Literature Review

AUSTRALIAN MEAT INDUSTRY COUNCIL

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ENERGY CONSUMPTION GUIDE FOR SMALL TO MEDIUM RED MEAT PROCESSING FACILITIES

Project Code: AM12-5066 Domestic Processors Energy Efficiency Program

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INTRODUCTION

This Energy Consumption Guide (ECG) is intended to raise awareness of the potential to improve the energy and environmental performance of small to medium sized red meat processing facilities[1], and to encourage positive management action. It describes four types of facilities which can form the basis for characterization and comparison against other similar facilities throughout the Australian Red Meat Processing Industry. It also outlines technical and management measures to identify and quantify energy saving opportunities.

The ECG was developed by Energetics Pty Ltd on behalf of the Australian Meat Processor Corporation (AMPC) under the program entitled 'Domestic Processors Energy Efficiency Program (DPEEP)', a program developed by AMPC to assist small to medium sized domestic processors in understanding and managing energy cost and use. The dataset used to develop the benchmarks was gathered from five sites in NSW and five sites in QLD.

Two additional documents have also been developed by Energetics on behalf of the Australian Meat Processor Corporation (AMPC) under the DPEEP. These documents include the Energy Consumption Guide for Small to Medium Scale Red Meat Processing Facilities (AM12-5066, Energetics, 2013) and the Literature review of Energy Efficiency Benchmarks and Technologies report (AM12-5066, Energetics, 2013).

STRUCTURE OF THE GUIDE

Although primarily written for plant engineers and environmental/energy managers, the ECG should also be of interest to a range of operational and managerial staff. The ECG starts by looking at broader energy issues and moves into progressively increasing detail.

WHAT ARE BENCHMARKS?

Energy performance benchmarks provide representative values for common types of facilities, against which other facilities can be compared. Comparison with simple benchmarks of annual energy use per unit of meat production output (such as tonnes of hot standard carcass weight (tHSCW)) will permit the standard of energy efficiency to be assessed and enable remedial action to be taken. More detailed benchmarks can help pinpoint problem areas within a facility.

Although rounded for clarity, the benchmark values presented in this ECG are derived from surveys of five small to medium red meat processing facilities. It is envisaged that the dataset underpinning the benchmarks for small to medium red meat processing facilities will be increased over time as the opportunity presents to capture and analyse the relevant data.

Benchmarks are applied to:

- facilities as a whole;
- energy consuming equipment such as heating, lighting and refrigeration;
- major processes within a facility such as slaughtering, boning, processing and rendering;
- units of production, such as tonnes of hot standard carcass weight (tHSCW).

Factors affecting energy cost and use

energy is used in all aspects of red meat processing and represents a significant operating cost at small to medium facilities, ranging from $10,000 for sites processing 500 tonnes of hot standard carcass weight (thscw) per annum to $1,000,000 for sites processing 12,000 thscw per annum.

[1] For the purposes of this project, small to medium processing facilities have been deemed to process in the order of 400 to 1,500 head per day.

Energy use varies between processing sites and is influenced by factors such as the type of species processed, the throughput, the extent of rendering activity, the amount of refrigeration and the level of further processing. The key factors which impact energy use are described in Table 1.

Table 1 – Factors impacting on energy use

<table>
<tr><th>Characteristic</th><th>Parameters</th><th>Impact on energy use</th></tr>
<tr><td>Location</td><td>• Different legislative requirements between States.
• Different electricity supply-mix, prices and tariffs between States.</td><td>Higher food safety regulations increases the energy required to keep meat refrigerated and chilled.

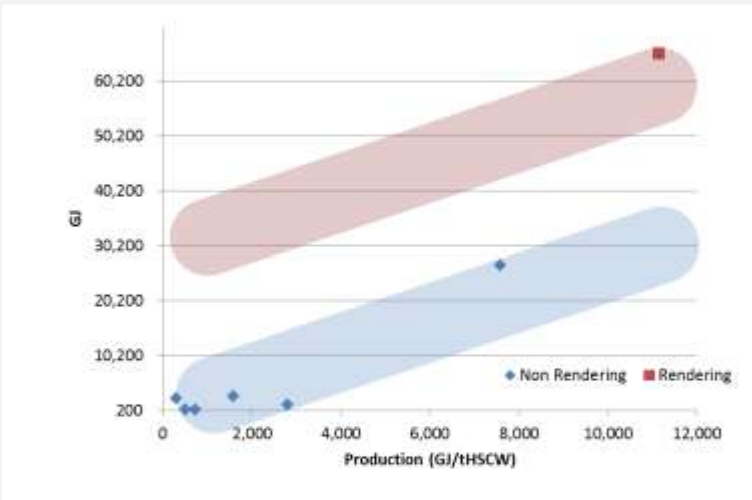
The cost of electricity varies between States. Average electricity costs across Australia are $160-190/MWh and half of this cost is due to network demand or capacity charges (these relate to the highest peak KW or KVA demand in the month). The tariffs (excluding demand/capacity charges) range from: 10-13 c/kWh for peak and shoulder, and 3-4 c/kWh for off-peak.

For small remote sites, the average electricity costs is often >190$/MWh.

The average LPG and natural gas costs are shown below:

<table><tr><th>Energy type</th><th>Average costs</th></tr><tr><td>LPG</td><td>$0.68-1.35/L -> $27.2-54/GJ</td></tr><tr><td>Natural gas</td><td>$8 – 14/GJ</td></tr></table></td></tr>
<tr><td>Throughput</td><td>Ranges from less than 5 tHSCW per day to over 35 tHSCW per day at small to medium facilities</td><td>↑ Total energy use increases with production, however energy intensity may not (i.e. energy consumed in producing each tHSCW).

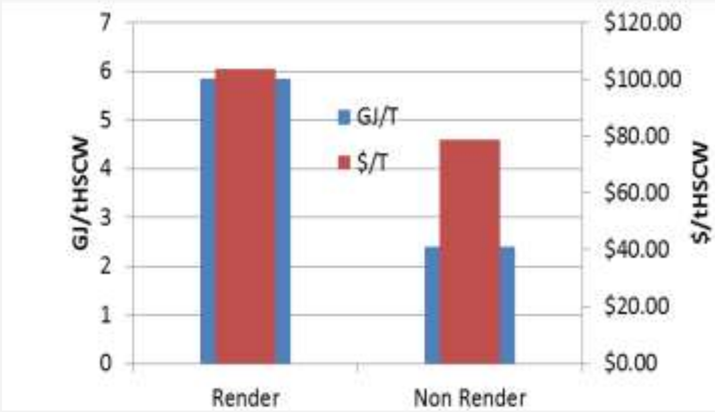
The total energy use decreases for small sites for which most of the processes are manual.



Source: AMPC DPEEP 2013</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th>Parameters</th><th>Impact on energy use</th></tr>
<tr><td>Processing level</td><td>

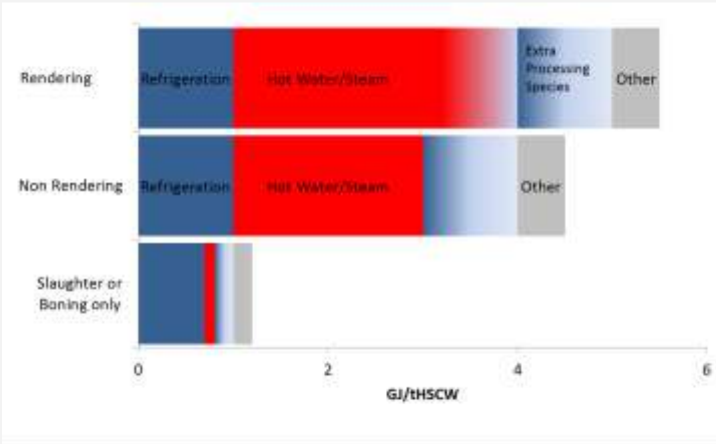
Slaughter floor only
Boning room only
Slaughter floor plus integrated boning room
Slaughter floor, boning room plus further processing
High value meat

</td><td>
↑ On site rendering increases the total energy usage.


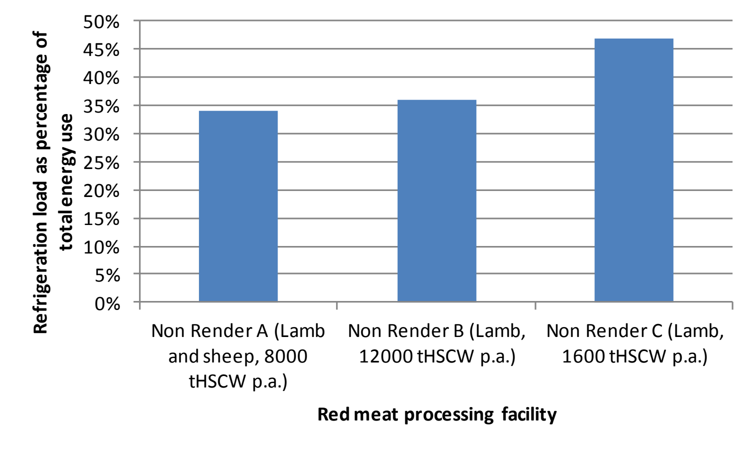
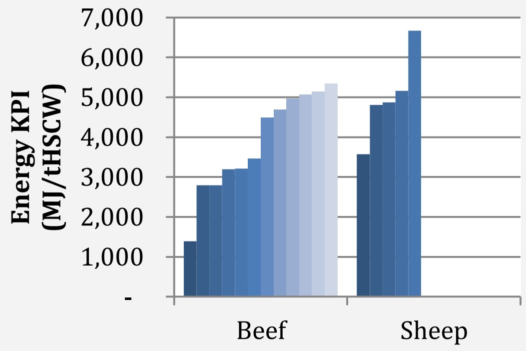
Source: AMPC DPEEP, 2013

↑ Offal cleaning and washing machines use large volumes of hot and cold water, which in turn uses energy to heat and pump the water.

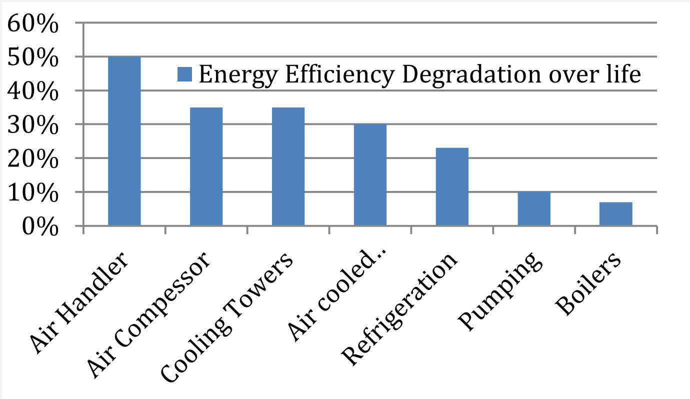
↑ Producing high value meat such as sausages or salami requires additional energy.

↓ Hot boning requires less energy, as the carcass does not require refrigeration or chilling prior to boning.


Source: AMPC DPEEP, 2013
</td></tr>
</table>

Characteristic	Parameters	Impact on energy use
	Export Domestic	↑ Meat for the export market requires more chilling/freezing to extend the shelf life and enable transportation. The chart below shows a large variation in refrigerant energy consumption across three non-rendering sites. This can be attributed to differing requirements for cooling based on amount and type of product stored.  Source: AMPC DPEEP, 2012
Production type	• Single species plant • Multi-species plant	↑ Cattle and sheep abattoirs tend to need significantly less hot water than pig plants. Around 80% of total energy use at pig abattoirs is for thermal energy generation (e.g. for heating scalding tanks, raising steam, singeing), as opposed to just 30–77% at cattle and lamb abattoirs. Sheep processing generally uses less than pigs or cattle principally because the animal is less bulky and less energy is required for chilling, sheep meat is not normally aged for as long, less processing is required for stomachs, and many sheep companies ship a lot of their product out as a whole carcass.  Source: AMPC DPEEP 2012, MLA 20112

[2] Meat and Livestock Australia 2011, Environmental data analysis (A.ENV.0090). Available at http://www.redmeatinnovation.com.au/project-reports/report-categories/environment/environmental-data-analysis

Characteristic	Parameters	Impact on energy use
Age of energy consuming equipment and maintenance	Operating efficiency over life Level of engineering support and maintenance	↑ Technology improvement has significantly reduced energy consumption of the equipment. For example, steam boilers manufactured in the 1970's were 70% - 75% energy efficient. New boilers are 80 - 85% efficient. The following chart indicates the degradation in efficiency over the lifetime of the equipment if regular and ongoing maintenance is not performed.  ↑ Poorly maintained equipment increases the energy use. For example, sites with compressed air leaks will have a higher energy use compared to well-maintained sites.

Source: www.greenroof.com. Planned-maintenance-whitepaper

TYPE OF FACILITY

Small to medium meat processing facilities can be categorized according to the activities performed at the facility: A) slaughter or boning only, B) slaughter and boning, C) processing and D) rendering.

Sites with further processing and value-adding activities such as rendering use more energy than sites with slaughtering only, as is depicted in
Figure 1. Within these categories, the amount of product cooling and species mix also impacts the energy use.

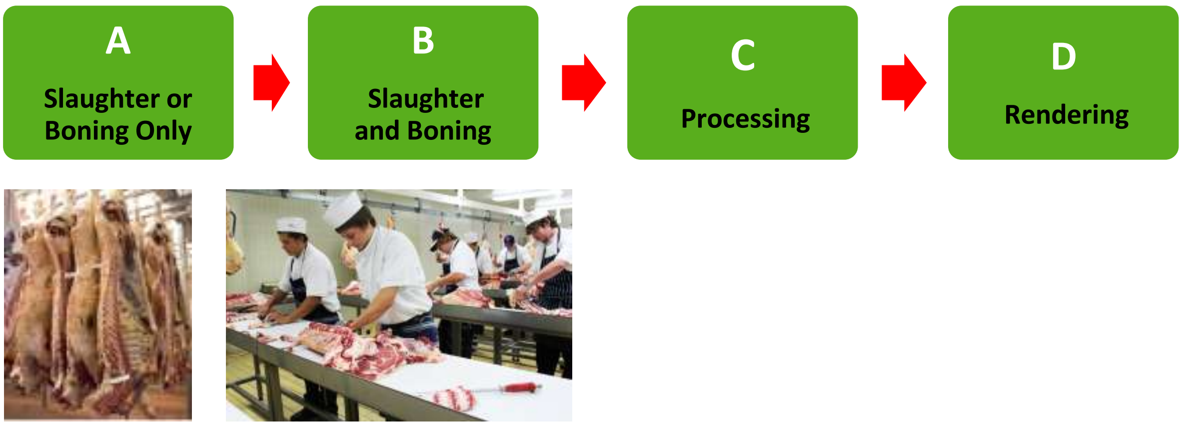


Figure 1: Relationship between site activities and energy use

The site categories are based on the following site characteristics obtained from the site audits conducted for the DPEEP:

A (Slaughter only):	B (Slaughter and boning)	C (Processing)	D (Rendering)
2800 tHSCW per annum of Pork and beef	8,000 tHSCW per annum of lamb and sheep;	12,000 tHSCW per annum of lamb	12,000 tHSCW per annum of lamb, beef and pork.
500 tHSCW per annum of Lamb, Beef , sheep and Pork	1,600 tHSCW per annum of lamb	300 HSCW per annum of beef and lamb	
	750 tHSCW per annum of Beef, sheep, goat and Pork		

ENERGY SOURCES

The primary energy sources consumed at the sites surveyed under the DPEEP were electricity, natural gas and liquefied petroleum gas (LPG). Wood, used in a wood fire system to generate hot water, was only observed for one site. Electricity is used for refrigeration, compressed air and lighting. Natural gas and LPG is used for the hot water and steam systems. Larger sites tend to use natural gas whilst smaller sites use LPG as they usually don't have access to natural gas.

There are significant differences in the energy breakdown for rendering and non-rendering sites. Non-rendering sites used equal amounts of gas and electricity. Rendering sites used more natural gas/LPG (60-80% of overall energy consumption) due to the additional steam required for the rendering process and wash down activities (Figure 2).

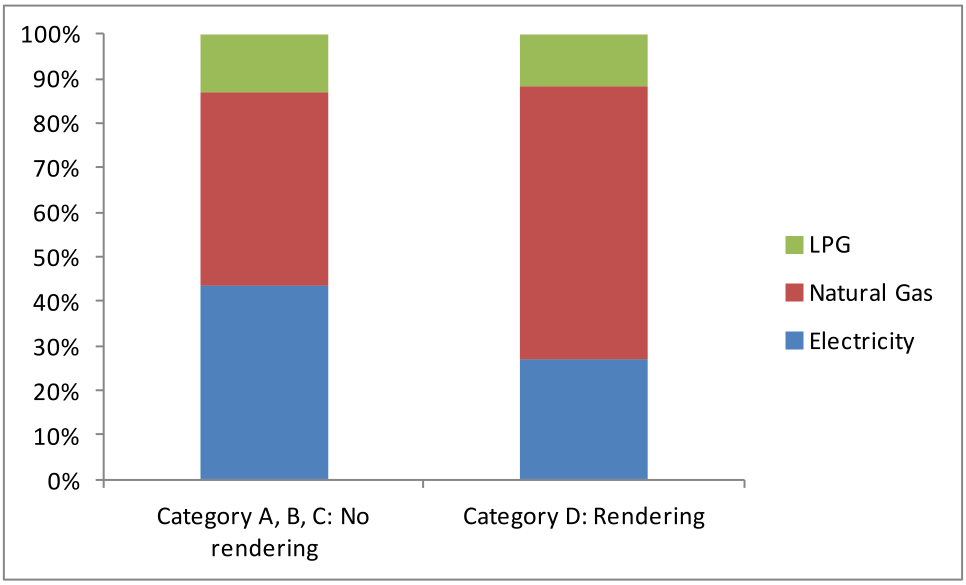


Figure 2: Breakdown of energy sources at sites surveyed under the DPEEP

ENERGY PROFILE

Based on the sites surveyed under the DPEEP, the energy consumption profiles have similar trends for all four categories of site. That is, the energy use will vary according to production level, but the energy trend will be similar for all sites. The energy profiles below are based on a Category D rendering site.

The weekly energy consumption profile shows high energy use and demand during plant operation (from 0430-0530hrs through to 1430-1530hrs, Monday – Friday) and low energy use on non-operational weekends (with the exception of planned maintenance and cleaning activities).

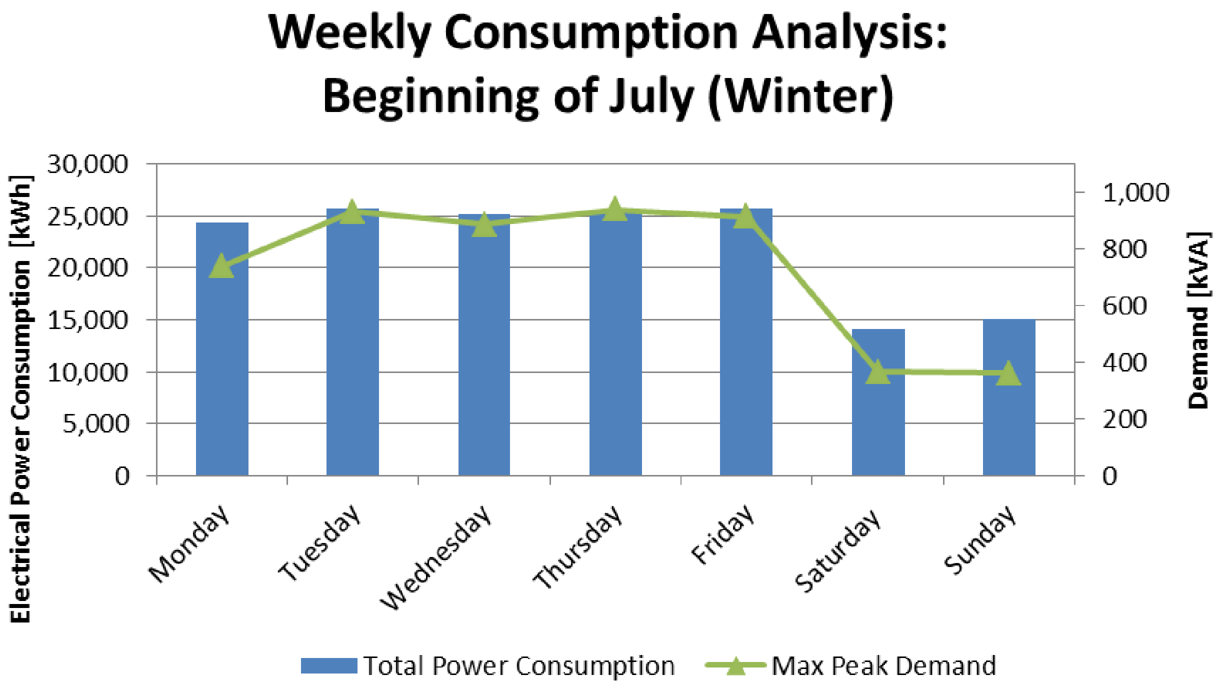
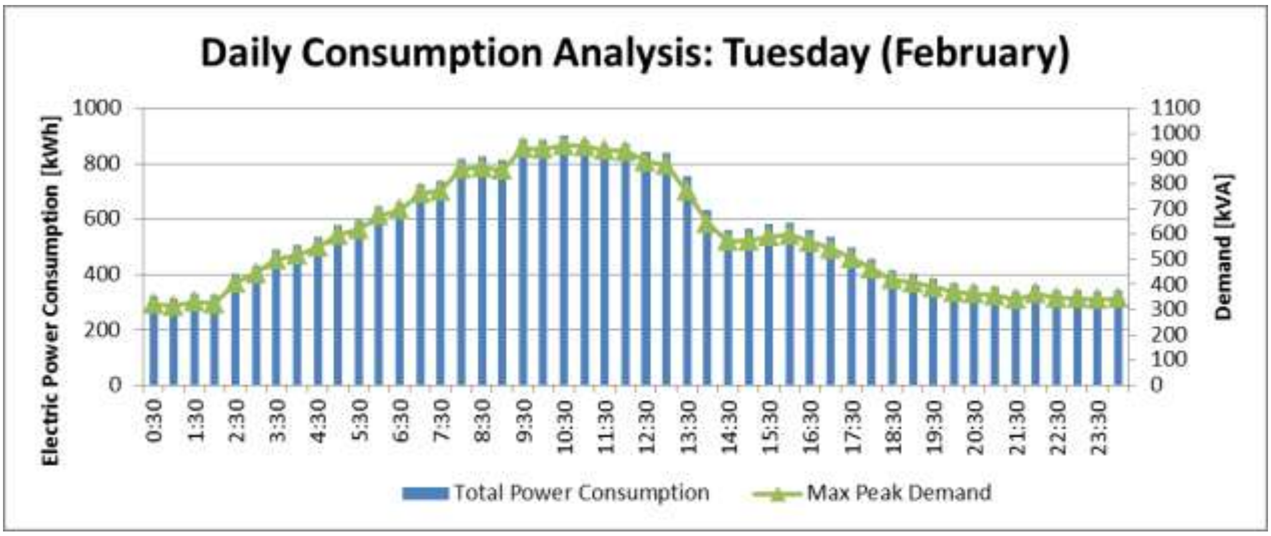


Figure 3 Weekly electricity consumption profile at a non-rendering site Category D (AMPC DPEEP, 2012)

On a daily profile, power consumption was highest during the boning and initial stages of carcass cooling (between 0500hrsand 1430hrs, Monday – Friday). The weekend electricity consumption profile was relatively constant, which was slightly lower than the base load during the weekdays (Figure).



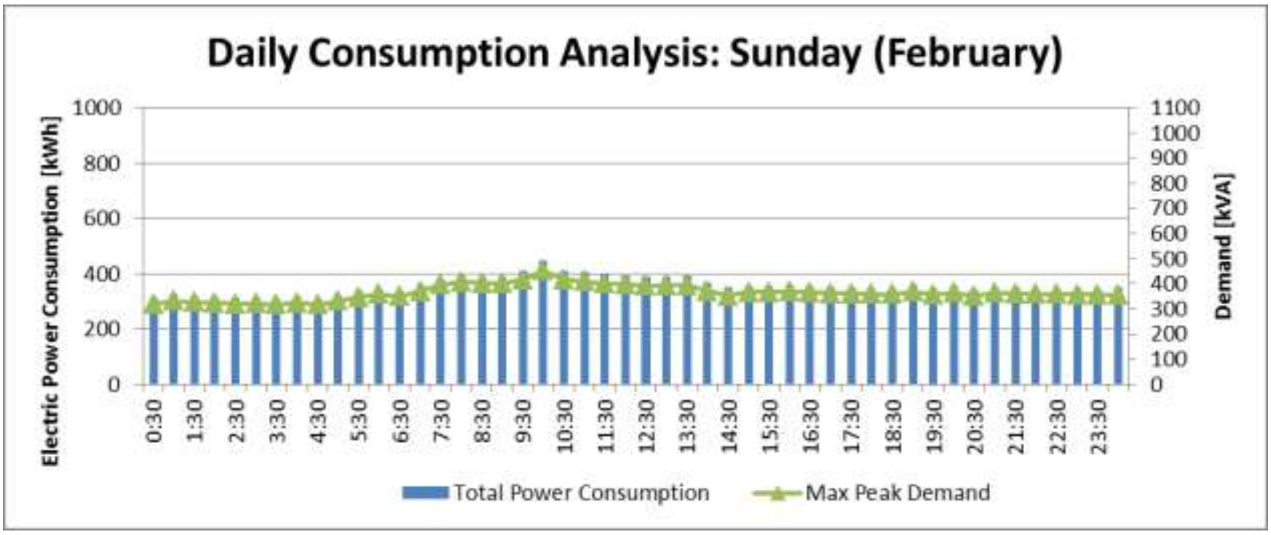


Figure 4: Weekday & weekend hourly profiles Category D (AMPC DPEEP, 2012)

The electricity consumption profile over the period May 2011 to April 2012 showed an increased load during summer months due to additional cooling and refrigeration needs.

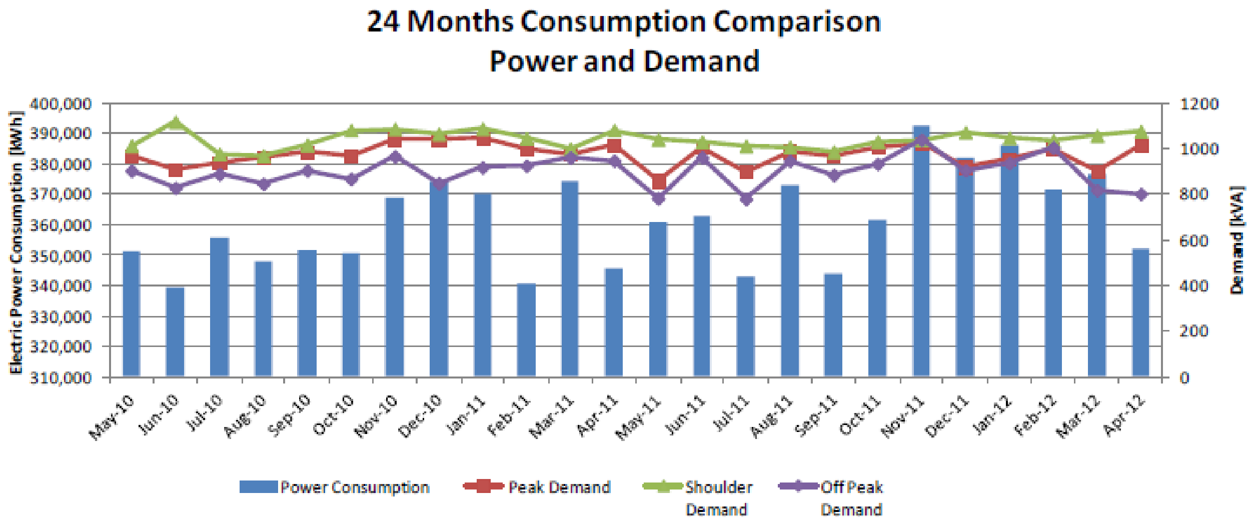


Figure 5 : Annual electricity consumption Category D (AMPC DPEEP, 2012)

The gas consumption over the period May 2011 to April 2012 showed higher consumption in the cooler months due to the higher load on the hot water system.

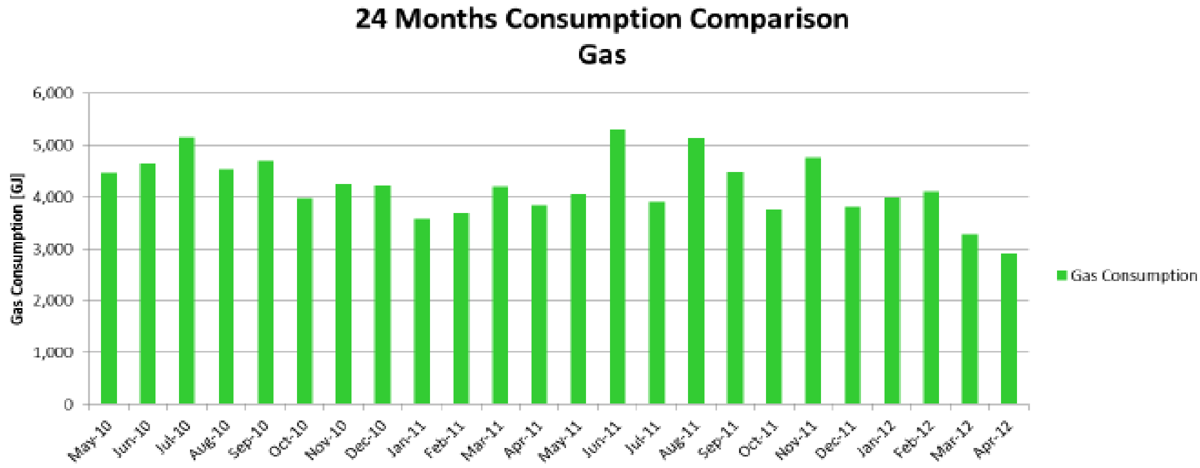


Figure 6: Annual gas consumption Category D (AMPC DPEEP, 2012)

WHERE DOES THE ENERGY GO?

The main energy consuming equipment found at the five sites included refrigeration plant, steam and hot water generating equipment, pump, lighting and air compressors. The actual percentage breakdown for the energy consuming equipment will differ depending on whether the site does rendering or not (Figure).

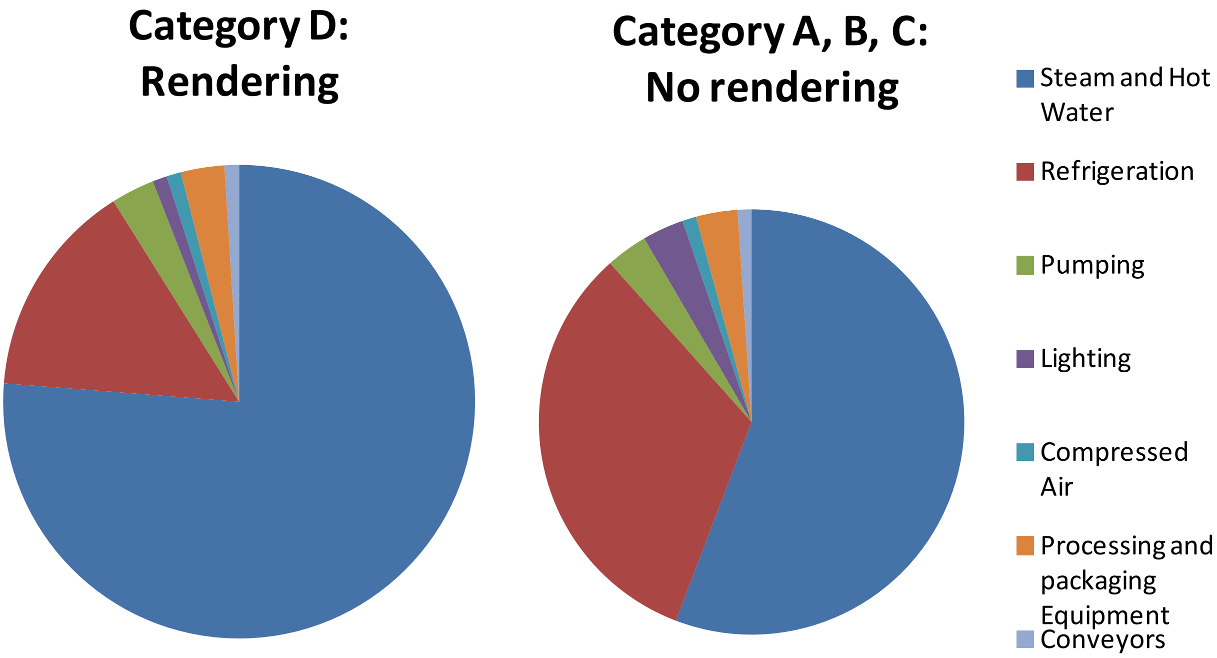


Figure 7: Energy consumption by equipment.

The main energy consuming equipment found at the five sites surveyed under the DPEEP and the factors that influence energy use by this equipment is shown in Table 2.

Table 2: Energy consuming equipment & factors influencing energy use

Energy consuming equipment	Percentage of site-wide energy use	Factors influencing energy use
Steam and hot water generators 	53-77%	Steam and hot water is produced by boilers which can be powered by gas, coal, electricity, oil or bi-products such as tallow. Steam and hot water is used for cleaning, sterilizing and rendering. For rendering sites, up to 77% of total energy consumption is used in the process of generating steam and hot water.

Energy consuming equipment	Percentage of site-wide energy use	Factors influencing energy use
Refrigeration equipment 	15-31%	Energy demand for refrigeration is dependent on the amount of meat stored and the location of the plant. For example, plants in Southern Australia have lower cooling requirements than plants in warmer locations such as northern New South Wales or Queensland where temperature and relative humidity is higher.
Pumps 	3%	Pumps are used for a number of purposes including circulation of fluids in refrigeration and hot water systems, water supply for stock, waste water treatment, recycled water and irrigation.
Processing Equipment 	2%	Processing equipment includes items such as screw press, hammer mill, band saws, skin tumbler and loin washers.
Packaging Equipment 	1%	Packaging equipment is used to seal the meat product after processing.
Air compressors 	1%	Compressed air is used to run air knives, animal handling apparatus, and pneumatic controls for automated machinery.

Energy consuming equipment	Percentage of site-wide energy use	Factors influencing energy use
Lighting 	3%	Lighting is installed throughout the site and in the chiller rooms. The most common fixtures in the five sites surveyed were twin and single 36 Watt (W) T8 fluorescents and 400W metal halide high bays.
Conveyors 	1%	Conveyors are used to transport waste material around the site.

BENCHMARKS

Based on data from the DPEEP and previous studies, benchmark energy use per unit production (GJ/tHSCW) is provided in Figure 2.

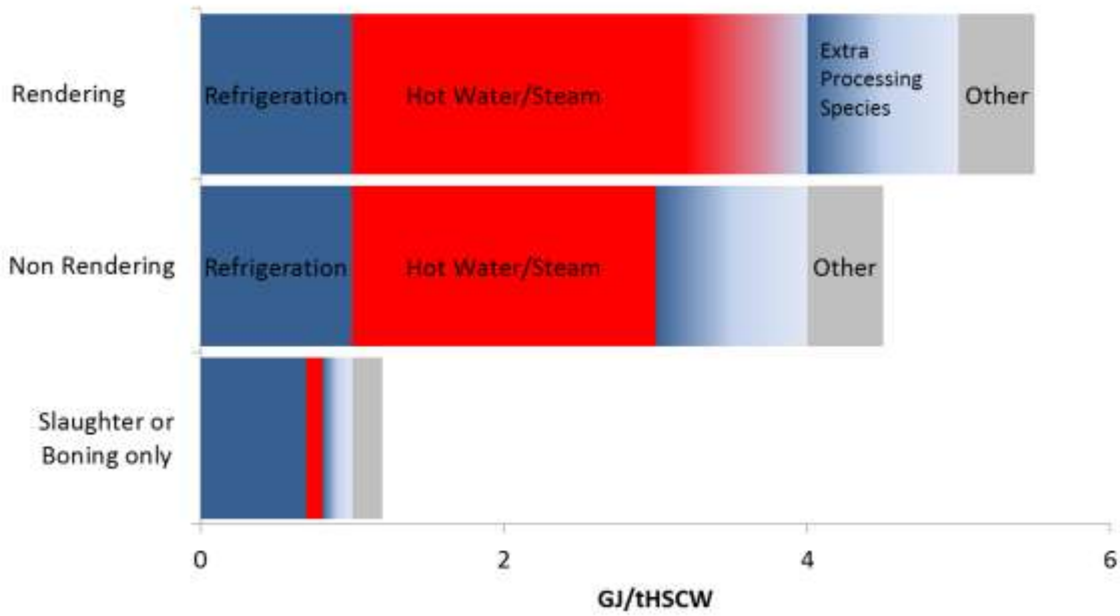


Figure 3: Energy breakdown by site type.[3]

[3] Rendering and non-rendering Categories are based on the DPEEP site audits and Slaughter only category is based on estimates from previous industry research papers including (Meat and Livestock Australia 2011, Environmental data analysis (A.ENV.0090) and on QLD site visit analysis. Available at http://www.redmeatinnovation.com.au/project-reports/report-categories/environment/environmental-data-analysis)

ENERGY SAVING OPPORTUNITIES

There are numerous energy efficiency opportunities and best practices that can be implemented at red meat processing facilities. These range from simply improved housekeeping through to upgrade or replacement of existing equipment.

Energy efficiency opportunities can be broadly categorised in four categories; (1) Energy efficient technologies. (2) Alternative energy systems (3) Maintenance, and (4) Behavioural and Procedural. The expected energy savings in these categories are shown Tables 3 and 4as well as the ensuing case studies which are based on the site surveys carried out under the DPEEP.

Table 3: Energy saving opportunities

Energy efficient technologies	Typical % of site energy consumption	Typical range of savings	Areas for improvement
1 Refrigeration	15-30%	15-45%	Reducing plant load, plant optimisation, equipment upgrade : improving condensing unit location, upgrading to glycol/CO2 systems, upgrading to ammonia plant, fan and compressors on VSDs, heat recovery.
2 Thermal Energy (Hot Water and Steam)	40-80%	0-15%	Boiler efficiency, Boiler blowdown Piping, steam traps and leaks, condensate recovery
3 Lighting	3-5%	20-50%	More efficient technology, lighting controls, voltage optimisation
4 Compressed Air	3%	10%	Equipment, controls, air quality and temp
5 High Efficiency Motors	5%	2-4%	Refrigeration compressors, conveyors belts, processing equipment, hydraulic equipment, fans and pumps.
6 Variable Speed Drives (VSD)	2-5%	25-40%	Fit VSDs to fixed-speed pumps, fans and compressors.

Table 4: Opportunities in alternative energy systems.

Alternative energy systems	Capital cost	Typical payback	Areas for improvement
7 Renewable energy **7.1 Solar PV** **7.2. Solar hot water** **7.3 Wind energy**	 \$2-3/Watt Peak (Wp)[1] \$2/Watt Thermal (Wt) \$2-3 Million/MW	 2-7 years 5-7 years 5-10 years	Technology manufacturer (low cost, low performance vs higher cost, higher performance), siting and positioning of equipment to maximize energy generation, maintenance.
8 Biogas capture and reuse	Note[4]	6 years	Optimising biogas generation in the AD system, biogas cleaning to remove impurities, biogas leaks or losses, maintenance.
9 Cogeneration	\$1000-2000/kW (electric)	>2 years (biogas) > 5 years (natural gas)	System sizing (matching output with demand to avoid oversupply of energy), maintenance.

Refer to the document ***"An Energy Management Plan for Red Meat Processing Facilities"*** (AM12-5066, Energetics, 2013) for a detailed check list of energy saving opportunities.

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[1] \$2-3/Watt Peak covers a wide range of system sizes.
[4] The capital cost for these systems are highly variable depending on scale, location, design, equipment type and end-use for the energy generated.

Case Studies: Small-medium meat processing sites in New South Wales and Queensland surveyed under the DPEEP.

Refrigeration opportunities

The audits undertaken at ten small to medium scale meat processing sites as part of the DPEEP provided a good indication of the most likely energy saving opportunity areas for refrigeration.
The energy saving opportunities for small to medium scale meat processing sites can be divided in two categories. One for the sites having a commercial refrigeration plant (Freon refrigerant) and another one with sites having an industrial refrigeration plant (ammonia as refrigerant).

For the meat processing sites having a commercial refrigeration plant, energy saving opportunities are the following:

Short term actions that can be undertaken are:

- Condensing unit placed on the ground and/or very closed to a wall can be moved to a level higher up and a well-ventilated area such as on the roof improves the efficiency of the unit by reducing the condensing temperature, and eliminates contamination of the condenser coils by dust and dirt.
- Solenoid valve on the condensing unit. Solenoid valves should be installed closed to the expansion valve. When installed on the condensing unit, as is common practice, the pump down period is extended resulting in higher energy consumption.
- Suction lines should always be insulated. If the unit is exposed to sunlight, the armaflex type insulation should be cladded to protect it from UV damage,

Long term actions that can be undertaken are:

- It is common in small abattoir to have several commercial refrigeration units which can be replaced by a centralised glycol unit or a centralised CO2 system to serve the cool rooms. For the freezer rooms, a fully hermetic stand-alone refrigeration unit running on R407F or a CO2 system connected to the glycol system or a low stage CO2 unit connected to the CO2 system can be implemented. This would result in a higher efficiency system, in lower electricity consumption and in lower refrigeration charge.
- For larger plant (over 300kW), ammonia systems are the best solution to reduce significantly the energy consumption. Besides reducing the energy consumption, it facilitates the heat recovery and reduces the risk of refrigerant leakage.
- High consumption of hot water can be reduced by using a heat recovery exchanger. Heat recovery can be implemented by using the discharge temperature of the centralised refrigeration system.
- Use of fan speed control on condenser and evaporator fans should be applied, especially for new units. In each case, the control logic used to reduce the fan speed when full speed is not required should be carefully considered.

For the meat processing sites having an industrial refrigeration plant, energy saving opportunities are the following:

- Ageing compressor packages as part of the refrigeration system. Compressor tests on industrial systems nationwide indicate wide spread inefficiencies which can be remedied by compressor package replacements (compressor package – compressor block, electric motor, instruments, oil separator
- Refrigeration system controls are done through a semi-automated control system that requires a lot of human intervention and is only providing limited means for optimisation and controlling energy efficiency.
- Compressors running in fixed speed modes with slide valve unloading for capacity control. This can result in compressors often running unloaded. If the compressor is currently on slide-valve controlled, it runs inefficiently for a large percentage of the year.
- Consider replacing the old electric motor (efficiency around 0.8) with a new high efficiency (efficiency around 0.95) motor, which will increase system reliability. Furthermore, old electric motors may have been re-wound which further decreases motor efficiency. Considerable energy savings can be achieved on an industrial refrigeration plant by variable speed control of screw compressors, especially during part load conditions.

<u>Hot water and steam system opportunities</u>

- Half of the sites surveyed (with rendering) had boiler systems that were over 40 years old and had limited performance capabilities. The sites had multiple boilers of varying usage patterns, efficiency and levels of maintenance. For these sites, the installation of new boilers with economisers, trim control and VSDs, automatic blow down and blow down heat recovery, load balancing and multi pass flue gas travel is recommended. Consideration of efficiency improvement to an existing boiler is also recommended where replacement is not viable. Uninsulated hot water and steam lines were also common. Hot water is used at various locations for washing of plants at a mid temperature watering points (43°C). These points use tempering valves to mix higher temperature (e.g. 82°C) water with ambient water. This method of heating water higher than required then cooling it back down by mixing with cold water is very energy inefficient. There were also opportunities to switch from electrical heating to gas heating in applications such as shrink tunnels or any electric heating of hot water.