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Establishing Energy Usage On Australian Piggeries To Enable Implementation Of Energy Reduction Strategies

Final Report
Project No 2012/2407

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Executive Summary

This industry-funded project involved the collection and detailed analysis of piggery energy data, with an emphasis on monitoring direct electricity consumption. Data presented in this project aims to increase awareness of energy efficiency through the identification of energy hotspots within piggeries, and practical opportunities to reduce energy use. The energy use efficiency of the piggeries examined was analysed in detail. Improving the energy efficiency of pork producers is a key priority of Australian Pork Limited (APL).

Energy use is a fundamental component of pork production from intensive piggeries. Due to the introduction of a carbon tax, along with other economic and political pressures, the price of electricity has increased between 25-40% across Australia over the past three years. Therefore, energy consumption and resource efficiency have become critical performance and sustainability indicators for industries in the Agricultural sector. A previous industry funded LCA research project on a limited dataset of six Queensland piggeries, showed a seven-fold variation in electricity usage between different sites with a range consisting of approximately 50 to 350 kWh/tonne of live weight produced. These results showed significant opportunity to improve energy usage and reduce energy costs, thus increasing the sustainability and productivity of farms. Various methods and analysis techniques to improve energy consumption are investigated in this project.

Energy monitoring was performed at six selected case study piggeries, named Piggery A to Piggery F in the report for confidentiality. The piggeries were chosen to provide a representative sample of climatic conditions, shed design, unit type and capacity. The selected piggeries provided a range of climatic conditions from hot, humid summer-dominant rainfall to cooler, winter-dominant rainfall zones. The piggeries were located in southern Queensland and Victoria. Shed design includes elements such as the ventilation system, lighting, feeders and effluent management. Unit type includes specific units such as grow-out or breeder, and complete farrow to finish piggeries.

Custom electrical monitoring equipment was used for the majority of energy monitoring instead of off-the-shelf products to allow more flexibility in monitoring various components. The equipment consisted of three power meters, various sizes of current transformers and a 10-channel logger equipped with a 3G modem to allow for remote access. The selected power meters and logger were able to store electricity use data in kilowatt hours (kWh) for time intervals of 10 min, hourly and daily. Initial electrical monitoring with a retail monitor was undertaken at Piggery A and E to obtain data relating to power factor.

Piggery energy consumption was obtained from various forms including, electricity, diesel, petrol and gas. To standardise all energy consumption results the units of measure were converted into mega joules (MJ). The energy data was obtained from monitoring over a two week period in summer and winter. Total direct energy usage is the combination of shed lighting, heating, ventilation systems, water supply, feed supply, effluent management, administration and minor activity uses (such as repairs, maintenance and pig management). Energy is also used indirectly through the transport of incoming and outgoing pigs and feed. Only direct on-site energy use was considered in this study.

Due to the size and type of each piggery, daily energy use varied greatly. To compare the six case study piggeries, the electrical energy use was analysed on a production unit basis. For the three farrow to finish piggeries, the production unit was per tonne of live-weight produced, the two breeder sites were reported per weaned pig while the finisher site was reported per pig place. For the farrow to

finish piggeries where the breeding sheds where individually measured the energy use could also be reported per weaned pig. The farrow to finish piggeries were also reported on a per pig place basis.

On each site, electrical energy was the predominant energy use type, 75% of the total. Diesel fuel was the second highest energy use source (15%); this is often used to run motors and pumps around the site. Energy use ranged from 600 to 1500 MJ/tonne of live-weight produced at the farrow to finish piggeries. When compared with the breeder units on a per weaned pig basis, energy use ranged from 14 to 67 MJ/weaned pig. Large variations were also seen in energy use per pig place with results ranging from 125 to 320 MJ/pig place. When comparing the data from this project to the data collected in the pig industry LCA, the trend of significantly differing energy use is still prevalent for both farrow to finish, and breeder piggeries.

The electrical energy consumption logged throughout the day over a two week period identified times of peak energy use. In naturally ventilated piggeries peak consumption occurred around the time piggery operations began in the morning. This was due to the starting of several motors around the site. In tunnel ventilated piggeries electrical energy use was higher from 09:00 to 18:00 due to the operation of ventilation fans. The base electrical load is a contribution of the feed system, water supply pump, effluent pumps and lighting.

Initial electrical energy monitoring was undertaken at Piggery A and E to test the power factor. At piggery A, the power factor of the total site and the bore pump was monitored while at Piggery C the total site and feed mill were logged. Ideally, it is good to maintain a power factor of 0.85 or higher. The total site power factor for both piggeries was generally above the recommended levels. However, at times the power factor dropped to 0.7, likely when the motors for effluent or hosing are started. The power factor of the bore pump at Piggery A dropped to 0.75 when the pump was active. This indicates the pump motor performance could be improved by maintenance (service, check wear) or by correctly sizing the pump according the discharge and flow rate requirements. The power factor for the feed mill at Piggery E often lowered to 0.2. The dips in power factor may be caused by the mill running at a minimum or empty load.

The energy use at the piggeries was broken down to identify the areas and components that are most energy intensive. The area that used the highest amount of electrical energy at the monitored natural ventilation piggeries was the farrowing sheds. The electricity consumption at the tunnel-ventilated piggeries was driven by the shed's ventilation system, including the control panel, exhaust fans, cooling pads and water pumps. Other significant energy use components at the monitored piggeries included bore pumps, waste reticulation pumps, feed mills, and workshop or workers amenities.

An energy use breakdown of a farrowing shed was performed by identifying the electrical use components and their properties within a shed, in conjunction with logging each energy use components daily time of use. The heating system (heat lamps) within the farrowing shed was responsible for a significant amount of energy usage (77%). The remaining energy use in the farrowing shed was from electrical motors used for pumps and feed supply.

Factors such as the local climatic conditions throughout the year and the type of systems the piggery has in place to control the pig's environment impacted seasonal variation in energy use. For example, the energy use at naturally ventilated piggeries containing farrowing sheds increased during the winter, as more energy was required for heating the piglets. In tunnel ventilated piggeries, energy use

increased during summer as more emphasis was placed upon the ventilation system (exhaust fans and cool pads) to control a comfortable climate for grower and finisher pigs.

With rising electricity costs and growing pressure to reduce greenhouse gas emissions, piggeries have a great incentive to improve energy efficiency, lowering their energy costs and carbon emission footprint. To begin the process of improving on-site energy use, piggery managers should locate where electricity is used on the site and measure how much is used. Electricity monitors are available for reasonable prices and will help piggeries produce a plan of action to reduce energy use. Alternatively, piggeries can log energy use around the site to identify energy use. To garner the best results, the piggery should target areas of high usage and areas that can be cheaply and easily improved.

For piggeries with farrowing, improvements to the heating system can greatly improve energy efficiency. The easiest way to improve heating is to reduce the area required heating and to minimise heat wastage. Other viable options are to switch from electrical energy to either gas or water heating systems.

Large piggeries with tunnel ventilated sheds can improve energy efficiency by ensuring the fan climate control is operating correctly, i.e. fan staging is controlled by several temperature sensors within the shed. The fan motors should be regularly cleaned and maintained to ensure they operate efficiently.

Other components of the piggery that can be improve energy efficiency are; selecting energy efficient lighting types, ensuring fuel and gas is used only as required, and by ensuring motors and pumps are well maintained and working to the correct capacity.

Managing and reducing peak energy loads can reduce energy costs. Peak energy often occurred during high tariff hours due to increased demand on the electricity grid. Where possible, a piggery should switch load to low tariff times, significantly reducing energy costs. Another option in reducing electrical energy costs is to negotiate with the supplier for a reduced tariff, this is reasonable especially if the piggery runs back-up diesel generators or other alternatives to reduce reliance on grid electricity during peak energy demand.

Large, high-energy use piggeries have the option to reduce energy demand on the electrical grid, therefore reducing energy costs, by implementing alternative energy sources. Alternative energy including solar, wind and biogas, can be produced on-site by the piggery to supplement electrical energy usage. Before installing these systems, piggeries are encouraged to conduct an economic feasibility study. The feasibility of alternative energy sources will improve as new technologies are developed and the costs decrease.

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I Introduction

This project aims to collect energy use benchmarking data, which will then enable an analysis of energy use management and efficiency for a range of piggeries. Currently there is very little information on energy usage from Australian piggeries. This project looks to increase awareness of energy efficiency through the identification of energy hotspots within piggeries, and practical opportunities to reduce energy use. Specifically it involves electricity benchmarking, combined with interactive site assessments of a range of piggeries (size, location, housing, production system, climate type etc.). The energy use efficiency of the piggeries will be profiled and analysed in detail. In lowering energy consumptions, piggeries have the potential to save operating costs and increase the productivity and value of their business. Improving the energy efficiency of pork producers is a key priority of Australian Pork Limited (APL). Producer and industry specialists have identified energy use, management and efficiency as one of the highest research and development priorities for 2012-2013.

Energy use is a fundamental component of pork production from intensive piggeries. Due to the introduction of a carbon tax, along with other economic and political pressures, the price of electricity has increased between 25-40% across Australia over the past three years. Therefore, energy consumption and resource efficiency have become critical performance and sustainability indicators for industries in the Agricultural sector. A previous industry funded LCA research project on a limited dataset of six Queensland piggeries, showed a seven-fold variation in electricity usage between different sites with a range consisting of approximately 50 to 350 kWh/tonne of live weight produced. These results showed significant opportunity to improve energy usage and reduce energy costs, thus increasing the sustainability and productivity of farms. Various methods and analysis techniques to improve energy consumption are investigated in this project. These include, profiling energy use and identifying energy hotspots for a range of piggery types, and conducting activities to disseminate information on practical measures to reduce their energy use. APL aim to empower pork producers with practical information via a series of easy to understand factsheets. This will enable producers to make informed decisions about energy use and efficient management practices.

1.1 Project Objectives and Outcomes

The project objectives include:

- Measure energy usage profiles at a range of representative piggery facilities.
- Increase Australian pork producer's awareness of the principles of energy efficiency and resource management.
- Increase Australian pork producer's awareness of the opportunities for energy efficiency.
- Develop an energy efficiency framework to enable Australian pork producers to measure, monitor and implement energy efficiency strategies.

The outcomes of this project will allow the pork industry to develop a better understanding of the total energy usage and the contributions that various piggery sector activities make to energy usage.

2 Background

There is strong industry interest in strategies to reduce agricultural energy consumption as the electricity price continues to increase. Throughout the last decade, electricity prices have risen by approximately 90% (QFF 2013). Queensland agriculture has experienced a sharp increase in price,

between 10% and 20% in the 2012-2013 financial year. The average cost of electricity for intensive piggeries can reach upwards of 10% of the operating costs (NFF 2012). Market profitability and Government actions have placed substantial economic and environmental pressure upon the piggery industry to become conscious of energy efficient practices.

With electricity prices in Australia rising by approximately 15% a year over the past three years, because of three major factors; transmission infrastructure upgrades, inflation due to increased cost of fuel and labour, and funding towards achieving renewable energy targets. Because of the three factors, the federal government has permitted tariff changes, increasing the electricity price within the agricultural sector.

Alternative energy has become more popular, resulting in an increase in network costs to general electricity users. For example, photovoltaic solar power uses the transmission network for storage throughout the day, while drawing on base load power during peak demand. Although solar power does not affect the capital investment required for peak demand, the use of fossil fuel energy sources are declining, however the cost of storing alternative energy within the system adds to network delivery costs. This results in an increase of charge rate per unit of power (due to less total power consumption). In addition, subsidies were introduced for both small-scale (e.g. solar) and large-scale (e.g. biogas) renewable energy generation, which does not fully utilise the network and artificially reduces base-load power competition.

The Australian Government introduced a cost on greenhouse gas emissions, via a carbon tax, on July 1 2012. It commenced with a fixed carbon price of \$23 per tonne CO₂ emitted in 2012-13 and will increase by 2.5% for three years. Following this initial period a market-based emissions trading scheme (ETS) was intended to be introduced. This tax is payable by organisations involved in activities that generate greenhouse gas emissions and they are progressively required to pay the full cost that the emission imposes on the environment. This creates economic incentive for organisations either to reduce emissions, or to purchase carbon offsets that involve paying others to mitigate emissions or sequester greenhouse gases from the atmosphere. Due to the change of Government in September 2013 the carbon tax bill has been repealed and will be removed on the 1st July 2014 (Department of the Environment 2014). The affect this will have upon electricity prices remains unclear.

Since the introduction of the carbon tax, electricity prices have risen by 18% in New South Wales and Queensland. A study conducted by the Queensland Competition Authority estimates that 9% is due to the carbon tax. The carbon tax increases energy prices for farms through two mechanisms; higher costs for energy intensive farm inputs, and an increase in price of downstream processors such as meatworks. The higher production costs will be transferred back to farmers via high processing costs or prices for farm products (Keogh 2012). A recent ABARES study modelled the effect of the carbon using the financial characteristics of several agricultural businesses, in association with normal assumptions such as farm productivity growth and future electricity price. The predicted additional cost of meat processing in the beef and sheep industries is shown in

Table 1. Similar price increases would be expected in the pig industry.

The current government is in the process of repealing the carbon tax, but this is unlikely to have a significant effect on energy costs due to the other drivers that effect energy prices.

TABLE I – ADDITIONAL FARM PROCESSOR COSTS (ABARES)

Sector	Source	Units	Additional Costs, 2013	Additional Costs, 2015 onwards
Beef Processing	ABARE	\$/head	\$1.59	\$7.96
Sheep Processing	ABARE	\$/head	\$0.15	\$0.75

To reduce the impact of increased energy costs, agricultural industries must increase future productivity growth to maintain profitability. Methods to reduce reliance on energy are also an important factor in mitigating rising energy prices. The pig industry's total energy use and the shed components contributing to total use will be analysed throughout this study. Strategies to reduce energy consumption and therefore increase profitability will be recommended based on the findings.

Major energy use components in piggeries include:

- Tunnel Ventilated Sheds (Fans) – High Usage
- Heat Lamps – High Usage
- Lighting – Low Usage
- Manure Management (Effluent Pumps, Agitators, Flushing System) – Low Usage
- Feed Delivery – Low Usage
- Cleaning/Drinking Water (Bore) Pumps and Hoses – Low Usage
- Office Facilities – Low Usage

Some piggeries may also have on-farm feed milling facilities that can contribute a considerable amount to the overall energy costs of the farm.

Recent life cycle assessment research from Wiedemann et al. (2012) showed variations in electrical energy use from 154 to 228 kWh / tonne of live weight produced for four different conventional piggery supply chains around Australia. One of these supply chains represented a group of small to medium size farms, with the variation in electrical energy use having a seven-fold variation. This is consistent with historical data where Meo and Cleary (2000) reported power and gas consumption ranging from 170 to 3650 MJ / tonne of live weight produced (average of 1390 MJ / tonne of live weight produced). If it assumed that that the majority of this energy (80%) is electrical energy, the electrical energy use ranges from 38 to 811 kWh / tonne of live weight produced (average of 309 kWh / tonne of live weight produced). Converting this into current prices at an average electrical energy cost of \$0.22 / kWh and a typical energy use of 2000 kWh / tonne of live weight, this represents \$44 / tonne of live weight produced, representing a substantial input cost for producers.

3 Methods

3.1 Overview

A primary objective of the project was to collect good-quality energy usage data and relate this to pig production to enable the information to be used across Australia. To that end, it was necessary to

ensure that the piggeries involved were representative and that reliable data could be obtained. The steps in the project were:

1. Select a range of piggeries across Australia that were representative of climatic zones, feeding regimes, management styles and pig markets.
2. Review the design and management of these piggeries to select those where reliable data could be collected at a reasonable cost.
3. Select the preferred piggeries and complete negotiations at each site.
4. Complete testing and benchmarking of electricity monitoring equipment
5. Install the energy monitoring instrumentation system at each piggery.
6. Regularly download energy data (remotely via modem link in office).
7. Analyse and review the data.

3.2 Study Sites

3.2.1 Site Selection

Six case study piggeries were selected to provide a representative sample of shed design, unit type and capacity. The selected case study piggeries provide a range of climatic conditions from hot, humid summer-dominant rainfall to cooler, winter-dominant rainfall zones. Shed design includes elements such as the ventilation system, lighting, feeders and effluent management. Piggery type includes grow-out or breeder only, and complete farrow to finish operations. In choosing a variety of piggeries, the variation in energy usage among a range of operations can be analysed, providing meaningful data for a greater proportion of the industry. To maintain confidentiality, none of the piggeries are identified by name and will be referred to as Piggeries A to F.

3.2.2 Site Characteristics

The key characteristics of the selected piggeries are displayed in Table 2. A conventional shed design involves an effluent flushing system where the pens have slated floors; the effluent runoff is captured in underground channels and is either pumped or flows directly via gravity into holding ponds. The ventilation system is either natural, where the shed is open to allow natural breeze in and out, or tunnel ventilated, where a closed shed with inlet vents, cooling pads and exhaust fans.

TABLE 2 – CHARACTERISTICS OF SELECTED CASE STUDY PIGGERIES

Piggery Name		A	B	C	D	E	F
		Climate					
Mean Annual Rainfall	mm	676	630.5	630.5	630.5	630.5	551
Rainfall Pattern		Summer dominant	Summer dominant	Summer dominant	Summer dominant	Summer dominant	Winter dominant
Locality		Southern Qld	Southern Qld	Southern Qld	Southern Qld	Southern Qld	Central Vic.
Mean Annual Class A Pan Evaporation	mm	2044	2263	2263	2263	2263	-
Mean Max Temp – January	°C	32	32.4	32.4	32.4	32.4	28.9
Mean Min Temp – June	°C	5.4	5.4	5.4	5.4	5.4	4.4
		Piggery Capacity and Design					
Capacity	SPU	4200	11350	14705	48064	2594	4289
Unit Type		Farrow to Finish	Farrow to Finish	Breeder	Finisher (Grow-out)	Farrow to Finish	Breeder
Shed Design		Conventional, slatted floors	Conventional, slatted floors	Conventional, slatted floors	Conventional, slatted floors	Conventional, slatted floors	Conventional, slatted floors
Ventilation System		Natural	Tunnel Ventilation	Tunnel Ventilation	Tunnel Ventilation	Natural	Natural

3.3 Energy Usage Measurement

To measure the energy use profile at selected piggeries, unique electricity monitoring equipment was developed. The development of this equipment from “off-the-shelf” components versus purchasing / hiring monitoring equipment allowed greater flexibility in measuring components of electrical energy at the selected piggeries.

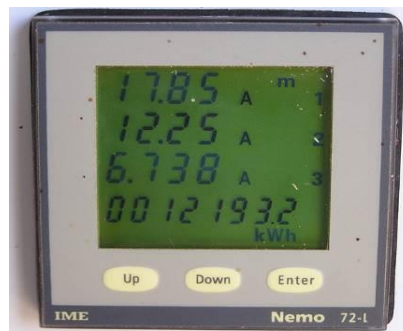
Condamine Electric Company (CEC) in consultation with FSA Consulting selected power meters to suit the type of installation required. The selection parameters included the cable size, the electrical capacity of the sub-main (amperage), current transformer (CT) size, type and quantity, and mounting requirements. Power meters and associated switchgear that were widely available were selected to best suit the farm installations.

Brief periods of initial monitoring were also conducted at Piggery A and E. At these sites, electrical energy was monitored using a powermonic portable three-phase power quality and disturbance analyser, which was hired out for several weeks. This meter was capable of accurately measuring the energy use and power factor of one electrical circuit and providing pulse outputs to a connected logging device. Due to high costs and limited flexibility, this logging equipment was not used during the energy monitoring at the other sites.

3.3.1 Electrical Energy Usage Measurement

3.3.1.1 Power Meter

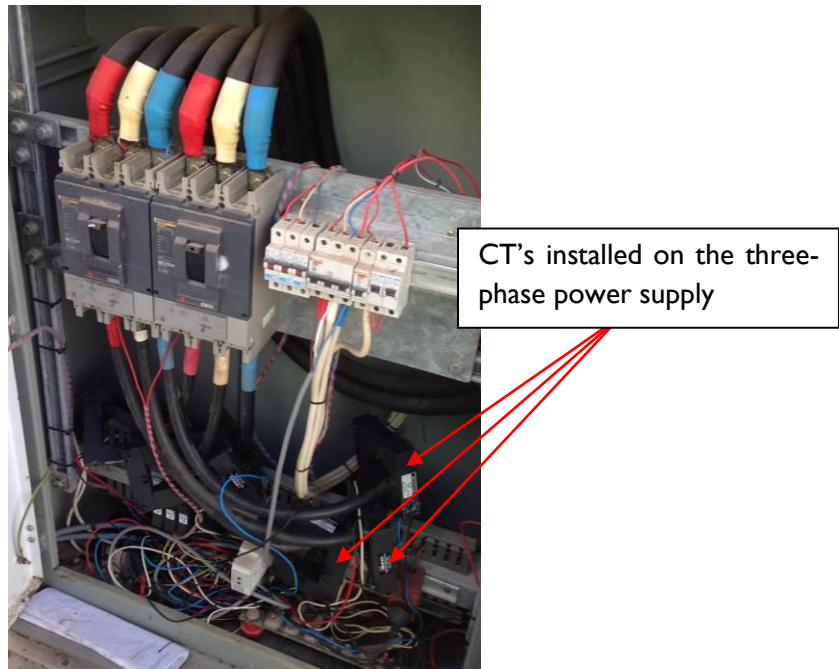
A power meter is required to provide a physical reading of the present electricity use at a particular site. The Nemo 72-L (Photograph I) is a programmable network monitor for low voltage produced by Rayleigh Instruments. It can monitor single phase (50-290v) or three phase (80-500V) networks and is shipped in a self-extinguishable polycarbonate enclosure and is flush mounted on the cabinet panel. All of the quantities of three phase network are monitored including voltage (phase and linked), current (phase and linked), power (phase and three phase active), power factor, frequency and working hours and minutes. The measurement quantities are displayed on different key activated pages on the backlit liquid crystal display. The unit has a reading accuracy for voltage (V) and current (a) of $\pm 0.5\%$, power (kWh) and power factor of 2% and frequency 0.2 Hz. Three current transformers (CT) are connected to monitor power in each phase of the power supply. The unit also has a programmable pulse output and RS485 communication for control and logging capabilities.



PHOTOGRAPH I – IME NEMO 72-L POWER METER

3.3.1.2 Current Transformer

To facilitate the safe measurement of large currents, a current transformer (CT) was installed on each phase circuit of the power meter. The circuit is largely unaffected by the insertion of the CT. A CT is a type of instrument transformer designed to provide a current in its secondary winding proportional to the alternating current flowing in its primary. The CT safely isolated the measurement circuitry from the high voltages typically present in each circuit measured. The secondary winding for all CT used in this work was 5 amperes. For example, a 100/5 CT provides an output current of 5 amperes when the primary winding was passing 100 amperes.



PHOTOGRAPH 2 – TYPICAL INSTALLED CURRENT TRANSFORMERS

3.3.1.3 Logger

To capture and store the real-time readings from the power meters, a logging device is essential. The Envirodata Weather Maestro, is a 10 Channel Data Logger designed to provide both on-site and remote access in a variety of climatic conditions. The logger can read pulse outputs from a variety of Envirodata sensors or custom interface sensors such as the Nemo 72-L power meter. There is 8 Mb of on-board flash memory, which stores up to a total of 1,000,000 values. With a logging frequency of 10 minutes and three connected power meters, the logger can store over a year of data. The data outputs as RS232 ASCII text, which is downloaded remotely via a Telstra next G modem. Envirodata's software program EasiAccess is then used to access the data.



PHOTOGRAPH 3 – ENVIRODATA WEATHER MAESTRO LOGGER

3.3.1.4 Electrical Power Measurement System

The three meters were stored in individual housing allowing simultaneous recording of multiple power sources. The power meters were connected to the relevant electrical circuits via CT's. The power meters were then wired to the data logger as shown in Photograph 4. A high strength aerial was attached to the next G modem contained within the logger allowing remote access to the data files; reducing travel and download time.



PHOTOGRAPH 4 – COMPLETE ELECTRICAL POWER MONITORING SYSTEM

3.3.2 Power Factor

The initial monitoring recorded the power factor ratio at Piggery A and Piggery E. Power factor is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, power authorities will usually charge a higher cost to customers where there is a low power factor. Hence, a power factor close to unity (1) is the aim.

3.3.3 Liquid Fuel Usage Measurement

Liquid fuel usage (petrol, diesel, LPG) were obtained from farm records. Ideally, the piggery had installed an in-line flow meter, which was recorded at regular intervals. Otherwise, an estimate was made based on fuel delivery receipts.

3.4 Case Study Sites

3.4.1 Piggery A

Piggery A is a 400 sow, naturally ventilated, conventional farrow to finish piggery located in southern Queensland. Electrical power use at Piggery A was initially monitored for nine days between the 13th March to 21st March 2012 using off-the-shelf loggers and again for approximately two weeks from the 26th February to 11th March 2013 using FSA designed equipment.

The electrical supply network at Piggery A consists of an overhead cable supplying power from the grid into a main switchboard. Electricity is distributed to various locations around the site via a series of sub-mains. The path and components of the piggery electrical circuit is displayed as a simple one-line diagram in Appendix A. Three sub-mains supply the office and amenities, the bore pump, and the four piggery sheds. The sheds are naturally ventilated and incorporate a conventional design with slatted floors for effluent capture. The following electrical equipment is supplied by the piggery sheds sub-main. All piggery sheds contain; a drinking water pump (1.5 kW), a hosing pump (2.4 kW), and a feed distribution system. The farrowing and weaner sheds also contain heat lamps (0.25kW). The effluent capture and treatment system consists of two agitator pumps (2.2 kW), an effluent pump (4.4 kW) and a reticulation pump 7.5 kW.

Initial power monitoring monitored the electrical load and power factor of the entire site for four days before being moved to monitor the bore pump for the following five days.

To monitor electricity consumption at Piggery A, three power meters were connected to the main switchboard using 100/5A current transformers. Power meter 1 logged total site, power meter 2 was connected to the bore pump sub-main and power meter 3 measured the piggery sheds sub-main.

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of live-weight produced. Liquid fuel usage was obtained from farm data records. There is no gas usage on-site.

3.4.2 Piggery B

Piggery B is a 1,650 sow, tunnel ventilated, farrow to finish piggery located in southern Queensland. The electrical energy consumption at Piggery B was logged for approximately three weeks, from the 12th April until the 30th April 2013 and from the 12th January to the 27th January 2014.

The electrical supply network at Piggery B consists of an overhead cable supplying power from the grid into a main switchboard which contains a series of sub-mains. The main switchboard for Piggery B contains two sub-mains. Each sub-main is backed-up by a diesel generator to provide power to the site in an emergency. A constant power supply is critical at this site as each shed incorporates a tunnel ventilation system with cooling pads and exhaust fans. Of the two sub-mains, one supplies the gestation shed, farrowing sheds, weaner shed, the office and the recycled water pump; while the other supplies the finishing sheds and the pump station. Details of the piggery electrical circuit are provided in Appendix A.

The three power meters were used to log sub-main 1, sub-main 2 and one farrowing shed (west) respectively. A 500/5 CT was attached to sub-main 1 while 250/5 CT's were used to monitor sub-main 2 and the individual farrowing shed. Total site power electricity consumption was calculated by adding the electricity logged PMI and PM2. Energy usage was broken down further by doubling the consumption from the western farrowing shed to allow the total farrowing usage to be estimated. The farrowing usage was then subtracted from the sub-main 1 total to produce energy use for the breeding phase. Performing these calculations allows a comparison between the energy use at the breeding, farrowing and finishing pig production stages.

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of live-weight produced. Liquid fuel usage was obtained from LPG meter readings and farm data records (petrol and diesel).

3.4.3 Piggery C

Piggery C is a 7000 sow, tunnel ventilated, breeder and wean to 6 weeks of age piggery located in southern Queensland. The electrical energy consumption at Piggery C was monitored from the 12th May 2013 until the 9th June 2013 and from the 29th January to the 9th February 2014.

The electrical supply network at Piggery C consists of an overhead cable supplying power from the grid into a main switchboard. There are three separate sub-mains throughout Piggery C supplied from the main switchboard via underground electrical cables. Sub-main 1 supplies five weaner sheds, dry sow sheds and the office. Sub-mains 2 supplies two farrowing sheds, while sub-main 3 supplies a farrow shed and weaner shed; the two sub-mains are approximately 130 meters apart. T Each sub-

main is backed up via a diesel generator to ensure an uninterrupted electricity supply to the sheds in an emergency. The sheds incorporate a tunnel ventilation system to maintain optimal conditions. Details of the piggery electrical circuit are provided in Appendix A.

Power meter 1 and 3 were used to monitor electricity use from individual farrowing sheds 3 and 2 respectively). Power meter 2 was attached to sub-main 3 to log electricity use at farrowing shed 1 and weaner shed 4. Total electricity consumption at sheds 1 to 4 can be calculated by summing data from each meter. As sub-main 2 and 3 are 130 meters apart a cable was run between power meter 2 and the logger situated at sub-main 2. The cable wiring was soldered to an Envirodata 3-pin male connector allowing the pulses to be sent through the extension cable into the logger.

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of live-weight produced. Liquid fuel usage was obtained from LPG meter readings and farm data records (petrol and diesel).

3.4.4 Piggery D

Piggery D is a 77,000 capacity pig place, tunnel ventilated, grower/finisher piggery located in southern Queensland. The electrical energy monitoring equipment was installed at Piggery D on the 12th June 2013 and energy data recorded until the 30th June 2013 and from 11th February to the 14th March 2014.

The electrical supply network at Piggery D consists of an overhead cable supplying power from the grid into the site's main switchboard. The main switchboard supplies the office, the pump station and two separate sub-mains via underground electrical cables. Sub-main 1 supplies the northern 20 grower/finisher sheds and sub-main 2 supplies the southern 20 grower/finisher sheds; the sub-mains are 350 meters apart. In each sub-main, there are five separate circuits, which each supply four grower/finisher sheds. Both sub-mains are supported by a diesel generator which ensures an uninterrupted electricity supply to the sheds. The sheds are tunnel ventilated to maintain optimal conditions. Details of the piggery electrical circuit are provided in Appendix A.

Power meter 1 was used to monitor electricity use from sub-main 2 which provides the total electricity used by the southern sheds at the site. A 500/5 CT was attached to power meter 1 due to the larger power draw. Power meter 2 was attached to a circuit within sub-main 2 to log electricity at finishing sheds 21-24. Power meter 3 was attached to a circuit within the sub-main's switchboard to monitor finishing sheds 33-36. Power meters 2 and 3 were both connected using 200/5 CT's. Total electricity consumption at Piggery D can be estimated by comparing electricity use from the southern sheds with production data for the total site.

Production data was obtained from farm logs for the data recording period to allow an analysis of electricity consumption per pig place and live-weight produced. Liquid fuel usage was obtained from LPG meter readings and farm data records (petrol and diesel).

3.4.5 Piggery E

Piggery E is a 320 sow, naturally ventilated, farrow to finish piggery located in southern Queensland. The piggery also has its own feed mill. Initial energy monitoring with off-the-shelf equipment occurred at Piggery E from the 27th March 2012 until the 5th April 2012. FSA's electrical energy monitoring equipment was installed at Piggery E from the 1st August 2013 to the 13th August 2013.

The electrical supply network at Piggery E comprises of an overhead cable supplying power from the grid to the site's main switchboard. The site's switchboard is located outside the storage shed. Electricity is distributed to various locations around the site via a series of sub-mains. Details of the piggery electrical circuit are provided in Appendix A.

Four sub-mains each supply the farrowing sheds, the growing unit, the finishing sheds and the feed mills. The sheds are naturally ventilated, with slatted floors for effluent capture. The underground effluent channels are flushed using 2 kW pumps. The site contains a feed mill that is powered by a 30 kW hammer mill motor. It also includes several other augers, conveyors and a batch mixer. The feed mill energy usage was monitored individually as the large motor has the potential to drastically increase total site usage while operating. Other electrical intensive components involve heat lamps in the farrowing sheds, effluent pumps, the feed distribution system, a bore pump and the workers amenities.

The initial power monitoring using off-shelf gear logged the entire site's electrical consumption and power factor rating for four days. The following five days were used to monitor the feed mill separate from the remainder of the site. Liquid fuel usage was obtained from farm data records. There is no gas usage on-site.

Power meter 1 (PM1) monitored electricity used at the feed mill, which is run on average three times per week for a few hours, depending on feed demand. Power meter 2 (PM2) was attached to the sub-main providing electricity to the site's farrowing facility. This includes a dry sow shed, two farrowing sheds and the workers amenities. Power meter 3 (PM3) recorded the total use from the site's switchboard. Due to the larger power load, PM 3 was attached to 500/5 CT's, while PM 1 and PM 2 used 250/5 CT's to provide better accuracy for smaller loads.

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of live-weight produced.

3.4.6 Piggery F

Piggery F is a 1080 sow, breeder only piggery located in southern Australia. Pigs are sold at 11 weeks of age. The dry sow sheds are naturally ventilated and the farrowing sheds contain cooling fans. The electrical energy monitoring equipment was installed at Piggery F on the 22nd August 2013 and removed on the 7th Dec 2013. This allowed for continuous monitoring over 106 days. Two-week periods from winter and summer were analysed, allowing a detailed comparison of energy use in cooler and warmer conditions.

The electrical supply network at Piggery F comprises of an overhead cable supplying power from the grid to the site's main switchboard. Electricity is distributed to various locations around the site via a series of sub-mains. Details of the piggery electrical circuit are provided in Appendix A.

There are three sub-mains supplying the farrowing sheds, the dry-sow sheds, and the workshop. The farrowing sub-main supplies electricity to two farrowing sheds with heat lamps and fans to control the climate in six rooms, the lights, and the feeder motors. The dry sow sheds sub-main powers the lights and feed motors. Finally, the workshop sub-main includes circuits for the water supply and bore pump, and electrical outlets for any power tools and / or machinery.

The farrowing sheds on this breeder unit site are climate controlled by heat lamps and fans, while the dry sow sheds are naturally ventilated. Both incorporate a conventional design with slatted floors for effluent capture.

Power meter 1 (PM1) monitored the entire site's power usage. A 500/5 CT was used to provide accurate readings of the large electricity draw. Power meter 2 (PM2) was attached to the sub-main providing electricity to the site's farrowing facility. This sub-main powers six separate farrowing rooms each with a heating system and fans to control the climate. The sub-main also contains circuits for the lights and feed system. Power meter 3 (PM3) recorded the electrical energy use from the dry sow sheds sub-main. This sub-main powers a gilt shed and the dry sow sheds. Power monitor 2 and 3 use a 250/5 CT to measure electricity. The final sub-main on the main switchboard supplies the workshop. The energy use for the workshop was calculated by subtracting PM2 and PM3 from the total site, PM1. The power meters and logger were secured to the main switchboard installation and the cables zip-tied to prevent any interference during the monitoring.

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of live-weight produced.

3.5 Data Analysis

The raw electrical logged data was imported into a spreadsheet. Data quality checks were undertaken to identify any obvious errors. Where anomalous data were detected, a thorough examination of possible error sources was performed. Anomalous data may have included a reduction in meter reading from previous or unexplained large increases in electricity usage. When it was possible to obtain fuel and gas readings this data was analysed in conjunction with electricity use over the same period.

Piggery performance data was imported into the same spreadsheet. Similarly, data quality checks were undertaken. Where anomalous data was detected, the participating piggery was contacted and the data were examined in more detail.

The spreadsheet then calculated the energy usage of the monitored piggery activities as a function of their respective indices, including on a per pig place, per farrow place and per tonne of live-weight produced. The feed mill monitored in piggery E was reported on a per tonne of grain processed basis.

4 Results and Discussion

4.1 Piggery Energy Use

Piggery energy consumption was obtained from various forms including, electricity, diesel, petrol and gas. To standardise all energy consumption results the units of measure were converted into mega joules (MJ) using the conversion factors displayed in Table 3.

TABLE 3 – ENERGY CONVERSION FACTORS FOR COMMON FUEL

Energy Form	Units of Measure	Energy Conversion Factor MJ
Diesel	Litres	38.6
Petrol	Litres	34.2
LPG – Propane	Litres	25.7
Natural Gas	m ³	38.5
LPG – Butane	Litres	28.1
LPG – Butane	m ³	122
Electricity	kWh	3.6

The energy data was obtained from monitoring over a two week period in summer and winter. Total direct energy usage is the combination of shed lighting, heating, ventilation systems, water supply, feed supply, effluent management, administration and minor activity uses (such as repairs, maintenance and pig management). Energy is also used indirectly through the transport of incoming and outgoing pigs and feed. Only direct on-site energy use was considered in this study.

Due to the size and type of each piggery, daily energy use varied greatly. Electrical energy data for each piggery is provided in as separate case studies in Appendix A. To ensure an accurate comparison of the six study piggeries the electrical energy use was analysed on a production unit basis. For the three farrow to finish piggeries, the production unit was per tonne of live-weight produced, the two breeder sites were reported per weaned pig while the finisher site was reported per pig place. For the farrow to finish piggeries where the breeding sheds where individually measured, the energy use was also be reported per weaned pig. The farrow to finish piggeries were also reported on a per pig place basis.

To produce the results on a per production unit basis over a 12 month period several assumptions were applied, including;

- Total yearly energy use was obtained from the power supplier bill.
- If power supplier data was not supplied, averages of the winter and summer total site energy use monitoring periods were applied over an entire year.
- Liquid energy use was obtained from farm records and applied on a yearly basis.
- Production data from farm records was analysed in PigBal.

Figure 1 presents the total direct energy use for the farrow to finish piggeries as per tonne of live-weight produced over a 12 month period. On each site, electrical energy was the predominant energy use type (75%). Diesel fuel was the second highest energy use source (15%); this is often used to run motors and pumps around the site. Petrol and LPG contributed to the remaining energy use around 5% each. The type of energy use varied depending on the piggery and the type of equipment and systems they have installed.

Piggery E was the most energy efficient site, using 600 MJ / tonne of live-weight produced, while Piggery B consumed the highest amount of energy per tonne of live-weight produced (1500 MJ/T). Piggery B is a large tunnel ventilated piggery while Piggery A and E are both smaller naturally ventilated piggeries. The results indicate that using natural ventilation produces better energy efficiency concerning

production. However, tunnel ventilation is effective in large piggeries located in hot climates as it improves pig comfort levels resulting in less mortalities and high production standards. Piggery E was the most energy efficient even though there is a feed mill on-site. This shows that Piggery E effectively manages and controls its on-site energy use while reducing indirect energy use through milling its own feed.

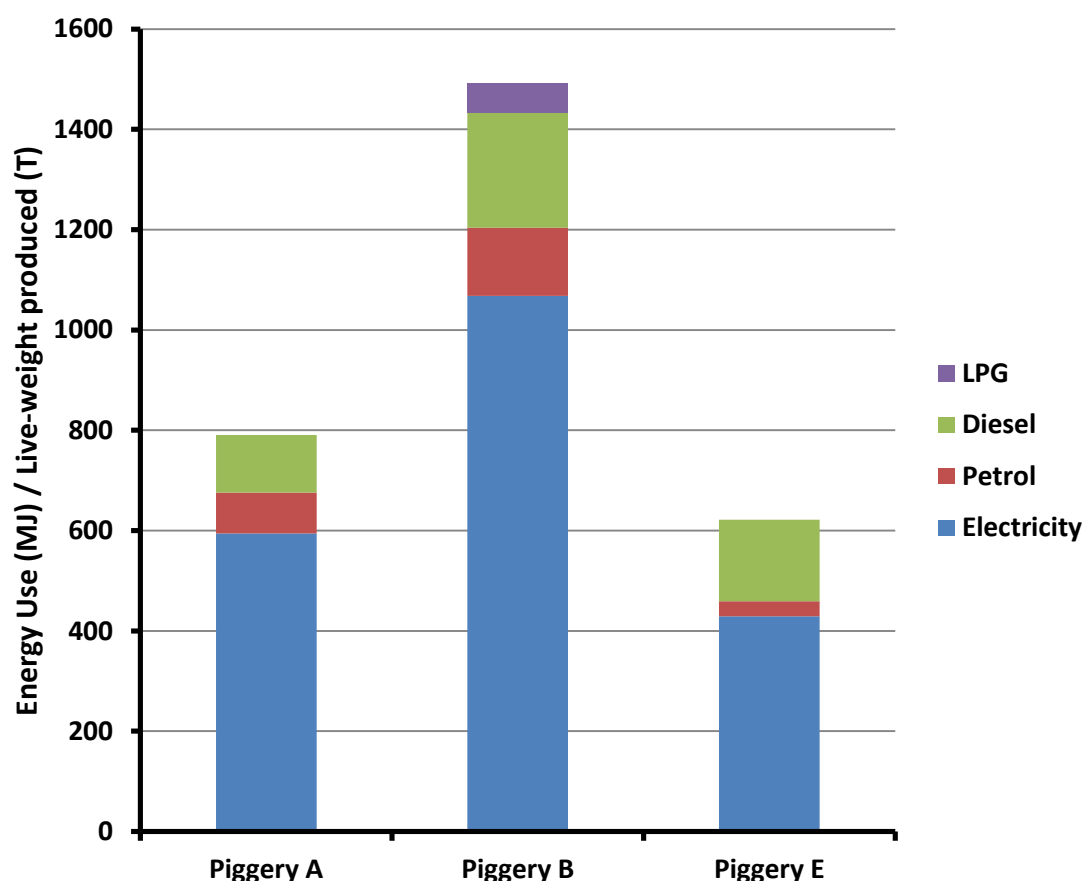


FIGURE I – ENERGY USE (MJ) PER T LIVE WEIGHT PRODUCED FOR FARROW TO FINISH SITES

A comparison of the energy used at the breeding sites and the breeding area within a farrow to finish piggery was reported on a per pig weaned basis (Figure 2). Electricity (77%) was the predominant source of energy at the breeder units, followed by diesel (15%), petrol (6%) and LPG (2%) respectively. Piggery C and F are breeder piggeries, while the other sites are farrow to finish. Piggery C sells there weaned pigs at six weeks of age where as piggery F sells at 11 weeks. Piggery B and C are tunnel ventilated and required more energy per weaned pig than the naturally ventilated sites. The tunnel ventilated breeder site (Piggery C) consumed the highest amount of energy on a per pig weaned basis. Amongst the naturally ventilated piggeries Piggery F use substantially more energy on a per pig weaned basis, and slightly less than the tunnel ventilated farrow to finish site.

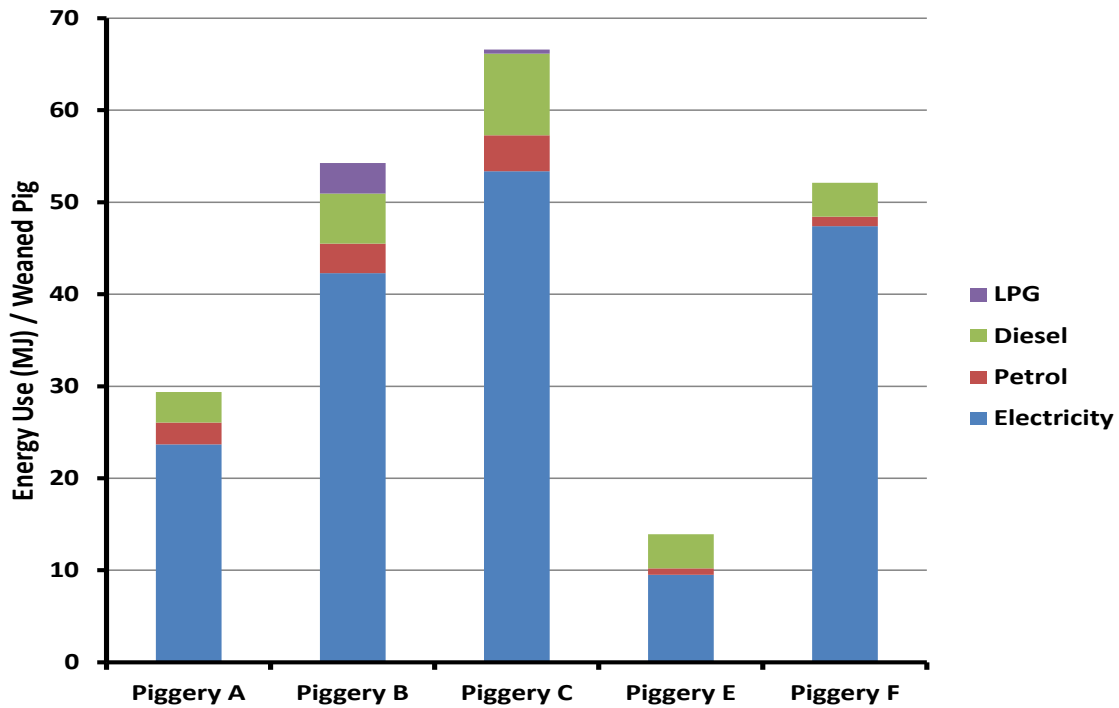


FIGURE 2 – ENERGY USE (MJ) PER WEANED PIG FOR BREEDING SITES

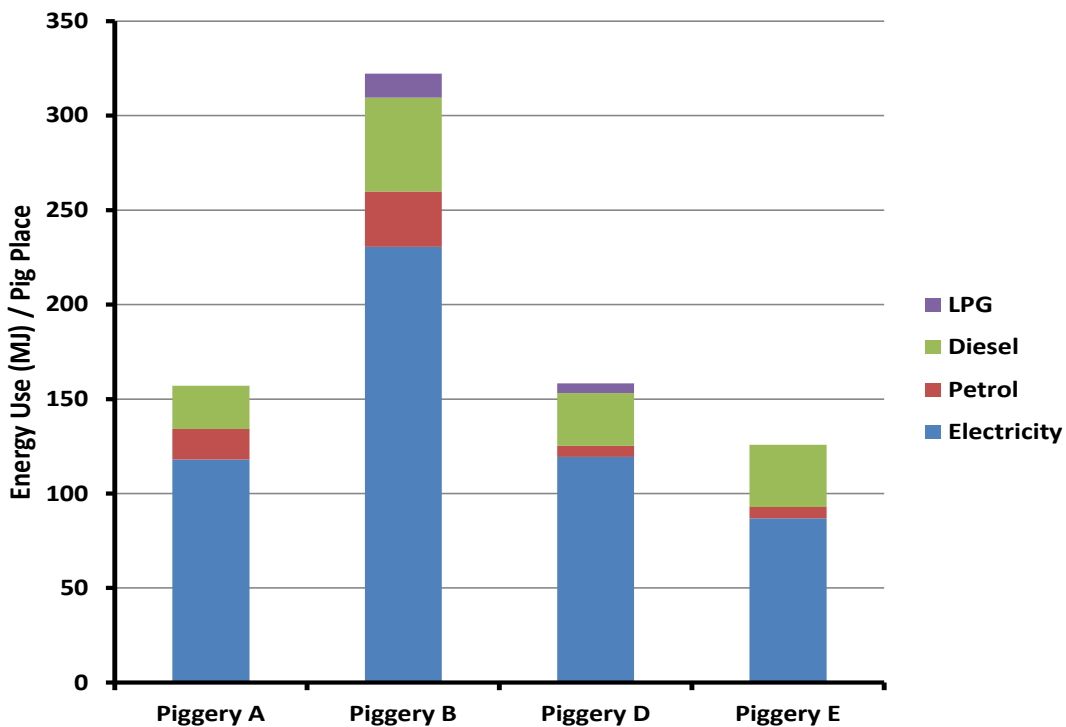


FIGURE 3 – ENERGY USE (MJ) PER PIG PLACE

Figure 3 shows the energy use on a per pig place basis. Piggery B used the most energy per pig place. The other three sites produced similar results in energy efficiency. Piggery D is a large tunnel ventilated finisher site. Results showed that the finisher site was much more energy efficient per pig place than a similar tunnel ventilated farrow to finish piggery. This was expected to be the case as on a per pig place a lot of energy is used for farrowing.

Energy use data from an Australian pig life cycle assessment (LCA) study was used to compare the energy efficiency from a variety of piggeries. Energy use per tonne of live-weight produced for a range of Australian farrow to finish piggeries was compared against monitored data in Figure 4. Energy use ranged from 350 MJ / tonne of live-weight produced to 2700 MJ / tonne of live-weight produced. The comparison showed that most piggeries primary energy source is electricity. However, some piggeries primarily used diesel or LPG. Specific details about the energy data collection for the LCA study piggeries were not provided. The comparison provides a guide to the variation in energy efficiency between Australian farrow to finish piggeries. There variation in energy efficiency indicates potential for piggeries to improve energy efficiency through on-site management and from upgrading infrastructure.

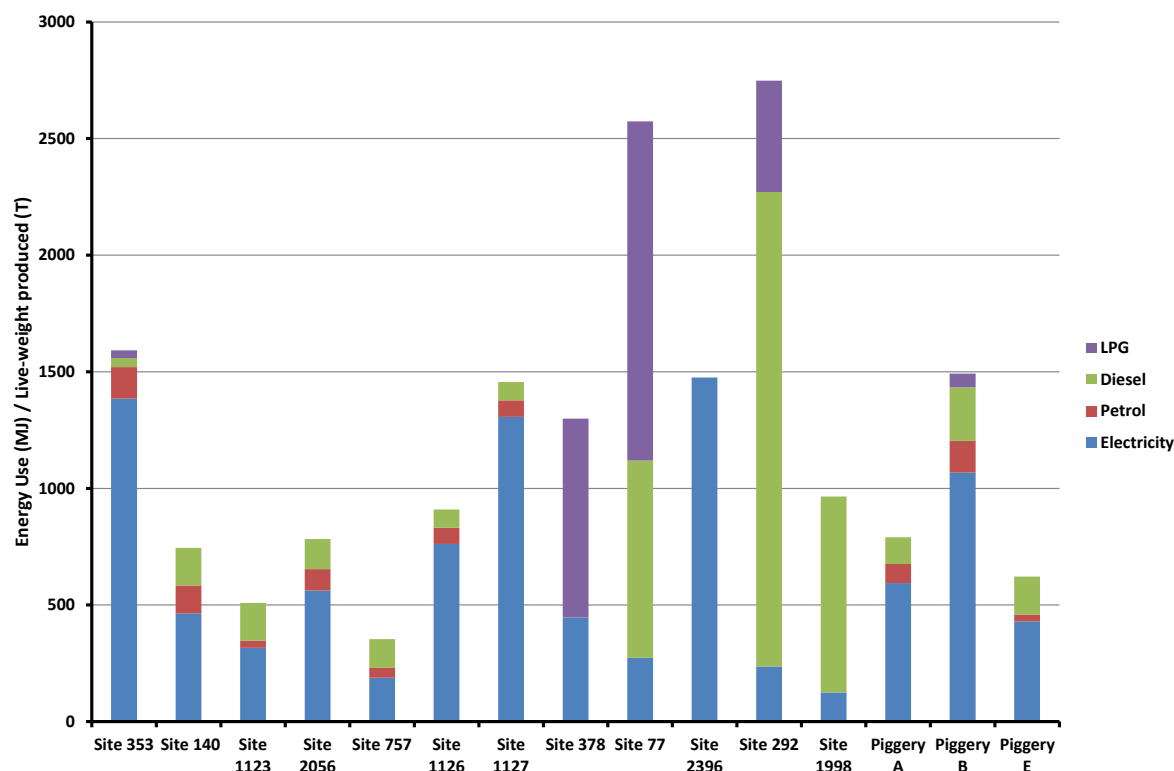


FIGURE 4 – COMPARISON OF ENERGY USE PER T OF LIVE-WEIGHT PRODUCED FOR A RANGE OF FARROW TO FINISH PIGGERIES

LCA energy use data for breeder piggeries was compared against the monitored sites on a per weaned pig basis (Figure 5). Energy use ranged from 110 MJ per weaned pig to 10 MJ per weaned pig. The primary energy use at breeder sites was electrical energy, however one piggery used a large amount of LPG to provide heating. The variation in energy efficiency shows there is potential to improve energy use in the breeding component of pig production.

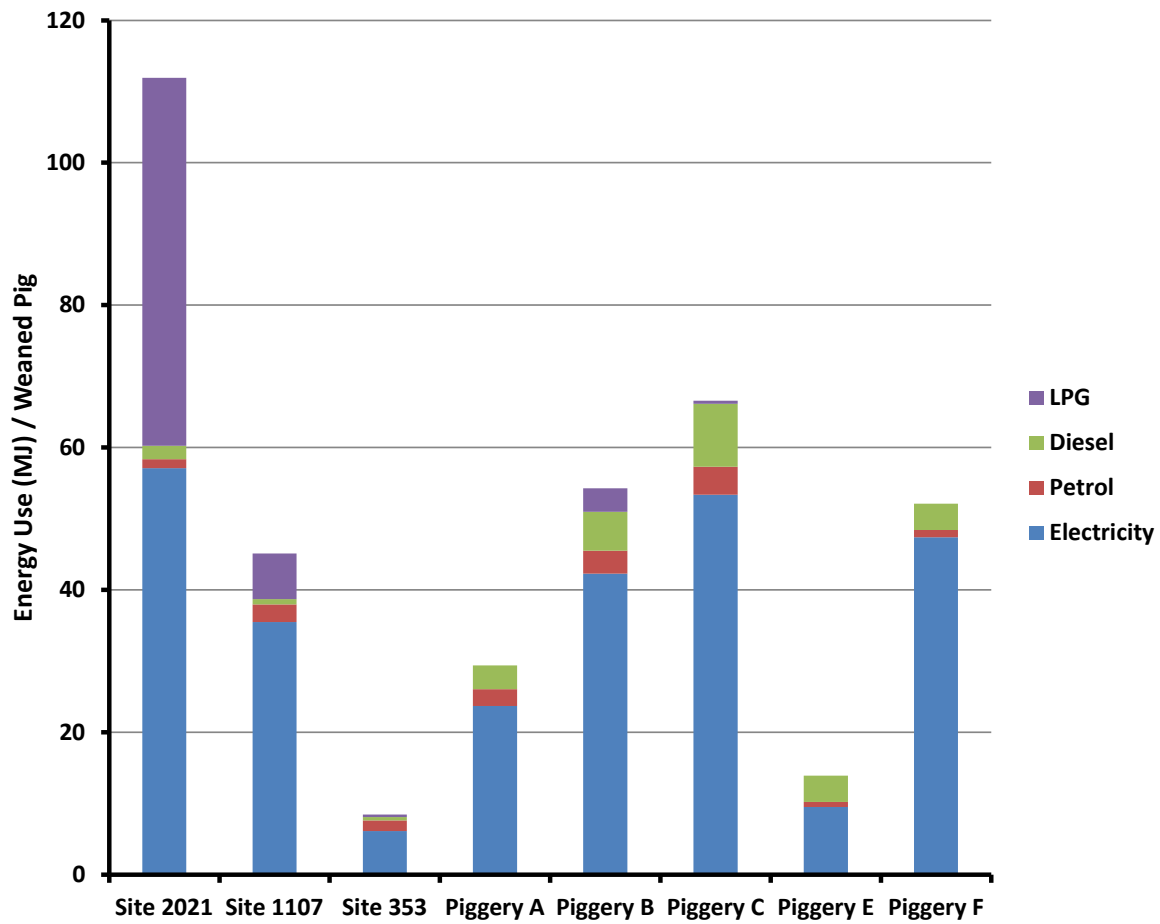


FIGURE 5 – COMPARISON OF ENERGY USE (MJ) PER WEANED PIG FOR A RANGE OF BREEDER PIGGERIES

4.2 Electrical Energy Use Benchmark Data

During the summer and winter monitoring period at the six study sites electrical energy use was benchmarked. The benchmarked data helps identify total electrical consumption and peak energy loads for various areas of the piggery. Data was collated in electrical use per day (kWh/day) and hourly energy use (kWh). Figure 6 and Figure 7 show a comparison of benchmarked daily electrical energy use at Piggery B for two-week periods in summer and winter. The electrical energy use for the total site and each sub-main increases in summer due to more fans operating in the tunnel ventilated sheds. On average, the total sites electrical energy use increases from 2000 kWh/day to 3500 kWh/day. This data provides piggery management with an understanding of daily electrical energy use and the change in electrical energy use with the seasons. Benchmark electrical data also provides a baseline for improvement to energy efficiency; once changes have been applied, the piggery can accurately quantify the reduction in electrical energy use. Daily electrical energy graphs for the other case study piggeries are included in Appendix A.

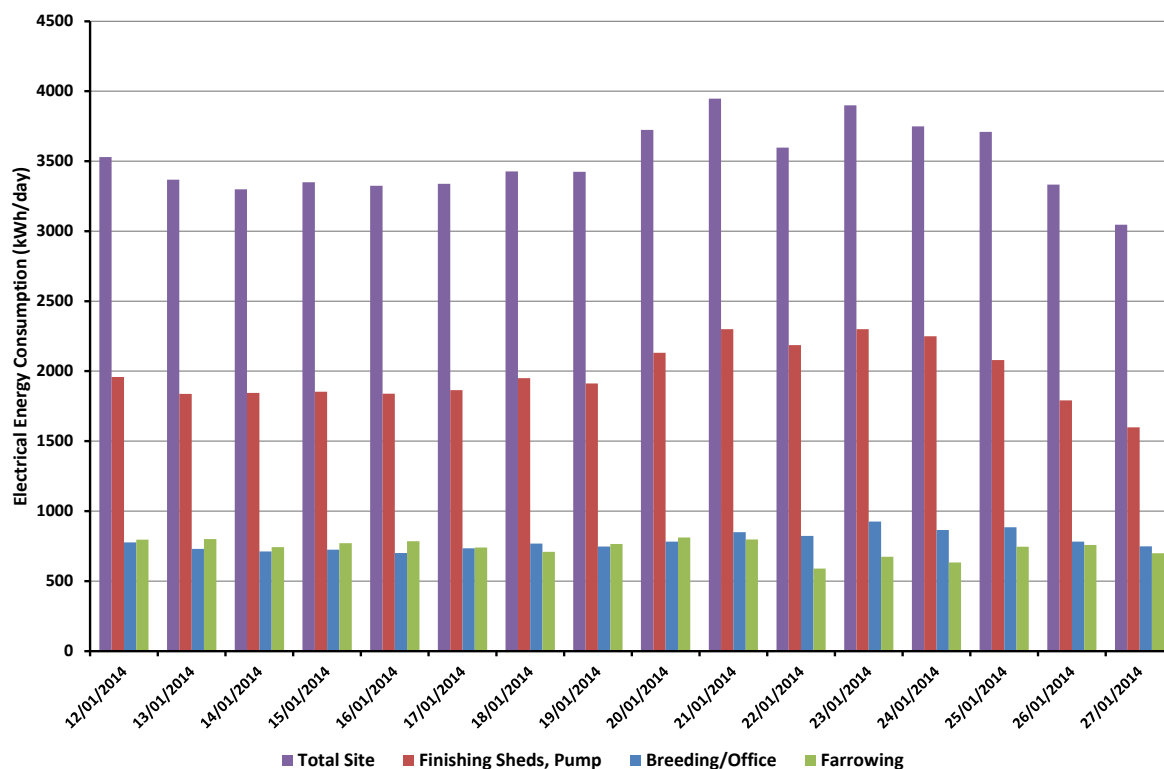


FIGURE 6 – DAILY ELECTRICAL ENERGY USE (kWh/DAY) IN SUMMER FOR PIGGERY B

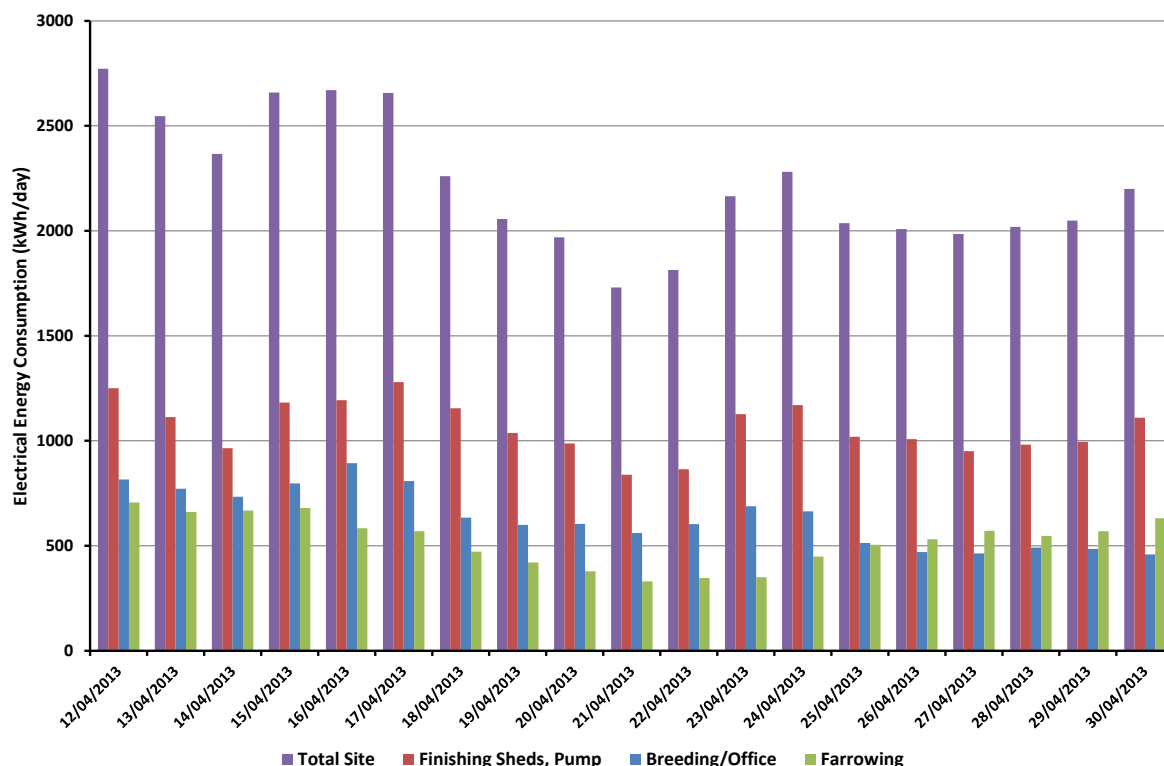


FIGURE 7 – DAILY ELECTRICAL ENERGY USE (kWh/DAY) IN WINTER FOR PIGGERY B

Hourly electrical energy use profiles (kWh) for summer and winter periods at Piggery F are shown in Figure 8 and Figure 9. Piggery F is a naturally ventilated breeder site in Southern Australia. The hourly electrical energy profile highlights peak load for each of the monitored sub-mains at the site. The total site's peak load is 47 kWh which occurred during winter and summer periods. The electrical use at

the site is driven predominantly by the farrowing sheds. Energy use during summer and winter was similar, indicating that the heating system is run the same all year. The temperature was also logged at this site. During the summer period, at times where the temperature exceeded 30°C the farrowing electricity and total site electricity use was greatly reduced. This is due to the heating system switching off under these conditions.

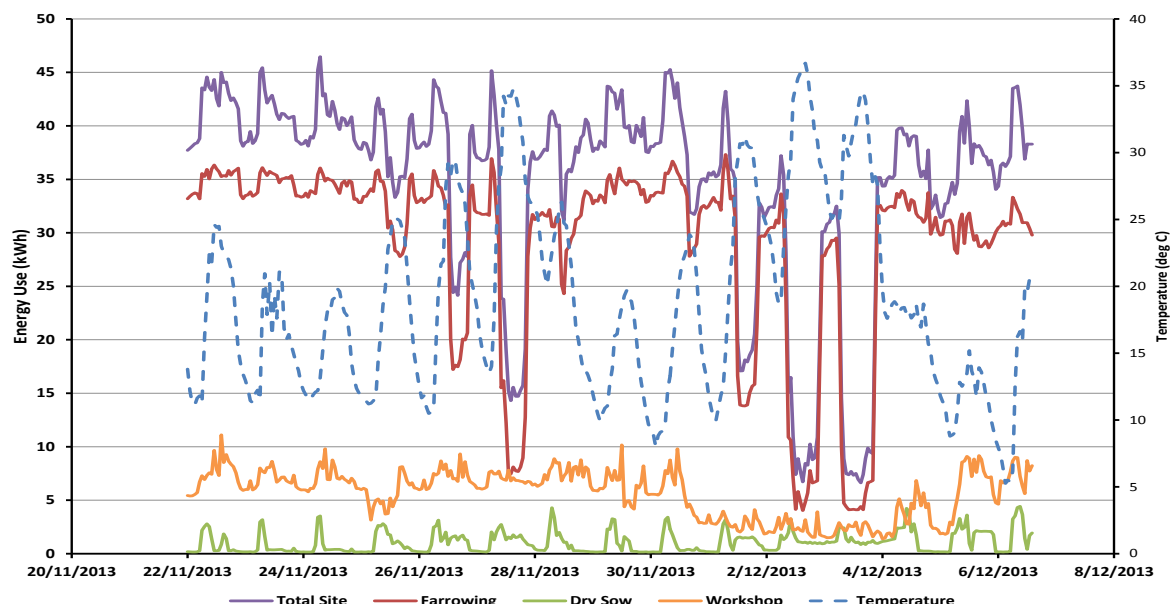


FIGURE 8 – HOURLY ELECTRICAL ENERGY USE PROFILE (kWh) IN SUMMER FOR PIGGERY F

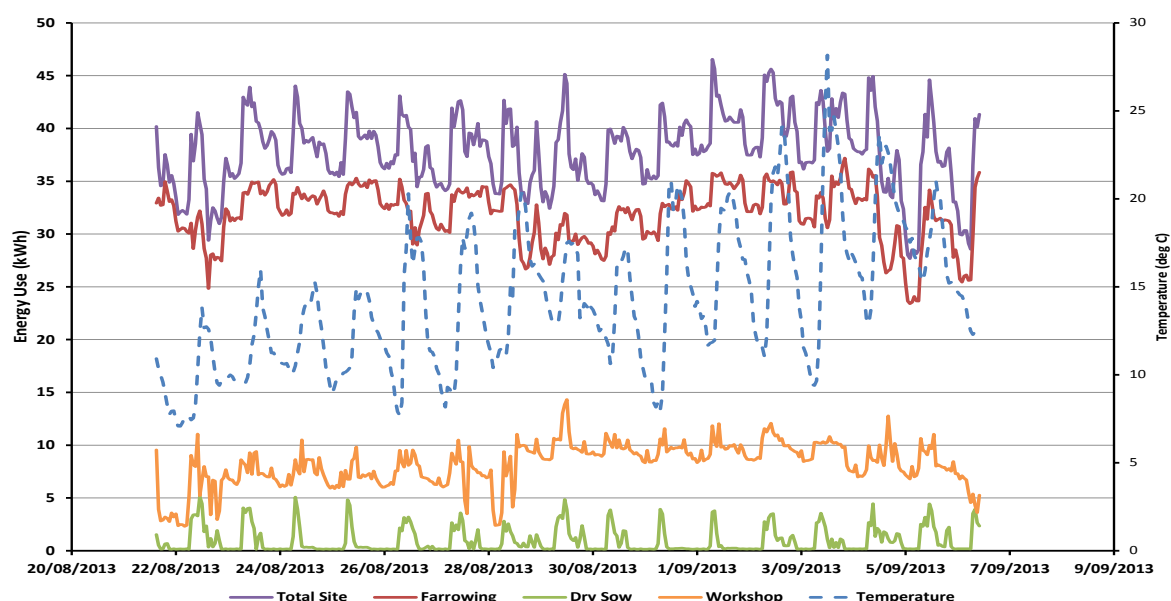


FIGURE 9 – HOURLY ELECTRICAL ENERGY USE PROFILE (kWh) IN WINTER FOR PIGGERY F

The hourly electrical energy use profiles can be further analysed to see the change in energy use throughout the day and identify the time that peak electrical energy use occurs. Figure 10 shows the electricity use over each hour at Piggery A averaged over the data logging period. The standard daily peaks averaged 21 kW and 9 kW for the total site and piggery sheds respectively. This occurred between 7:00 am and 9:00 am. Farm activity logs show that various electrical motors are switched on during this time in preparation for the day's work. There was a noticeable drop in electricity consumption between 12 noon and 6 pm due to the farm operator switching off heat lamps. A spike

in electricity at 3 pm may be caused by a combination of the bore pump and agitators. Figure 10 also shows that the bore pump runs intermittently through the day.

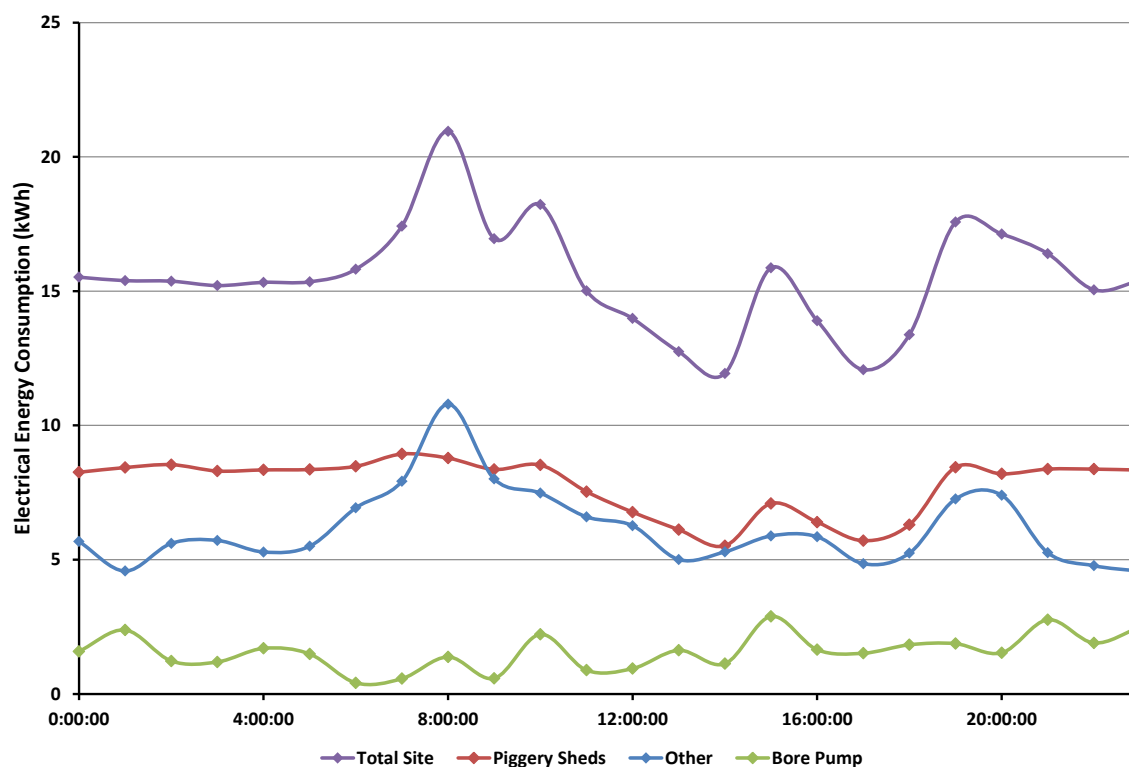


FIGURE 10 – PIGGERY A AVERAGE ELECTRICITY CONSUMPTION OVER A DAY

The average electrical energy use throughout the day at Piggery B is displayed in Figure 11. The tunnel ventilated sheds use automatic fan staging which is controlled by temperature sensors in the shed. Therefore, total site electrical energy use fluctuates with temperature. This data shows that the primary electrical energy use at the site is the ventilation system, in particular the fans. The fans operate from 9:00 to 18:00 on most days. The base electrical load is a contribution of the feed system, water supply pump, effluent pumps and lighting.

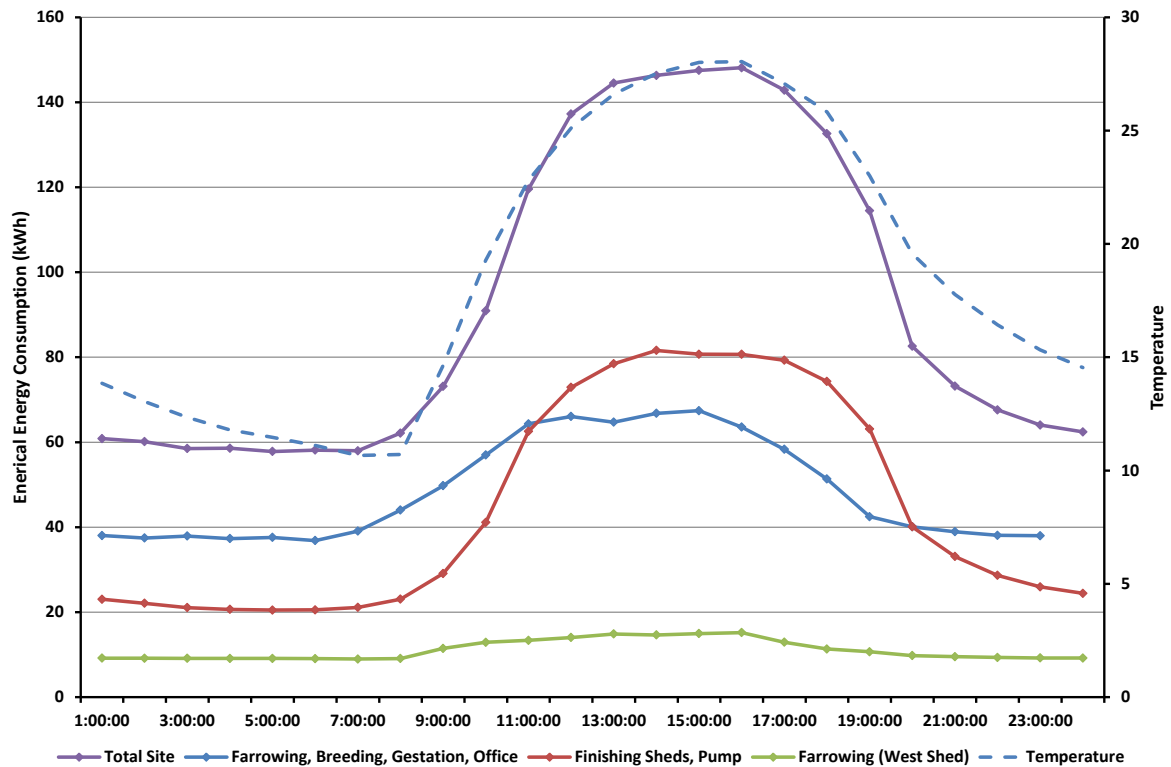


FIGURE 11 – PIGGERY B AVERAGE ELECTRICAL CONSUMPTION OVER A DAY

4.3 Initial Energy Monitoring – Power Factor

Initial electrical energy monitoring was undertaken at Piggery A and E to test the power factor and gain an understanding of the expected energy use and load at piggeries. Off-the-shelf electrical monitors were used for their ability to analyse both kW usage and power factor.

At Piggery A, the power factor of the total site and the bore pump was monitored. Ideally, it is good to maintain a power factor of 0.85 or higher. Figure 12 shows that the power factor for the total site is in the recommended zone for the majority of time. At times, the power factor reduces to around 0.7. This could be when the motors for effluent or hosing are started. The power factor of the bore pump is shown in Figure 13. Once again, the power factor drops to 0.75 when the pump is active. This indicates the pump motor performance could be improved by maintenance (service, check wear) or by correctly sizing the pump according the discharge and flow rate requirements.

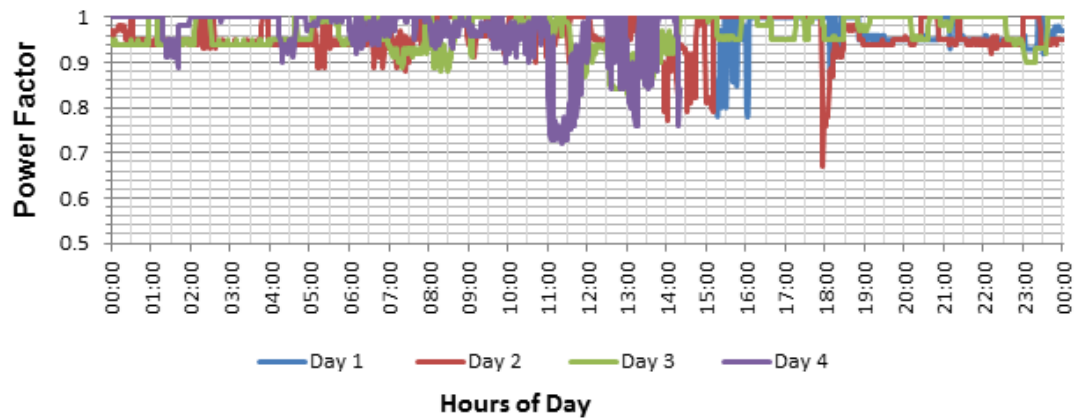


FIGURE 12 – PIGGERY A TOTAL SITE POWER FACTOR

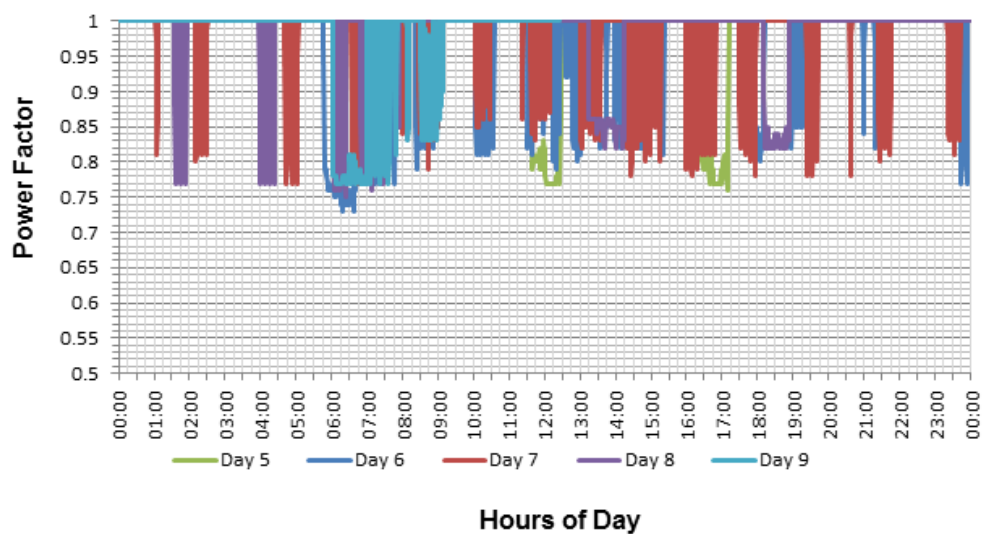


FIGURE 13 – PIGGERY A BORE PUMP POWER FACTOR

At Piggery E the power factor of the total site (less the feedmill) and the feedmill were monitored. Figure 14 shows the total site power factor, the power factor reduces below the recommended level (0.85) at certain times. The power factor is often lower between 7 am and 5 pm. This directly correlates with the operating hours of the piggery where electric motors are used for hosing, effluent management, water supply and feed lines etc. The power factor for the feed mill (Figure 15) often reaches unacceptable low levels, 0.2. The dips in power factor may be caused by the mill running at a minimum or empty load. This is an example of underutilised motors leading to a poor power factor.

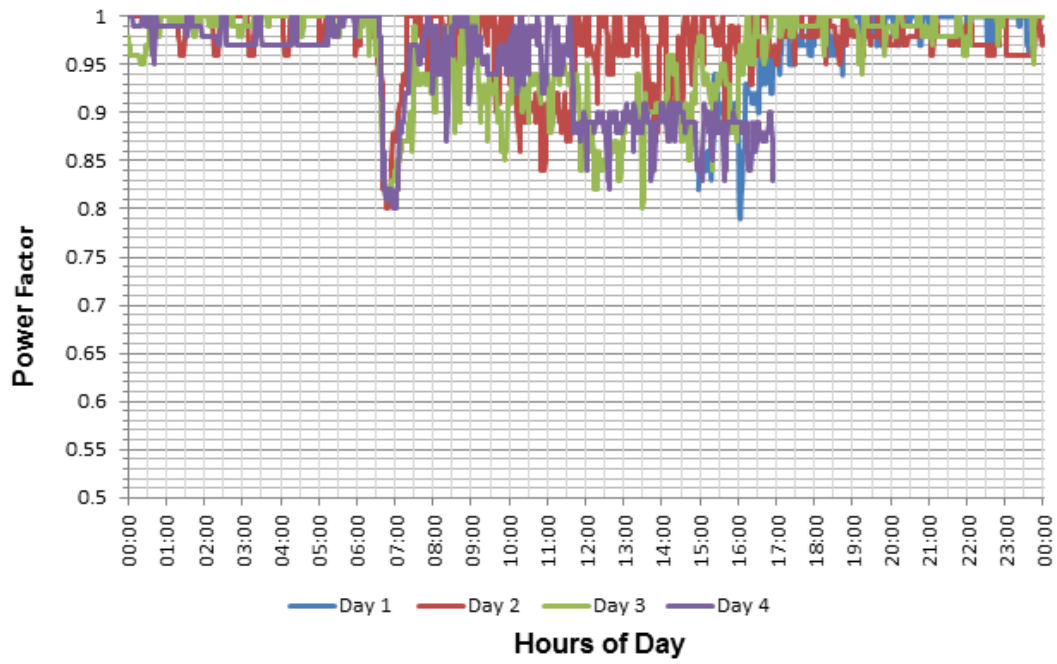


FIGURE I4 – PIGGERY E TOTAL SITE POWER FACTOR

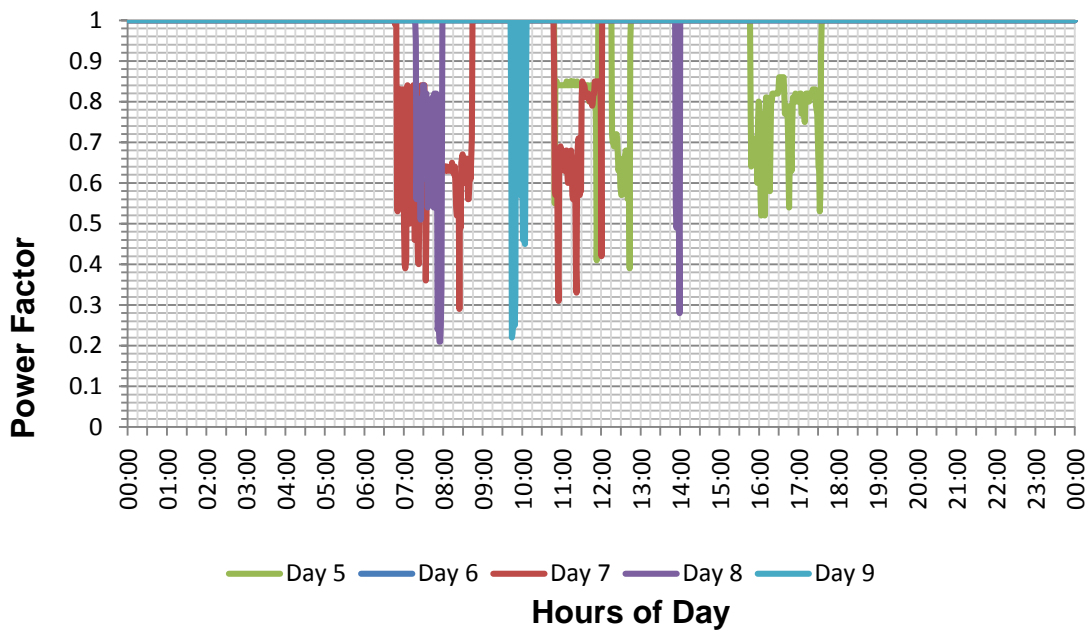


FIGURE I5 – PIGGERY E FEED MILL POWER FACTOR

4.4 Energy Use Breakdown

The contribution of various components to electrical energy use was monitored at four of the six study piggeries.

Table 4 shows these results as average kWh/day over the monitoring periods. Results show that farrowing sheds are often the major contributing component to total site electrical energy usage. This is of significance when considering that the farrowing section of a piggery is usually greatly out-sized by the grower and finisher areas.

TABLE 4 – ENERGY USE COMPONENTS AT FOUR PIGGERIES

<i>Units: kWh/day</i>	Piggery A	Piggery B	Piggery E	Piggery F
Production System	F2F*	F2F*	F2F*	Breeder
Farrowing	150	1169	123	753
Bore Pump	39			
Finishing	36	1383	10	
Feed mill			45	
Dry sow Sheds				27
Workshop / Amenities	145	156	9	121
Total Site	371	2809	187	900
% Farrowing of Total Site	40%	42%	66%	84%

F2F – farrow to finish

These results highlight the heavy contribution of farrowing sheds to the piggeries overall electrical energy use. Optimising energy consumption in the farrowing sheds has the greatest potential to reduce total site energy consumption and therefore low energy costs.

Piggery A had a higher than average energy use contribution from the workshop and amenities sub-main. This is due to a house and office located on-site which the farm manager and workers use. The house and office are supplied with electricity through the workshop sub-main. If the house and office were negated from the total site energy use, the contribution of farrowing to the total site electrical energy use would increase.

Piggery B had similar electrical energy contribution from the finisher and farrowing sheds. This is likely due to all of the sheds on-site using a similar tunnel ventilation system, which consume a similar amount of electrical energy.

Piggery E had lower total electrical energy consumption. The farrowing sheds contributed to 66% of the total site electrical energy use. There was also a feedmill on-site, which used on average 45 kWh/day or 24% of the total electrical energy.

Piggery F had the highest farrowing contribution to total electrical energy use at 84%. There were no other major intensive energy use components on-site. A small amount of electricity was used in the dry sow sheds and the workshop (pumps, motors, lighting etc.)

4.5 Farrowing Shed Breakdown

The farrowing shed has been identified as an energy use hot spot at piggeries. To gain a better understanding of the energy use within an individual farrowing shed it is possible to breakdown the shed into each energy consuming component. This will help identify areas where energy use can be reduced. The farrowing shed at Piggery A was broken down as an example for which it is recommended other piggeries follow.

The first step in breaking down the energy use at a farrow shed is to identify the motor size (kW) of each piece of energy consuming equipment. If liquid fuels, power equipment the number of litres required over a pre-determined time interval should be recorded. The farrowing shed sub-main at Piggery A supplied the following equipment.

- 96 heat lamps (250 watt bulb)
- Hosing pump (2.4 kW)
- Effluent agitator motor (2.2 kW)
- Effluent pump (4 kW)
- Waste reticulation pump (7.5 kW)
- Feeder motor (1.2 kW)

The second step is to record the time of use for each piece of equipment throughout the day. The farm manager of Piggery A provided a log of equipment used over the electricity monitoring period. Using this data, the breakdown of energy use components within the farrowing shed was estimated (Figure 16). This process can be used to further breakdown the power at any piggery shed. It enables the manager to make an informed decision on which area to target to improve energy efficiency.

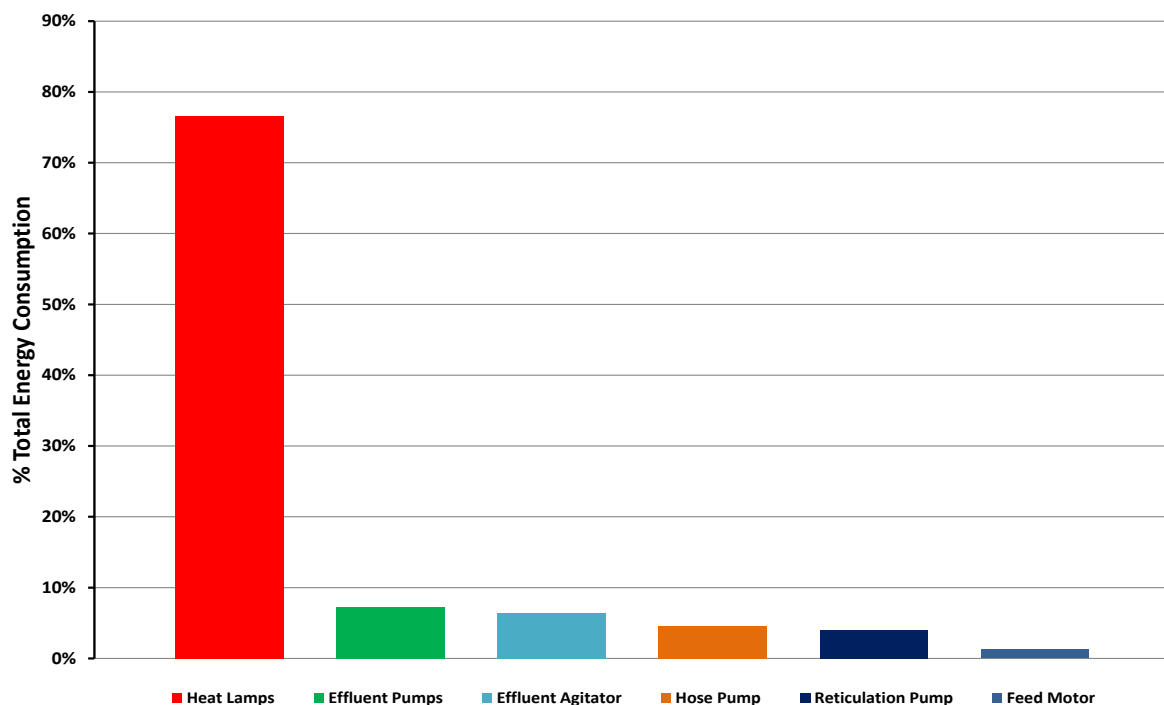


FIGURE 16 – ELECTRICITY BREAKDOWN FOR AN INDIVIDUAL FARROW SHED AT PIGGERY A

Heat lamps were the major contributor to farrowing shed electricity use, totalling 77% of total electricity. The three pump motors (used for effluent, hosing and waste reticulation) and the effluent agitator motor combined, contributed 22% of the total shed. Feed distribution motors accounted for the remaining energy use. The contribution of the heat lamps to the total farrow to finish piggeries was estimated at 38%. These results highlight the significance of the farrow heating system with regards to energy use. Improvements to the heating system can drastically reduce energy use and associated costs. Energy use can be further improved by ensuring pumps are operating efficiently and are well maintained.

4.6 Summer and Winter Comparison

To access the difference in energy use in summer (warm) and winter (cool) climate conditions energy monitoring was conducted in both periods. Results from the electrical energy benchmark data showed high variation in electrical from summer to winter (Table 5).

TABLE 5 – AVERAGE DAILY ELECTRICAL CONSUMPTION DURING SUMMER AND WINTER

Site	Average Total Site Energy Use (kWh/day)	
	Winter	Summer
Piggery A	389	371
Piggery B	2223	3504
Piggery C	2592	3768
Piggery D	2069	5480
Piggery E	187	138
Piggery F	921	834

Electricity consumption was higher during the winter at Piggery A, E and F, all naturally ventilated sites. This is due to the heating system in the farrowing sheds being used more due to the cooler climate. Most other electrical consuming activities at naturally ventilated sites (effluent pumps, lighting, feed supply etc.) will remain consistent throughout the year.

At the tunnel ventilated sites, Piggery B, C and D, electrical consumption was higher in summer. This is due to the ventilation system running with more fans on in an effort to keep the shed apparent temperature at a comfortable level. In winter, the fans running is reduced the natural vents are used when required to control the shed climate.

Other factors influencing electrical energy use during summer and winter is the type (ventilation and pig production) of the piggery and the climatic location of the piggery. For example, naturally ventilated breeder sites in a cool climate will likely use more energy during winter due to greater heating requirements in the farrowing shed. This is the case for Piggery F, which used 921 kWh/day in winter and only 834 kWh/day during summer. However, for tunnel ventilated finisher piggeries in a warm climate the energy use will be highest during summer as the ventilation system will be running at maximum capacity keeping the pigs at a comfortable temperature (cooler than ambient temperature). This is the case with Piggery D which increases from 2069 kWh/day in winter to 5480 kWh/day in summer, a 2.65 times increase.

The average energy use throughout a summer and winter's day for Piggery B is provided in Figure 17. The energy consumption decreases in the each area of the piggery. The capacity and length of time, which the tunnel ventilation fans are running, decreases during winter. The energy use during winter at the breeder sheds decreases by 5 kW (peak load) during winter as the fans are offset to some degree by the increased heating energy consumption. The energy use at the finisher sheds decreases by 20 kW (peak load) during winter which is purely driven by the ventilation system.

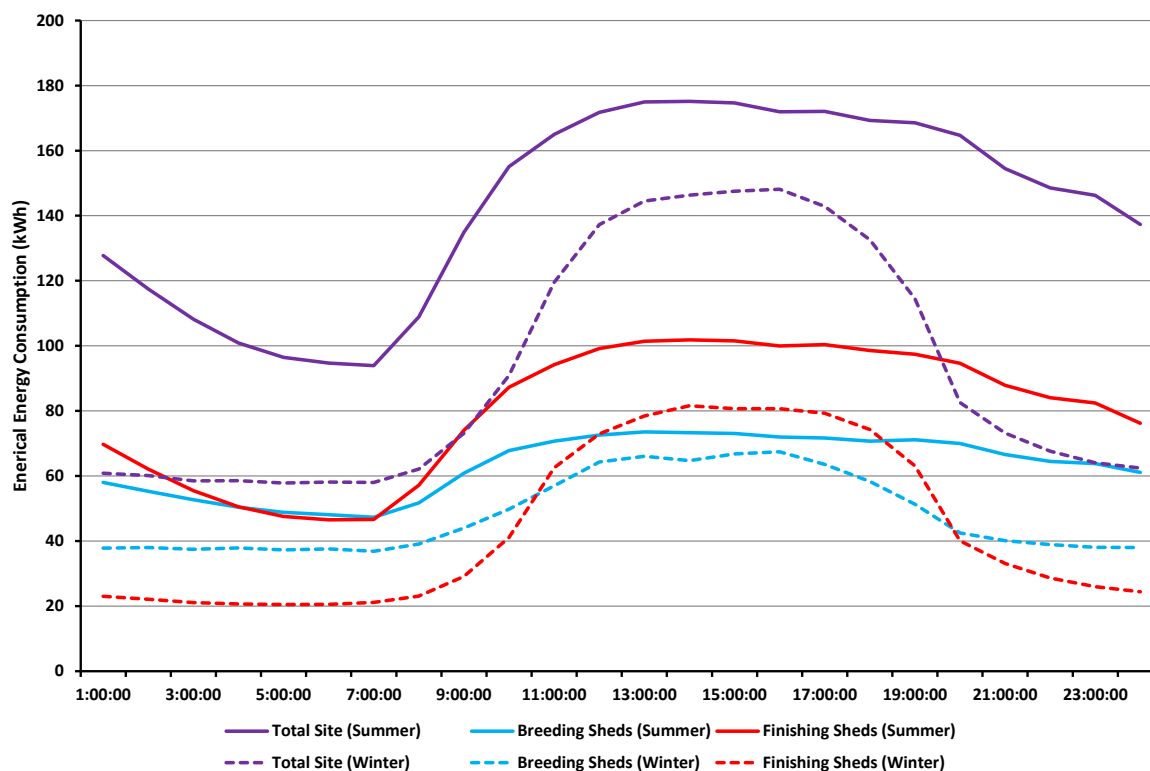


FIGURE 17 – PIGGERY B SUMMER / WINTER ELECTRICAL ENERGY USE COMPARISON

5 Energy Efficiency Recommendations

Energy use is a growing cost for pork production; further price rises are forecast in the future. Decreasing on-site energy use is a viable option to increase the economic performance of pork production. Piggery operators have a responsibility to minimise energy use to reduce pressure on energy reserves and to reduce contributions to greenhouse gas (GHG) via energy use. These issues make energy efficiency a growing priority for the industry.

Energy efficiency can be improved by implementing improved management practices and/or installing new equipment. The cost of installing new equipment needs to be assessed from a cost/benefit analysis however. Improving energy efficiency has the positive effect of reducing the costs associated with producing pigs. The following components of a piggery are vital to energy efficiency, heating, ventilation and cooling, lighting, and management practices. Management practices include managing gas and fuel usage, managing peak energy loads, and operating pumps, feed systems and administration

activities that require energy.

Understanding the importance of power factor is vital to improving energy efficiency. Power factor is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. In an electric power system, a load with a low power factor (<0.85) draws more current than a load with a high power factor (>0.85) for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, power authorities will usually charge a higher cost to customers where there is a low power factor. Hence, a power factor close to unity (1) is the aim.

Improvements to energy efficiency can only be accurately assessed and confirmed by measuring usage. Measuring energy use can be aided by installing additional electricity, fuel and gas meters to allow measurement of individual shed sub-mains and components within sheds. Electricity usage meters provide a measurement of energy consumption (kWh) and also record total energy consumed. This provides a valuable tool for assessing the electrical performance of sheds and will assist in reviewing energy efficiency measures.

5.1 Heating Efficiency

Results from the energy breakdown analysis show that heating is the greatest contributor to energy use at a conventional (non-mechanically ventilated) farrow to finish piggery or breeder only piggery, as demonstrated in Figure 16. Heating energy is the heat lamps in the farrowing unit, which are used to keep weaner pigs warm during the initial growth stage. The most effective way to reduce heating energy use and its associated cost is to ensure excess heating or heat wastage is not occurring. The area requiring heating can be reduced by using small-insulated huts or housing within the farrowing shed crate design, this prevents heat from escaping into the larger shed area. Excessive heating can be controlled by installing thermostats that control when the lamps operate. Once the temperature inside the pens has exceeded a set interval the lamps will automatically dim or switch off saving large amounts of energy. It is useful to monitor the temperature fluctuation (maximum and minimum temperatures) in the pig shed; this can be done by installing temperature loggers.

Heat wastage can be improved in several ways. It is vital that piggeries with tunnel ventilation systems check that ventilation is working in tandem with the heating system. The ventilation system may counteract the shed heating resulting in unnecessary, increased heating energy costs. This will not affect air quality but will sharply increase energy use.

Quality shed insulation will also prevent heat loss. Either poor insulation, low quality (poor thermal retention) or damage (leaks) will cause heat to be lost lowering the efficiency of the system. Walls and ceiling should be insulated with high quality materials with suitable U values (heat transfer coefficient – i.e. describes how effectively a building element conducts heat). The condition of existing insulation should be checked for any signs of wear or damage.

A new approach to improving heating efficiency is the installation of heat to air pumps that heat the heating pads in a farrowing unit. These systems extract heat from ambient air and heat water up to 55 °C via heat exchange. These systems have a higher capital cost but are effective at reducing long-term fuel costs. It is recommended piggeries investigate the long-term economic feasibility of installing heat pumps before committing.

Piggeries can also consider reduce heating energy use by switching from electrical to gas as a thermal heating source (space heaters). Tiles beneath the farrowing area can also be heated by using recirculated water that is heated via gas (including biogas).

5.2 Ventilation and Cooling Efficiency

Tunnel ventilation systems can be a heavy contributor to energy use at a piggery. Tunnel ventilated sheds are able to control shed climate better than natural ventilation systems. Modern tunnel ventilation sheds rely on two factors to keep the pigs comfortable and productive, the combination of air movement by the fan system and the evaporative air-cooling by the cooling pads. Quality shed insulation is equally important for cooling as heating, as it reduces the external heat load entering the shed during hot summer conditions, enabling the cooling pads to cool air and the fans to mix the cool air throughout the shed.

The fan motors within the ventilation system are a major source of energy demand. Methods for improving fan performance and energy efficiency include:

- 1) Regularly cleaning fan blades, motors and shutters.
- 2) Replace burnt-out motors with energy efficient motors.
- 3) Investment in more capital (e.g. energy efficient fans and cowlings). This decision should be based on potential pay-back.
- 4) Ensuring shed ventilation (fan performance) is meeting manufacturer requirements.
- 5) When constructing new tunnel ventilation pig sheds select energy efficient fans, pay attention to the fan's energy efficient rating (cfm/watt) and air flow ratio.
- 6) Reducing the fan speed with a variable frequency drive (VFD) unit reduces airflow rate and the energy consumption of the fan; operate in accordance with ventilation requirements.
- 7) Data from the US shows for every 2 CFM / watt increase, power usage is reduced by approximately 10%.

Good management of the cooling pads can also improve energy efficiency. This involves regularly cleaning the cooling pads to ensure air flow is not restricted, minimising the load on the fans. During use, the cooling pumps should be running continuously to keep the pads wet and as clean as possible.

5.3 Lighting Efficiency

Energy use for shed lighting is another contributor to energy demand in all piggeries. There is great potential for energy savings from lighting due to the rapid development of technology. New lighting technology should be investigated as a viable option for replacing poor energy efficient, aging lighting

infrastructure. Traditional incandescent bulbs are inefficient as they only convert 5% energy into light, the remaining energy is given off as heat. Piggeries should be replaced these with energy efficient types such as, compact fluorescent bulbs, and fluorescent strips. These lighting types drastically use less energy and have a much longer lifetime, values are displayed in Table 6.

TABLE 6 – RELATIVE ENERGY EFFICIENCIES OF VARIOUS LIGHT SOURCES

<i>Lamp Type</i>	<i>Lamp Size (W)</i>	<i>Lumen Efficacy (lumens/kW)</i>	<i>Typical Lamp Hours</i>
Incandescent	25-200	36-71	1000
Compact fluorescent	5-50	47-82	8000+
Fluorescent strip	32-120	66-82	16,000+
LED (Light-emitting diodes)	25	50-100	30 000 to 50 000

Light emitting diodes (LED) are the most recent development in long lasting, energy efficient lighting types. They are more expensive to install but last much longer and are more energy efficient as they do not produce excess heat. They are a worthwhile investment, as future energy costs will be reduced. They are highly recommended, particularly for new pig sheds.

5.4 Fuel and Gas Efficiency

With high costs of gas and fuel (petrol and diesel) piggeries can reduce costs by using these energy sources more efficiently. For piggeries that use gas for heating purposes, usage may be reduced by installing curtains inside the shed to restrict the area that requires heating. Gas used for heating can also be minimised by ensuring sheds well sealed from cold air leaks.

Piggeries use fuel and diesel to operate generators and equipment within the shed such as pumps and motors. Fuel and diesel use should be recorded routinely so the piggery is aware of consumption. Fuel and diesel use can be reduced by good management practices and by maintaining and using suitable equipment. Good management involves running pumps and motors when required and switching off once done, regular servicing of equipment will ensure fuel use is maintained at manufacturer's specifications. When selecting the type of motors for a particular job, the motor capacity should be chosen based on the specific requirement. Fuel will be wasted choosing a large, powerful motor for a job that requires less energy.

5.5 Pumping Efficiency

Simple on-farm checks can assist in improving the energy efficiency of the pumping equipment at a piggery. Wear rings and impeller clearances are critical. Anything that causes these tolerances to open will cause internal recirculation that is wasting energy as the fluid is returned to the suction of the pump. If the wear ring is rubbing, the generated heat is consuming excess energy. Implementing a servicing and maintenance program will ensure worn out parts are quickly identified and either repaired or replaced. Farm staff should routinely check around the pumps and water systems for leaks that lead to inefficient energy use due to cycling of the motor.

5.6 Managing Peak Energy Loads

Although not necessarily reducing energy use, energy costs can be reduced by managing and reducing peak energy loads. Peak energy often occurred during high tariff hours due to increased demand on the electricity grid. Where possible a piggery should switch load to low tariff times, significantly reducing energy costs. Another option in reducing electrical energy costs is to negotiate with the supplier for a reduced tariff, this is reasonable especially if the piggery runs back-up diesel generators or other alternatives to reduce reliance on grid electricity during peak energy demand. Peak electricity use can be monitored by installing electrical power meters on the power supply of each shed to monitor energy usage over a desired period.

The results section Figure 10 and Figure 11 display times during the day when peak energy usage occurred. Both tunnel ventilated and naturally ventilated piggery types were included. Peak energy loads from the tunnel-ventilated systems, Piggery B, C and D, occurred between 12:00 noon and 16:00. This was caused by the warmer temperatures intensifying the cooling requirement of the sheds. Energy use increased due to higher fan activity and the cooling pads working harder. The piggeries with tunnel ventilation had the largest SPU and consumed the most energy. This analysis does not represent their energy efficiency regarding pork production. The smaller capacity, naturally ventilated piggeries, A, E and F, experienced peak energy use at different times compared to the tunnel ventilated systems. Peak energy use was experienced between 7:00 and 9:00 a.m. This was caused by the piggery managers switching on pump motors and other electrical machinery in preparation for the day's work. Due to the low overall energy consumption, the impact of these energy use components was more noticeable than at energy intensive tunnel ventilation sheds. The base energy load at piggeries with a farrowing unit is likely the heat lamps, which contribute heavily to the overall consumption.

As piggery E contained an energy intensive feed-mill, peak energy use will likely occur whenever milling takes place (Figure 41).

Peak energy loads at tunnel ventilated piggeries may be reduced by minimising the operation of any additional equipment while the system is operating at full capacity. At smaller piggeries, the motors and electrical machinery either be switched on gradually or left on standby to reduce the peak load caused by several motors starting up simultaneously. As mentioned, back-up generators can be used to reduce the electrical requirement on the grid during peak demand hours. Another option in reducing costs related to peak energy use is running any high-powered motors or pumps (bore pump, effluent reticulation pump etc.) during off peak hours.

Piggery A energy use shows the impact a bore pump can have upon peak energy use. By using the bore pump at off peak hours the piggery can significantly reduce energy cost. Figure 10 shows that there is higher use of the pump between 6am to 5pm on certain days. This is when the pigs are consuming more water and farm staff is using water to wash pens. Consideration could be given to dual tariff metering and level control of the pumps to offer additional control over when pumps can be used according to the consumption of water as when required during the peak hours. Also increasing the storage capacity to facilitate shifting power consumption to off peak periods.

5.7 Alternative Energy Sources

Piggeries have the option to reduce energy demand on the electrical grid, therefore reducing energy costs, by implementing alternative energy sources. Alternative energy including; solar, wind and biogas; can be produced on-site by the piggery to supplement electrical energy usage. Before installing these systems, piggeries are encouraged to conduct an economic feasibility study. The feasibility of alternative energy sources will improve as new technologies are developed and the costs decrease.

5.7.1 Solar

Existing fossil fuel energy consumption can be replaced by using photovoltaic (PV) cell systems. The cells are designed to fit on available roof space which most piggeries have available. At large tunnel ventilated facilities, solar cells are used to reduce peak electrical energy load during hot periods of the day. They are also useful at smaller piggeries due to the ability to store energy for use in any energy intensive activity. As mentioned, decreasing peak load allows farm management to negotiate cheaper rates with power suppliers by reducing the burden on electrical infrastructure. However, the payback may not be worth the initial investment at smaller, low energy use piggeries.

5.7.2 Wind

Wind power is a similar approach to solar considering options to produce alternative, renewable energy. Wind turbines will also reduce peak electricity usage by providing back-up power when required. Piggeries looking to install wind turbines must be located in geographical areas that receive consistent and meaningful wind speed.

5.7.3 Biogas

The piggeries included in the energy monitoring all incorporated a conventional, liquid effluent treatment system, i.e. anaerobic ponds. There is potential to use the methane produced in the effluent breakdown process to generate heat and/or electrical energy to supply the piggery, greatly improving energy efficiency and reducing energy costs. It also reduces the amount of greenhouse gases emitted which greatly benefits the reputation of the entire pork industry. Biogas energy production can be achieved by installing a covered effluent pond system, to capture methane, coupled with the generation of thermal and/or electrical energy. Electrical energy can be created from biogas via a biogas generator (or combined heat and power system) to convert the gas to usable energy.

The cost of purchasing the required parts and installing these systems are substantial. It is recommended interested piggeries access if the energy savings are economically feasible. Feasibility studies (Murphy et al. 2012) have reported a covered anaerobic pond with an energy generation system had a payback period from 8 to 2.8 years for piggeries ranging in size from 3500 to 75000 SPU respectively. Note that these results are based on revenue streams that are heavily influenced by government legislation, and therefore subject to change. However, the installation of a covered pond biogas energy generation system has great potential for piggeries, especially those with high energy demand (intensive heating, tunnel ventilation, feed mills etc.).

5.8 Improving Power Factor

Various improvements can be made within an electrical system that will improve the site's power factor including:

- Existing motors can be replaced with more energy efficient ones.
- Ensure motors are correctly sized for their application and duty cycle.
- Use high power factor lighting ballasts.
- Install power capacitors.

The installation of Power Capacitors is the easiest and most cost efficient method of improving power factor.

A cheaper method is the installation of a centrally located automatic switching power factor correction bank (APFC). This capacitor bank is controlled by a microprocessor-based relay, which continually monitors the reactive power requirements. The relay then connects or disconnects capacitors to supply capacitance as needed.

Regardless of which strategy is implemented, careful planning should be undertaken to ensure maximum benefit is derived from the correction. Other factors that need to be taken into consideration during this planning phase are harmonics on the electrical system as well as any known future expansions to the facility.

Having a high power factor will reduce the amount of current carried by the electrical system. This can result in infrastructure cost savings when planning expansions. Low power factor is usually associated with motors, pumps and transformers. With low power factor loads, current flowing through the electrical system components is higher than necessary for the required work. This results in excess heating, which can damage or shorten the life of equipment. A low power factor can also cause low-voltage conditions, resulting in dimming of lights and sluggish motor operation.

Note: Queensland is the only state that still charges electricity in kW (Volts x Amps x PF). All other states & mostly around the world the sale of electricity has moved to being kVA (Volts x Amps).

At present, in Queensland, there is no penalty imposed on consumers who are falling under a low Power factor category, but in other states and around the world, penalties are being imposed on consumers failing to meet the Power factor of 0.85 or above. This is something to be aware of as an opportunity to make savings as the market changes and power factor becomes a component when purchasing power. Laws will change into the future, however right now it is not necessary to feel you have to race out and address this. If a consumer is considering becoming "contestable" type client, power factor will be a requirement, operating at 0.85 to 0.95 ranges.

6 Conclusions

Intensive electrical energy monitoring at six unique Australian piggeries was completed between 2012 and 2014. There were large differences in the piggeries raw electrical usage (kWh) which was expected given the variety of sizes and piggery operations. To better compare the data energy usage was reported on a per pig production unit basis. Results showed that energy use as a function of pork production (per tonne of live-weight produced, per pig weaned and per pig place) varied greatly

between piggeries. The predominant source of energy was electrical, followed by diesel, petrol and LPG respectively.

The area that used the highest amount of electrical energy at the monitored natural ventilation piggeries was the farrowing sheds. By identifying the electrical use components and their properties within a farrowing shed, and with a log containing their time of use, an energy use breakdown of the shed was performed. Upon investigating the data, it was found that the heating system (heat lamps) within the farrowing shed were responsible for a significant amount of energy usage (77%). The remaining energy use in the farrowing shed was from electrical motors used for pumps and feed supply.

The main energy use component at the monitored tunnel ventilated piggeries was the ventilation system and its components (control panel, exhaust fans, cooling pads, water pumps etc.). Energy usage increased by well over 100% when the ventilation systems were running. The fan motors are the primary source of electricity use within the ventilation system.

Other major energy components at the monitored piggeries included bore pumps, waste reticulation pumps, feed mills, and workshop or workers amenities.

Energy use at most piggeries was driven by the climate, i.e. seasonal temperature. The location of a piggery will also impact the annual energy use variations depending on the climatic conditions throughout the year and the type of systems the piggery has in place to control the pig's environment. For natural ventilated piggeries containing farrowing sheds energy use increased during the winter as more energy was required for heating the piglets. In tunnel ventilated piggeries energy use increased during summer as more emphasis was placed upon the ventilation system (exhaust fans and cool pads) to control a comfortable climate for grower and finisher pigs.

Initial energy monitoring to gather data about power factor showed that there is room for improvement. When a large motor was running the power factor at the monitored piggeries dropped to below the recommended level of 0.8. This results in inefficient energy consumption. Power factor can be improved by ensuring the motors are in good condition, by correctly sizing the motor to the required job, and by ensuring the motor is not run at low capacity.

With increasing cost on electricity and rising greenhouse gas pressures, piggeries have great incentive to improve energy efficiency which reduces their energy costs and carbon emission footprint. It is recommended that piggery managers gain an understanding of where electricity is used on the site and how much is used. Electricity monitors are available for reasonable prices and will help piggeries produce a plan of action to reduce energy use. Piggeries can create a log of energy use from different areas around the site to identify changes in energy use. After implementing energy saving plans, the piggery can then quantify its improvements through the electricity meters. To garner the best results at improving energy efficiency, the piggery should target areas of high usage and areas that can be cheaply and easily improved.

For piggeries with farrowing, improvements to the heating system can greatly improve energy efficiency. The easiest way to improve heating is to reduce the area required heating and to minimise heat wastage. Other viable options are to switch from electrical energy to either gas or water heating systems.

Large piggeries with tunnel ventilated sheds can improve energy efficiency by ensuring the fan climate control is operating correctly, i.e. fan staging is controlled by several temperature sensors within the shed. The fan motors should be regularly cleaned and maintained to ensure they operate efficiently.

Other components of the piggery that can be improve energy efficiency are; selecting energy efficient lighting types, ensuring fuel and gas is used only as required, and by ensuring motors and pumps are well maintained and working to the correct capacity.

Although not necessarily reducing energy use, energy costs can be reduced by managing and reducing peak energy loads. Peak energy often occurred during high tariff hours due to increased demand on the electricity grid. Where possible a piggery should switch load to low tariff times, significantly reducing energy costs. Another option in reducing electrical energy costs is to negotiate with the supplier for a reduced tariff, this is reasonable especially if the piggery runs back-up diesel generators or other alternatives to reduce reliance on grid electricity during peak energy demand.

Large, high-energy use piggeries have the option to reduce energy demand on the electrical grid, therefore reducing energy costs, by implementing alternative energy sources. Alternative energy including; solar, wind and biogas; can be produced on-site by the piggery to supplement electrical energy usage. Before installing these systems, piggeries are encouraged to conduct an economic feasibility study. The feasibility of alternative energy sources will improve as new technologies are developed and the costs decrease.

In conclusion, the energy monitoring at six Australian piggeries has shown significant variation in energy use between different sites. This indicates that most piggeries will have room to reduce energy use and save money. For further information on the energy use components at piggeries, the results of this project, ways to measure energy use and methods on how to improve energy efficiency, there is a factsheet series available from Australian Pork Limited.

7 Acknowledgements

FSA Consulting would like to acknowledge the farm managers and staff at the six piggeries involved in the electrical energy monitoring, for allowing site access, for cooperating through the installation and removal of the energy monitoring equipment, and for supplying the required data. Large thanks also go to the electricians at Condamine Electrical Company for installing the monitoring equipment.

8 References

Department of the Environment (2014). Repealing the Carbon Tax. [online] <http://www.environment.gov.au/topics/cleaner-environment/clean-air/repealing-carbon-tax>, Department of the Environment, Australian Government.

Keogh, M. (2012). The carbon tax - what does it mean for grain and livestock producers? Grains Research & Development Corporation, GRDC, Australian Government.

Meo, H. and G. Cleary (2000). PigStats99. Australian Pork Corporation and PigResearch and Development Corporation. Sydney and Canberra.

Murphy, C. M., E. J. McGahan and S. G. Wiedemann (2012). Assessment of treatment technologies and strategies to mitigate GHG emissions. Final Report, APL Project No. 2011/1013.397. Canberra, ACT, Australian Pork Limited.

NFF (2012). Submission to Senate Select Committee on electricity prices, National Farmer's Federation.

QFF (2013). Submission on regulated retail electricity prices. Brisbane, QLD, Queensland Farmer's Federation.

Wiedemann, S., E. McGahan and C. Murphy (2012). Energy, water and greenhouse gas emissions in Australian pork supply chains: A life cycle assessment. Toowoomba, QLD, Co-operative Research Centre for an Internationally Competitive Pork Industry.

APPENDIX A – CASE STUDY PIGGERIES

Case Study One - Piggery A

Piggery A is a 400 sow, naturally ventilated, conventional farrow to finish piggery located in southern Queensland. Electrical power use at Piggery A was initially monitored for nine days between the 13th March to 21st March 2012 using off-the-shelf loggers and again for approximately two weeks from the 26th February to 11th March 2013 using FSA designed equipment.

The electrical supply network at Piggery A consists of an overhead cable supplying power from the grid into a main switchboard. The main switchboard is located inside the workshop shed. Electricity is distributed to various locations around the site via a series of sub-mains. The path and components of the piggery electrical circuit is displayed as a simple one-line diagram in Figure 18. Three sub-mains supply the office and amenities, the bore pump, and the four piggery sheds. The sheds are naturally ventilated and incorporate a conventional design with slatted floors for effluent capture. The following electrical equipment is supplied by the piggery sheds sub-main. All piggery sheds contain; a drinking water pump (1.5 kW), a hosing pump (2.4 kW), and a feed distribution system. The farrowing and weaner sheds also contain heat lamps (0.25kW). The effluent capture and treatment system consists of two agitator pumps (2.2 kW), an effluent pump (4.4 kW) and a reticulation pump 7.5 kW.

Initial power monitoring monitored the electrical load and power factor of the entire site for four days before being moved to monitor the bore pump for the following five days.

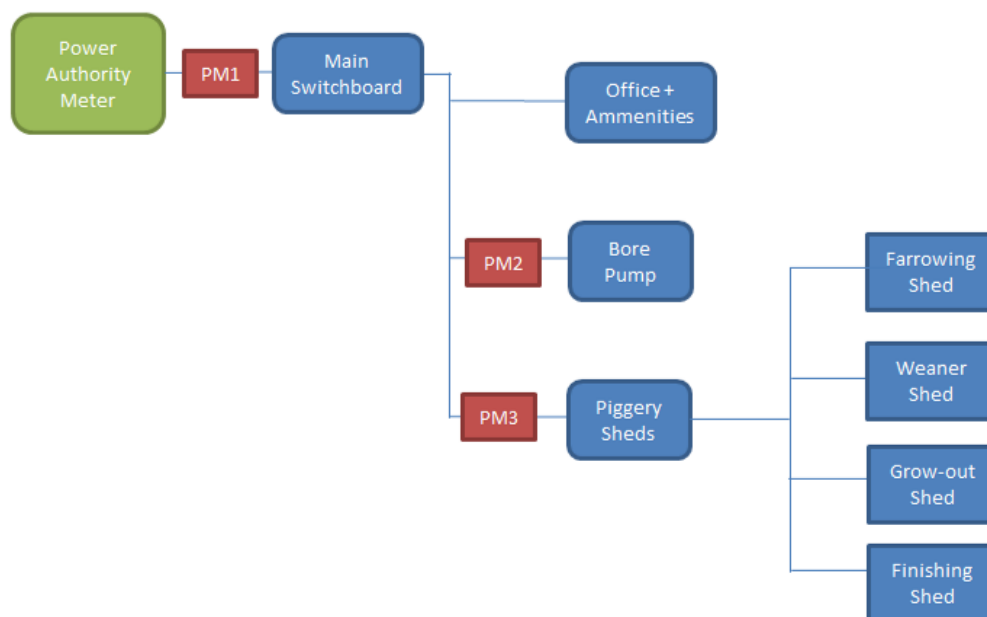


FIGURE 18 – PIGGERY A ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

To monitor electricity consumption at Piggery A, three power meters were connected to the main switchboard using 100/5A current transformers as displayed in Photograph 5. Power meter 1 logged total site, power meter 2 was connected to the bore pump sub-main and power meter 3 measured the piggery sheds sub-main as shown in Photograph 5. Each power meter was connected to the logger through custom lead cables (Photograph 6) allowing the pulses to be converted to text format and stored.



PHOTOGRAPH 5 – INSTALLED POWER METERS AT PIGGERY A



PHOTOGRAPH 6 – ENVIRONDATA LOGGER WIRING AT PIGGERY A

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of production. Electrical energy usage for the piggery was 165 kWh per tonne of live-weight produced, 6.6 kWh per weaned pig produced and 33 kWh per pig place.

Liquid fuel usage was obtained from farm data records. There is no gas usage on-site. Total energy use for the piggery was 791 MJ per tonne of live-weight produced, 29 MJ per weaned pig produced and 157 MJ per pig place.

Figure 19 shows the daily electrical energy consumption for summer for Piggery A. Figure 20 shows the hourly electrical energy profile for summer for Piggery A. Figure 21 and Figure 22 shows the initial detailed electrical energy monitoring for the total site and the bore pump respectively for Piggery A.

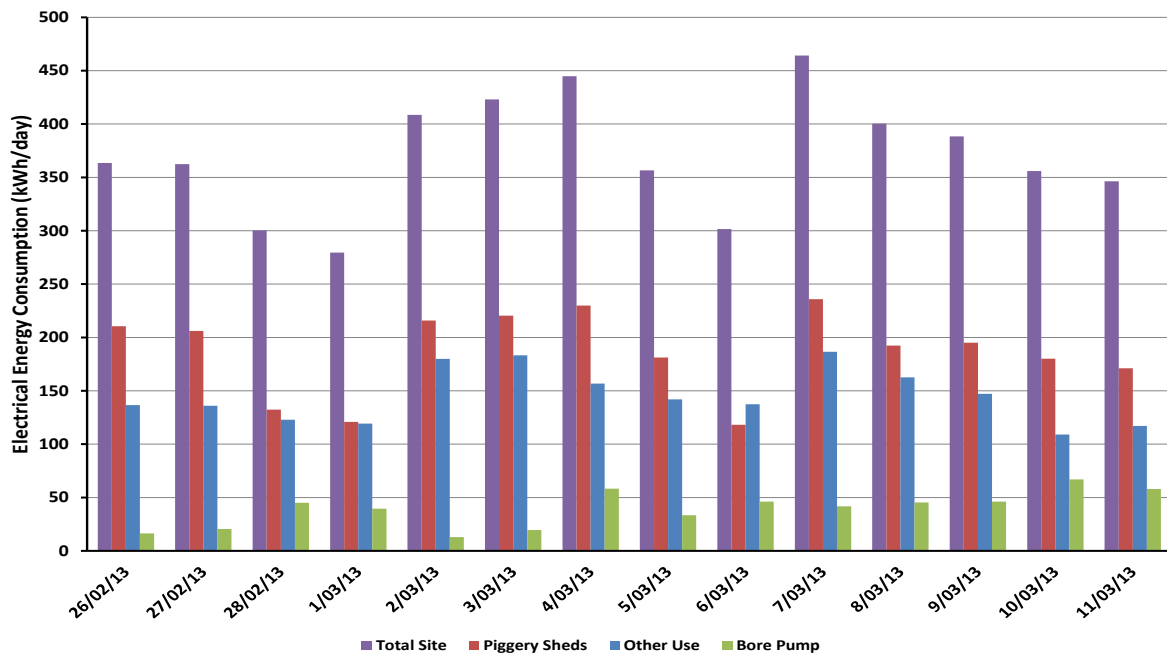


FIGURE 19 – PIGGERY A SUMMER DAILY ELECTRICITY CONSUMPTION

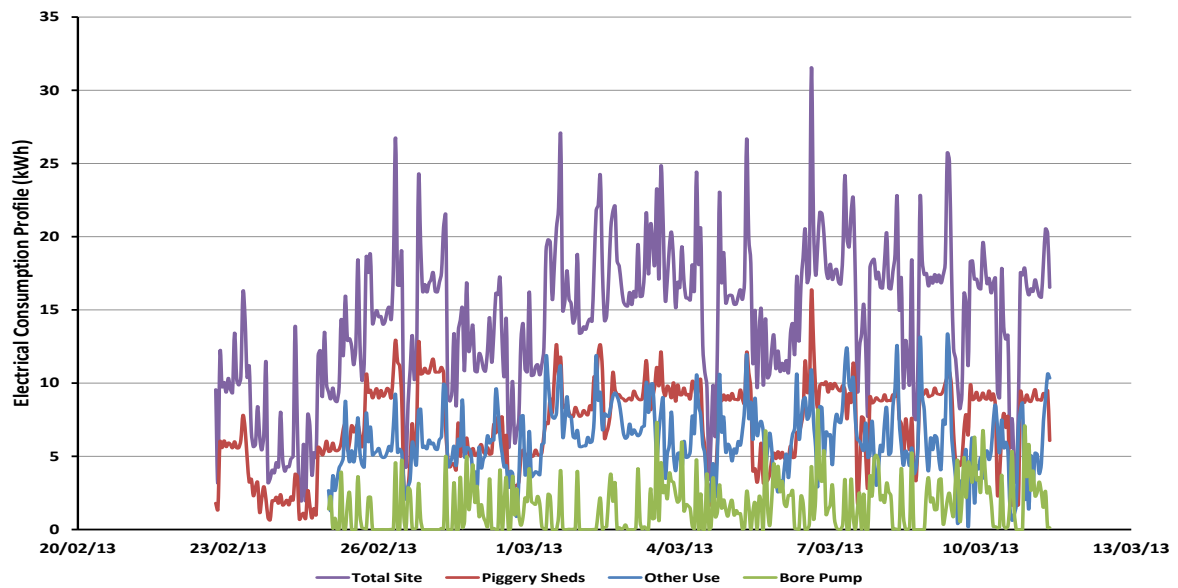


FIGURE 20 – PIGGERY A SUMMER HOURLY ELECTRICITY PROFILE

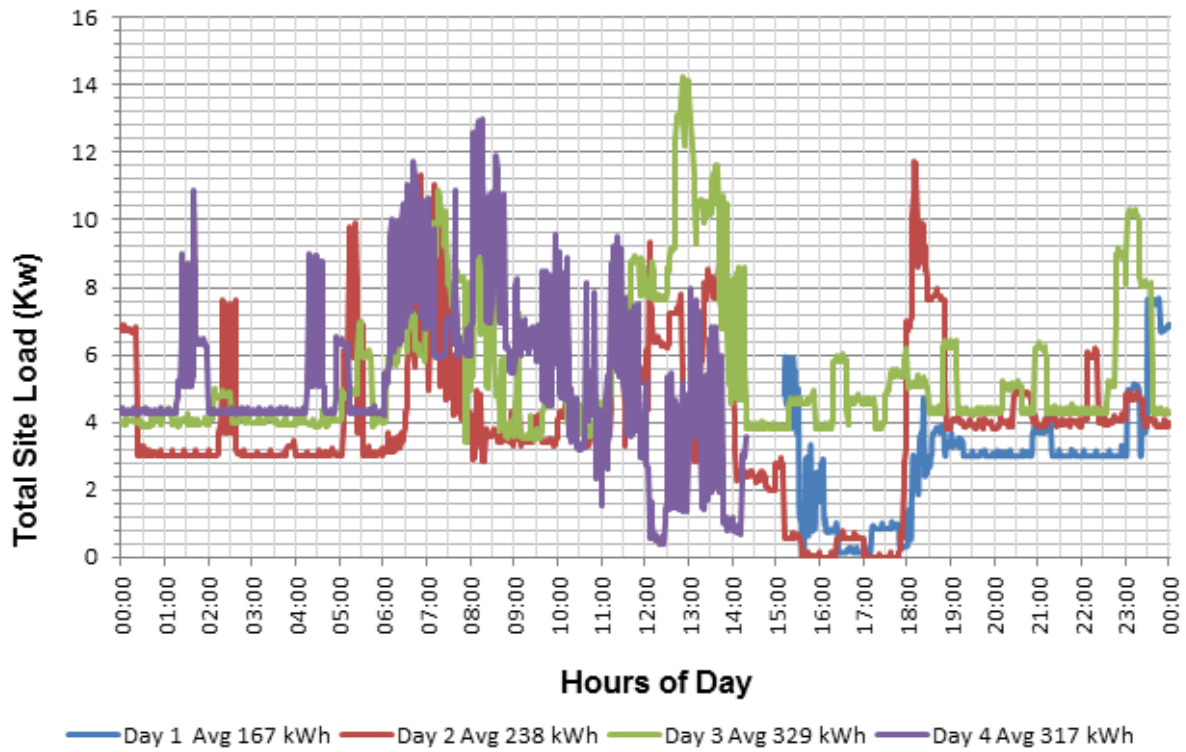


FIGURE 21 – PIGGERY A INITIAL MONITORING AT TOTAL SITE

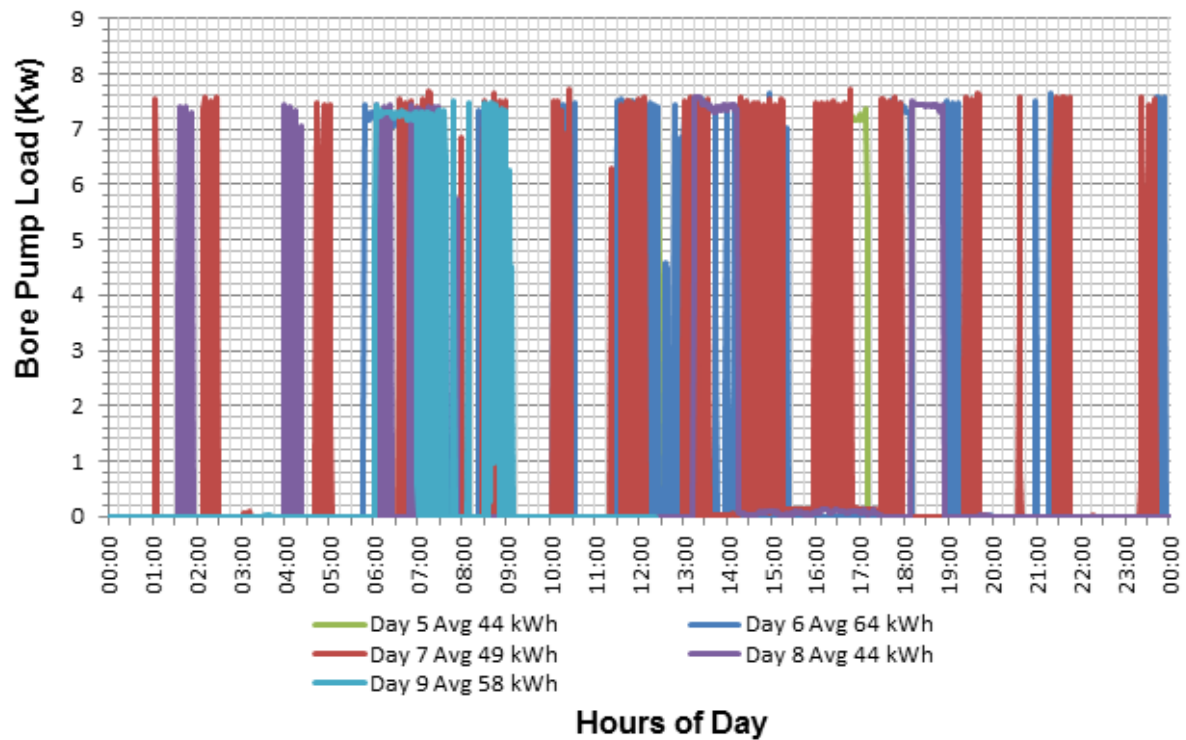


FIGURE 22 – PIGGERY A INITIAL MONITORING AT BORE PUMP

Case Study Two - Piggery B

Piggery B is a 1,650 sow, tunnel ventilated, farrow to finish piggery located in southern Queensland. The electrical energy consumption at Piggery B was logged for approximately three weeks, from the 12th April until the 30th April 2013 and from the 12th January to the 27th January 2014.

The electrical supply network at Piggery B consists of an overhead cable supplying power from the grid into a main switchboard which contains a series of sub-mains. The main switchboard for Piggery B contains two sub-mains. Each sub-main is backed-up by a diesel generator to provide power to the site in an emergency. A constant power supply is critical at this site as each shed incorporates a tunnel ventilation system with cooling pads and exhaust fans. Of the two sub-mains, one supplies the gestation shed, farrowing sheds, weaner shed, the office and the recycled water pump; while the other supplies the finishing sheds and the pump station. The electrical circuit one-line diagram in Figure 23 shows the electrical pathway and components through the site and the position of the three power meters within the switchboard.

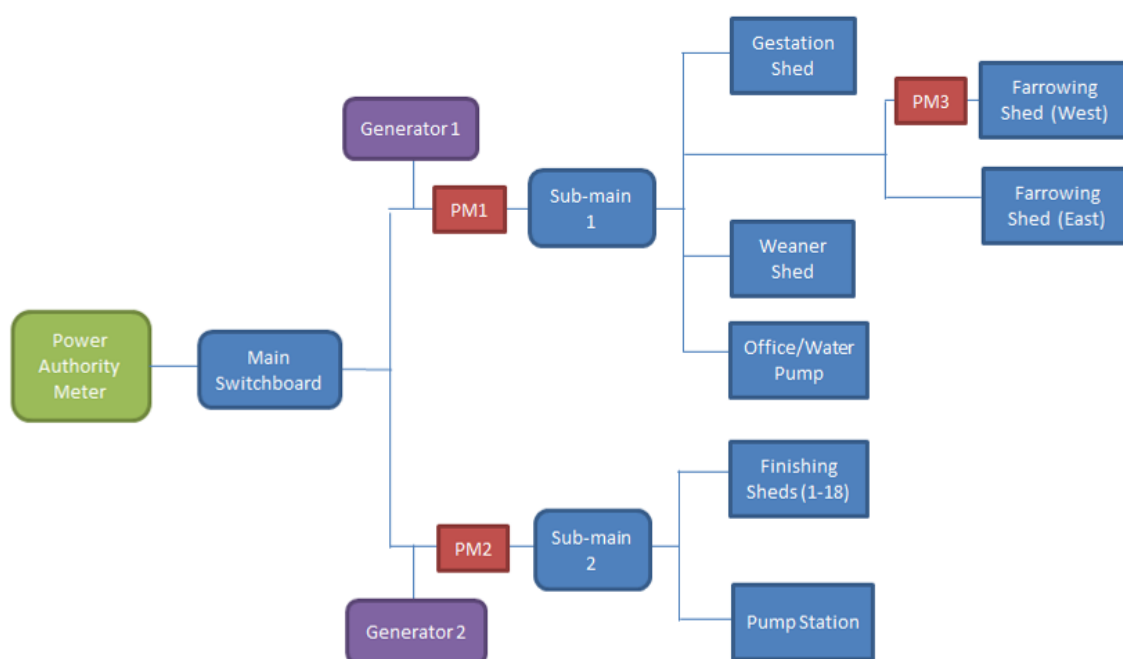


FIGURE 23 – PIGGERY B ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

The three power meters were used to log sub-main 1, sub-main 2 and one farrowing shed (west) respectively as shown in

Photograph 7. A 500/5 CT was attached to sub-main 1 while 250/5 CT's were used to monitor sub-main 2 and the individual farrowing shed as shown in

Photograph 7. Total site power electricity consumption was calculated by adding the electricity logged PM1 and PM2. Energy usage was broken down further by doubling the consumption from the western farrowing shed to allow the total farrowing usage to be estimated. The farrowing usage was then subtracted from the sub-main 1 total to produce energy use for the breeding phase. Performing these calculations allows a comparison between the energy use at the breeding, farrowing and finishing pig production stages.



PHOTOGRAPH 7 – INSTALLED POWER METERS AT PIGGERY B

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of production. Electrical energy usage for the piggery was 297 kWh per tonne of live-weight produced, 11.7 kWh per weaned pig produced and 64 kWh per pig place.

Liquid fuel usage was obtained from meter readings (LPG) and farm data records (petrol and diesel). Total energy use for the piggery was 1492 MJ per tonne of live-weight produced, 54 MJ per weaned pig produced and 322 MJ per pig place

Figure 24 and Figure 25 shows the hourly electrical energy profile for winter and summer respectively for Piggery B. Figure 26 and Figure 27 shows the average daily electrical energy use for winter and summer respectively for Piggery B.

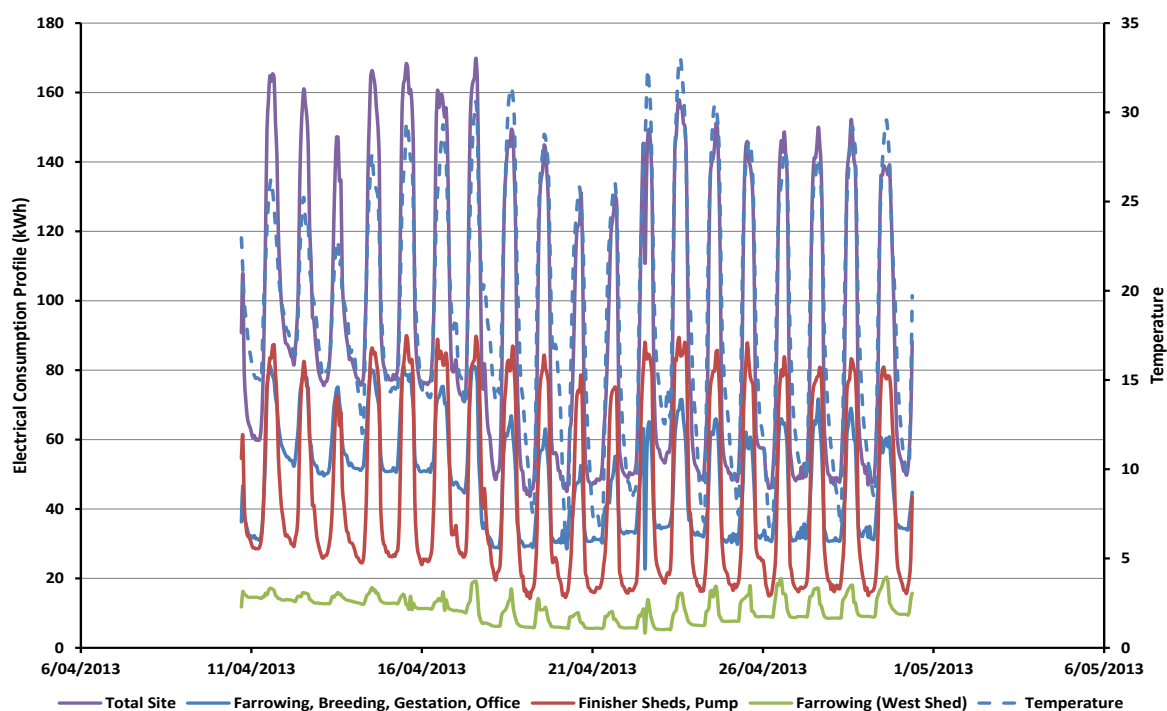


FIGURE 24 – PIGGERY B WINTER HOURLY ELECTRICITY PROFILE

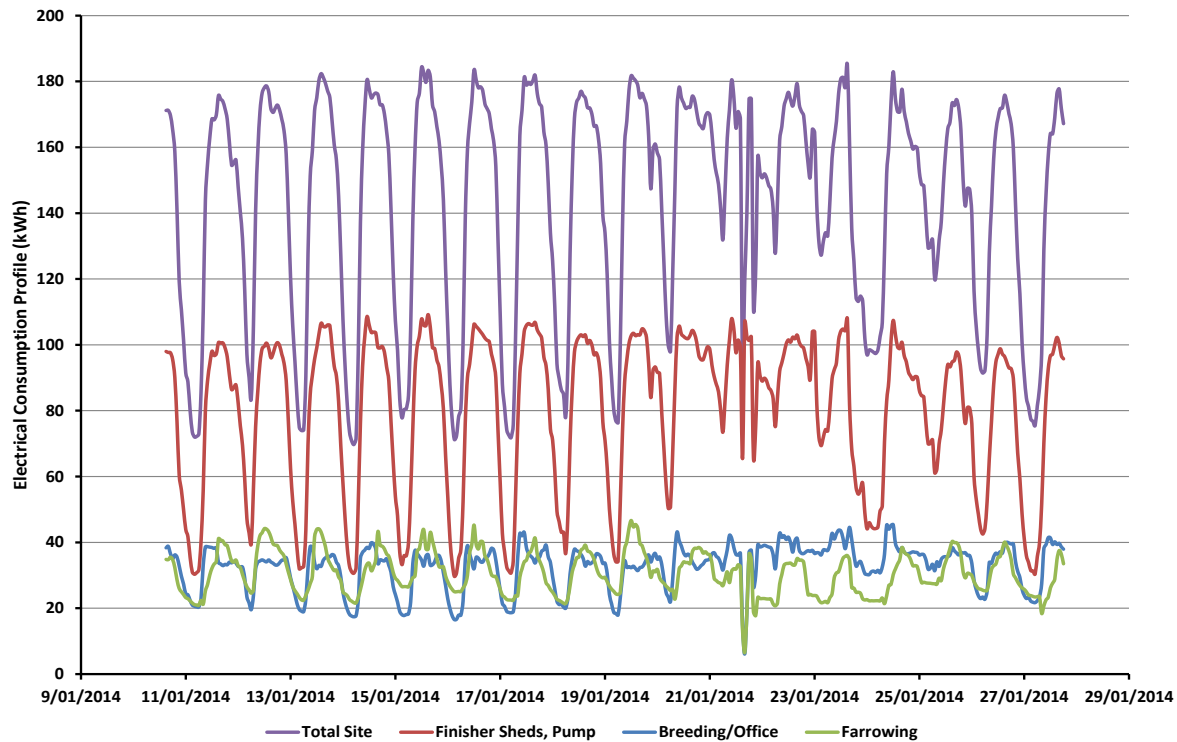


FIGURE 25 – PIGGERY B SUMMER HOURLY ELECTRICITY PROFILE

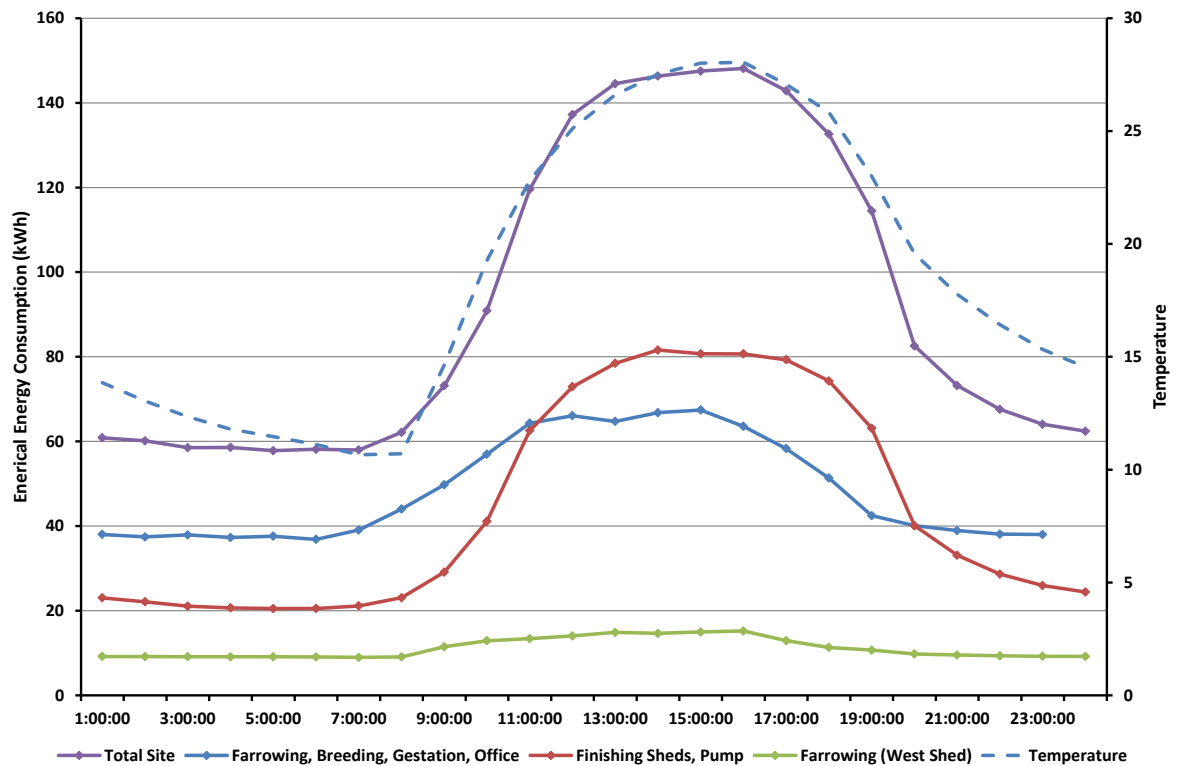


FIGURE 26 – PIGGERY B WINTER AVERAGE ELECTRICITY USE OVER A DAY

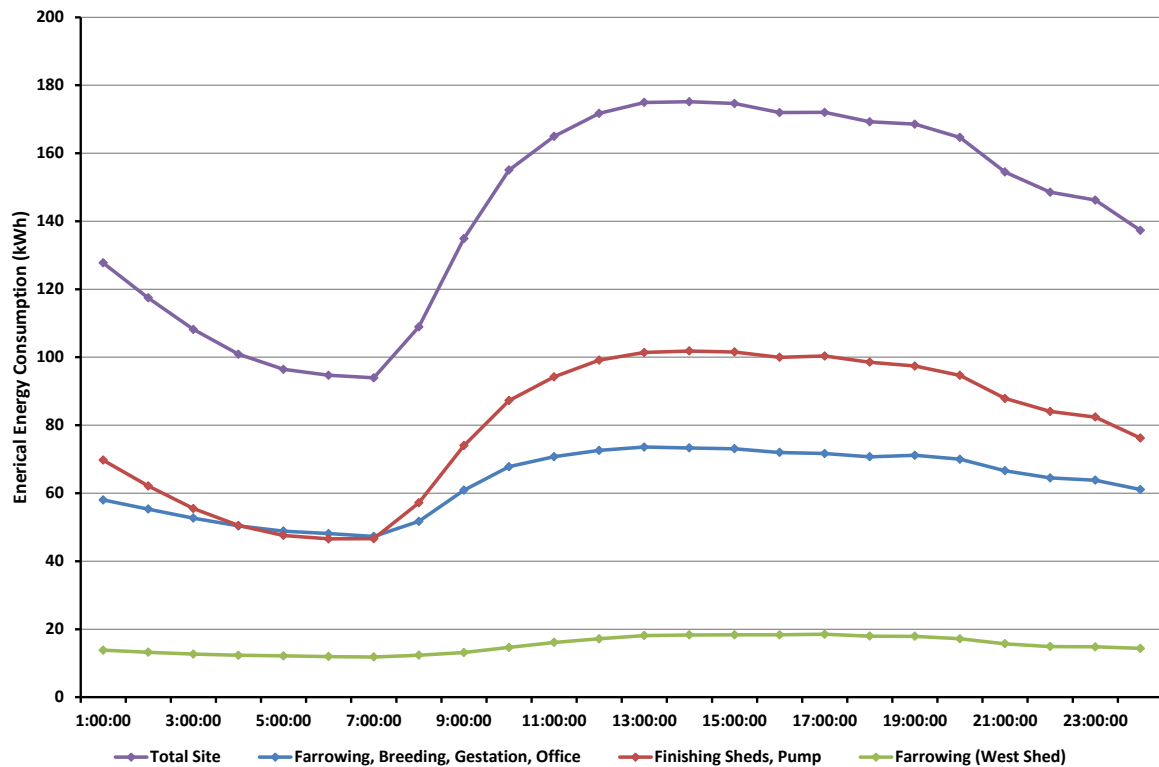


FIGURE 27 – PIGGERY B SUMMER AVERAGE ELECTRICITY USE OVER A DAY

Case Study Three - Piggery C

Piggery C is a 7000 sow, tunnel ventilated, breeder and wean to 6 weeks of age piggery located in southern Queensland. The electrical energy consumption at Piggery C was monitored from the 12th May 2013 until the 9th June 2013 and from the 29th January to the 9th February 2014.

The electrical supply network at Piggery C consists of an overhead cable supplying power from the grid into a main switchboard. There are three separate sub-mains throughout Piggery C supplied from the main switchboard via underground electrical cables. Sub-main 1 supplies five weaner sheds, dry sow sheds and the office. Sub-mains 2 supplies two farrowing sheds, while sub-main 3 supplies a farrow shed and weaner shed; the two sub-mains are approximately 130 meters apart. The electrical circuit one-line diagram in Figure 28 shows the electrical pathway and components through Piggery C. Each sub-main is backed up via a diesel generator to ensure an uninterrupted electricity supply to the sheds in an emergency. The sheds incorporate a tunnel ventilation system to maintain optimal conditions.

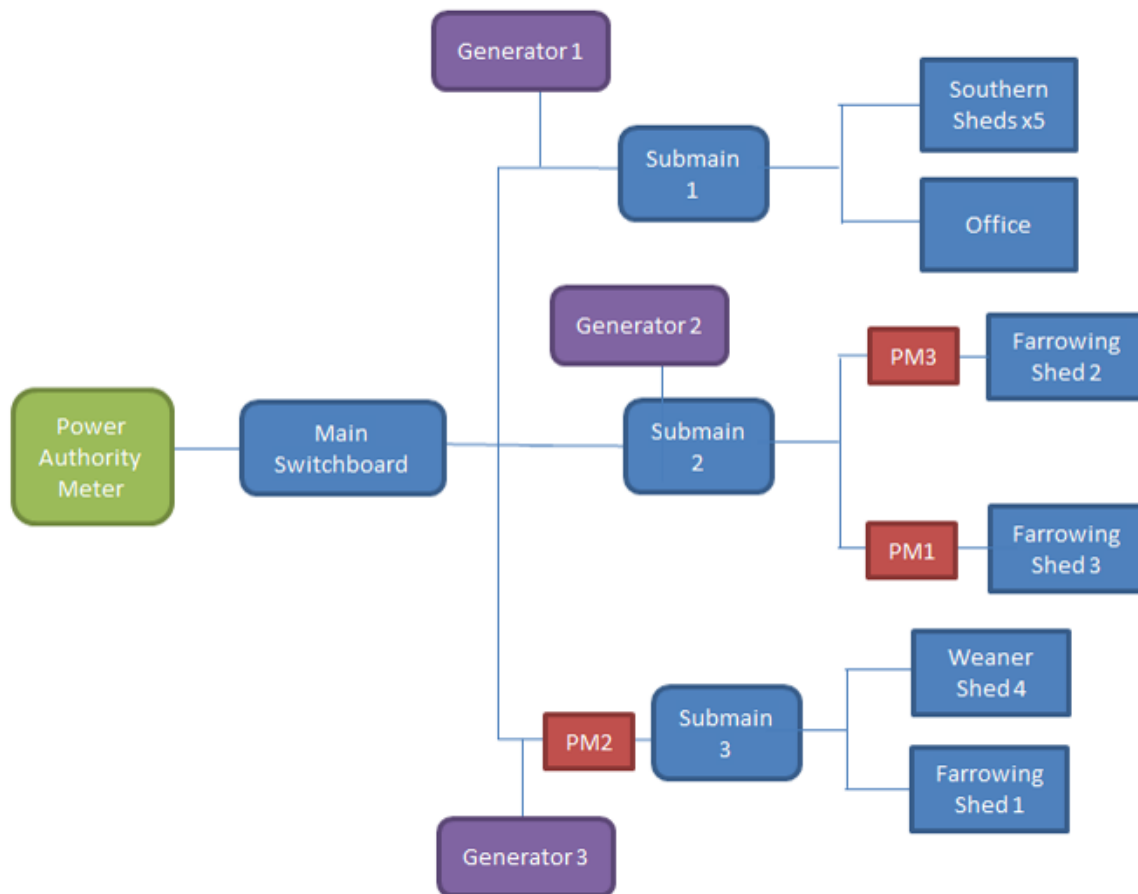
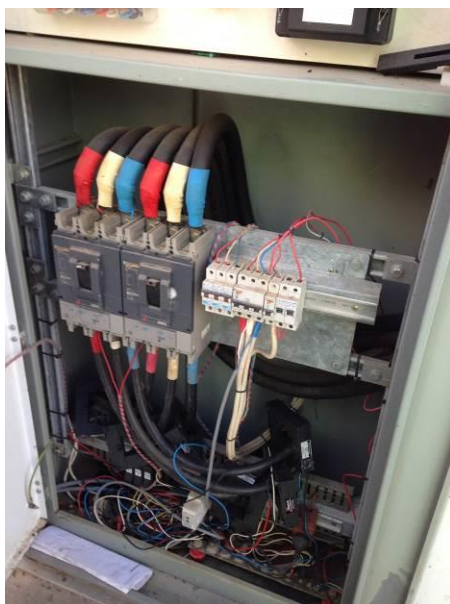


FIGURE 28 – PIGGERY C ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

Power meter 1 and 3 were used to monitor electricity use from individual farrowing sheds 3 and 2 respectively (refer Photograph 8). 250/5 CTs were attached to the three phase wires to monitor these sheds. Power meter 2 was attached to sub-main 3 to log electricity use at farrowing shed 1 and weaner shed 4. Total electricity consumption at sheds 1 to 4 can be calculated by summing data from each meter. As sub-main 2 and 3 are 130 meters apart a cable was run between power meter 2 and the logger situated at sub-main 2. The cable wiring was soldered to an Envirodata 3-pin male connector allowing the pulses to be sent through the extension cable into the logger. The data logger and power meters 1 and 3 assembled at Piggery C are shown in Photograph 8.



PHOTOGRAPH 8 – INSTALLED POWER METERS AT PIGGERY C

Production data was obtained for the data recording period to allow an analysis of electricity consumption per weaned pig. Electrical energy usage for the piggery was 14.8 kWh per weaned pig produced.

Liquid fuel usage was obtained from meter readings (LPG) and farm data records (petrol and diesel). Total energy use for the piggery was 67 MJ per weaned pig produced.

Figure 29 and Figure 30 shows the daily electrical energy consumption for winter and summer respectively for Piggery C. Figure 31 and Figure 32 shows the hourly electrical energy profile for winter and summer respectively for Piggery C. Figure 33 shows the average daily electrical energy use for winter for Piggery C.

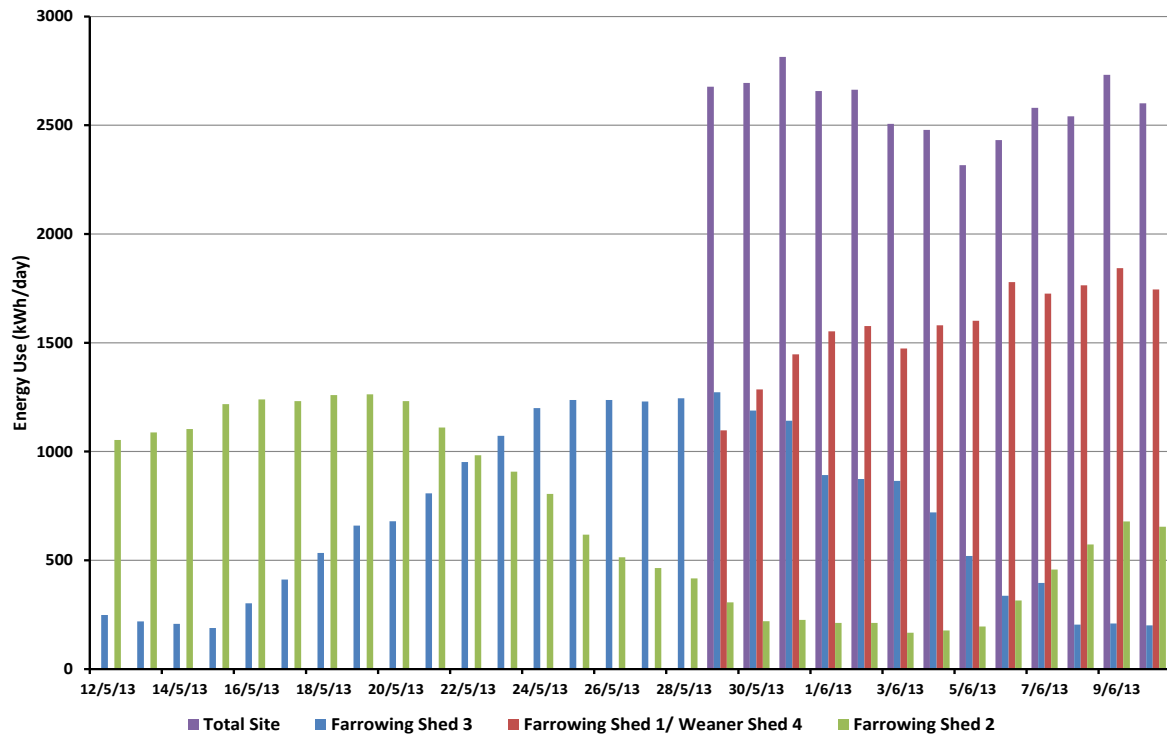


FIGURE 29 – PIGGERY C WINTER DAILY ELECTRICITY CONSUMPTION

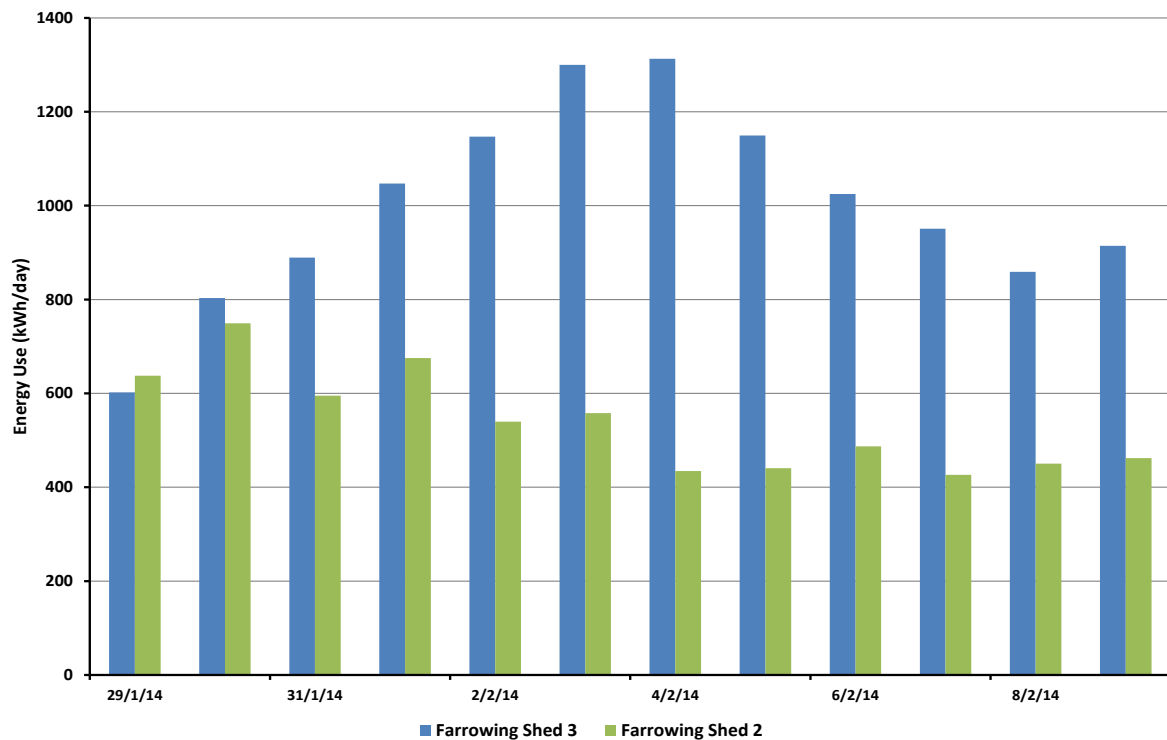


FIGURE 30 – PIGGERY C SUMMER DAILY ELECTRICITY CONSUMPTION

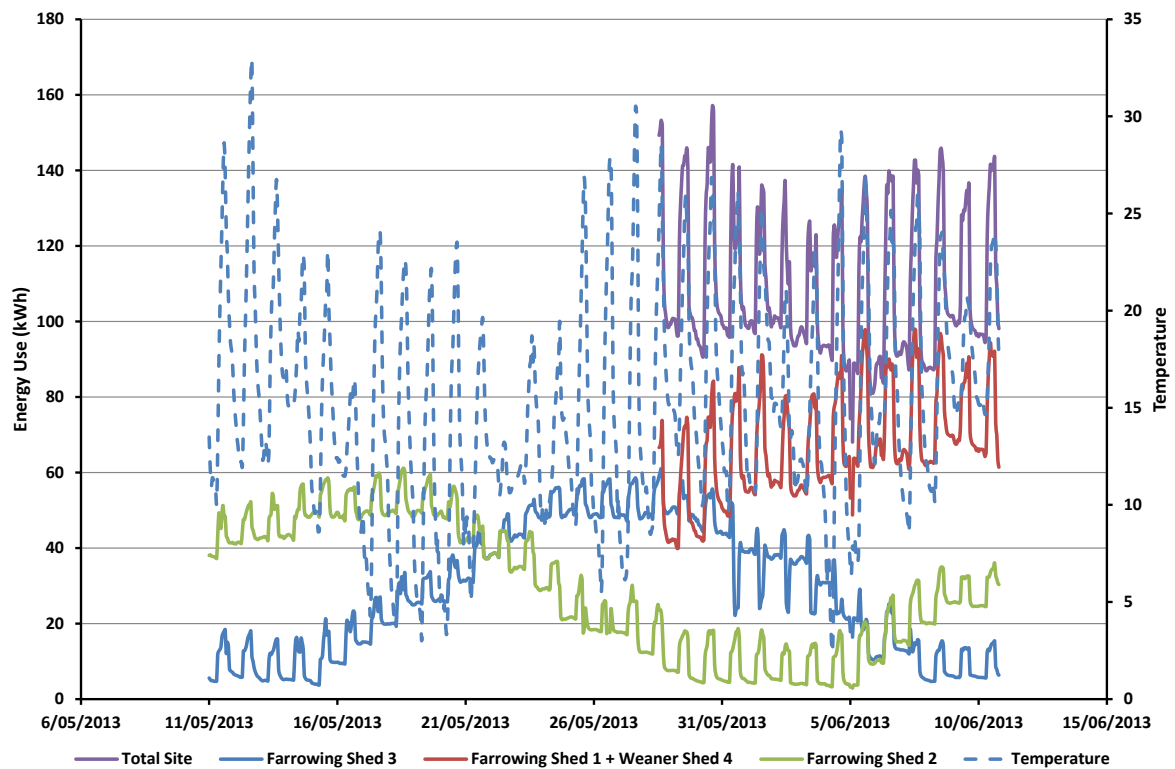


FIGURE 31 – PIGGERY C WINTER HOURLY ELECTRICITY PROFILE

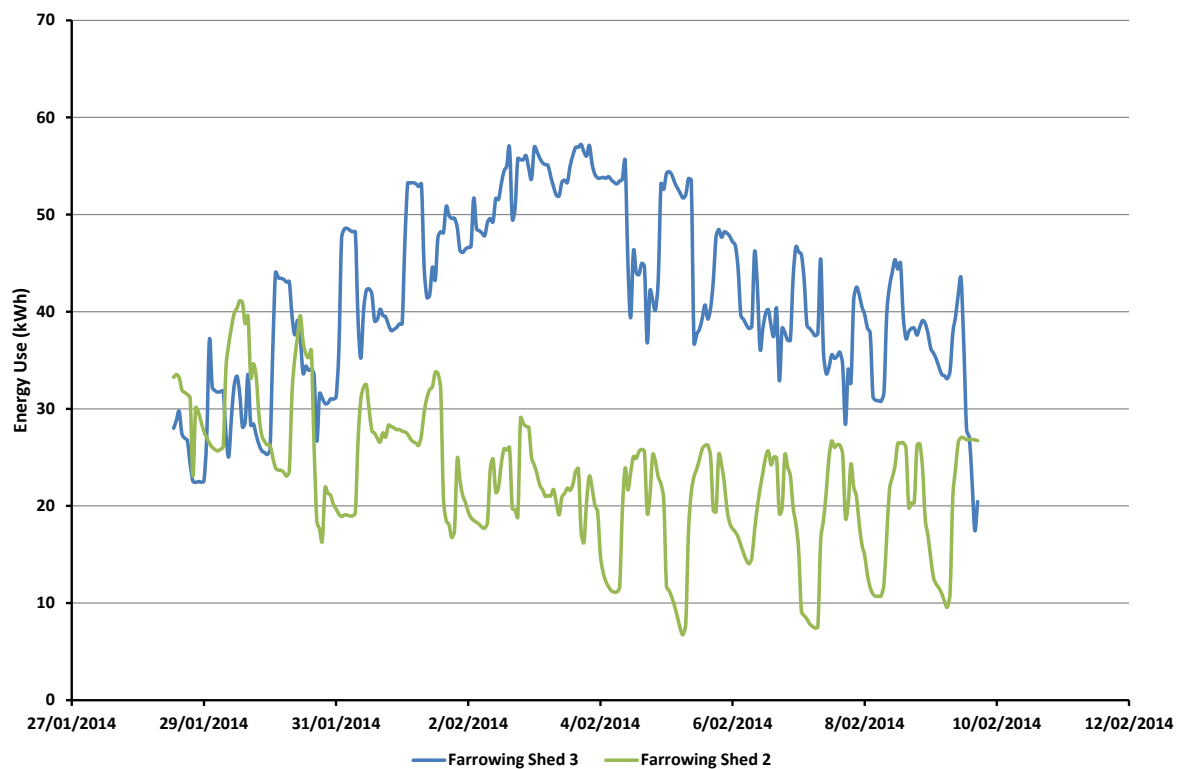


FIGURE 32 – PIGGERY C SUMMER HOURLY ELECTRICITY PROFILE

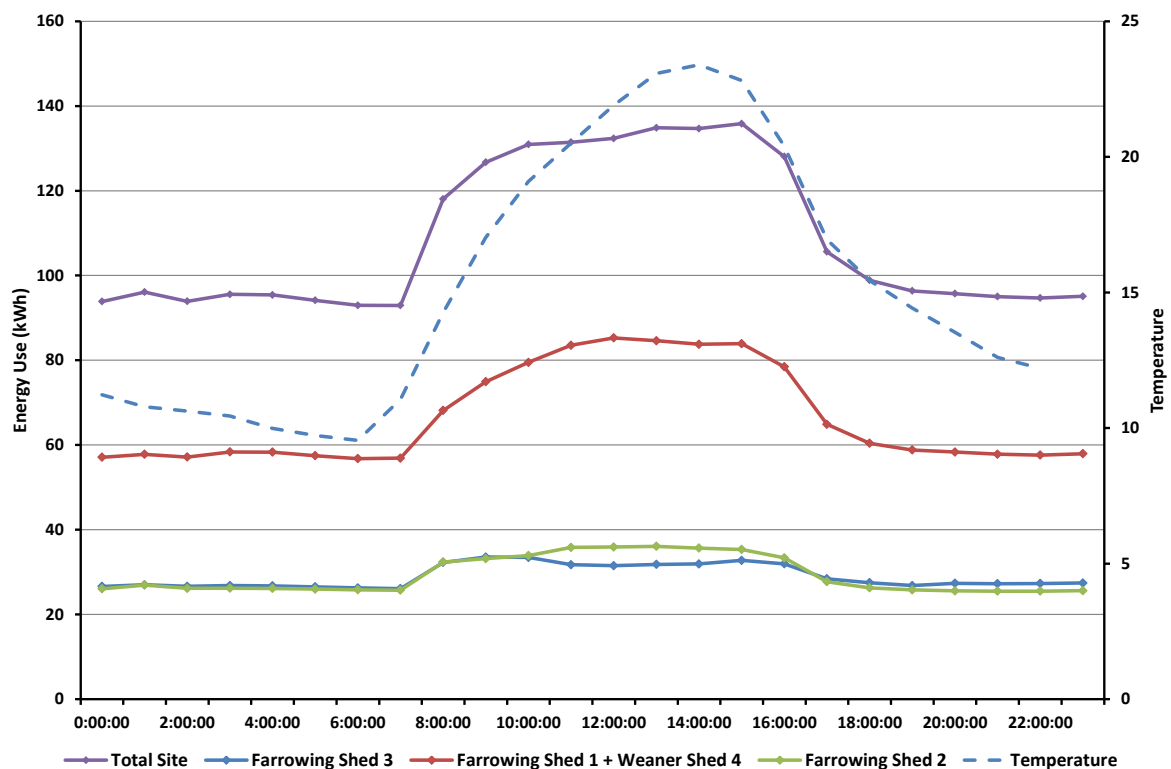


FIGURE 33 – PIGGERY C WINTER AVERAGE ELECTRICITY USE OVER A DAY

Case Study Four - Piggery D

Piggery D is a 77,000 capacity pig place, tunnel ventilated, grower/finisher piggery located in southern Queensland. The electrical energy monitoring equipment was installed at Piggery D on the 12th June 2013 and energy data recorded until the 30th June 2013 and from 11th February to the 14th March 2014.

The electrical supply network at Piggery D consists of an overhead cable supplying power from the grid into the site's main switchboard. The main switchboard supplies the office, the pump station and two separate sub-mains via underground electrical cables. Sub-main 1 supplies the northern 20 grower/finisher sheds and sub-main 2 supplies the southern 20 grower/finisher sheds; the sub-mains are 350 meters apart. In each sub-main, there are five separate circuits, which each supply four grower/finisher sheds. The electrical circuit one-line diagram in Figure 34 shows the electrical pathway and components through Piggery D. Both sub-mains are supported by a diesel generator which ensures an uninterrupted electricity supply to the sheds. The sheds are tunnel ventilated to maintain optimal conditions.

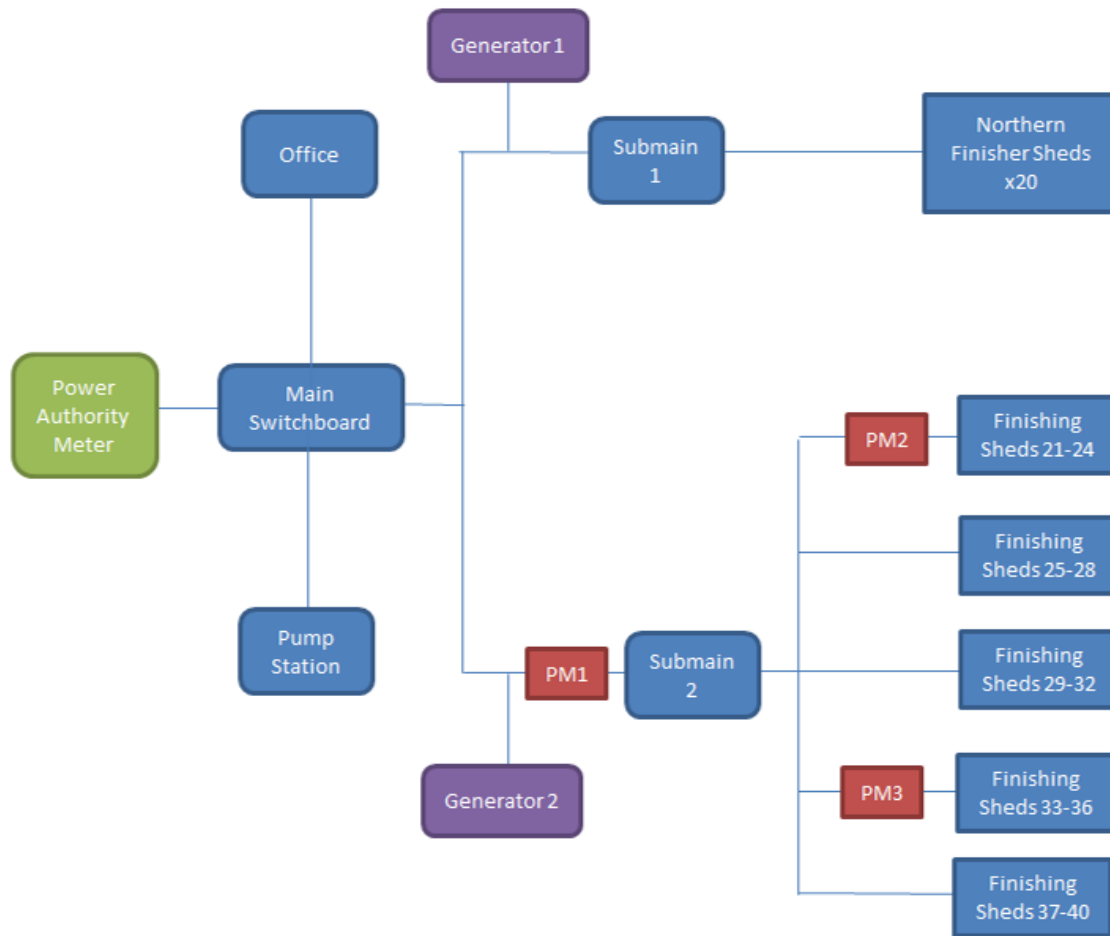
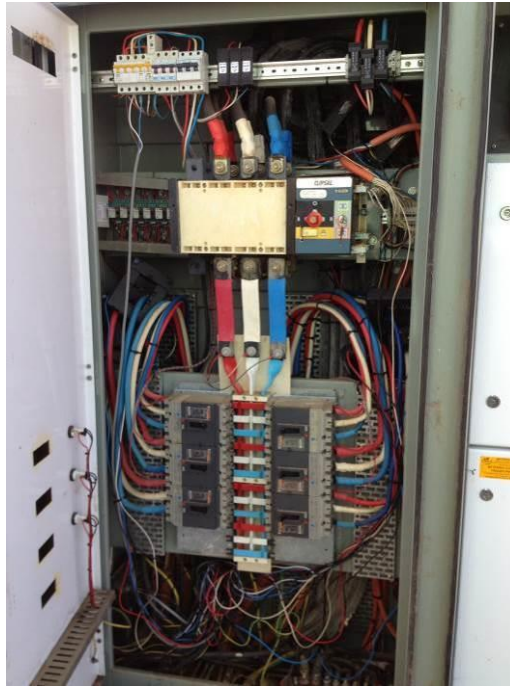


FIGURE 34 – PIGGERY D ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

Power meter 1 was used to monitor electricity use from sub-main 2 which provides the total electricity used by the southern sheds at the site. A 500/5 CT was attached to power meter 1 due to the larger power draw. Power meter 2 was attached to a circuit within sub-main 2 to log electricity at finishing sheds 21-24. Power meter 3 was attached to a circuit within the sub-main's switchboard to monitor finishing sheds 33-36 as displayed in Photograph 9. Power meters 2 and 3 were both connected using 200/5 CT's as shown in Photograph 9. Total electricity consumption at Piggery D can be estimated by comparing electricity use from the southern sheds with production data for the total site. The whole site's electricity consumption for a period could not be measured with one data logger as it was not possible to run 350 meters of electrical cable between the two sub-mains.



PHOTOGRAPH 9 – INSTALLED POWER METERS AT PIGGERY D

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of production. Electrical energy usage for the piggery was 33 kWh per pig place.

Liquid fuel usage was obtained from meter readings (LPG) and farm data records (petrol and diesel). Total energy use for the piggery was 158 MJ per pig place

Figure 35 and Figure 36 shows the daily electrical energy consumption for winter and summer respectively for Piggery D. Figure 37 and Figure 38 shows the hourly electrical energy profile for winter and summer respectively for Piggery D.

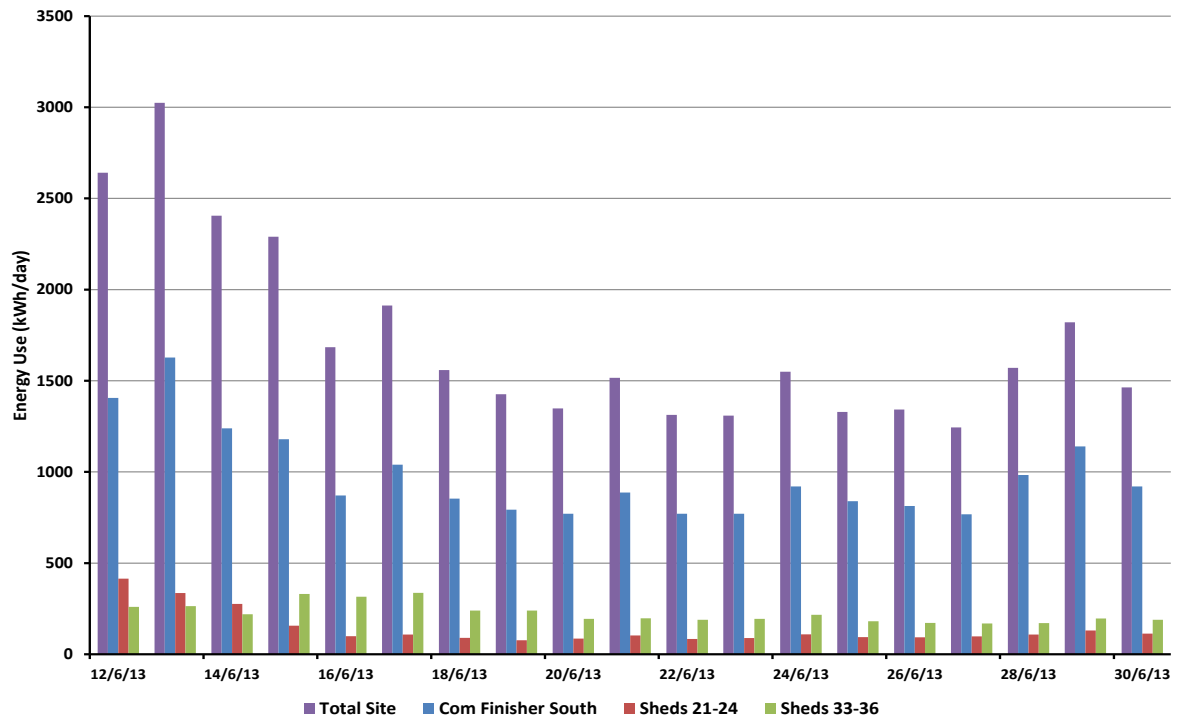


FIGURE 35 – PIGGERY D WINTER DAILY ELECTRICITY CONSUMPTION

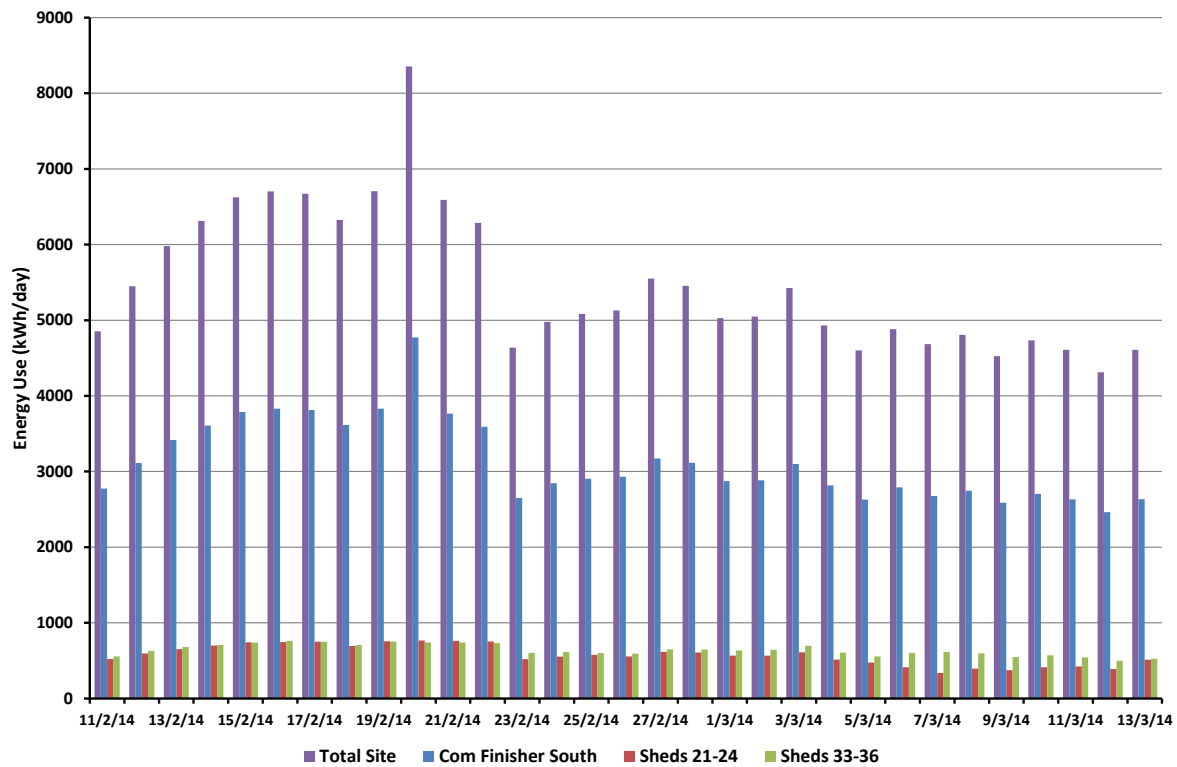


FIGURE 36 – PIGGERY D SUMMER DAILY ELECTRICITY CONSUMPTION

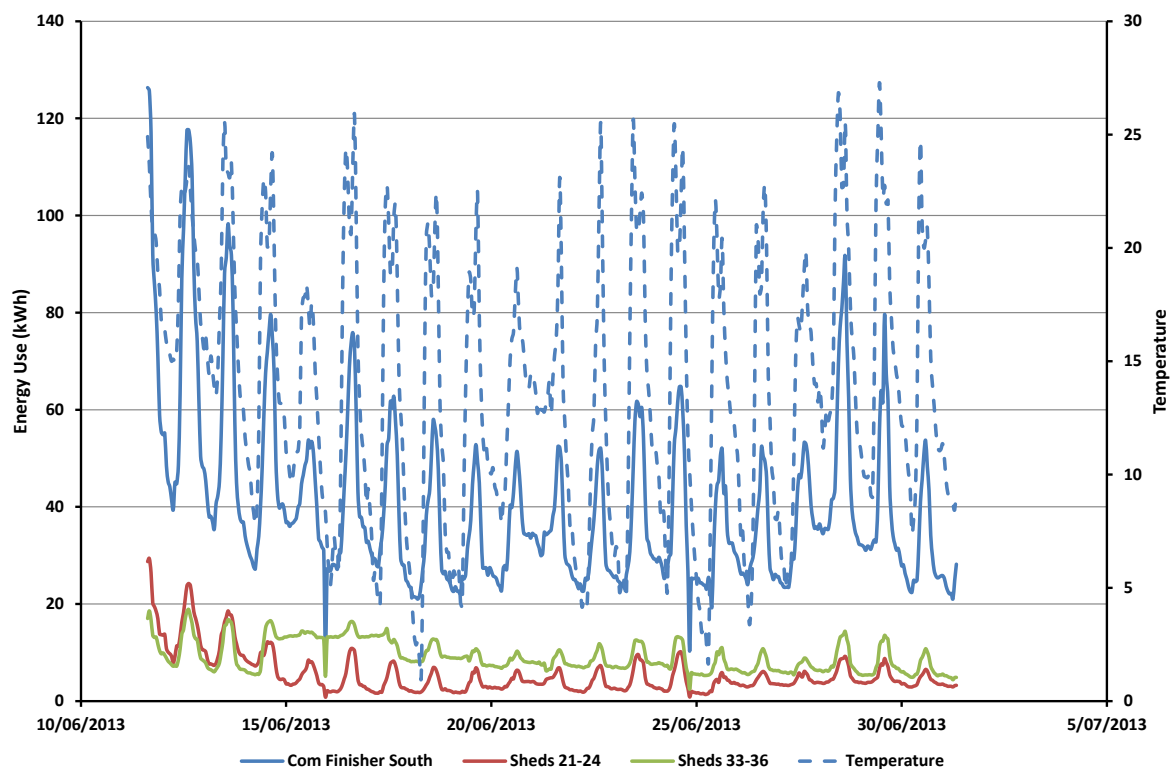


FIGURE 37 – PIGGERY D WINTER HOURLY ELECTRICITY PROFILE

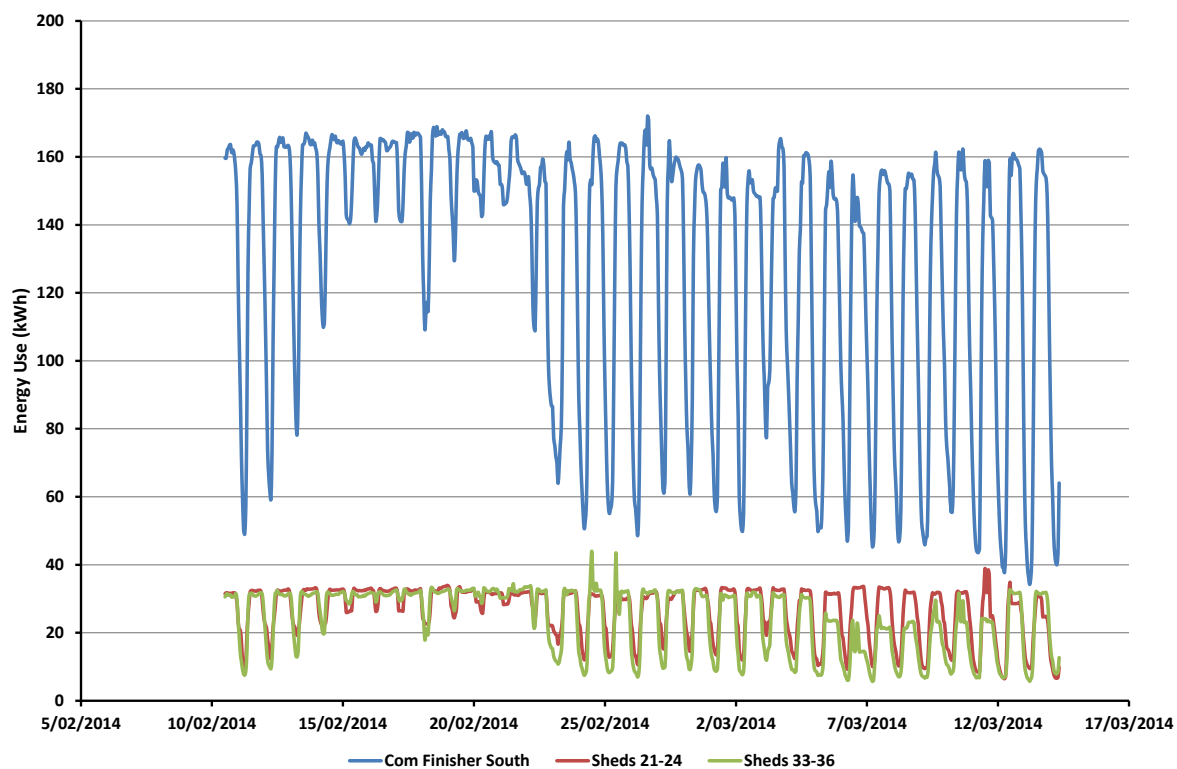


FIGURE 38 – PIGGERY D SUMMER HOURLY ELECTRICITY PROFILE

Case Study Five - Piggery E

Piggery E is a 320 sow, naturally ventilated, farrow to finish piggery located in southern Queensland. The piggery also has its own feedmill. Initial energy monitoring with off-the-shelf equipment occurred

at Piggery E from the 27th March 2012 until the 5th April 2012. FSA's electrical energy monitoring equipment was installed at Piggery E from the 1st August 2013 to the 13th August 2013.

The electrical supply network at Piggery E comprises of an overhead cable supplying power from the grid to the site's main switchboard. The site's switchboard is located outside the storage shed. Electricity is distributed to various locations around the site via a series of sub-mains. The path and components of the piggery electrical circuit is displayed as a simple one-line diagram in Figure 39. Four sub-mains each supply the farrowing sheds, the growing unit, the finishing sheds and the feed mills. The sheds are naturally ventilated, with slatted floors for effluent capture. The underground effluent channels are flushed using 2 kW pumps. The site contains a feed mill that is powered by a 30 kW hammer mill motor. It also includes several other augers, conveyors and a batch mixer. The feed mill energy usage was monitored individually as the large motor has the potential to drastically increase total site usage while operating. The site's feed mill and storage silos are shown in Photograph 10. Other electrical intensive components involve heat lamps in the farrowing sheds, effluent pumps, the feed distribution system, a bore pump and the workers amenities.



PHOTOGRAPH 10 – FEED MILL AND SILO'S AT PIGGERY E

The initial power monitoring using off-shelf gear logged the entire site's electrical consumption and power factor rating for four days. The following five days were used to monitor the feed mill separate from the remainder of the site.

Liquid fuel usage was obtained from farm data records. There is no gas usage on-site.

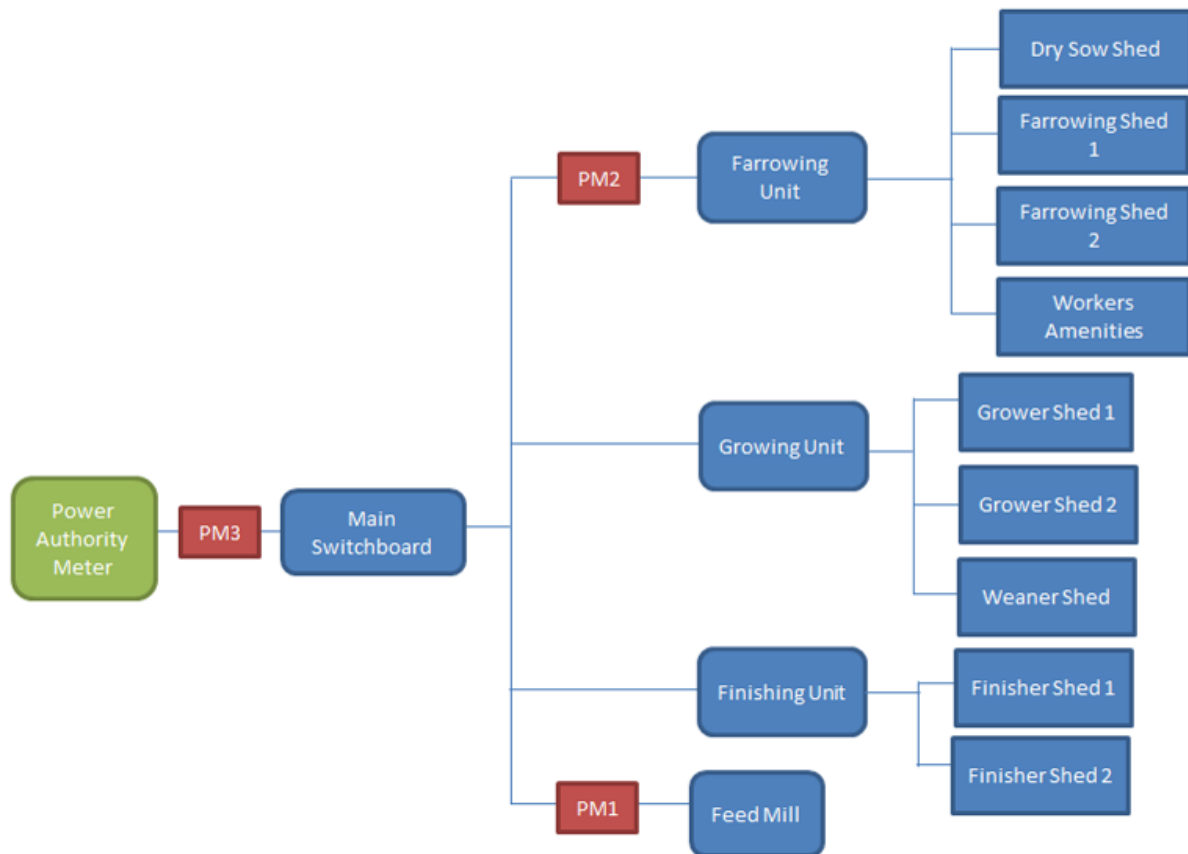


FIGURE 39 – PIGGERY E ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

Power meter 1 (PM1) monitored electricity used at the feed mill, which is run on average three times per week for a few hours, depending on feed demand. Power meter 2 (PM2) was attached to the sub-main providing electricity to the site's farrowing facility. This includes a dry sow shed, two farrowing sheds and the workers amenities. Power meter 3 (PM3) recorded the total use from the site's switchboard. Due to the larger power load, PM 3 was attached to 500/5 CT's, while PM 1 and PM 2 used 250/5 CT's to provide better accuracy for smaller loads. The complete energy monitoring equipment set-up at Piggery E is shown in Photograph 11.



PHOTOGRAPH 11 – INSTALLED POWER METERS AT PIGGERY E SWITCHBOARD

Production data was obtained for the data recording period to allow an analysis of electricity consumption per unit of production. Electrical energy usage for the piggery was 119 kWh per tonne of live-weight produced, 2.6 kWh per weaned pig produced and 24 kWh per pig place.

Liquid fuel usage was obtained from farm data records (petrol and diesel). Total energy use for the piggery was 621 MJ per tonne of live-weight produced, 14 MJ per weaned pig produced and 126 MJ per pig place

Figure 40 and Figure 41 shows the daily electrical energy consumption for winter and summer respectively for Piggery F. Figure 42 and Figure 43 shows the hourly electrical energy profile for winter and summer respectively for Piggery F.

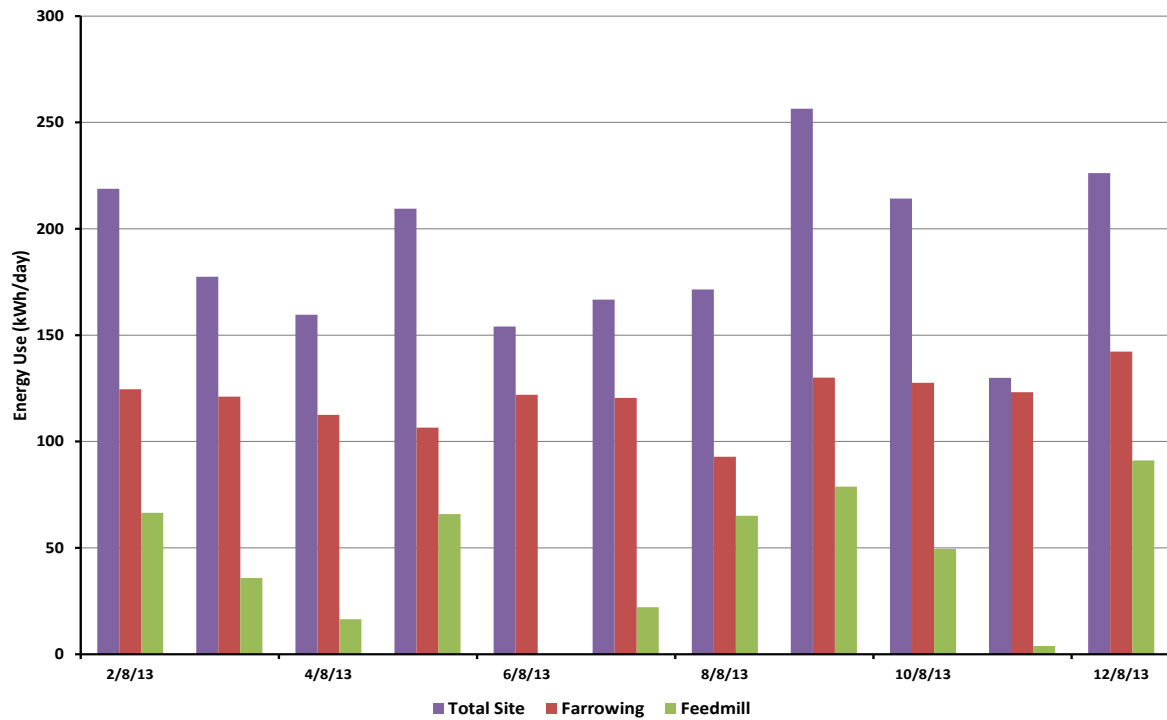


FIGURE 40 – PIGGERY E WINTER DAILY ELECTRICITY CONSUMPTION

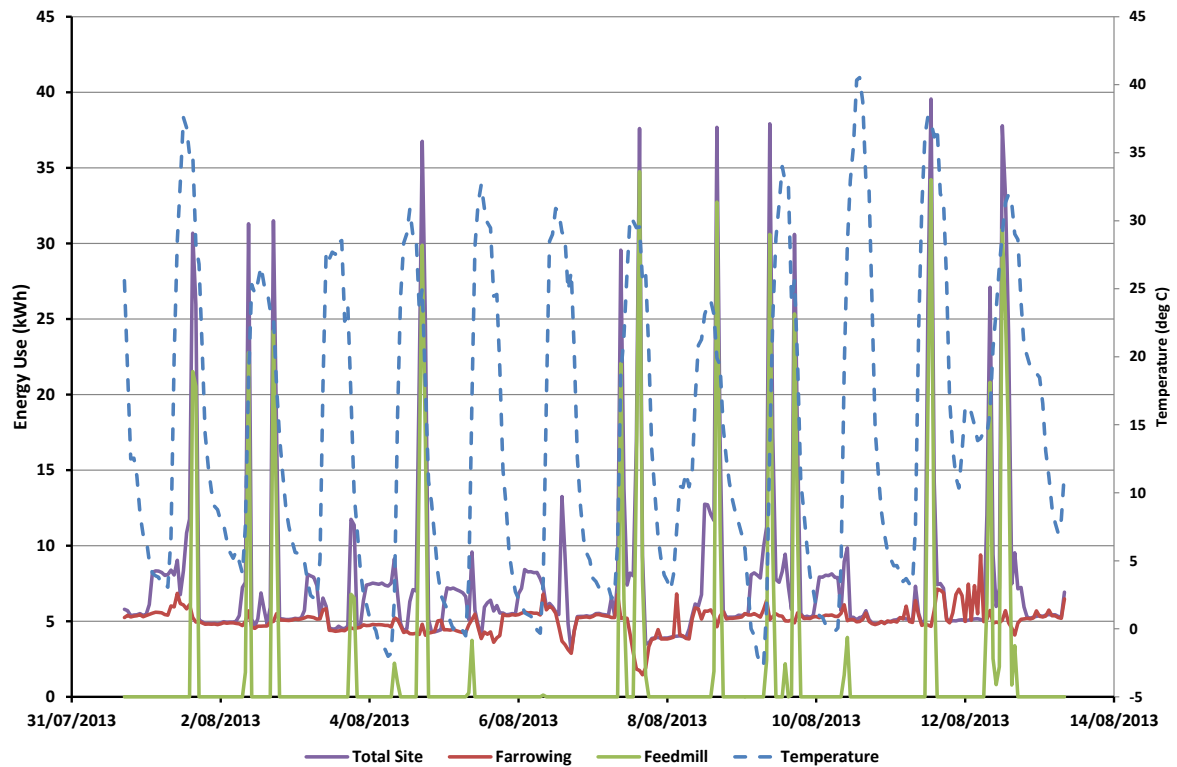


FIGURE 41 – PIGGERY E WINTER HOURLY ELECTRICITY CONSUMPTION

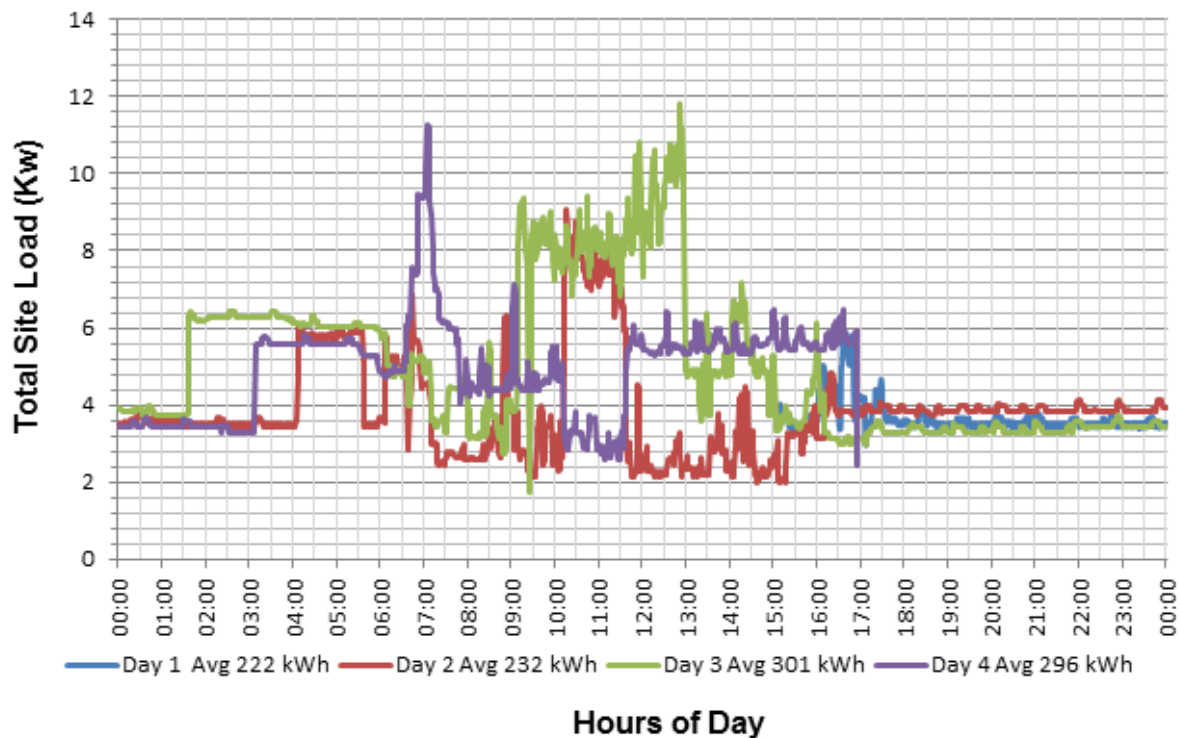


FIGURE 42 – PIGGERY E INITIAL MONITORING OF TOTAL SITE

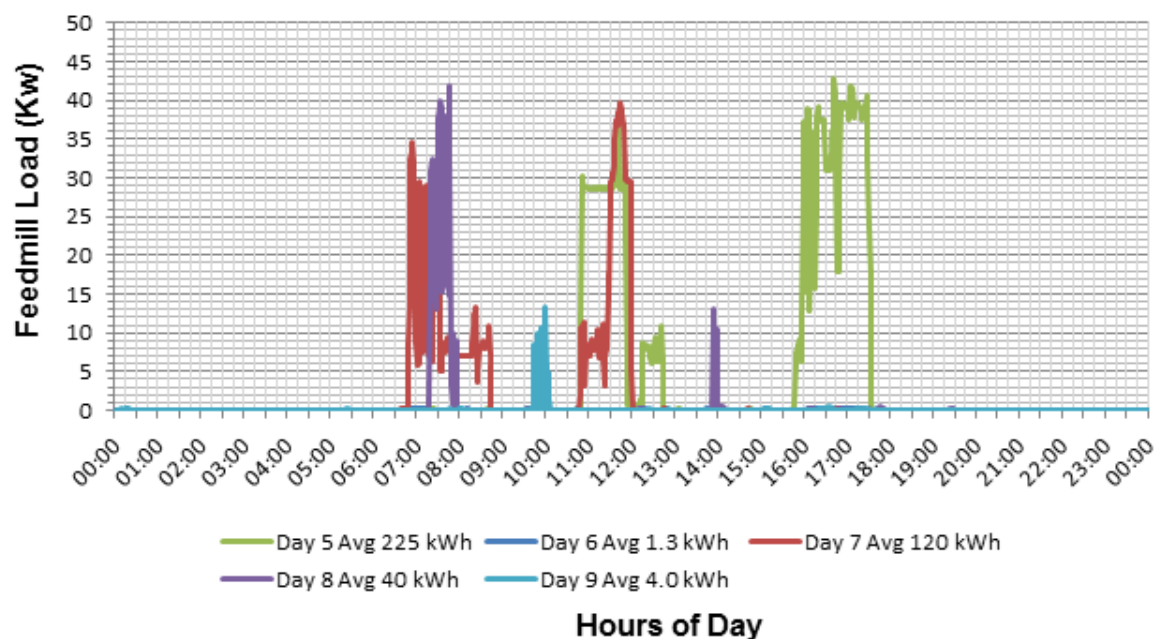


FIGURE 43 – PIGGERY E INITIAL MONITORING OF FEED MILL

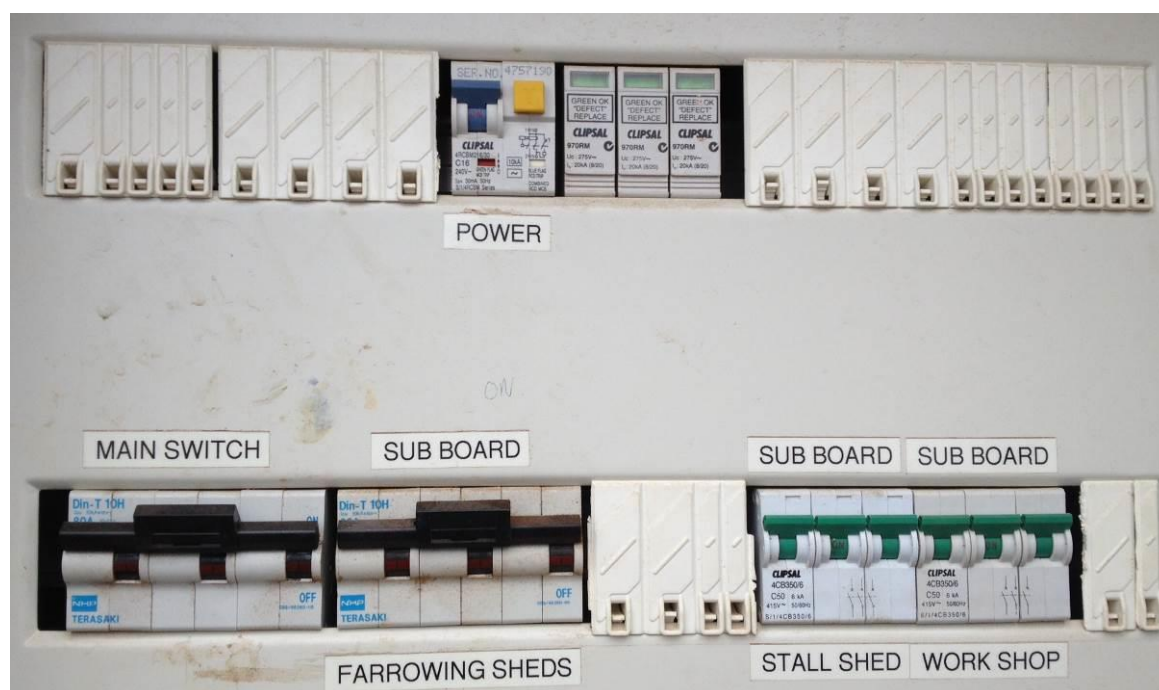
Case Study Six - Piggery F

Piggery F is a 1080 sow, breeder only piggery located in southern Australia. Pigs are sold at 11 weeks of age. The dry sow sheds are naturally ventilated and the farrowing sheds contain cooling fans. The electrical energy monitoring equipment was installed at Piggery F on the 22nd August 2013 and removed on the 7th Dec 2013. This allowed for continuous monitoring over 106 days. Two-week

periods from winter and summer were analysed, allowing a detailed comparison of energy use in cooler and warmer conditions.

The electrical supply network at Piggery F comprises of an overhead cable supplying power from the grid to the site's main switchboard. Electricity is distributed to various locations around the site via a series of sub-mains. The components and paths of the piggeries electrical circuit is displayed in the one-line diagram in Figure 44. There are three sub-mains supplying the farrowing sheds, the dry-sow sheds, and the workshop as can be seen on the main switchboard in Photograph 12. The farrowing sub-main supplies electricity to two farrowing sheds with heat lamps and fans to control the climate in six rooms, the lights, and the feeder motors. The dry sow sheds sub-main powers the lights and feed motors. Finally, the workshop sub-main includes circuits for the water supply and bore pump, and electrical outlets for any power tools and / or machinery.

The farrowing sheds on this breeder unit site are climate controlled by heat lamps and fans, while the dry sow sheds are naturally ventilated. Both incorporate a conventional design with slatted floors for effluent capture.



PHOTOGRAPH 12 – PIGGERY F MAIN SWITCHBOARD

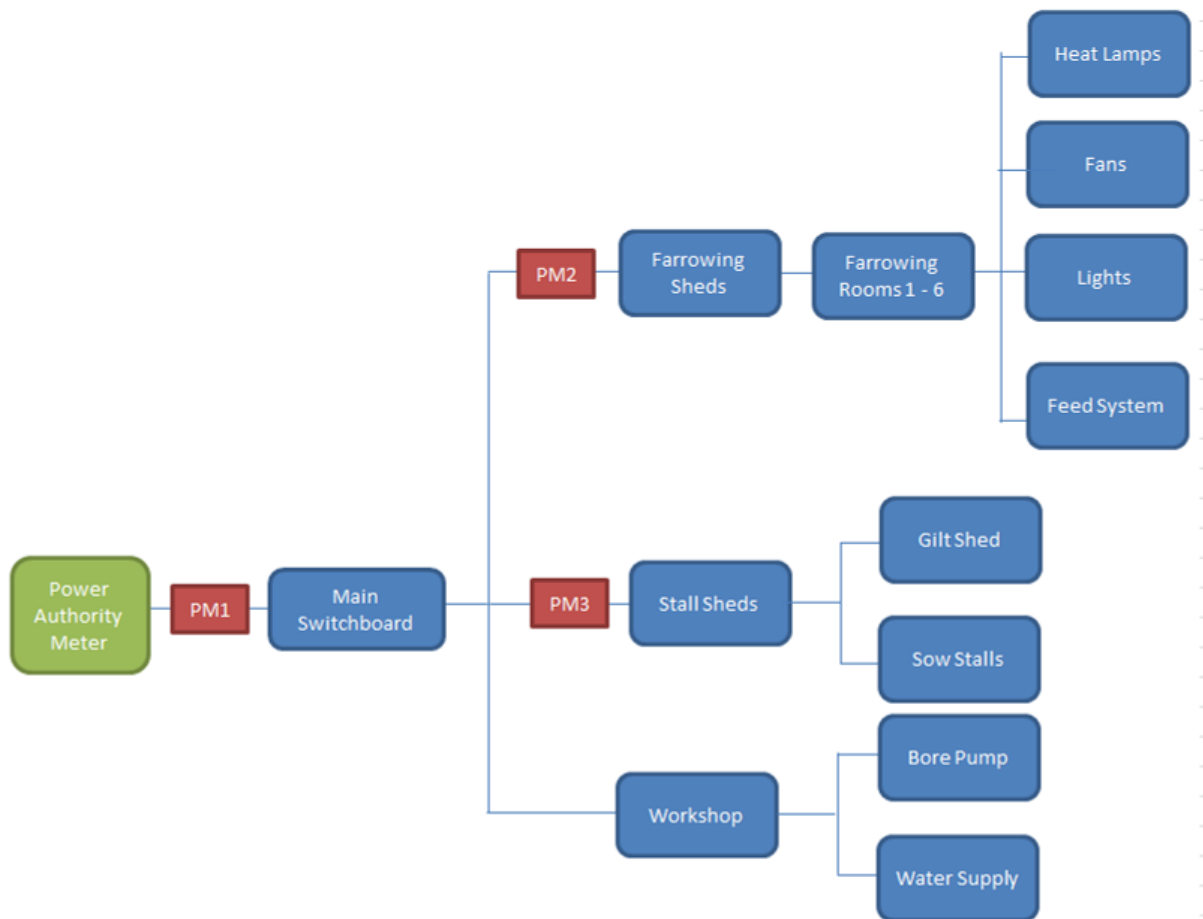


FIGURE 44 – PIGGERY F ELECTRICAL CIRCUIT ONE-LINE DIAGRAM

Power meter 1 (PM1) monitored the entire site's power usage. A 500/5 CT was used to provide accurate readings of the large electricity draw. Power meter 2 (PM2) was attached to the sub-main providing electricity to the site's farrowing facility. This sub-main powers six separate farrowing rooms each with a heating system and fans to control the climate. The sub-main also contains circuits for the lights and feed system as demonstrated in Photograph 13. Power meter 3 (PM3) recorded the electrical energy use from the dry sow sheds sub-main. This sub-main powers a gilt shed and the dry sow sheds. Power monitor 2 and 3 use a 250/5 CT to measure electricity. The final sub-main on the main switchboard supplies the workshop. The energy use for the workshop was calculated by subtracting PM2 and PM3 from the total site, PM1. The power meters and logger were secured to the main switchboard installation and the cables zip-tied to prevent any interference during the monitoring. The complete energy monitoring equipment set-up at Piggery F is shown in Photograph 13.



PHOTOGRAPH 13 – INSTALLED POWER METERS AT PIGGERY F SWITCHBOARD

Production data was obtained for the data recording period to allow an analysis of electricity consumption per weaned pig. Electrical energy usage for the piggery was 13.2 kWh per weaned pig produced.

Liquid fuel usage was obtained from arm data records (petrol and diesel). There was no gas usage for heating on the site. Total energy use for the piggery was 52 MJ per weaned pig produced.

Figure 45 and Figure 46 shows the daily electrical energy consumption for winter and summer respectively for Piggery F. Figure 47 and Figure 48 shows the hourly electrical energy profile for winter and summer respectively for Piggery F.

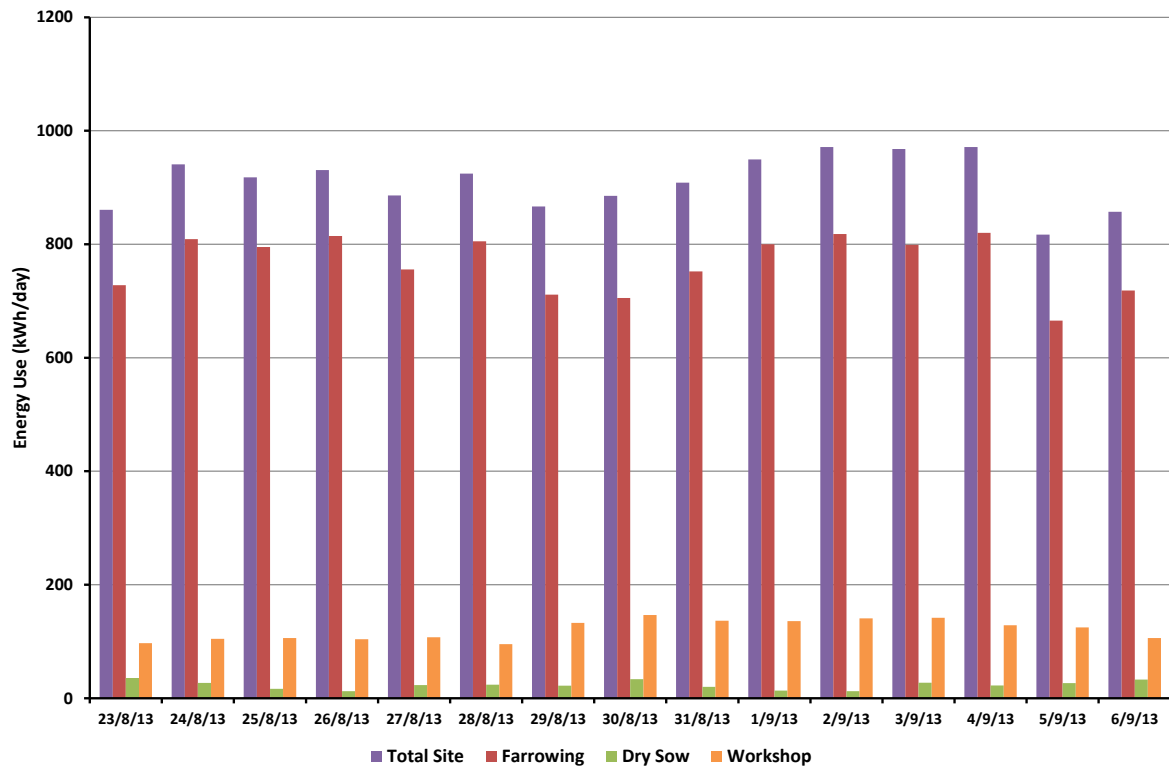


FIGURE 45 – PIGGERY F WINTER DAILY ELECTRICITY CONSUMPTION

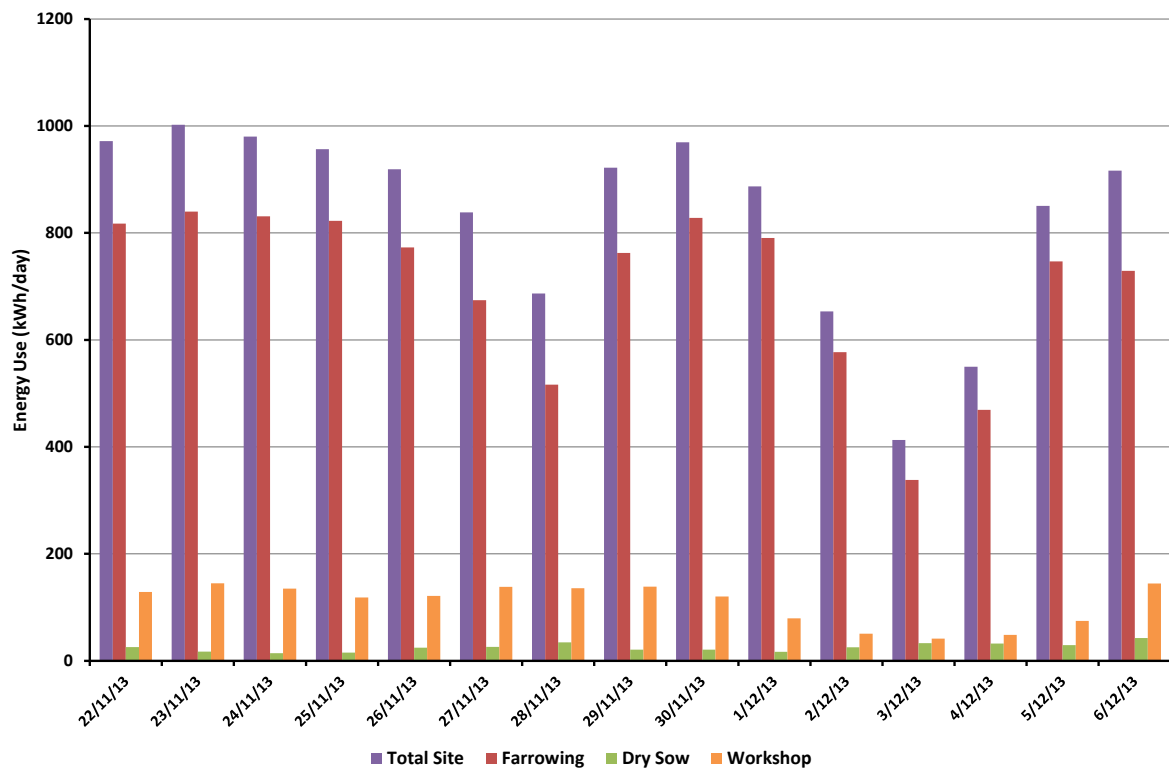


FIGURE 46 – PIGGERY F SUMMER ELECTRICITY CONSUMPTION

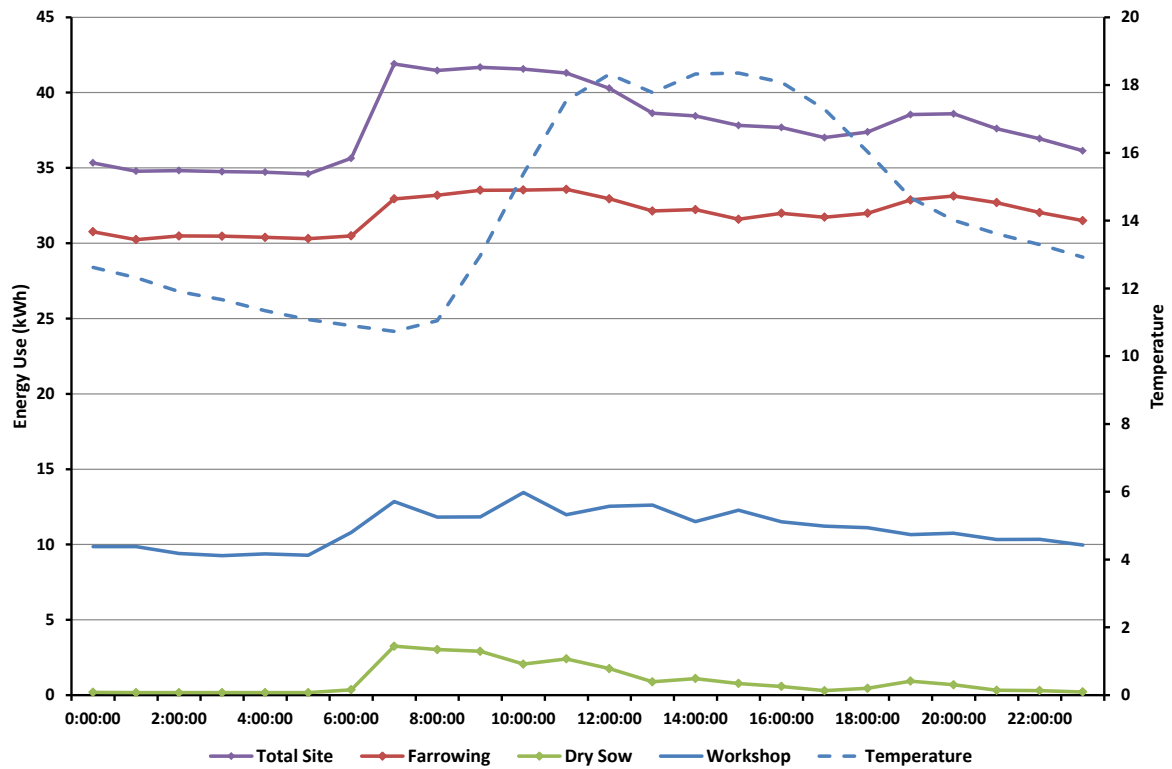


FIGURE 47 – PIGGERY F WINTER AVERAGE ELECTRICITY USE OVER A DAY

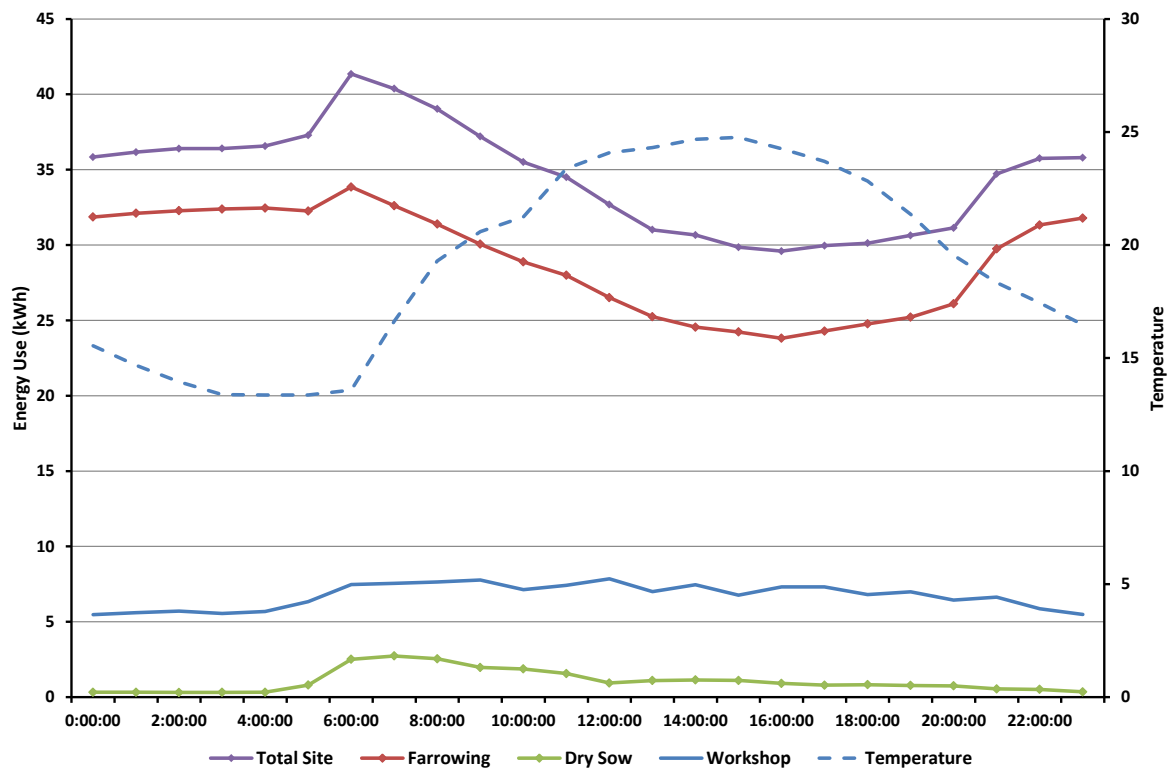


FIGURE 48 – PIGGERY F SUMMER AVERAGE ELECTRICITY USE OVER A DAY

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