trigen project may be eligible for funding under Government incentive programs targeting energy efficiency and greenhouse gas mitigation.

A project which is fuelled by biogas may be eligible for Renewable Energy Certificates (RECs) for the electricity created. More information on renewable energy power stations and Renewable Energy Certificates (RECs) can be found at the link below. RECs generated for biogas projects are discussed in the AMPC factsheet "Anaerobic digestion".

EXAMPLE COST-BENEFIT ANALYSIS

An abattoir uses about 700MWh of electricity annually, with a peak load of about 100kW, and wants to reduce energy costs. A modest heat load exists at the site, which is currently met with about 10,000GJ of natural gas a year. Of the 700MWh of electricity used each year, about 300MWh is used in refrigeration.

The abattoir engineering manager discovers an 80kW(electric) genset that looks suitable for the site. In weighing up the costs and benefits of the genset, the annual costs are considered, based on an electricity price of $0.25/kWh and a gas price of $8/GJ. These costs are shown in table 1.

Table 7: Current costs p.a.

Electricity ($)	Natural Gas ($)
175,000	80,000

It is assumed that the genset will operate with an 80% utilisation factor and is 25% efficient at converting gas to electricity. Electricity will not be exported from the genset to the grid. Waste heat from the genset is sent to the boiler. It is assumed that 20% of the heat generated is unrecoverable, so 80% of the waste heat goes to the boiler.

The energy and financial inputs and outputs of the project are shown in table 2. The existing boiler will use less natural gas because of the waste heat recovered from the genset. It is assumed that boiler energy use will be reduced by the same amount as the heat sent from the engine; the boiler captures heat to water at the same rate regardless of the source.

Table 8: Cogeneration inputs and outputs p.a.

Gas required for the engine (GJ input)	Cost of gas for cogen ($)	Electricity generated by the engine (kWh output)	Electricity cost saving ($)	Waste heat to boiler (GJ output)	Saving of gas at boiler ($)
8,064	64,500	560,000	140,000	4,838	38,700

The overall cost saving per annum are shown in table 3.

Table 9 Scenario cost comparison

	Electricity cost ($)	Gas ($)	Total ($)
Existing system	175,000	80,000	280,000
Cogen system	(175,000-140,000) **=60,000**	(80,000+64,500-38,700) **=105,800**	**165,800**
Change	-115,000	+ 25,800	**- 89,200**

A conservative estimate of $20,000 per annum is used for maintenance and spare parts, leaving an annual saving of $69,200 ($89,200 - $20,000). The estimated capital cost of the project is $400,000, therefore the simple payback of the project is less than 6 years.

In this scenario the waste heat has the same value as the gas it offsets; 4,838GJ of waste heat is captured, achieving a $38,700 reducing in gas costs each year. If an absorption chiller were installed, this heat could be used to provide cooling for refrigeration. As this heat would have to be diverted from the boiler where it is offsetting gas use, its value is the same as the gas use that could be offset.

Adding a trigeneration cooler to reduce their refrigeration load is estimated to cost an extra $200,000. The cooler is evaporative and has a coefficient of performance of 0.5, so 1GJ of heat captured from the genset offsets 0.5GJ of coolth from the refrigerator. The existing refrigerator uses electricity and has a COP of 4, so requires 0.25GJ of electricity per 1GJ of cooling.

The absorption chiller could provide cooling at $1.36/GJ less than the existing refrigeration system ($17.36 - $16, as shown in table 4). The current system uses 300MWh of electricity each year. The refrigerator has a COP of 4, so 300MWh electricity provides 1,200MWh cooling, or 4,320GJ, each year. Assuming the absorption chiller could provide all of this, it would save $5,875 each year, indicating a payback on the capital cost of the absorption chiller ($200,000) in the order of 40 years.

Table 10 Trigeneration chiller

	Coefficient of Performance	Fuel cost ($/GJ)	Cost of cooling ($/GJ)
Existing Refrigerator	4	69.45 (based on an electricity tariff of 25c/kWh)	17.36
Absorption chiller	0.5	8 (cost of natural gas avoided in boiler)	16

FURTHER INFORMATION

This fact sheet is number 6 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

THE BUSINESS CASE FOR INDUSTRIAL-SCALE BATTERIES

TECHNOLOGY OVERVIEW

Batteries store electricity as chemical energy so that it can be recovered for later use. There are many different battery types; the most common being lead-acid, lithium ion and nickel-metal-hydrides.

Flow-batteries, where the reaction agents are stored in separate tanks until required for electricity production, are becoming available at smaller sizes. Units are available for integration with residential solar photovoltaic systems. Flow batteries and sodium-sulphur batteries are considered a mature technology and have been used in many grid-support applications. Refer to Table 1 for more detail on the range of different battery types available.

Type	Description	Status
Lead-acid	A commercially mature battery type. Relatively low cost and have been used in automotive and small power storage applications for many years. Use in energy management has been limited due to short life cycle, particularly when fully discharged. The largest application is a 40 MWh system in Chino, California, built in 1988.	These batteries have reached their full commercial potential.
Lithium-ion	Li-ion batteries have typically been used in mobile applications due to their excellent energy density. The cathode in these batteries is metal oxide containing lithium ($LiCoO_2$, $LiMO_2$, etc.) and the anode is made of graphite. The electrolyte is made up of lithium salts (such as $LiPF_6$) dissolved in organic carbonates. Lithium-ion batteries have a high energy density (300 - 400 kWh/m3) and long cycle life (3,000 cycles at 80% depth of discharge).	Several companies are working to reduce the manufacturing cost of lithium-ion batteries. The high cost comes from the special packaging required and internal overcharge protection circuits.
Metal-air	These are the most compact and, potentially, the least expensive batteries available. They are also environmentally benign. Electrical recharging of these batteries is however very difficult and inefficient. The anodes in these batteries are commonly available metals with high energy density like aluminium or zinc. The cathodes or air electrodes are often made of a porous carbon structure or a metal mesh covered with catalysts. The batteries work by transferring oxygen from the air as OH^- through a conductor such as KOH to the metal anode where the metal is oxidised. The oxidation releases energy.	While the high energy density and low cost of metal-air batteries may make them ideal for many primary battery applications, the problems with recharging limit use. Development effort is focused on this issue.
Sodium sulphur cells	A sodium sulphur (NaS) battery consists of molten sulphur at the positive electrode and molten sodium at the negative electrode as active materials separated by an alumina ceramic electrolyte. The electrolyte allows only the positive sodium ions to pass through it. The sodium ions combine with the sulphur to form sodium polysulfides. As with ZEBRA batteries, the temperature must be kept near 300°C to keep the electrolyte liquid. These batteries are an effective means of stabilising renewable energy output. NaS batteries have been demonstrated at over 190 sites in Japan totalling more than 270 MW with stored energy suitable for 6 hours daily peak shaving. The largest NaS installation is a 34 MW, 245 MWh unit for wind stabilization in Northern Japan. U.S. utilities have deployed 9 MW for peak shaving, backup power, firming wind capacity and other applications.	The application of these batteries for peak shaving, backup power, and firming wind capacity will develop further with the global push to renewable energy.
Sodium Nickel Chloride battery (ZEBRA)	Very similar in operation to a sodium-sulphur battery, these use liquid sodium salt as an electrolyte. As a result, the internal temperatures need to be kept above 300°C, which is usually managed by the battery electronics. This particular molten salt chemistry was developed to address some of	Market demonstration – General Electric have recently built a factory to manufacture these batteries. There are a few demonstration battery banks in operation.

Type	Description	Status
	the technical issues of sodium-sulphur batteries.	
Vanadium Redox Batteries	Vanadium Redox Batteries store energy using vanadium redox couples. During the charge/discharge cycles, H^+ ions are exchanged between the two electrolyte tanks through a membrane. Vanadium Redox Batteries are an example of a flow battery. The key feature is the use of liquid electrolytes to store the energy. The stored electricity is released as the electrolyte is pumped through an electrolytic cell. The electrolyte is stored in tanks and the size of these tanks is not linked to the size of the cells. Therefore, the power and energy ratings of Vanadium Redox Batteries are independent of each other. Vanadium Redox Batteries were pioneered by the University of New South Wales in the early 1980's and the technology is currently licensed to Sumitomo Electric Industries.	Vanadium Redox Batteries storage of up to 5MWh have been installed in Japan.
Zinc-Bromide	Zinc-Bromide batteries are another example of flow batteries. In each cell of a ZnBr battery, two different electrolytes flow past carbon-plastic composite electrodes in two compartments separated by a microporous polyolefin membrane. This chemistry is being explored at both residential and grid support scales. The net efficiency of this battery is about 75%.	ZnBr batteries are used in integrated energy storage systems.
PolySulfide Bromide battery (PSB)	These are regenerative fuel cells involving a reversible electrochemical reaction between two salt-solution electrolytes: sodium bromide and sodium polysulfide.	Early deployment. There have been no successful demonstration projects as yet.

Table 11: Battery types

HOW CAN BATTERIES BE USED AT YOUR MEAT PROCESSING FACILITY?

Batteries can be used at your facility to maximise the value of on-site renewable energy production. For example, they link well with solar photovoltaic systems to shift generation to match load and higher cost electricity.

Additionally, batteries can be used to reduce peak electricity demand at a site, or to manage peak demand if the alternative is adding extra capacity (which can be very costly).

DEVELOPING THE BUSINESS CASE

The main factors to consider when developing a business case for a battery storage system include the electricity cost and consumption profile at the site, power quality delivered to the site, and availability of financial incentives.

ELECTRICITY COST AND CONSUMPTION PROFILE

Batteries can be used to store cheap electricity for later use to offset more expensive electricity. If solar electricity is used, this will be generated during the day and ideally used to offset peak electricity in the evening. Determine how much peak electricity is typically used and how much it costs, to calculate total cost savings for the project.

POWER QUALITY

Some equipment, such as IT equipment, is sensitive to power quality or the consistency of voltage supply. While few industrial machines have this problem, it is worth considering as it may impact the final equipment choice.

FINANCIAL INCENTIVES

At this point in time, batteries do not qualify for financial incentives available through the State or Federal Governments. However, Germany and California have both recently introduced incentives for battery storage and Australian programs have typically been guided by the experience in these jurisdictions.

EXAMPLE COST-BENEFIT ANALYSIS

Storage is most attractive when low-cost power can be captured to offset high-cost power. An emerging and common example of this is using batteries to extend the delivery of intermittent renewable energy (generated from solar photovoltaics (PV) for example) to periods when the renewable energy supply is not available, and/or when grid-sourced electricity is most expensive.

Consider the illustrative site profile for a small abattoir, shown in Figure 1. This represents a site with daytime operation only. Energy use rises in the morning as the shift commences at 6am, then drops of after 5pm. Peak period is from 2pm until 8pm weekdays and shoulder period is from 7am to 1pm and from 8pm until 10pm. The peak rate is 35c/kWh, shoulder rate 20c/kWh and the off peak rate is 10c/kWh.

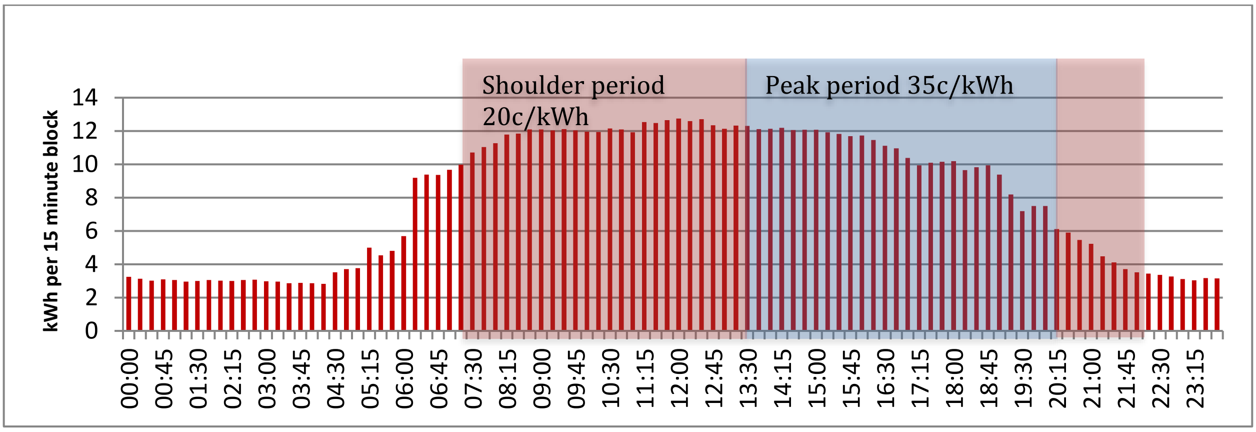

Figure 1: Illustrative site profile. Peak demand is approximately 50kW.

If a solar PV system were installed at this site, it would generate electricity between about 7am and 5pm. A very simple solar electricity generation profile can be modelled and laid over the sites electricity consumption profile to determine interaction between the two profiles. For illustrative purposes, an 80kW system is shown in Figure 5The system starts generating electricity at 7am and stops at 5pm, with peak generation occurring around midday.

The solar PV system in this scenario offsets 341kWh of purchased electricity each day. The value of the solar PV generated electricity is shown in Table 1. The total value generation by the system in a year, as electricity cost reductions and sale to the grid of excess electricity generated between 10am and 2pm, is $30,885 (assuming 365 days of operation). A solar PV system of this size would cost about $160,000 to install (based on current market prices). This equates to a simple payback period of around 5 years. Note that this simple example has not accounted for different peak, shoulder and off-peak times at weekends.

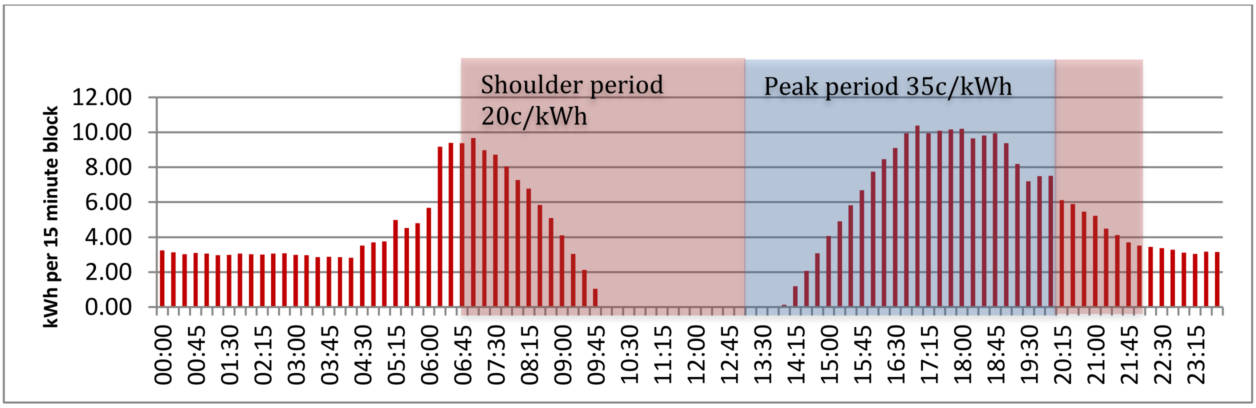

Figure 2: Purchased electricity profile, with illustrative solar profile deducted.

	Electricity (kWh p.a.)	Value (c/kWh)	Annual Total ($)
Peak electricity offset	28,470	35	**9,964**
Shoulder electricity offset	95,995	20	**19,199**
Exported electricity	21,535	8	**1,722**

Table 12: The value of the solar PV generated electricity from an 80kW system.

If a battery with a 64kWh capacity was added to this site, the excess electricity generated between 10am and 2pm could be stored for later use. This effectively transfers the exported electricity to the peak period offset (i.e. 21,535kWh p.a. / 365 days). This situation is shown in Figure 3.

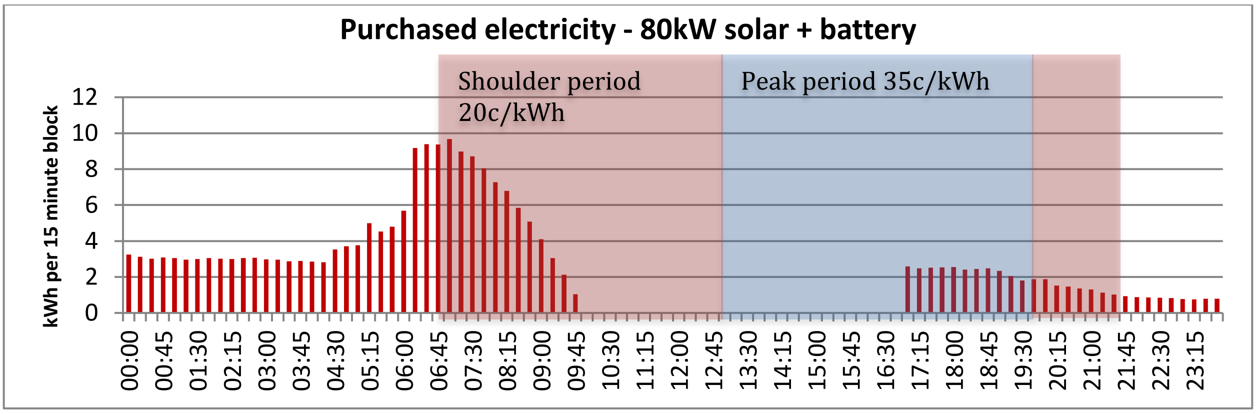

Figure 3: Purchased grid electricity with the addition of 80kW solar and a 64kWh battery.

Adding a battery to this system saves the excess electricity generated by the solar PV system, which was previously exported, for use during the peak period. The table below shows the value of the solar PV generated electricity, with battery storage. Adding a battery to this system generates additional value of $5,815 in a year, for a total of $36,700 each year. A battery of the size assumed would cost around $64,000, depending on the battery type.

	Electricity (kWh p.a.)	Value (c/kWh)	Annual Total ($)
Peak electricity offset	28,470 + 21,535 = 50,005	35	**17,501**
Shoulder electricity offset	95,995	20	**19,199**
Exported electricity	0	8	**0**

Table 13: The value of 80kW solar PV system with a 64kWh battery

FURTHER INFORMATION

This fact sheet is number 7 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

THE BUSINESS CASE FOR GRAPHITE BLOCK THERMAL ENERGY STORAGE

TECHNOLOGY OVERVIEW

Graphite block storage systems are one of several systems that store solar energy by using the sun to heat a material and later extract the heat when the sun is not shining. The material can be concrete, molten salt or graphite, the example in this fact sheet. In a graphite block storage system, solar energy is stored by using a field of mirrors to reflect sunlight to a central block of graphite where it is absorbed. When steam or hot water is required, water is pumped through the block. The temperature of the water exiting the block depends on the flow rate but temperatures in excess of 300°C are possible. This system has been demonstrated for electricity production and has potential in process heat applications. This system, if appropriately sized, can deliver energy generated from solar sources 24 hours a day.

Graphite is used as a heat storage medium because of its low emissivity and high specific heat. These characteristics enable systems that can store a large amount of energy per unit mass and hold it for long periods with little loss. Concrete is also being investigated as a massive solid to store heat, but there have been no projects using this technology in Australia.

This is a relatively new technology, with one company developing the technology in Australia. The company was a recipient of an Advanced Energy Storage Technology grant in 2009, which delivered a proof of concept project in Cooma, followed by a scale demonstration project at Lake Cargelligo in NSW. In this project heliostat arrays were used to reflect sunlight onto a central block of graphite which stored thermal energy during the day for use at night. Much of the information below is based on the system developed by this company.[81]

This technology is at an early stage of development and the project economics are not attractive. However, the technology could be attractive if fuel current costs where to increase dramatically (i.e. a three-fold increase) and the technology cost were to decrease substantially (i.e. a three-fold decrease).

[81] http://www.ret.gov.au/energy/Documents/clean-energy-program/acre/studies/AEST-Final-Report-Lloyd.pdf

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

This technology has been demonstrated to deliver electricity, but is most promising for meat processing sites as an option to supply process steam. It is however, not yet a commercial technology and is still being developed. It will not be cost-effective to the end user for several years without the receipt of significant R&D support from organisations such as the Australian Renewable Energy Agency (ARENA).

- Best for sites with large heat loads, particularly those sites with rendering
- One module in this system requires in the order of 2,800m^2 (40m x 70m) to provide 3MWh of heat per day
- Requires a flat area with good solar access

HOW TO DEVELOP YOUR BUSINESS CASE

The main factors to consider when developing a proposal for a graphite storage system include:

- The amount of sunlight (insolation) received at your site
- Whether there is space available for the central towers and mirrors
- The potential use for the heat
- Funding options

THE AMOUNT OF SUNLIGHT (INSOLATION) RECEIVED AT YOUR SITE

Insolation is the amount of solar energy received per unit area. It varies around Australia and is generally presented as a map, like the one below. These values are often normalised to equivalent midday insolation received per day, to make the comparison between areas easier. Higher values indicate more favourable solar conditions.

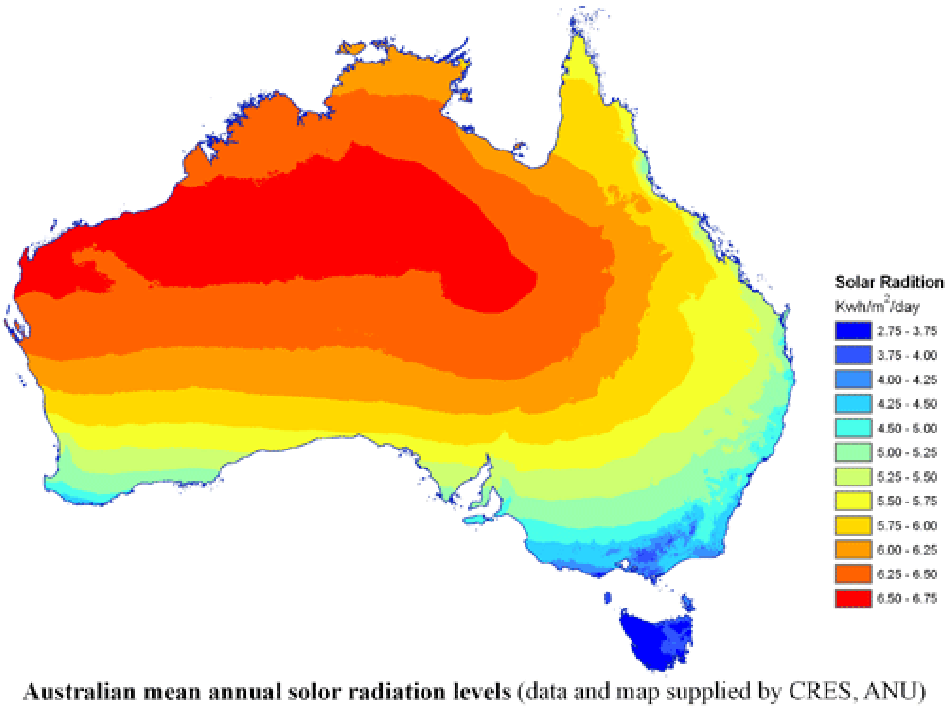

Figure 28 Solar radiation across Australia

IDENTIFY A SUITABLE AREA

You will need a large expanse of flat land without shading. One module in this system requires in the order of 2,800m2 (40m x 70m) to provide 3MWh of heat per day.

THE POTENTIAL USE FOR THE HEAT

The heat available from the graphite block can be used to heat water or steam that would otherwise be generated in a boiler that uses natural gas or another fuel.

FUNDING OPTIONS

The application described here generates heat rather than electricity and so would not be eligible for Renewable Energy Certificates.

There may be funding available on a matched basis through other public funding sources, such as the Australian Renewable Energy Agency (ARENA) or the Clean Energy Finance Corporation (CEFC).

EXAMPLE COST-BENEFIT ANALYSIS

An abattoir with rendering plant in Darwin is looking to reduce their boiler fuel costs, which is currently fuelled with natural gas, which they buy at $8/GJ. The boiler uses 3,300GJ of gas each year, which costs $26,400. They are particularly concerned about rising gas prices and have been told to expect gas prices to double in the next five-years.

To reduce the boiler load they investigate a graphite thermal storage system. They will keep the boiler as a back-up.

The system they investigate is rated to provide 3MWh heat per day. They model the system output as 2MWh per day averaged over a whole year, to account for cloudy days and that on some days not all the heat from the block will be delivered. This means the system will deliver about 730MWh each year and offsets 2,628GJ of gas.

The total cost of installing the solar collector and graphite block is $800,000. An illustrative simple payback period is shown in the table below

System capacity	Upfront cost ($)	Annual gas offset (GJ)	Gas cost reduction ($)	Simple payback
3MWh	$800,000	2,628	$21,024	38 years

Based on the existing cost of the system and the cost of natural gas, the graphite system looks very unattractive.

As this stage, this system is not financial viability; however as it matures and the cost of the system reduces, and if gas prices rise, the system will become more attractive.

FURTHER INFORMATION

This fact sheet is number 8 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

THE BUSINESS CASE FOR GEOTHERMAL ENERGY

TECHNOLOGY OVERVIEW

Geothermal energy systems use heat produced by the Earth's core to provide space heating and electricity generation. The systems employed can be broadly divided into two categories; naturally occurring hot aquifers such as those that occur in areas of high volcanism, like Iceland, and engineered geothermal systems which use the heat of radioactive decay captured in large, underground granite bodies.

The hot aquifer geothermal (hydrothermal) resources in Australia are generally poor. Australia is a large and old continent with little active volcanic activity and very stable plate tectonics. However, there are places in Australia where magmatic intrusions bring heat closer to the surface and provide visible hydrothermal activity, such as Hepburn Springs and the Otway Ranges region in Victoria. Recent thermal prospecting in Australia coordinated by Geoscience Australia suggest that the potential for engineered geothermal in Australia is much greater, with viable heat for electricity production found in the Cooper Basin and some parts of Victoria. These resources are found at around 4km below the surface.

Much of the capital cost associated with geothermal energy is used in drilling holes. The subsurface temperature increases by about a 3°C per 100m, with higher temperatures achieved in some places. The geothermal power industry uses a rule of thumb of about $1 million per kilometre of hole drilled. Combining these estimates, a 500 meter deep hole can be expected to cost $500,000 and access heat 15°C warmer than the surface temperature.

Maps of this resource are complex and expensive to produce. A portion of Victoria Tourism's geothermal resource map, released in 2007 is reproduced in Figure 11 below and can still be found at the below reference.[82]

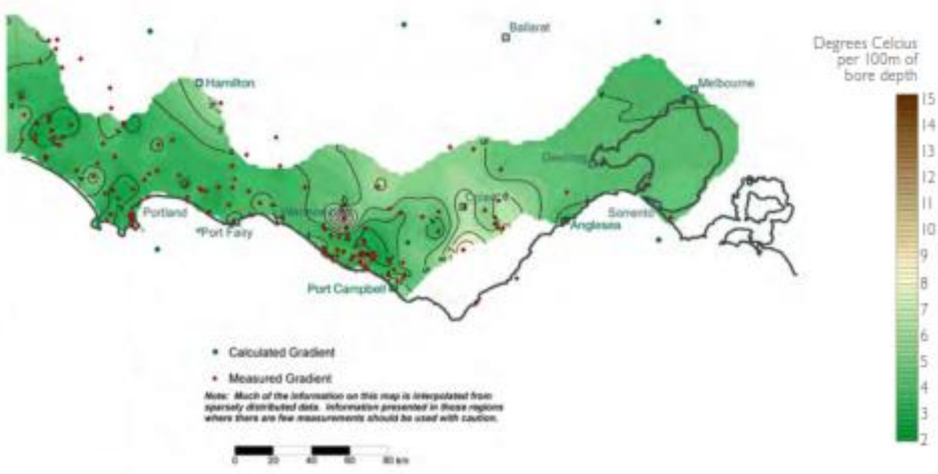

Figure 29: Geothermal resource map created by Tourism Victoria

Geoscience Australia have also mapped the geothermal resource, but as this was intended for the power industry, it maps the resource at a level far deeper with the higher temperatures needed for power generation.[83]

[82] http://www.tourism.vic.gov.au/images/stories/Documents/StrategiesandPlans/Geothermal-natural-spa-tourism.pdf

[83] http://www.ga.gov.au/image_cache/GA10036.pdf

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

Except in cases where the geothermal resource essentially occurs at the surface (which is the case in areas of active volcanism such as Iceland, New Zealand and Japan) this technology requires the drilling of multiple boreholes and is very expensive. The costs associated with deep drilling required for electricity production make it prohibitive as site electricity supply.

In cases where there is a shallow source of hot water, there is potential to use the water for general purposes such as hand cleaning or a pre-heated feed to a boiler or hot water system. This is especially useful if the water is extracted for other purposes such as a fresh water supply.

As the drilling cost is high and effectively fixed, the viability of geothermal projects is based on the cost of energy which it offsets, and any co-benefits, like water access, which come with the project.

A hybrid geothermal/cogeneration system was installed at Midfield International in Warrnumbul, Victoria.[84] This is the only known installation is this type in the Australian red meat processing industry

HOW TO DEVELOP YOUR BUSINESS CASE

The actions to take when developing a business case for a geothermal energy project include:

- Determine your heat load
- Determine your geothermal resource potential
- Consider the future cost and risks of your current heat supply

DETERMINING YOUR HEAT LOAD

How much heat do you need daily, annually? Unlike electricity, there is no market for businesses to sell heat into. However, there may be opportunities to partner with other businesses in your area which have significant heat loads as well. Also consider too what you could do if you had access to low cost heat. Much of the cost in a geothermal project is the fixed cost of drilling, so the marginal increase of delivering extra heat is small. This heat could be used to meet future requirements created by expansion in processing capacity.

DETERMINE YOUR GEOTHERMAL RESOURCE POTENTIAL

Establish how much potential there is for geothermal energy in your area. A good indicator of a geothermal resource is the presence of hot springs, as on the Mornington Peninsula in Victoria. Beyond this, there are resource maps available through state and federal agencies such as Tourism Victoria and Geoscience Australia.

At the completion of this stage you should have an idea of the temperature gradient in the earth beneath your site and how deep you will have to go to access the heat. This will help quantify the drilling costs.

Related to the resource potential is the ability to access this resource, potentially limited by water access and development approvals. Seek in-principle approval from the relevant authorities and explore any limits on heat production.

CONSIDER THE FUTURE COST OF HEATING

The value of geothermal heat projects is directly correlated to the cost of fuel it offsets. While projects might not be attractive at current costs, consider where these costs might move in future years. Gas prices are forecast to rise when the Australian gas market becomes linked to the international market, with wholesale prices predicted to move from about $4/GJ to $8/GJ and higher. Future resource costs should be built into your cost model. A geothermal energy project might have as long as a twenty year lifetime, allowing a lot of time for costs to change.

EXAMPLE COST-BENEFIT ANALYSIS

A meat plant in rural Victoria is worried about the security of their brown coal briquette supply and the impact a carbon price might have in future years. Briquettes are currently supplied at $8/GJ, including shipping. Located near the

[84] http://www.ampc.com.au/site/assets/media/Factsheets/Climate-Change-Environment-Water-Waste-Energy-Sustainability/11-AMPC-MLA-Cogen-Geothermal-Midfield-Group.pdf

springs in central Victoria they believe there might be a reasonable geothermal resource under their site and decide to investigate it as an alternate heat source.

The resource map of their area is quite high-resolution due to their proximity to the hot springs and they determine the gradient is 12°C/100m. With this information they seek quotes from drilling contractors and find one which is prepared to charge $80,000/100m to a maximum depth of 400m.

The local authorities set strict caps on artesian water use, concerned about the impact on the local springs. To overcome this they will use a closed-loop system which circulates the same water constantly, down a dual wall pipe. Water flows down the outside pipe on the way down, heating as it goes, then comes back up the centre. Water flows down the outside pipe on the way down, heating as it goes, then comes back up the centre. Heat is extracted through a heat exchanger in contact with the plant water heater and the water is recycled.

The flow rate is capped based on the size of the piping. They calculate that a maximum flow rate of 200 m^3 per day is possible. A suitable plate heat exchanger is available to extract the heat from the circulating water and use it to heat boiler feed water. However, contractors have estimated that the cost to connect the bores and the boiler feed to the plate heat exchanger will be in the order of $50,000.

The wells are drilled to 400 meters so the water comes from the ground at approximately 63ºC and returns at 30ºC.

Heat supplied by the briquettes (GJ p.a.)	Cost of fuel p.a.	Cost to drill the wells and install the heat exchanger	Simple payback
10,074	$80,592	$370,000	4.6 years

FURTHER INFORMATION

This fact sheet is number 9 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

THE BUSINESS CASE FOR BIOMASS BOILERS

TECHNOLOGY OVERVIEW

Some agricultural wastes, such as farm stubble, animal bedding and forestry wastes, can be used to offset coal use in combustion boilers for process heat. Of the wastes available through red meat processing activities, dewatered paunch waste is the most promising and has been examined in research previously administered by AMPC and MLA.[85] This work found that up to 30% of boiler fuel needs could be met with dewatered paunch waste, with no major ill-effects on the boiler.

However, this was tested in a boiler designed for burning sawdust; augmenting coal boilers with dewatered paunch waste may not deliver a satisfactory result. Particle size and moisture content need to be tightly controlled to achieve the correct burn time within the boiler.

IS IT SUITABLE FOR YOUR MEAT PROCESSING FACILITY?

This technology is broadly applicable to the meat industry. However, the most important factors influencing the viability of a project is the logistics of supplying the biomass to the boiler, and preparing the biomass to meet the fuel specifications of the boiler. This is particularly important if the biomass is the only fuel for the boiler i.e. it is a dedicated biomass boiler.

If the biomass is co-fired with another fuel, such as coal, then a steady supply of biomass is less important but it is then necessary to consider the type of boiler. The most favourable projects would be those that use existing waste streams which currently have a disposal cost and can be burnt using an existing boiler. An example would be to dewater paunch waste and burn it in an existing coal or saw dust boiler.

HOW TO DEVELOP YOUR BUSINESS CASE

The actions to take when developing a business case for biomass boilers include:

- Determine the availability of a suitable biomass supply
- Investigate the type of boiler used at the site
- Calculate the cost of fuel.

THE AVAILABILITY OF A SUITABLE BIOMASS SUPPLY

Dewatered paunch waste is the most promising of the biomass streams generated by meat processing facilities. Previous research administered by AMPC and MLA has shown that co-firing a sawdust boiler with 5% paunch waste had no impact on the boiler, but increased the rate of ash formation. Paunch waste could provide up to 30% of fuel for a non-dedicated biomass boiler, however this could have an adverse impact on the operation of the boiler and would need to be tested before implementation.

The paunch waste will need to be collected, dewatered and then transported to the boiler. It may also need to be stored near the boiler if the demand for heat and the constraints on the feeding of the biomass into the boiler do not match the rate of supply of the paunch waste.

[85] http://www.ampc.com.au/site/assets/media/Climate-Change/On-site-Energy-Generation-Research/Use-of-paunch-waste-as-a-boiler-fuel.pdf

Other waste streams generally have too high a moisture content or have too much protein content, and tend to be more suitable for waste to energy applications such as methane recovery and reuse.

THE TYPE OF BOILER USED AT THE SITE

Ideally, the site would have an existing boiler designed to burn moist solid material. A natural gas boiler will not be suitable, however if the biomass was converted to biogas via anaerobic digestion or pyrolysis then a natural gas boiler would be ideal.

A pulverised coal boiler is also unlikely to be suitable, although such boilers tend to be very large and used in the power generation industry. A moving grate boiler could be able to combust the biomass efficiently, depending on the homogeneity of the biofuel.

THE COST OF FUEL

The economic feasibility of a biomass boiler project is strongly correlated to the cost of the biomass relative to the cost of the fuel it offsets (i.e. coal). While using on-site waste such as paunch waste might be cost effective, purchasing off-site waste, such as forestry waste, and transporting it to site is likely to be less attractive.

EXAMPLE COST-BENEFIT ANALYSIS

A large abattoir has a coal fired boiler and wants to reduce its fuel costs. Paunch waste is a potential source of biofuel and they have estimated that 25% of coal use could be replaced by paunch waste. The coal costs $80/tonne and has a heating value of 28GJ/tonne. The boiler currently uses 0.8 tonnes/hr of coal for 12 hours a day and 0.4 tonnes/hr for the other 12 hours of the day. The abattoir operates for 5 days per week for 50 weeks per year.

The site uses 3,600 tonnes of coal per year, at a cost of $288,000. Approximately 900 tonnes of coal can be replaced by paunch waste each year. This will reduce the cost of coal by $72,000/year.

The paunch waste has a calorific value of 10.4 GJ/wet tonne and so approximately 2,450 tonnes of paunch waste goes to the boiler each year, instead of being sent to landfill. As the cost of this disposal amounts to $15/tonne, there is a further saving of $36,750/year.

The cost to modify the boiler to take the paunch waste and add the systems to deal with the paunch feed was found to be around $250,000. The simple payback on the investment is 2.3 years. The key figures in this calculation are shown in the table below.

Fuel saving ($ p.a.)	Reduced disposal cost ($ p.a.)	Cost to upgrade boiler ($)	Simple payback
72,000	36,750	250,000	2.3 years

FURTHER INFORMATION

This fact sheet is number 10 of a 10-part series relating to renewable energy and energy storage technologies applicable to the red meat processing industry. For further information relating to this fact sheet or related factsheets, please contact AMPC via email info@ampc.com.au or by phoning the office on 02 8908 5500.

Technical and Practical Barriers to the Installation of Renewable Energy and Energy Storage Technologies

INTRODUCTION

This discussion paper presents information on the technical and practical barriers to the adoption of the ten most applicable renewable energy and energy storage technologies to the Australian red meat processing industry. The paper forms part of the project '2013/4003 Renewable Energy and Energy Storage Technologies Applicable to Red Meat Processing Manufacturing businesses', and should be read in conjunction with the final report and the series of ten fact sheets relating to renewable energy and energy storage technologies applicable to the red meat processing industry.

TECHNICAL AND PRACTICAL BARRIERS

Many technical and practical barriers are common across the ten technologies. The table below presents the barriers that relate to each of the technologies; an '×' indicates that the specific barrier should be considered with this technology. These barriers may restrict or prevent the deployment of these technologies and should be considered in detail before proceeding with a project.

More details on the nature of these barriers are provided following the table. An explanation of each technology is provided in the ten fact sheets that accompany this paper.

Technology	Available space	Resource availability	Planning restrictions	Network restrictions	Site demand	Maintenance capabilities
Solar PV	×	×		×	×	
Wind	×	×	×	×	×	×
Evacuated solar thermal tubes	×	×			×	
Air-source heat pumps	×					
Geothermal	×	×		×		×
Anaerobic digestion	×	×	×			×
Biomass boilers	×	×	×			×
Cogeneration / trigeneration	×	×	×	×	×	×
Batteries	×			×	×	
Graphite block storage	×				×	

AVAILABLE SPACE

At a basic level each of these technologies will require suitable space to be installed. The space each technology requires can extend beyond the physical footprint of the unit being installed to include space for maintenance access, fuel processing/storage/delivery and relevant monitoring and control equipment.

The solar technologies (solar PV and evacuated tubes) are generally weatherproof and robust, but require a large area to be installed, as shown in the table below. They can either be installed on available roof space or ground space; if roof space is used, the roof must be structurally able to support the weight of the equipment. Similarly, graphite block storage requires a large, flat area for the tower and associated heliostat array.

The remaining technologies need to be housed out of the weather or steps must be taken to weatherproof sensitive components. Air flows in and out of the combustion and heat transfer technologies (heat pump, boilers, and cogeneration) will need to be considered and carefully planned as failure to do so can significantly reduce the performance of the unit. For heat pumps this means at least one metre of clear area in front of and behind the unit to allow air to pass through the heat exchanger unimpeded. Boilers and cogeneration units will both require an exhaust system to vent the combustion products to the atmosphere and keep them from the working environment. Boilers, particularly solid-fuel boilers, will require adequate space and equipment to ensure a continuous supply of fuel. This may include a bunker for storing fuel, machinery, such as conveyors or front end loaders, for moving the fuel to the boiler, and adequate space to enter the boiler to remove ash. Fuel deliveries will need space onsite, plus safety equipment to separate staff from frequent vehicle movements. For gaseous fuels, the gas lines may need to be upgraded, a meter added in a convenient location and safety equipment installed to prevent accidental collision.

The table below provides an indication of the space requirements for each technology.

Technology	Space requirement
Solar PV	1m^2 of roof or ground space in good sun is needed per 100-150 watts.
Wind	Ground space is needed. The turbine footing depends on the size, but between 10m x 10m for medium (about 300kW) or 30m x 30m (grid scale) is needed. The most important space consideration is clear space in the prevailing wind direction.
Evacuated solar thermal tubes	1m^2 of roof or ground space in good space is needed per 900 watts.
Air-source heat pumps	Internal units are wall or ceiling cavity mounted and take up to 2m^2 for each wall unit. External units use up to 2m^2 footprint for each 10kW (cooling).
Geothermal	Footprint depends on end use; if supplying heat, the well-head is the main space use, as little as 1-2m^2 per well. If generating electricity, a more significant structure is required, with up 10-20m^2 for a turbine house and additional space for transformers and switch gear.
Anaerobic digestion	Digester tanks can be large, as much as 30m diameter for a sewage treatment plants. The size will depend on the effluent load. Piping between the digester and the plant may also be significant.
Biomass boilers	A typical boiler will have a small footprint of 2m x 2m or a little above. The main space requirements for biomass are the fuel handling and ash cleaning. Allow a dedicated shed in the order of 15m x 15m.
Cogeneration / trigeneration	Depends on the total equipment package. A turbine generator and heat supply for space heating could be housed in a 10m x 10m space and is the minimum to allow. A large piston engine, with heat capture and evaporative cooling, could be twice that.
Batteries	A single 8kWh flow battery fits on a standard pallet. Larger batteries (~1MWh) need space the size of a shipping container, including switching and controls.
Graphite block storage	One 2,800m^2 installation will supply about 3MWh of heat per day.

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RESOURCE AVAILABILITY

This is particularly important for the combustion technologies; cogeneration/trigeneration, biomass boilers and anaerobic digestion, but will also be considered in any of the renewable energy technologies. At a minimum, any fuel that must be purchased should be secured through contracts or planning assessments for the amount of time required for the project to meet its break-even point, plus a margin of error. As examples, gas supply should be secured for cogeneration and trigeneration units through negotiations with your gas supplier; internal planning is needed to suitable size anaerobic digestion to the waste streams at your facility and internal planning is needed to set out the use of sufficient biological wastes in the digester; and a contract with a saw mill supplying saw dust can secure supply for a biomass boiler.

Solar and wind resources are available to some degree all over Australia, but in varying degrees. The resource availability must be determined to calculate the forecast energy generation and overall project economics. The specific methods to assess these resources are included in their respective fact sheets, available through AMPC.

The table below provides an indication of the required resource(s) for each technology.

Technology	Resource requirement
Solar PV	Above 5kWh/m^2/day is a good benchmark, but still viable below this.
Wind	Average wind speed, at hub height, of 7m/s and above.
Evacuated solar thermal tubes	Above 3kWh/m^2/day is a good benchmark but may be cost effective below this.
Geothermal	Temperatures above 40°C should be sought for heat generation. Above ~120°C for electricity generation
Anaerobic digestion	Offal can supply about 900m^3 biogas per tonne, while cow manure is closer to 300m^3.[86]
Biomass boilers	Continual, reliable supply is more important than total resource.
Cogeneration / trigeneration	Appropriate gas supply to meet demand, or biogas using the anaerobic digestion calculation above.

PLANNING RESTRICTIONS

Some renewable technologies are subject to explicit restrictions on their placement with respect to existing dwellings. For example, state governments in Victoria and NSW have enacted legislation which prevents wind turbines being built within a set radius of existing dwellings and includes provisions for public opposition to prevent developments entirely.

The combustion technologies may be impacted by regulations governing atmospheric pollution, particularly in residential areas. Similarly, anaerobic digestion may not be permitted on odour grounds. Despite anaerobic digesters being specifically designed to capture the gases they emit, experience with sewage treatment digesters suggests that odours will escape during operation, particularly during maintenance or when removing the digestate.

Technologies that require a new building may also be subject to planning constraints, often depending upon the local council's planning controls.

The table below shows a summary of the main planning restrictions and guidelines for each technology. Note: this excludes some specific localised planning regulations.

Technology	Planning guidance
Wind	State based regulations change periodically. Most restrictive is currently Victoria[87]

86 http://www.ids.ie/PDF/Digestion-slaughterhouse_food-waste_KF%20%282%29.pdf
87 http://www.dpcd.vic.gov.au/planning/planningapplications/moreinformation/windenergy

Technology	Planning guidance
Anaerobic digestion	May trigger National Pollution Inventory
Biomass boilers	May trigger National Pollution Inventory
Cogeneration / trigeneration	May trigger National Pollution Inventory

NETWORK RESTRICTIONS

While there are currently few examples of this occurring, it is possible that in the near future network operators will limit the connection of on-site generators to the electricity network. Distributed generation, such as solar and cogeneration can significantly alter the flow of energy in an electricity network, with implications for safety and grid reliability. Even in projects where the intent is not to export electricity, a grid connection will still be required for back up. There are technical solutions available should utilities move to prevent onsite generation, but these will significantly increase the project cost, with little benefit. Options include isolating the onsite generator on a circuit that does not connect to the network, or complete islanding of the plant using storage or dispatchable generation.

Aside from outright preventing network connections, there are fees and technical requirements which can hamper the connection of new generators. Network operators may require specific equipment to be installed before the generator connection is allowed, and there may be delays in inspecting and commissioning this equipment. There will also be costs associated with these requirements, which will be borne by the project proponent. It can often take more than 12 months to receive approval to connect a distributed generator to the network.

This is a difficult area, with work underway to make this process simpler and more transparent. The Australian Energy Market Operator has a rule change underway to simplify this process. More information can be found at the link below.[88]

The table below shows the network restrictions in place across the main network operators in Australia.

Technology	Restrictions
Solar PV	Requires permission from local network provider to connect to the electricity network
Wind	Requires permission from local network provider to connect to the electricity network
Geothermal	Requires permission from local network provider to connect to the electricity network No network restrictions for heat capture
Cogeneration / trigeneration	Requires permission from local network provider to connect to the electricity network
Batteries	No specific regulations known at this stage, but expected to be similar to generator/solar panel connections

SITE DEMAND

Wind and solar power are intermittent sources of energy (without storage); solar power availability tends to peak in the middle of the day and decay to zero at dusk, while wind output varies daily with the weather and seasonally throughout the year. Matching these profiles to times of high electricity use will maximise the value from these technologies project and reduce the payback period. More information on predicting and maximising this relationship can be found in the fact sheets for the individual technologies.

The same principle applies when using renewable energy to generate heat or cold, such as evacuated tubes. These systems need to be supported by conventional backups, like instant gas hot water or building chillers, and so the system should be designed to deliver heat or cold when it is most needed.

88 http://www.aemc.gov.au/electricity/rule-changes/open/connecting-embedded-generators.html

The availability of renewable energy can be better matched with when energy is needed on site by coupling it with an energy storage system, such as batteries. The renewable system should be sized to generate more energy than is needed at times when the energy source is available; the excess energy is stored and later used when the renewable energy source is not available. This is discussed in more detail in the AMPC report '*Renewable Energy and Energy Storage Technologies Applicable to Red Meat Processing Manufacturing businesses*' and the relevant AMPC factsheets.

Your usage profile will also change the impact of a cogeneration or trigeneration system. Heat output from the system will roughly follow electricity output, and so the heat use profile should also be matched. Similarly, in a trigeneration system cool output will roughly follow the engine heat output. In both cases the use of this heat/cool could be buffered with the use of thermal storage systems, such as water stored in tanks, but this will affect the project cost and profitability.

MAINTENANCE CAPABILITIES

Biomass technologies, such as anaerobic digestion or biomass fuelled boilers may require skills not previously required in the maintenance team. While these systems are not complex or necessarily require specific training, a lack of these skills could result in significant outages and reduced profitability. Similarly, biogas digesters will generally be located in confined spaces, as defined by occupational health and safety legislation, and will require maintenance staff to be appropriately accredited.

A number of the other technologies such as wind turbines and geothermal power generators may also require specialist maintenance staff, which is generally provided by the supplier of the technology.

The key maintenance activities associated with each technology are shown in the table below.

Technology	Maintenance requirements
Wind	Mechanical fitting, electrical testing, high-access permit required
Geothermal	Mechanical fitting, electrical testing
Anaerobic digestion	Fuel and waste handling, digester management and maintenance
Biomass boilers	Fuel and waste handling, boiler maintenance
Cogeneration / trigeneration	Mechanical fitting, electrical testing