Red Meat Processing Industry
Energy Efficiency Manual

Prepared by:

Hydro Tasmania Consulting
89 Cambridge Park Drive,
CAMBRIDGE, TAS 7170

for

Meat & Livestock Australia
Locked Bag 991
North Sydney, NSW 2059

Red Meat Processing Industry Energy Efficiency Manual

Project No: A.ENV.0065

ISBN – 1 74036 XXX X (MLA to provide)

Summary

Against a background of rising energy prices and increasing concerns about greenhouse gas emissions, Meat and Livestock Australia (MLA) commissioned the current *Red Meat Processing Industry Energy Audit* in 2008.

The purpose of the audit was to obtain a snapshot of energy efficiency performance across the industry, and to provide the participating plants with individual assessments of their energy use and energy saving opportunities.

Energy surveys conducted at 12 participating plants revealed significant energy saving opportunities. Despite the limited scope of those surveys, energy cost savings of between 15% to as high as 60% were identified.

This manual is a summary of the most common energy saving opportunities identified for the participating plants. A series of examples, calculators, and other tools are also included to assist the industry with improving energy efficiency and reducing greenhouse gas emissions.

Participating Plants and Overall Energy Use

As shown in Table S-1 below, five integrated beef plants, four integrated sheep plants, and three mixed species plants participated in the audit between March-June 2008.

Plant	Species Processed	On-site Rendering	Elect. Index (kWh/t HSCW)	Main Fuel	Fuel Index (MJ/t HSCW)	Total Energy Index (MJ/ t HSCW)	Energy Related Emissions (kg CO_2-e/t HSCW)
A	Cattle	Yes	194	N-Gas	2,254	2,953	292
B	Cattle	Yes	207	N-Gas	1,427	2,172	261
C	Cattle	Yes	360	N-Gas & Coal	3,228	4,523	579
D	Cattle	Yes	268	N-Gas	2,096	3,060	348
K	Cattle	Yes	307	Coal	3,572	4,676	603
E	Sheep	Yes+other processes	623	N-Gas	5,917	8,159	862
F	Sheep	No	250	N-Gas	1,553	2,454	386
G	Sheep	Yes	263	N- Gas	786	1,734	276
H	Sheep	No	79	N-Gas	549	832	124
I	Mixed	No	239	N-Gas	1,507	2,367	370
J	Mixed	Yes	43	N-Gas	2,908	3,062	185
L	Mixed	Yes	423	N-Gas	2,899	4,422	667
	Average		**271**		**2,391**	**3,368**	**410**

Table S-1: Energy and emission indices for participating plants

Whilst there were significant differences in the operations of each plant, the average energy consumption across the twelve plants was found to be 3,368 MJ/t HSCW (mega Joules/tonne Hot Standard Carcass Weight) as shown in Figure S-1. The median energy index for the twelve sites was calculated as 3,006 MJ/t HSCW.

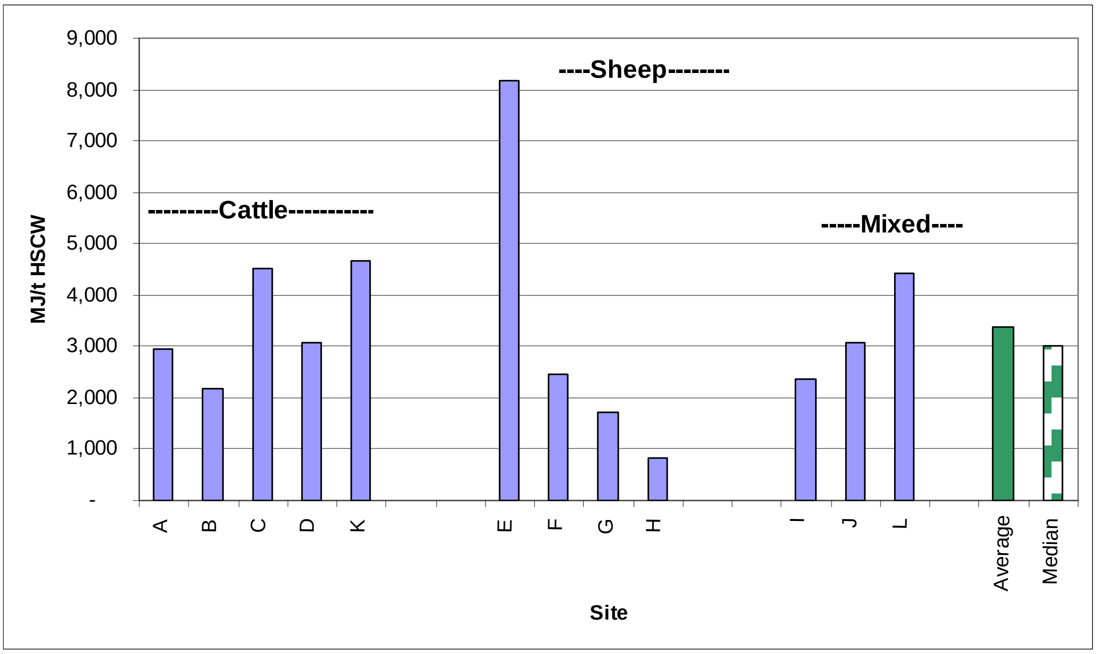


Figure S-1 Total energy index (MJ/t HSCW) for the 12 participating plants

Despite the small sample size, the above energy index is very close to MLA's 2003 index of 3,389 MJ/t HSCW for a similar sample size, and an earlier 1998 index of 3,411 MJ/t HSCW. Those changes in the energy index indicate a relatively small (1.3%) improvement in energy efficiency between 1998 and 2008.

However, adjusting for the unusually high energy index at site E (due to additional processes), a lower average of 2,868 MJ/t HSCW can be calculated. That is 16% lower than1998 energy index of another random sample.

Electricity Use in Meat Processing Plants

As can be seen from Figure S-2, despite the significant differences in electricity use for each of the participating plants, an average electricity use index of 272 kWh/t HSCW may be calculated.

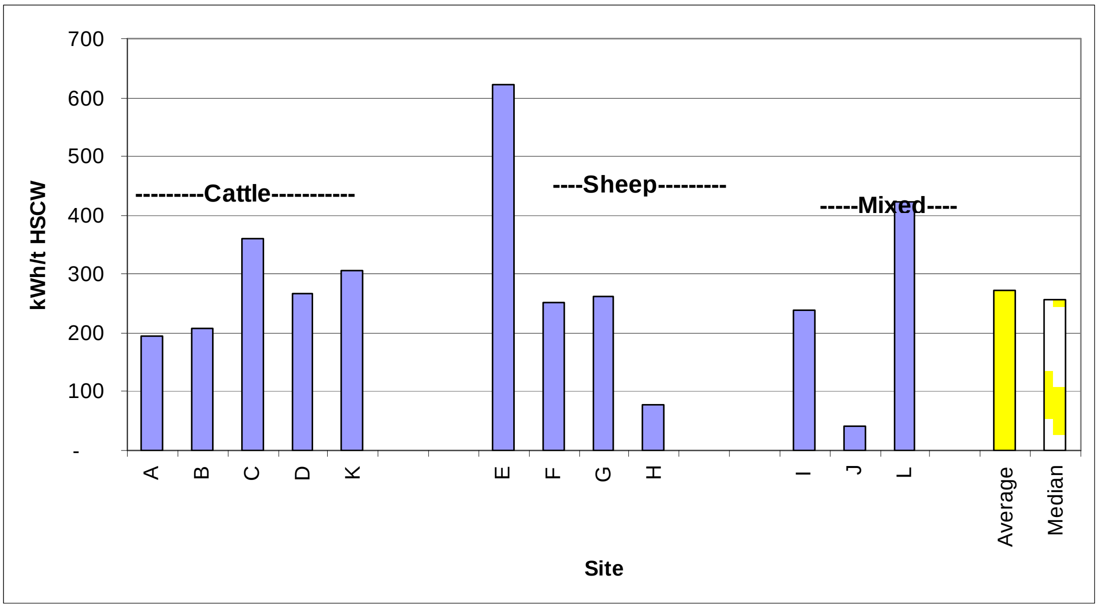


Figure S-2 Electricity use index (kWh/t HSCW) for the 12 participating plants

Whilst electricity consumption accounted for an average of only 30% of the sites' total energy consumption, it accounted for an average of 65% of total energy costs and greenhouse gas emissions.

Electricity end- use efficiency

The largest users of electricity in meat processing plants are refrigeration compressors, accounting for over 55% of total energy use.

The overall refrigeration efficiency for most plants was relatively low due to a combination of factors including manual operations, inefficient low part-load performance of compressors, sub optimal design of systems (which are often a mix of old and new equipment), and deteriorated insulation and vapour barriers.

The main areas of efficiency included advanced controls, improved part load performance, and reduction in the minimum discharge pressures set point, as well as improved house keeping, discussed further in this manual.

Large numbers of electrical motors, air compressors, and lighting were other smaller components of electricity use. These smaller components are discussed under separate sections, along with some of the most common energy efficiency opportunities identified.

Absence of sub metering is a common feature of most sites, making benchmarking of individual processes difficult. Use of existing SCADA systems or new wireless and web based metering options are also discussed as effective options for improving electricity sub metering across the industry.

Thermal Energy Use in Meat Processing Plants

For an average energy index of 2,390 MJ/t HSCW, thermal energy from combustion of natural gas (or coal, in the case of two plants) accounted for over 70% of the total energy use in participating plants.

On-site rendering was by far the largest user of thermal energy, followed by hot water heating which varied in magnitude depending on the extent of heat reclaim from the rendering process.

Thermal energy efficiency opportunities discussed in this manual are presented under three sections:

- Steam Generation,
- Steam Distribution and
- Steam Use.

These sections cover a range of topics including burner efficiency and tuning, use of economisers, blowdown practices, insulation, flash steam and condensate recovery. Worked examples and calculators are also included to assist with the initial estimates of energy saving measures.

Energy Related Greenhouse Gas Emissions

The *energy related* greenhouse emissions for a meat processing plant can be divided into two main categories;

- Direct emissions from combustion of fuels such as natural gas and coal within the site (i.e. Scope 1 emissions)

- Emissions associated with purchased electricity (Scope 2 emissions)

Whilst there are other greenhouse emissions such as methane from anaerobic ponds and waste, for the purpose of this manual, only the above energy related emissions were calculated for the participating plants as shown in Figure S-3.

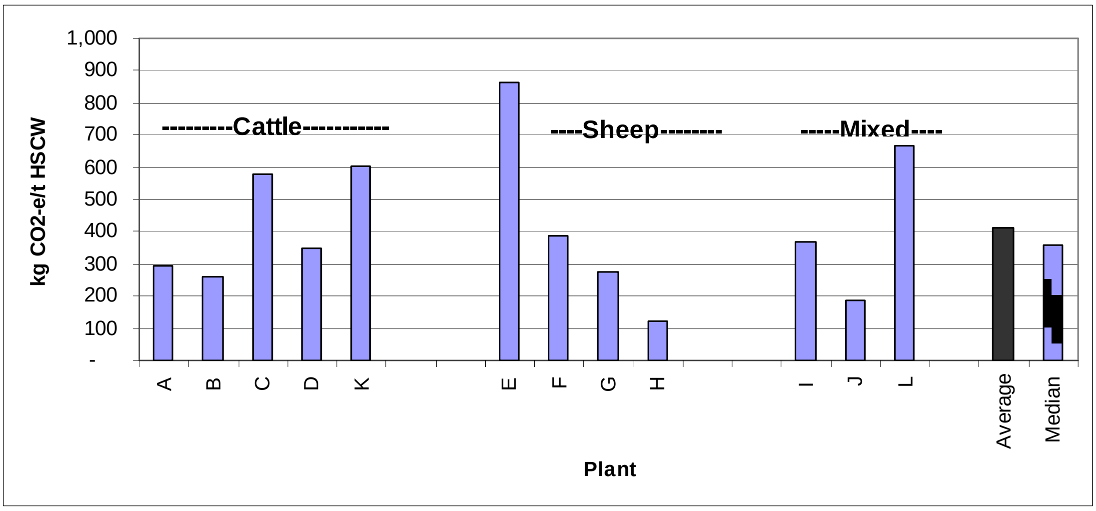


Figure S-3 Energy related emission indices (kg CO_2-e/t HSCW) for the 12 sites audited

Due to their size, the majority of meat processing plants are not likely to be included in the proposed Carbon Pollution Reduction Scheme (CPRS) expected to commence in 2010. However, the industry as a whole will be affected through the resulting increased in electricity and fuel prices.

Identifying and implementing energy saving opportunities will be one of the most cost effective solutions for the industry to reduce the impact of the expected energy price rises.

Energy Saving Opportunities

Table S-2 below gives a summary of energy saving opportunities identified at each of the twelve participating plants.

Potential Energy Saving Measure\Site	A	B	C	D	K	E	F	G	H	I	J	L
Thermal Energy												
Boiler burner tuning	•	•	•	•	•	•	•	•	•	•	•	•
Flash steam recovery	•		•	•	•	•		•	•		•	•
Boiler drum TDS level			•	•	•	•		•	•		•	•
Blowdown heat recovery				•	•	•		•			•	
Boiler Economiser	•	•		•	•	•	•	•	•	•	•	•
Cooker Waste Heat Recovery	√	√	•	•	•	•		•			•	•
Increased Condensate Recovery	•		•	•	•	•		•	•		•	•
Sterilisers' waste heat recovery	•		•	•	•	•	√		•	•	•	•
Improved Boiler Part load Performance	•	•	•	•	•	•	•	•	•	•	•	•
Reduction in How Water Use	•	•	•	•	•	•	•	•	•	•	•	•
Refrigeration												
Sub metering (Monitoring & targeting)	•	•	•	•	•	•	•	•	•	•	•	•
Reducing Refrigeration lift	•	•	•	•	•	•	•	•	•	•	•	•
Reviewing Boning Rm. Fresh Air intake	•	•	•	•	•	•	•	•	•	•	•	•
Use of Plate Freezers	√	√	√				√	•	•	•	•	√
Use of dehumidifiers in Freezers	•	•	√	•	•	•	•	•	•	√	•	•
Automated Refrigeration System Control	•	•	•	•	•	•	•	•	•	•	•	•
Floating Head Condenser Control	•	√	•	•	•	•	•	•	•	•	•	•
Evaporative/chilled water spray pre-cooling	•	•	•	•	•	•	•	•	•	•	•	•
VSD on trim screw compressors	•	•	•	•	•	•	•	•	√	√	•	•
VSD's on evaporator fans	√	√	•	√	•	•	•	•	•	•	•	•
Other Energy Saving Opportunities												
Eliminating compressed air leaks	•	•	•	•	•	•	•	•	•	•	•	•
VSD on screw air compressors	√	•	•	•	•	•	•	•	•	•	•	•
Optimised Sequencing of air compressors	√	•	•	•	•	•	•	•	•	•	•	•
Demand Side Management	•		•	•		•	•	•	•	•	•	•
Power Factor Correction				•		•		•	•	√	•	•
Purchasing energy efficient motors	•	•	•	•	•	•	•	•	•	•	•	•
Improved Lighting Control	•	•	•	•	•	•	•	•	•	•	•	•
Biogas capture and use:	•	•	•	•	•	•	•		•		•	
Cogeneration	•	•	•	•	•	•	•	•	•	•	•	•

• *Energy Saving Opportunity*
√ *Implemented Energy Saving Measure*

Table S-2- Summary of energy saving opportunities at participating plants

Top seven energy saving opportunities

The top seven energy and emission saving opportunities identified at the participating sites included:

- Energy Sub-metering *(you can not manage what you can not measure!)*
- Biogas Recovery from Anaerobic Ponds (especially for sites with odour issues)
- Combined Heat and Power (CHP) or Cogeneration (especially for sites without access to waste heat from rendering operations)
- Chilled Water Spray or Evaporative Pre-cooling of Carcasses
- Reduction of Refrigeration Lift (floating head, increased suction, etc.)
- Waste Heat Recovery (from cookers, flash steam, increased condensate recovery)
- Boiler Plant Optimisation (inc. boiler tune up, and use of economisers)

Finally, a number of non-technical topics equally important in a successful energy management program are discussed in the last section of this manual. Under *Developing an Energy Management System*, the need for high level leadership, sub-metering and monitoring of energy use, setting key performance indicators (KPI's), targets, and in particular training, are discussed. A series of guidelines and checklists for conducting an energy audit and implementing energy efficiency projects are also included as appendices and attachments.

Energy and Emission Benchmarks

Whilst the above energy and emission benchmarks are in reasonable agreement with the earlier environmental performance reviews by MLA, there are significant differences from site to site as can be seen on Figures S1 to S3.

These benchmarks can be useful for a broad and indicative comparison. However given that each plant has its own unique characteristics, a more accurate benchmarking should be carried out for each plant as a baseline to measure energy performance and greenhouse emissions.

Table of Contents

1 Introduction

Rising energy costs, growing concerns over greenhouse gas emissions, and expected new legislations were among the key strategic drivers for the commissioning of the Red Meat Processing Industry Energy Audit by MLA in early 2008.

The audit covering twelve plants across Australia, conducted by Hydro Tasmania Consulting (HTC), was carried out between March and June 2008. The 12 plants were selected by MLA from three representative types of meat processing plants in Australia namely; Integrated Beef, Integrated Sheep, and Mixed Species plants. Individual energy audit reports were prepared and submitted to each of the participating plants.

This Manual gives an overview of the findings from those representative plants, including their energy use index, and common energy saving opportunities identified which are likely to be applicable to similar plants.

A series of checklists and calculators are also presented as part of the tool kit supplied with this Manual to enable Plants to conduct limited self audits and to facilitate the early assessment of energy and greenhouse saving opportunities.

1.2 Acknowledgment

Participation of the twelve meat processing sites in this Audit, in particular the input provided by staff from each plant, from MLA personnel, and the AMPC/MLA Environment Program Technical Advisor; Dr Mike Johns are acknowledged.

1.3 Disclaimer

The information provided in this Manual is intended to assist meat processing sites with the early identification of energy efficiency and greenhouse reduction opportunities.

There has been no attempt to promote or endorse any particular technology or product that may have been featured in this Manual.

Readers are advised to carry out their own detailed studies and obtain information on technologies and costs independently and from multiple sources prior to implementation.

2 The Red Meat Processing Industry Energy Audit

Energy audits equivalent to Level 2 audits (AS/NZS 3598:2000) were conducted at twelve meat processing plants including five integrated beef plants, four integrated sheep plants, and three mixed species plants between March and June 2008. Energy audits included reviews of historical energy use at those plants, assessment of energy and emission intensities associated with different operations, and assessment of potential opportunities for reducing energy intensity, energy costs, and greenhouse gas emissions.

- The selected beef plants were mostly large plants (>300 tonne HSCW/day) with on-site rendering facilities.
- The four sheep plants were medium to large facilities. Two plants had on-site rendering.
- The three mixed species plants were medium to large plants producing on average 300 t HSCW with different ratios of between 60% to 75% cattle: sheep. Two plants had on-site rendering facilities.

2.1 Energy Indices

Table 1 below gives an overview of the participating sites electrical, thermal, and total energy indices.

Plant	Species Processed	On-site Rendering	Elect. Index (kWh/t HSCW)	Main Fuel	Fuel Index (MJ/t HSCW)	Total Energy Index (MJ/ t HSCW)	Energy Related Emissions (kg CO2-e/t HSCW)
A	Cattle	Yes	194	N-Gas	2,254	2,953	292
B	Cattle	Yes	207	N-Gas	1,427	2,172	261
C	Cattle	Yes	360	N-Gas & Coal	3,228	4,523	579
D	Cattle	Yes	268	N-Gas	2,096	3,060	348
K	Cattle	Yes	307	Coal	3,572	4,676	603
E	Sheep	Yes+other processes	623	N-Gas	5,917	8,159	862
F	Sheep	No	250	N-Gas	1,553	2,454	386
G	Sheep	Yes	263	N- Gas	786	1,734	276
H	Sheep	No	79	N-Gas	549	832	124
I	Mixed	No	239	N-Gas	1,507	2,367	370
J	Mixed	Yes	43	N-Gas	2,908	3,062	185
L	Mixed	Yes	423	N-Gas	2,899	4,422	667
	Average		**271**		**2,391**	**3,368**	**410**

Table 1 Energy and emission indices for participating plants

The average energy index across the 12 plants, 3,368 MJ/t HSCW, can be seen from Table 1 above. This result is almost identical to the MLA (2003) index of 3,389 MJ/t HSCW from a sample of 10 different plants. The current index is also similar to an earlier 1998 MLA index of 3,411 MJ/t HSCW, indicating a relatively small (1.3%) gain in energy efficiency over the past decade.

Figures 1, below, illustrates the total energy index in MJ/t HSCW for each of the surveyed plants.

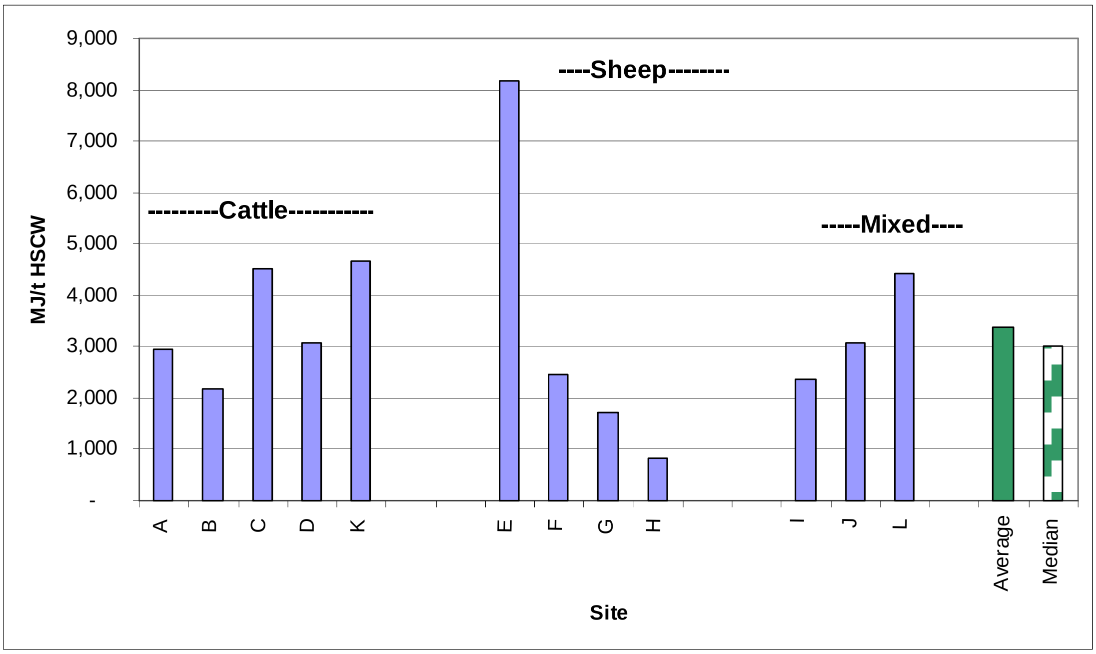


Figure 1 Total energy index (MJ/t HSCW) for the 12 sites audited

2.1.1 Energy Index vs. Production Levels

Adjusting for the unusually high energy index at site E (due to additional processes), a lower average energy index of 2,868 MJ/t HSCW can be calculated as shown in Figure 2 below.

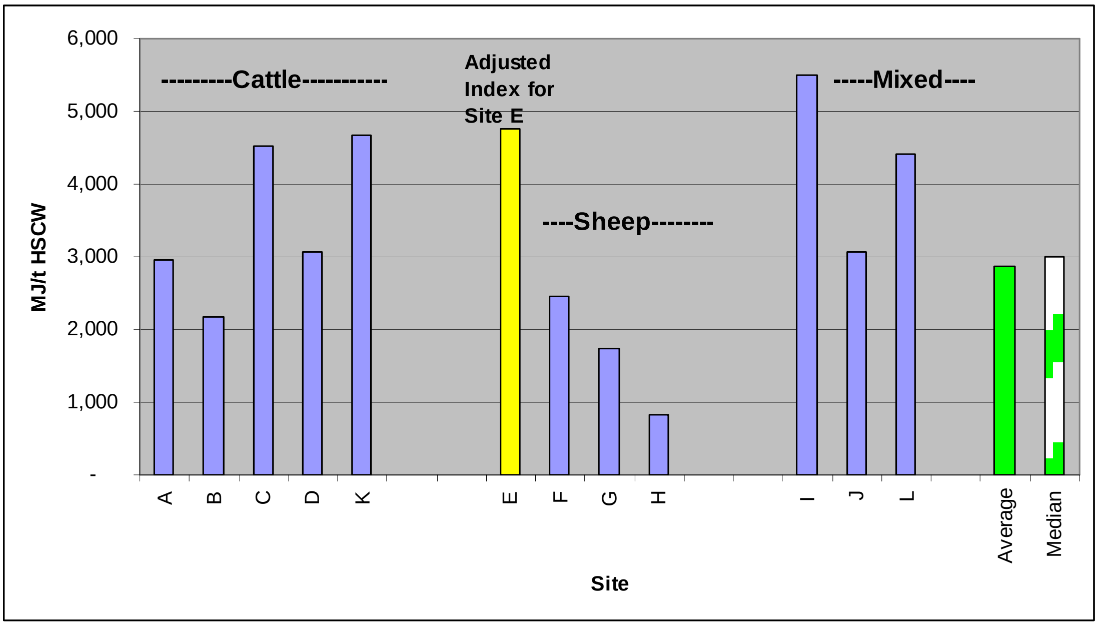


Figure 2 Total energy index (MJ/t HSCW) for the 12 sites with Adjusted Index for Site E

Figure 3 below illustrates the total energy index for the 12 sites (including the adjusted index for Site E) compared with each site's annual production (compared with the largest site audited).

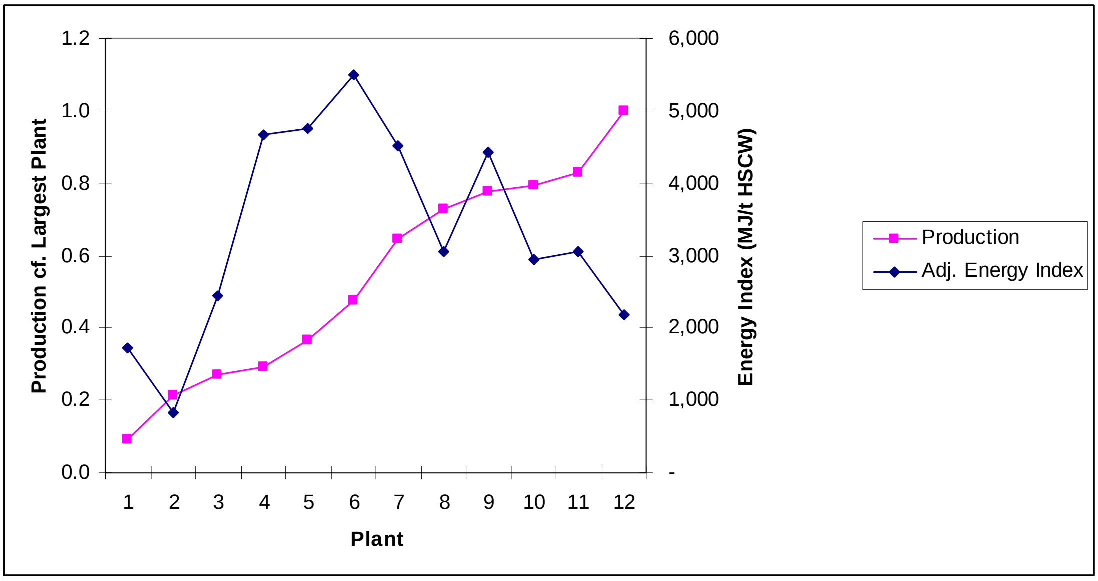


Figure 3: Annual Production vs. Total Energy Index for the 12 sites

As can be seen from Figure 3 above, there is no direct relationship between the throughput and the total energy index across the twelve sites. However individual sites show a clear reduction in their energy indices for periods of high production levels as discussed in Section 11.1 of this manual.

2.2 Thermal Energy Index

For an average thermal energy index of 2,391 MJ/t HSCW, natural gas (and coal in two plants) account for more than 70% of total energy use for the twelve sites audited.

Rendering process (for those plants with on-site rendering) was by far the largest user of thermal energy accounting for over 70% of thermal energy use, followed by hot water heating which varied in magnitude depending on the extent of heat reclaim from rendering processes.

Figure 4, illustrates the significant variations in thermal energy use at different plants.

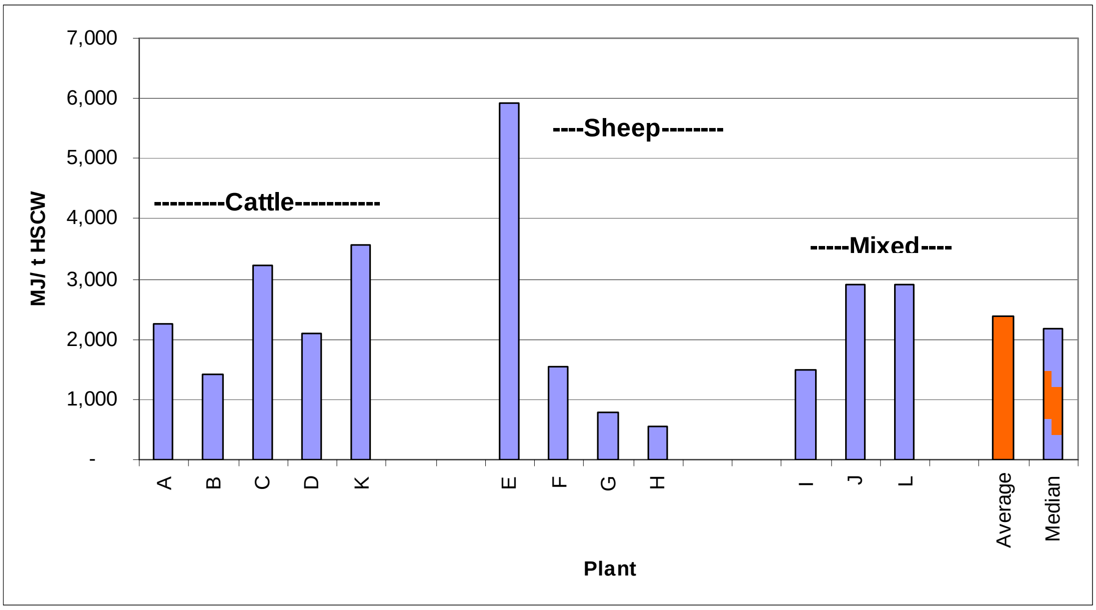


Figure 4- Thermal energy index (MJ/t HSCW) for the 12 sites audited

Whilst the average thermal energy use of 2,391 MJ/t HSCW as can be seen from Figure 4 above is close to 70% of total energy index for the twelve audited sites, the average cost of thermal energy in most plants were less than 35% of total energy costs. Similarly, the corresponding greenhouse emissions from thermal energy were just under 35% of the combined emissions from thermal energy and electricity purchases.

2.3 Electricity Index

Whilst the average thermal energy across the 12 sites accounted for close to 70% of energy *consumption as discussed above,* electricity purchases accounted for an average 65% of total energy *costs* (for 30% of total energy consumption). Figure 5, illustrates the range of electricity use indices for each site in kWh per tonne HSCW.

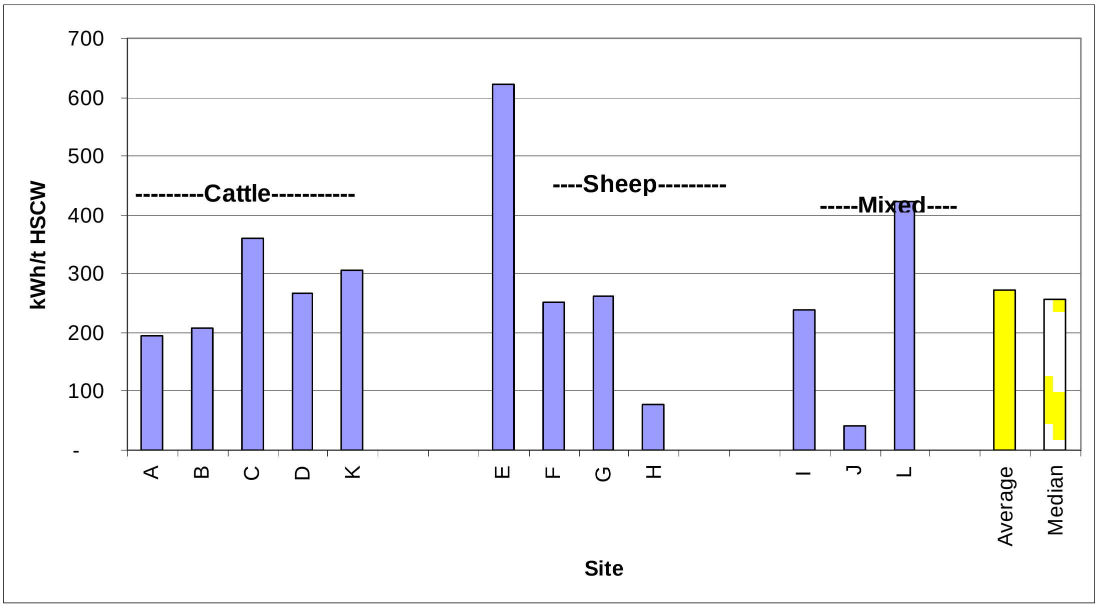


Figure 5 Electricity use index (kWh/t HSCW) for the 12 sites audited

The average electricity use for the 12 sites audited was 272 kWh/t HSCW. However as can be seen from Figure 5 above, there are significant variations between electricity use at each individual site.

2.4 CO_2 Index

The *energy related* greenhouse emissions for a meat processing plant can be divided into two main categories;

- Direct emissions from combustion of fuels such as natural gas, coal, etc. within the site (i.e. Scope 1 emissions)

- Emissions associated with purchased electricity (Scope 2 emissions)

For the purpose of this manual, the above Scope 1 and Scope 2 energy related emissions were calculated for each of the participating plants as shown in Figure 6 below.

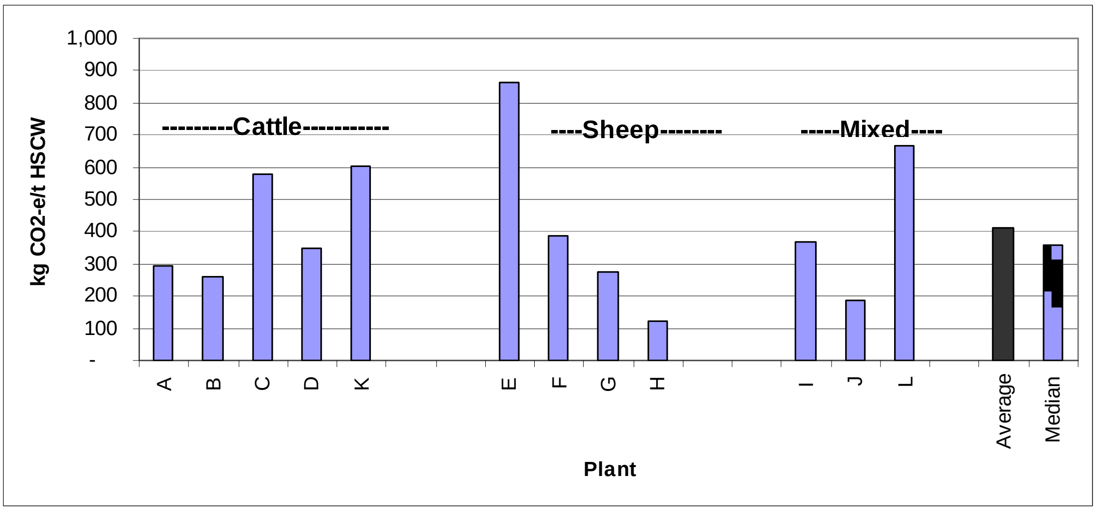


Figure 6 Energy related emission index (kg CO_2-e/t HSCW) for the 12 sites audited

As can be seen from Figure 6 above, despite the significant differences between plants, an average *energy related* emission index of 413 kg CO_2-e/ t HSCW may be calculated for those 12 plants. The average share of electricity related emissions (Scope 2 emissions) as can be seen from Table 2 account for two thirds (2/3) of the average energy related emission index.

Site	Scope 2 Emissions (Purchased Electricity)	Scope 1 (Direct Gas/Coal Usage)	Total ENERGY Related Emission Index
Code	kg/t HSCW	kg/t HSCW	kg/t HSCW
A	176	116	292
B	188	73	261
C	326	253	579
D	240	108	348
K	278	325	603
E	558	304	862
F	306	80	386
G	236	40	276
H	96	28	124
I	292	77	370
J	36	149	185
L	518	149	667
Average	***271***	***142***	***413***
Median	259	112	359

Table 2 *Energy Related* Scope 1 and Scope 2 Greenhouse Gas Emissions for the 12 Sites

Note that there are other emission sources in a typical meat processing plant such as organic waste and transport fuels which are not included in the above index. More importantly the greenhouse gas emissions from anaerobic ponds are not included in the above index. Methane emissions from anaerobic ponds can add additional 20% or 70 to 100 kg/t HSCW to the above index.

2.5 Energy Efficiency Practices

Despite the limited scope of the energy audits conducted at the 12 participating plants, energy saving opportunities ranging from 15% to 60% of annual energy costs were identified. Table 3 below gives a summary of the main energy saving opportunities at the 12 sites audited.

Potential Energy Saving Measure\Site	A	B	C	D	K	E	F	G	H	I	J	L
Thermal Energy												
Boiler burner tuning	●	●	●	●	●	●	●	●	●	●	●	●
Flash steam recovery	●		●	●	●	●		●	●		●	●
Boiler drum TDS level			●	●	●	●		●	●		●	●
Blowdown heat recovery				●	●	●		●			●	
Boiler Economiser	●	●		●	●	●	●	●	●	●	●	●
Cooker Waste Heat Recovery	√	√	●	●	●	●		●			●	●
Increased Condensate Recovery	●		●	●	●	●		●	●		●	●
Sterilisers' waste heat recovery	●		●	●	●	●	√		●	●	●	●
Improved Boiler Part load Performance	●	●	●	●	●	●	●	●	●	●	●	●
Reduction in How Water Use	●	●	●	●	●	●	●	●	●	●	●	●
Refrigeration												
Sub metering (Monitoring & targeting)	●	●	●	●	●	●	●	●	●	●	●	●
Reducing Refrigeration lift	●	●	●	●	●	●	●	●	●	●	●	●
Reviewing Boning Rm. Fresh Air intake	●	●	●	●	●	●	●	●	●	●	●	●
Use of Plate Freezers	√	√	√				√	●	●	●	●	√
Use of dehumidifiers in Freezers	●	●	√	●	●	●	●	●	●	√	●	●
Automated Refrigeration System Control	●	●	●	●	●	●	●	●	●	●	●	●
Floating Head Condenser Control	●	√	●	●	●	●	●	●	●	●	●	●
Evaporative/chilled water spray pre-cooling	●	●	●	●	●	●	●	●	●	●	●	●
VSD on trim screw compressors	●	●	●	●	●	●	●	●	√	√	●	●
VSD's on evaporator fans	√	√	●	√	●	●	●	●	●	●	●	●
Other Energy Saving Opportunities												
Eliminating compressed air leaks	●	●	●	●	●	●	●	●	●	●	●	●
VSD on screw air compressors	√	●	●	●	●	●	●	●	●	●	●	●
Optimised Sequencing of air compressors	√	●	●	●	●	●	●	●	●	●	●	●
Demand Side Management	●		●	●		●	●	●	●	●	●	●
Power Factor Correction				●		●		●	●	√	●	●
Purchasing energy efficient motors	●	●	●	●	●	●	●	●	●	●	●	●
Improved Lighting Control	●	●	●	●	●	●	●	●	●	●	●	●
Biogas capture and use:	●	●	●	●	●	●	●		●		●	
Cogeneration	●	●	●	●	●	●	●	●	●	●	●	●

● *Energy Saving Opportunity*
√ *Implemented Energy Saving Measure*

Table 3- Summary of energy saving opportunities at participating plants

There were few sites amongst the twelve sites audited that had conducted energy audits in recent years. Those sites with recent audits had no comprehensive energy management programs for the implementation of audit findings. However, energy management practices have begun to change mainly due to the greenhouse issue and the proposed changes to the regulatory environment, as well as increases in energy prices

The main reasons for energy efficiency not being a focus for some plants included factors such as:

- Shortage of qualified staff and resources
- Key focus being on production
- Little or no sub-metering of energy
- Access to information
- Electricity contracts negotiated at the time of low electricity prices
- Uncertainties during mergers/ownership changes.
- Different views on urgency of energy efficiency/required hurdle rates
- Perceived disruptions to normal operations and production
- Absence of energy management systems or programs
- Energy costs are considered as a fixed cost.
- Believing that there are not many opportunities for energy efficiency

Table 4 below, lists some of the common drivers and barriers to implementing energy efficiency opportunities in surveyed plants.

Drivers	Barriers
Energy Efficiency Opportunities (EEO) program http://www.energyefficiencyopportunities.gov.au	Access to information
Greenhouse Challenge Plus Program http://www.environment.gov.au/settlements/challenge	Absence of clear Energy Management Systems and Policies
Vic. Govt. Environment and Resource Efficiency Plan http://www.epa.vic.gov.au/bus/erep	Shortage of technical staff and engineers
National Greenhouse and Energy Reporting (NGER) http://www.greenhouse.gov.au/reporting	Focus on production
Proposed Carbon Pollution Reduction Scheme (CPRS) http://www.climatechange.gov.au/greenpaper (Ref. also to MLA project Env.063)	Historical low energy costs Production and QA priorities Perceived disruption to processes
Rising costs of electricity and Fuel Corporate Sustainability and Corporate Image Drivers	Expectation of rapid payback,

Table 4 Drivers and barriers to energy efficiency for participating plants

3 Electricity Use in Meat Processing Plants

There are major differences in the electricity use index at different meat processing plants depending on the operations, age, location, and practices. However, there are clear similarities in the number and type of electricity end-uses in those plants.

As shown in Figure 5 above, the average electricity use index for the twelve audited plants was 271 kWh/t HSCW with a median of 257 kWh/t HSCW. Whilst the average electricity consumption accounted for less than 30% of the total energy use at the audited sites, the average electricity costs were over 64% of the total energy costs(with a median of 68% of total energy costs).

There were significant differences in electricity prices depending on location, contractual arrangements, demand management practices, load factor, and power factor.

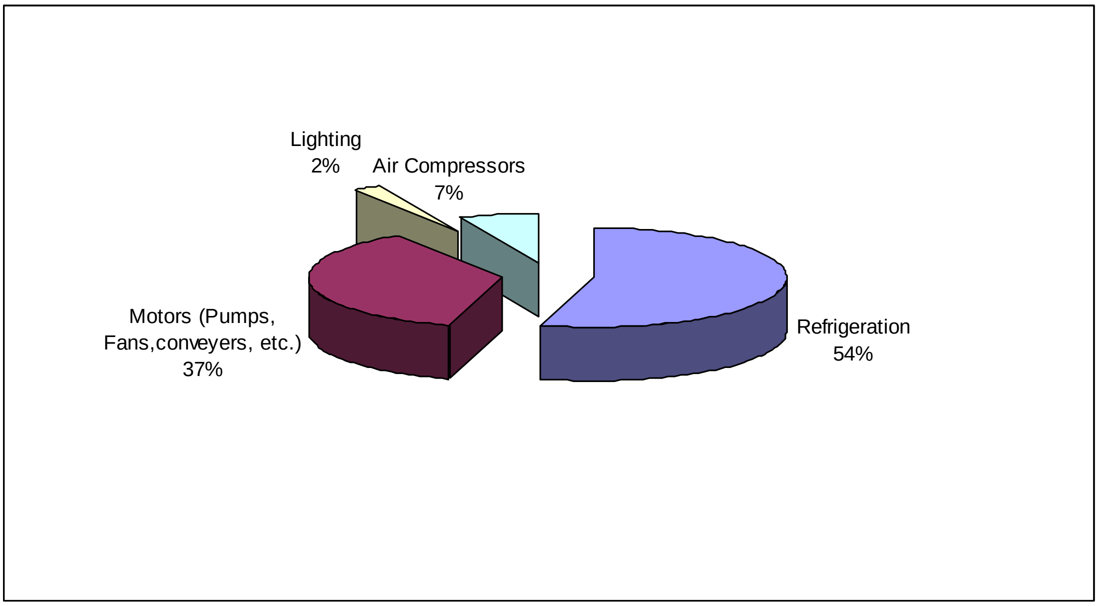
However the most important factor in energy prices were existing contracts negotiated earlier at the time of low electricity prices. The majority of those contracts were due to expire by the end of 2008.

The absence of electricity sub-metering in the surveyed plants does not allow an accurate apportioning of electricity end use. However Table 5 and Figure 7, below, show the main components of electricity end use in a plant with 150 t HSCW/day production using data from an earlier UNEP(1999) study used in Eco-Efficiency Manual (2002). The total electricity index of 272 shown in Table 5 is in close agreement with the average electricity index of 271 kWh/ t HSCW (median 257 kWh/t HSCW) shown earlier in Figure 5.

Electricity End Use	kWh/day	kWh/t HSCW
Refrigeration	22,222	148
Motors (Pumps, Fans, conveyors, etc.)	15,000	100
Lighting	833	6
Air Compressors	2,778	19
Total	**40,833**	**272**

Source: Eco-Efficiency Manual, MLA 2002

Table 5-Main components of electricity end use at a meat processing plant



Source: Eco-Efficiency Manual for Meat Processing, MLA 2002

Figure 7- Relative share of electricity end uses at a typical meat processing plant

4 Refrigeration

Refrigeration system is by far the largest user of electricity in meat processing plants. However, none of the sites audited had any sub metering of their refrigeration plants which were estimated to account for 55% to 75% of their total electricity use.

There are a large number of varied electric motors operating auxiliary equipment including evaporator and condenser fans, condenser pumps, liquid ammonia pumps, glycol pumps, air handling units and others. Comparatively, in a refrigeration system, the majority of the electricity is used by refrigeration compressors.

The main refrigeration systems in eleven of the twelve audited plants were two-stage ammonia systems using a mix of old reciprocating compressors and more recent screw compressors. As the only exception Plant H uses separate single stage ammonia systems serving chillers and a plate freezer at different locations at the site

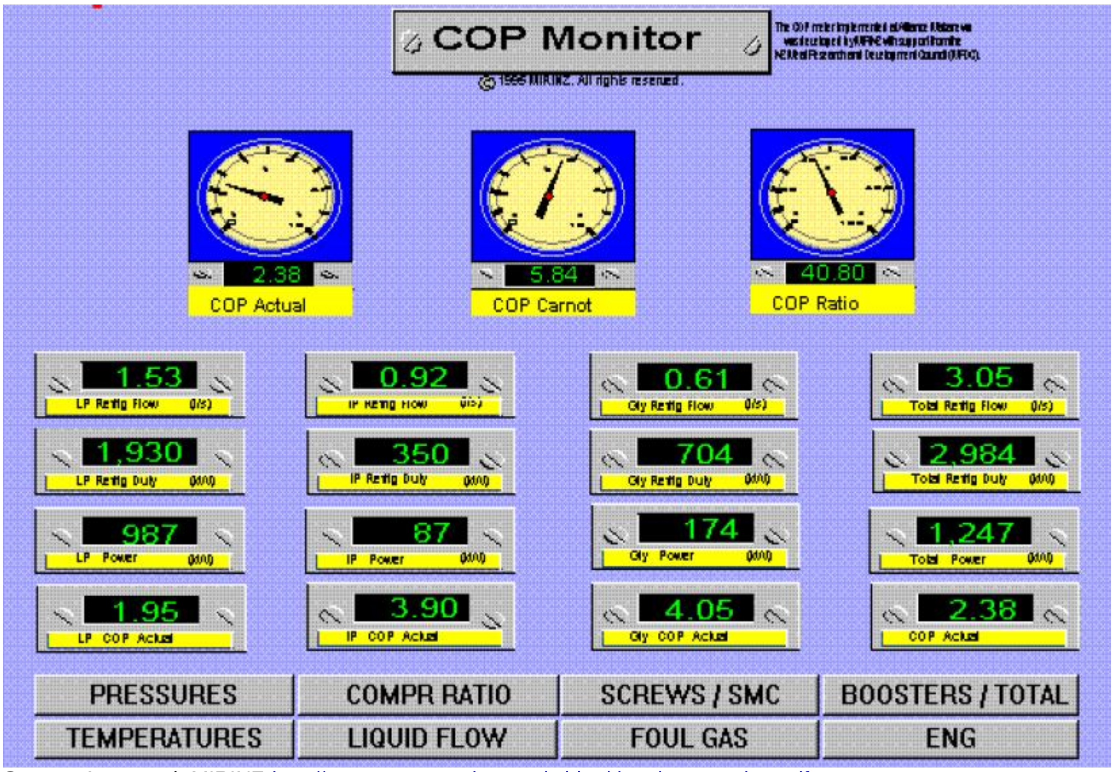
Refrigeration Efficiency (or Coefficient of Performance)

The energy efficiency of a refrigeration system can be expressed as the Coefficient of Performance (COP) for that plant.

COP = Refrigeration Load in kW Refrigeration (kWr) ÷ Electrical Load in kW

Therefore a higher COP for a refrigeration system indicates a higher efficiency of the electricity used in that system.

Ideally, individual plants' COP's should be assessed and monitored to ensure the refrigeration system is operating efficiently. Plants' existing SCADA systems or tools such as the MIRINZ COP monitor below (Figure 8) can assist with measuring refrigerant flows, calculating refrigeration system efficiency, and presenting the data in real time and in a useful format.



Source: Agreseach MIRINZ http://www.agresearch.co.nz/mirinz/docs/cop-monitor.pdf

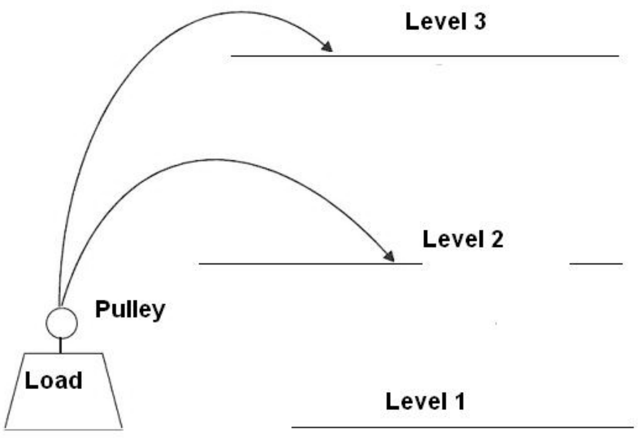
Figure 8- 'MIRINZ' COP monitor for refrigeration systems

Most meat processing plants in Australia have grown significantly since their original refrigeration plants were designed. This has resulted in a mix of old and new equipment which are often operated manually. While design of a refrigeration system is one of the most important factors in its lifetime efficiency, the focus of this manual is on existing plants and improvements in performance of existing systems.

Before discussing refrigeration energy efficiency it might be helpful to use the following analogy which can provide a visual aid in explaining the energy efficiency topics below.

Heat Pulley Analogy

A refrigeration system may be thought of as a heat pulley system (Figure 9) where the objective is to capture an amount of heat at low temperature, and then 'lift' it up to a higher temperature (level) where it can be rejected to the atmosphere.



Source: Food & Drink Industry Refrigeration Efficiency Initiative, Carbon Trust Networks Project

Figure 9- Heat pulley analogy for a refrigeration system

For example, when a certain number of hot carcasses are loaded into a chiller at 4 ºC set point, the heat content of those carcasses is loaded on the heat pulley system at a temperature just below 4 ºC and then it is lifted to a temperature just above the condensing temperature of refrigerant where it can be rejected into the atmosphere via condensers.

Therefore the same broad principles that can improve mechanical efficiency of a pulley system would apply to efficiency of a refrigeration system namely:

1. Reducing the size of the heat ‘load’ (e.g. through evaporative pre-cooling, insulation, etc.),

2. Reducing the refrigeration ‘lift’ (or temperature difference between suction and discharge sides), and

3. Improving ‘efficiency’ of the system and equipment (e.g. efficient compressors, automated control, improved part load performance etc).

4.1 Reducing the Load

The heat load in the above analogy may be represented by the weight attached to the pulley. Therefore the heavier the load, the higher the energy demand for lifting that load.

The heat load in a typical meat processing plant may be divided into two broad categories:

- Product (pull-down) load (i.e. the heat content of hot carcasses)
- Other heat loads (mainly heat gains through building envelope, outside air intakes and infiltration, lights, open doors, etc.)

4.1.1 The product load

The product load or the ‘pull down’ load is dependent on production rates and there are limited options to reduce this load.

However, there are a number of pre-cooling options, such as evaporative pre-cooling or chilled water spray (a system used widely used overseas), which could reduce the product load.

The product load is expected to be the main component of refrigeration load in meat processing plants, accounting for up to 80% of the total heat load (Refrigeration Energy Strategies, MLA, 2006). However, the product loads in some surveyed plants were as low as 20% of the installed refrigeration capacity.

Table 6 presents Specific Heat figures for beef and lamb carcasses which are used in the following worked examples to estimate the product loads for a 500 head/day cattle processing plant.

	Unit	BEEF	LAMB
Specific heat (above freezing)	kJ/kg deg K	2.9-3.4	2.8-3.2
Specific heat (below freezing)	kJ/kg deg K	1.6-1.8	1.6-1.7
Latent heat	kJ/kg	206-257	200-233
Water content	%	62%-77%	60%-70%

Source: Copeland Refrigeration Manual, Part 3, The Refrigeration Load

Table 6 Specific heat coefficients for beef and lamb carcasses

Example:

Estimating the product or pull down part of the refrigeration load can highlight remaining non-product loads such as chillers' heat gains.

The example below estimates the product pull down load for chillers and freezers of a plant with the following characteristics:

Production Rate:	500 head of cattle/day
Average Wight:	300 kg HSCW/head
Water loss per carcass:	3.3 kg (1.1% shrinkage)
Carcass Temp. Reduction in Chillers:	38 ˚C to 4 ˚C
Temp. Reduction in Freezers:	15 ˚C to -10 ˚C heat
Freezer Daily Loading:	100 tonnes per day
Coeff. Of Performance (COP):	2.0

Chillers Product Load:

Sensible Heat:

500*300* 3.2 kJ/kg/˚C*(38-4)/3600/2 — 2,267 kWh/day

Latent Heat:

500*3.3 kg*2500 KJ/kg/3600/2 — 573 kWh/day

Product Chilling Load (exc. evap. cooling effect):	**2,840 kWh/day**
Annual Consumption (250 working days/Yr):	**710,000 KWh/Yr**
Annual Costs at 10 Cents per kWh:	**$71,000/Yr**

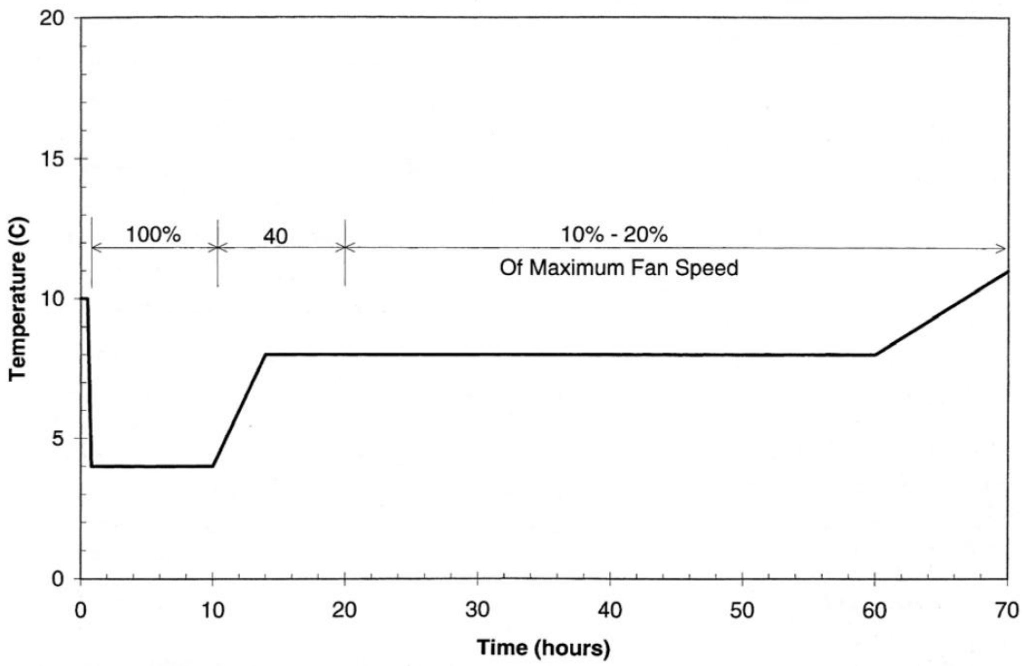
Similarly the pull down load of the freezers can also be estimated as follows:	
Freezer Product Load:	
Sensible Heat:	
100 tonne/Day*1000*3.2 kJ/kg Deg C*(15-0)/3600/2	667 KWh/day
Plus:	
100 tonne/day*1000*1.7 kJ/kg Deg C*(0-(-10))/3600/2	236 kWh/Day
Latent heat of fusion:	
100 tonne/day*1000* 232kJ/kg/3600/2	3,222 kWh/Day
Total Product Freezing Load:	**4,125 kWh/day**
Annual Consumption (250 working days/Yr)	**1,031,306 KWh/Yr**
Annual Costs at 10 Cents per kWh:	**$103,130/Yr**
Total Product Load (chillers and Freezers):	**1,741,306 KWh/Yr**
Comparing that figure with the actual annual electricity use by the refrigeration plant can highlight other non-product loads on the refrigeration system	

4.1.2 Product overcooling

There are a variety of practices in chiller operations with chiller set points ranging from just above 0 degrees Celsius to just below 7 degrees Celsius. Whilst correct cooling procedures are paramount in product's shelf life and quality, in some plants product overcooling results in significant energy expenditure.

Overcooling in some cases also requires reheating of carcasses prior to boning, adding more energy to the process.

MLA has extensive publications and research on chiller temperatures and Refrigeration Index topics including MLA publication; Refrigeration Energy Strategies (MLA, 2006), and Refrigeration Index Training Manual (MLA, 2005) which can be used to determine the correct level of cooling.



Source: Refrigeration Energy Strategies (MLA, 2006)

Figure 10- MLA's recommended chiller air temperature and fan speed

As can be seen from Figure 10 above, MLA's recommendation for chiller air temperature and fan speeds can provide some guidance for chiller operation.

The strict quality control and different animal sizes (with different fat contents) processed at different plants however may require specific chilling regimes for each plant.

MLA's Refrigeration Index Calculator and a series of research papers in this area are useful resources.

4.1.3 Evaporative Cooling (Pre-cooling)

Whilst this option is not widely used in Australia, evaporative pre-cooling in combination with conventional refrigeration may warrant a closer examination by the industry in the light of increasing energy costs.

Internal heat of a hot carcass is often the main driver of initial carcass cooling even in a refrigerated chiller. Evaporative cooling can be observed during early stages of chiller operation where 'fogging' of chillers (due to water evaporation from carcasses) results in a large latent heat on the refrigeration system.

Use of evaporative cooling during favourable outdoor air conditions and with sufficient ventilation air, can reduce the product load cooling demand by up to 50% according to Eco-Efficiency Manual for Meat Processing (MLA, 2002).

Use of chilled water spray is also a common method of pre-cooling in some North American meat processing plants (ASHRAE, Refrigeration, 1994).

Use of chilled water spray is also likely to reduce shrinkage rates. Assuming a reduced shrinkage from 1.1% in a conventional chiller to 0.9% (Eco-efficiency Manual 2002) there would be a reduction of 20% in product losses through shrinkage. Reduced shrinkage losses can result in significant savings as can be seen from the worked example below.

Example:

High air movement and moisture extraction in conventional chiller refrigeration can lead to excessive weight loss (shrinkage) as well as high energy use.

Reducing shrinkage from 1.1% to 0.9% through evaporative cooling for the plant discussed in the above example is equivalent to:

500 heads/day * 300 kg/head HSCW*250days/Yr* (1.1%-0.9%)/1000=75 tonnes/year

At say $5000/tonne Product* 75 t/year =$375,000 annual savings

Whilst implementation of a complete evaporative cooling could be considered for new developments in suitable climatic regions (i.e. cool and dry regions), a hybrid option comprising an initial period of evaporative pre-cooling (while carcasses are still hot) may also be examined in combination with conventional chillers.

4.1.4 Building Envelope and Other Loads

Building envelope loads are mostly sensible heat gains from walls and ceilings of chillers, freezers and holding areas. Latent heat also develops from moisture ingress into refrigerated areas from door opening, damaged vapour barriers and other actions.

It is not uncommon for old chillers to have damaged and water logged insulation which is likely to place a large and continuous demand on the refrigeration system.

Given the large non-product related refrigeration load in most plants surveyed, the effective use of chillers, holding rooms, stores, and freezers including optimum loading, residence time, controls and door opening regimes should be closely examined for all plants. Three common areas of unnecessary loads on refrigeration systems are discussed in more details below.

a) ***Open Doors***

A door left open to the slaughter floor can add 33 kW to a chiller's total heat load (Refrigeration Energy Strategies, MLA, 2006).

Assuming a chiller is loaded over a period of 2 hours with doors left open, the annual refrigeration for a plant with 6 chillers will be close to $5,000 p.a.

(6chillers*33 kW*2 hrs/day*250 days/ COP2*$0.1/kWh=$4,950

Reducing that time to 1/3, by batching carcase outside chillers, could save $3,300 p.a.

b) Lighting Load

A common practice with many plants is to leave lights in chillers operating even after the chiller doors are closed. The example below shows the potential energy savings by reducing the unnecessary operation of lights.

Example:

4x400 Watt High Intensity Discharge (HID) lights operate in a plant with six identical chillers.

The annual electricity costs of those lights operating continuously would be close to 14,000 kWh p.a. or $1,400 per chiller.

In addition, lights generate heat which needs to be removed by the refrigeration system. Assuming a COP of 2, the refrigeration costs will be close to an additional 7,000 kWh p.a. or $700 per year per chiller for the above example.

Reducing lighting to the loading time of say 2 hours per working day will reduce that load by 94%, saving $2,000 per chiller or $12,000 p.a. for a plant with 6 chillers

Lighting energy efficiency is discussed further in Section 7 of this Manual.

c) Boning Room Air Conditioning

There is a need for adequate fresh air intake into Boning rooms to meet the ventilation requirement of an occupied area as set out by AS1668 Part 2. Outside air is also provided to maintain a positive pressure difference to prevent adjoining Kill floors' air ingress into Boning rooms.

Most Boning rooms surveyed have additional fresh air intakes to replace the indoor air losses through cryvac machine vacuum pumps, exhaust fans and wall openings.

For example three (3) cryvac machines in one Boning room were estimated to exhaust close to 2,350 l/s of additional conditioned air from that Boning room. At an estimated average of 15 to 20 degree Celsius temperature difference between outdoor air and the Boning room, the additional sensible heat load alone on refrigeration plant was estimated to cost over $8,000 per year. (There is an additional latent heat component from condensation of moist outside air on cooling coils further adding to those costs).

The increased rate of exhaust air from Boning rooms is likely to be compensated by equally higher intake air quantities in order to maintain a positive pressure difference between Boning rooms and adjoining areas effectively air conditioning those areas. It is therefore recommended to measure the actual outside air intake levels to Boning rooms and compare with AS1668 Part 2 requirements.

The outside air intake can then be reduced to the amount required for ventilation plus a positive pressure between Boning room and Kill floor. Alternatively barriers can be constructed to prevent conditioned air losses from boning rooms.

Use of air to air heat exchangers to pre-cool the incoming fresh air with the exhaust air from Boning rooms should also be considered if the two air streams are sufficiently close to each other.

4.2 Reducing the Lift

Refrigeration lift is the difference between suction pressure and discharge pressures. If in the heat pulley analogy illustrated in Figure 9, the refrigeration load could be symbolised by the weight attached to the pulley, the difference between the suction pressure and discharge pressure can be symbolised by the height to which that weight (or load) is lifted.

Refrigeration energy demand can be reduced by reducing the size of the load (as discussed above), and by reducing the height to which that load is lifted, (and also by improving efficiency of the pulley system by reducing friction as discussed in Section 3.1.3)

The refrigeration lift can be reduced by:

- reducing the Discharge Pressure, and/or by
- increasing the Suction Pressure

4.2.1 Reducing Minimum Discharge Pressure and Floating Head

The performance of an evaporative condenser is determined by the condensing temperature of the refrigerant relative to the ambient wet bulb temperature. The difference between refrigerant's condensing temperature and ambient wet bulb temperature is known as condenser's *approach* which is typically about 10ºC for most evaporative condensers.

Note that the refrigerant discharge pressure and discharge temperature are directly related and often expressed interchangeably. For example Ammonia refrigerant at 1,000 kPa gauge pressure is equivalent to 1,100 kPa absolute pressure which has a saturation temperature of 28ºC. Assuming a condenser approach of 10 ºC, the corresponding ambient wet bulb (WB) temperature would be 18 ºC WB. Reducing the condenser approach by increasing condenser capacity will allow lower discharge pressures and hence reduced compressor energy consumption.

Not to be confused with condenser *approach*, however is the *minimum discharge pressure* which is a set point below which the discharge pressure is not allowed to fall irrespective of outdoor wet bulb conditions (See Fig. 11).

Setting the minimum discharge pressure too high will prevent the system from operating more efficiently during favourable outdoor conditions (i.e. periods with low wet bulb temperature including night times and winter months).

For example, the minimum discharge pressures at some plants were set at 1,000 to 1,100 kPa gauge (all year round, day and night). That is equivalent to 28-30 ºC condensing temperature for ammonia. Assuming a 10 degree Celsius condenser approach, those minimum set points correspond to 18-20 ºC wet bulb temperature which is often a summer design condition well above normal operating conditions for most of the year at many locations.

It is however a common practice to artificially keep the minimum condensing temperatures high for a range of reasons which may include legitimate concerns over issues such as:

- insufficient flow during hot gas defrosting,
- liquid delivery (in flooded systems),
- oil separator performance (which often works fine, although it is recommended for manufacturers to be consulted for setting very low minimum pressures).

As discussed above, the condensing temperature (and pressure) falls with decreasing ambient temperature. Floating of discharge (head) pressure will enable the system to take advantage of cooler outdoor condition and operate at lower head pressures. Figure 11 below illustrates the difference between a fully floated discharge pressure compared with a fixed minimum discharge pressure (temperature) set point.

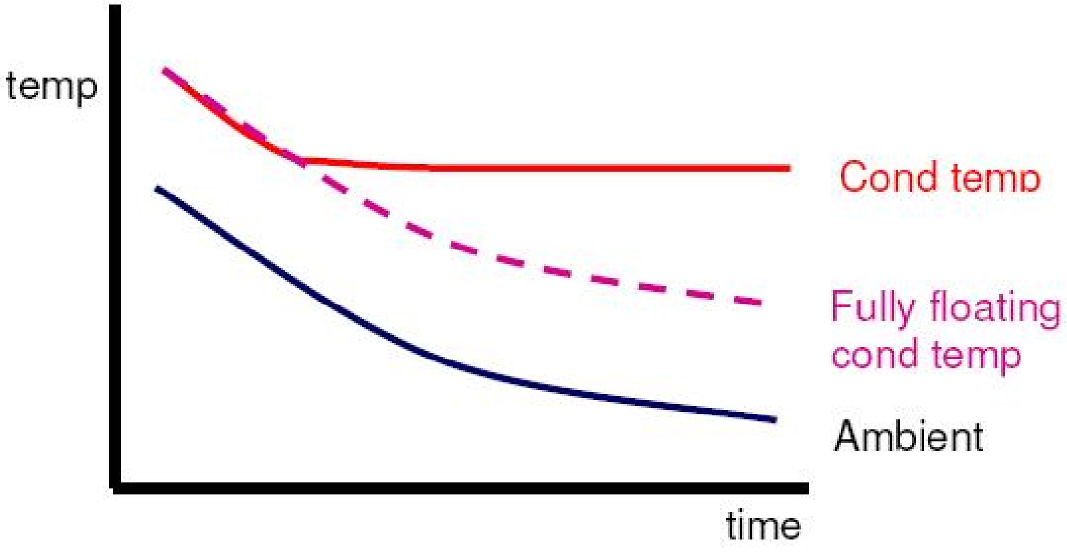


Figure 11 Floating discharge pressure temperature, compared with a high *minimum discharge pressure* set point

As a rule of thumb, the efficiency of a compressor increases by about 2.5% to 3.5% per ºC reduction in condensing temperature.

Example:

Setting minimum discharge pressures too high can force compressors to work harder than necessary during favourable outdoor conditions when wet bulb temperatures are lower than summer design conditions.

For example, the discharge set point at the time of the audit for Plant X was 1,100 kPa gauge pressure (31 ˚C). The option of reducing that set point was discussed with the Plant's Engineer.

The minimum condensing temperature was reduced from 31 ˚C to 25 ˚C (for 900 kPa gauge) as part of a trial.

Assuming that the new set point is adequate for 50% of the total annual operation hours, the average savings would be equivalent to 7.5% reduction in compressors annual energy consumption, or close to $60,000 p.a. per year for that plant.

6 ˚C* 2.5% per ˚C *50% of the year =7.5% of compressors energy consumption at $800,000/Yr)

A more accurate modelling of energy savings based on the local wet bulb temperature data was therefore recommended.

4.2.2 Increasing Suction Pressure

Comparing a refrigeration compressor to a pump, it can be easily visualised that the reduced head or discharge pressure (discussed above) can result in reduced work and energy consumption by the pump. Similarly, a higher suction pressure can result in lower work and energy consumption by the pump (compressor) compared with a lower suction pressure.

Therefore increasing suction pressure/temperature is another way of reducing refrigeration lift.

As a rule of thumb, the efficiency of a compressor in an industrial ammonia refrigeration system increases by about 3.5% per ˚C in suction temperature.

A wide range of intermediate (high side) suction pressure set points of between 120 kPa gauge pressure (-16˚C) to 240 kPa gauge (-6 ˚C) were observed in the surveyed plants.

With the lowest chiller air temperature set point of just above zero ˚C, the evaporator temperature differences (TDs) as high as 16 ˚C are common in some older systems. Best practice evaporator designs should not require temperature differences of more than 5 or 7 ˚C.

Whilst the low capacities of under sized evaporators in some older chillers often dictate a lower than optimum suction temperature, there may still be room for increasing suction temperature and pressure if those set points are unnecessarily low. Excessive pressure drop in the system is another factor forcing lower than optimum suction pressure.

It is therefore worthwhile to carry out a review of all evaporator set points, pressure losses with the aim of increasing suction pressure.

Example:

In some plants suction pressure set points do not correspond the actual cooling requirements and evaporator temperature difference (TD's) required in chillers and cool stores.

Those plants need to review those suction pressure set points and adjust those set points based on the actual requirements of the areas being refrigerated.

Assuming the intermediate (high side) suction pressure in a plant could be raised from the current 170 kPa to 200 KPa gauge pressure.

The corresponding suction temperature is then raised from -12 ˚C to -9 ˚C (3 ˚C difference). For an estimated 3.5% per ˚C reduction in compressors energy consumption, an estimated high side compressors efficiency gain of nearly 10% can be achieved. For a plant where high side compressors' electricity demand is $500,000 per year, the annual savings would be close to $50,000.

A review of suction pressure set points with the aim of increasing those set points should therefore be considered.

4.3 Improving efficiency of system and equipment

Improving efficiency of equipment, systems, and controls in a refrigeration system is analogous to reducing friction and improving the overall performance of the pulley system discussed earlier. Below is a list of some of the most common areas of refrigeration equipment and system performance improvements.

4.3.1 Compressor efficiency and part load performance

Compressors are the largest group of electricity users in the refrigeration system accounting for between 50% and 60% of total electricity use in a typical meat processing plant. It is therefore important to choose the most efficient compressor during refurbishments or new developments.

Reciprocating and screw compressors are the most common types of refrigeration compressors used in the meat processing industry. Most plants have both types of compressors installed as part of their expansion at different times.

Reciprocating compressors use pistons to compress refrigerant gas within their cylinders. Most reciprocating compressors have good capacity control through cylinder unloading.

Photo: Existing multi-stage reciprocating compressors can be used as trim compressors to avoid running large screw compressors at low part load

Screw compressors operate by drawing refrigerant vapour into the space between two rotating screws where it is trapped and compressed before being discharged from the opposite end of the compressor. Screw compressors can accommodate higher compression ratios compared with reciprocating compressor (e.g. up to 20:1 vs. 8:1 for reciprocating compressors for Ammonia)

As a rough guide, reciprocating compressors use between 0.27 - 0.29 kWe/kWr at full load while screw compressors use between 0.18 - 0.22 kWe/kWr.

Table 7 shows advantages and disadvantages of both reciprocating and screw compressors:

Compressor Type	Advantages	Disadvantages
Reciprocating Compressors	• Low cost • Simple maintenance • Efficient Unloading • Compact	• Frequent Maintenance • High Maintenance Cost • Limited Capacity/Size • Discrete Unloading • Many Moving Parts • Limited Pressure Differential
Screw Compressors	• Long maintenance intervals • Available in large capacity • Slide valve with infinite control • Few moving parts	• High initial cost • Factory Level service requirements • Inefficient unloading • Large package size

Source: Industrial Refrigeration Best Practices Guide (2007)

Table 7 Advantages and Disadvantages of Screw and Reciprocating Compressors

Operating screw compressors at low part load or unloaded has a significant efficiency penalty. For example a screw compressor operated at 20% of the load has still close to 66% of its peak power consumption as slide valves are only effective at higher part-loads as shown in Table 8 below.

Screw compressor at mid-range pressure ratio					
% of capacity	100	80	60	40	20
% of full-load power	100	87	79	72	66
Part-load efficiency	1.0	0.92	0.76	0.56	0.30
% Increase in energy per unit of refrig.	0	9	32	80	230

Source: Cleland, A. C., Cleland, D. J., "Cost-effective Refrigeration" in *IIR Workshop Proceedings,* 1992

Table 8-Penalty of operating screw compressors at low part-load

As can be seen from Table 8 above there are efficiency penalties for operating screw compressors at part loads below their rated capacity. It is important therefore to sequence different size compressors to respond to changing demand and ambient conditions efficiently.

Optimised sequencing algorithms written into a fully automated control system can respond to those changing conditions in a more dynamic and effective way compared with the manual control practised in most plants.

Use of screw compressors operating at full capacity to meet the base load in combination with multi-stage reciprocating compressors meeting the load fluctuation is also an effective strategy for the plants using both types of compressors.

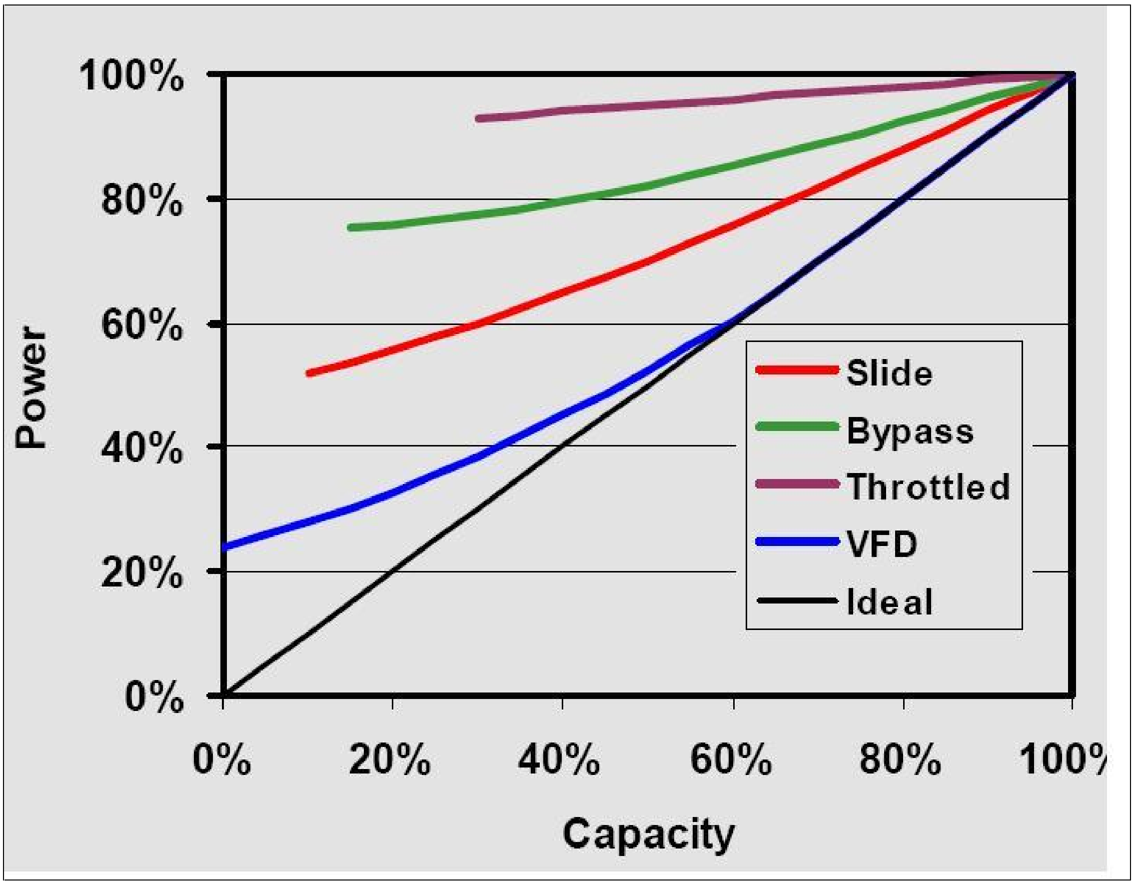
Used of Variable Speed Drives (VSD's) on trim screw compressors can also assist with load increments smaller than capacities of any single compressor.

4.3.2 Variable Speed Drives (VSDs)

The use of Variable Speed Drive (VSD) controllers can improve part load performance of screw compressors. A VSD fitted compressor can be used as a trim compressors allowing for smaller load fluctuations. It is however, important to have one VSD fitted compressor per suction line in a multi stage system. Fitting VSD's to the larger compressor on each suction line can also simplify compressor sequencing and minimise slide valve unloading.

A control system needs to allow VSD fitted screw compressors to slow to minimum speed before unloading slide valves to enable benefits of VSD to be realised. In retrofit applications the compressor manufacturers should also be consulted about the minimum and maximum allowable speeds.

Figure 12 shows the effectiveness of VSD's (VFD's) compared with other methods of capacity control for screw compressors.



Source: Cascade Energy Engineering

Figure 12-VSD (VFD) control of screw compressors compared with other methods

Use of VSD's for control of evaporator and condenser fans is also relevant to most meat processing plants. Section 5.2 below discuss VSD's in more details for a range of electric motors.

4.3.3 Automation of Refrigeration Plant Control

Manual control of refrigeration plants is still the most common practice in the meat processing industry. None of the twelve audited sites had a fully automated refrigeration control system, although SCADA systems are increasingly being used for monitoring and partial control of the refrigeration systems.

However it is not uncommon to operate multiple compressors at low part load conditions for extended periods to allow for rapid load fluctuations. Unsupervised operations overnight and on week-ends also increase the difficulties of manually controlling a complex refrigeration system at optimum energy efficiency.

While most operators have an intimate knowledge of their plants, the rapid and frequent changes in load and outdoor conditions require dynamic response through an automated control system with optimised algorithms.

As a first step however, a detailed review of the entire refrigeration system by an industrial refrigeration control specialist with the aim of identifying inefficiencies and developing optimisation algorithms for an automated control system is a useful exercise. For the majority of the plants already monitoring the refrigeration system through their SCADA systems, the move towards a fully automated advanced control would be a relatively easy step.

4.3.4 Evaporators

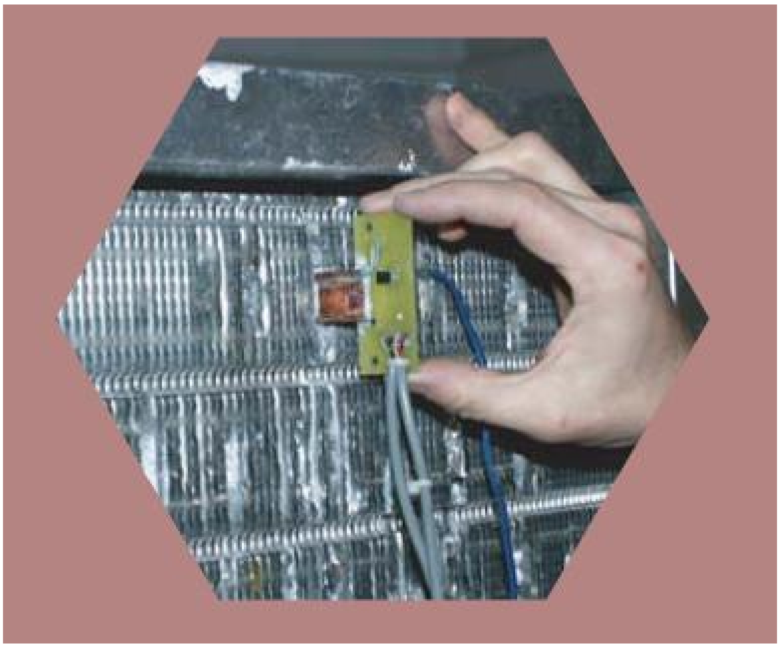
Evaporators form a critical part of a refrigeration system - enabling the transfer of heat from the space and products being cooled into the refrigerant so that it can be carried away and released externally. Evaporator coils need to be generously sized and be free from ice for maximum heat transfer and energy efficiency.

Below is a list of options for consideration when selecting and operating evaporators for maximum energy efficiency.

- Generously sized evaporators can save energy by allowing smaller Temperature Difference (TD) between air and liquid refrigerant allowing lower suction pressure and compressor energy savings as discussed earlier in Section 4.2.2.

- Use of flooded or liquid recirculation is more efficient than direct expansion (DX) evaporators. This is due to de-rating of DX coils because of reduced internally wetted surface areas, and limitations that DX coils place on minimum condensing pressure (Refrigeration Best Practice 2007)

- Defrosting of evaporator coils in most plants is pre-scheduled irrespective of the actual coil conditions and outdoor conditions. Defrosting schedules set for worse conditions during high humidity summer months, if used throughout the year can waste significant amounts of energy.
- Control systems allowing defrosting to be carried out based on demand using frost sensors can also offer a more efficient method of defrosting.



Source: Adatech Technologies

Photo: A Frost Sensor Developed as part of a demand based defrost control by Adatech Technologies (www.adatech.com/default.asp)

- Use of VSD's are now common for most chillers' fan-coil units, offering better temperature control , air movement control as well as energy efficiency.

- Back-pressure control and ambient air defrosting in chillers. This should eliminate the need for defrosting in most chillers.

- Use of dehumidifiers and the reduction of moist air ingress into freezers would also reduce the need for frequent defrosting and improve energy efficiency and productivity.

4.3.5 Condensers

The refrigerant (e.g. ammonia) absorbs heat in the evaporator by changing phase from liquid to gas. It releases that heat by a second phase change from gas to liquid in the condenser.

If the condensing temperature is higher than necessary due to reduced condenser capacity or a higher than necessary minimum discharge pressure set point, then the compressors have to work harder and the system becomes less efficient as discussed earlier in Section 4.2.1.

Below is a list of further options for consideration when selecting and operating condensers for optimum energy efficiency performance.

- Optimised control, based on ambient temperature and load conditions should be considered for operating condenser fans. Condenser fan energy savings should always be balanced against the increased compressor energy use at higher discharge pressures.

- Generously sized condensers operating at full capacity to allow minimum discharge pressures can result in more efficiency gains than an attempt to reduce fan energy use. Reducing the fan energy use can result in high discharge pressures and higher compressor energy consumption.

Photo: Condenser maintenance programs should ensure clean condenser surfaces, reduced spray water dispersion, and removal of non-condensable gases from the system

- Use of efficient motors for condenser fans and pumps, and VSD's should also be considered during replacements and upgrades.

- Periodic maintenance and monitoring of heat transfer surfaces, purging of non-condensable gases and fan belt conditions are all important factors in condenser efficiency.

- Automatic purgers are also an important consideration for systems operating below atmospheric pressure (those with low side suction systems for freezers) where there is a strong likelihood of non-condensable gases entering into the refrigeration system. It is equally important to maintain auto purgers regularly to ensure that they are functioning well.

Source: Hansen Technologies Corporation

Photo: Automatic Purging of non-condensable gases is a worthwhile investment for refrigeration systems operating below atmospheric pressure

5 Electric Motors

Electric motors form the second largest electricity users in meat processing plants after refrigeration compressors. Given that compressors are also driven by electric motors, in fact close to 98% of electricity use in meat processing plants is consumed by electric motors.

The majority of the smaller motors operate conveyors belts, processing equipment, hydraulic equipment, and a large number of fans and pumps.

Photo: Variable Speed Drive (VSD) Control of motors offer a more energy efficient alternative to throttling of pumps with variable flow requirements.

The most obvious energy efficiency option is to turn those drives off when they are not needed (e.g. during breaks, after-hours, and especially on week-ends), the use of high efficiency motors and VSD's for motors with variable demand are the other main areas of energy efficiency as discussed below.

5.1 High Efficiency Motors (HEMs)

The focus on High Efficiency Motors (HEMs) is limited in most plants, as the replacement of an existing motor with an energy efficient motor may not be justified financially if the total operation hours of the motor is limited.

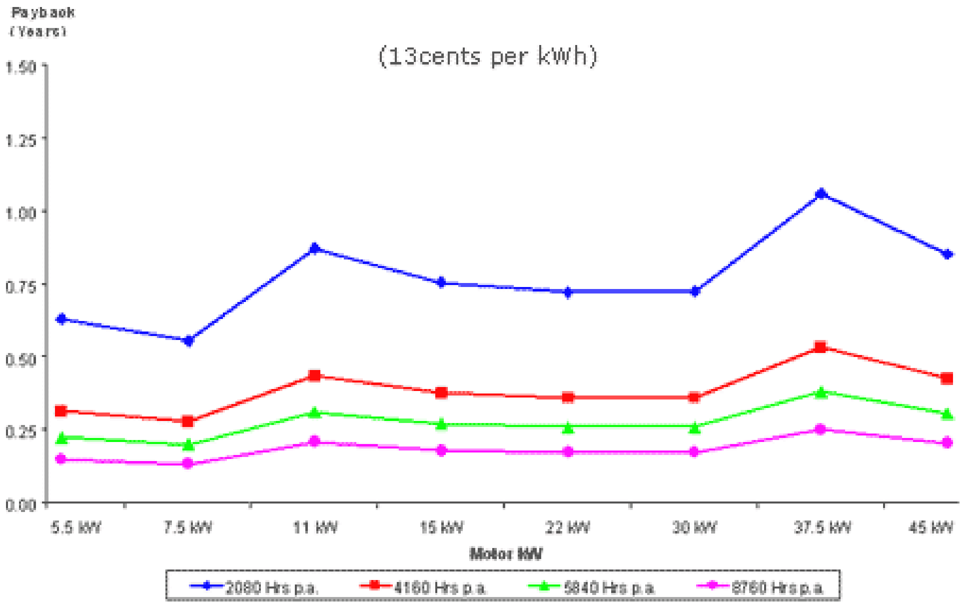
However, it is important to ensure energy efficient motors are considered when motors with long operating hours are due for replacement. Purchasing of HEMs could also be included in the purchasing policy of the company so the entire motor fleet could be replaced with HEM's over a number of years.

HEM's are usually manufactured from materials which incur lower energy losses compared with standard motors. Generally more care is taken with the design and geometry of the motor construction. HEM's are often improved in the following four areas:

- Longer core lengths of low loss steel laminations to reduce flux densities and iron losses.
- Maximum utilization of the slots and generous conductor sizes in the stator and rotor to reduce copper losses.
- Careful selection of slot numbers and tooth/slot geometry to reduce stray losses.
- Less heat is produced by a more efficient motor so the cooling fan size is reduced. This leads to lower windage losses and therefore less wasted power.

Depending on duty cycles (total operation hours per year), and electricity prices the savings achieved by replacing standard motors with high efficiency motors can give different payback periods as shown in Figure 13 below.

The high efficiency motors are more cost effective when a new motor is purchased or a failed motor requires replacement.



Source: Synergy http://www.synergy.net.au/Business_Segment/Energy_Management/High_Efficiency_Motors.html

Figure 13 Estimated pay back periods for high efficiency motors at different annual operation hours (at 13 Cents per kWh electricity price)

5.2 Variable Speed Drives (VSDs)

As a more efficient means of capacity control, large motors with variable loads operating for long periods can benefit from VSD.

VSDs work by converting AC signals to DC using rectifiers and then inverting these DC signals back to AC. There are several types of VSD drives, including frequency drives (maintaining a constant volts per hertz ratio), flux vector drives and servo drives. There are also several types of Variable Frequency type Drives (VFDs) including current source, variable voltage and Pulse-Width Modulated (PWM) drives. The PWM devices are claimed to be the most reliable, affordable and smallest type of VFD, with a constant volts per hertz ratio.

VSD's are cost effective for motors that operate equipment with variable demands such as throttle valve controlled water pumps, variable flow requirements for evaporator fans, air compressors and others.

VSDs provide additional benefits such as soft starting, over speed capability, and power factor improvements.

Note however that there will little or no savings from VSD installation on a properly sized motor operating at full load. Motor Solutions Online (www.environment.gov.au/settlements/energyefficiency/motors) can provide useful information on VSD's and a range of other motor solutions including a motor selection software and motor efficiency case studies.

5.3 Power Factor Correction

The large number of induction motors in meat processing plants, as discussed above, often results in low power factor for those sites. Power factor is an indicator of how much of the power system's capacity is available for productive work. Power factor is defined as the ratio of real power to apparent power. A useful analogy often used to describe the concept of real and apparent power is that of the *'head'* in a glass of beer as shown below:

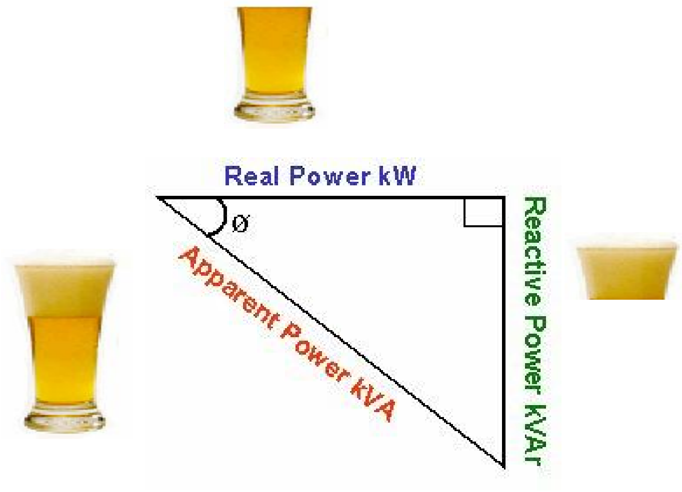


Figure 14 Beer Analogy of Power Factor and Apparent Power (kVA) vs. Real Power (kW)

Power Factor= Cosine ø, **OR** Real Power (kW) / Apparent Power (kVA)

Alternatively;

Real Power (kW) = Apparent Power (kVA) * Power Factor

Some of the expanding plants faced with on site capacity constraints have already installed power factor correction equipment (capacitor banks).

The existing tariff structures in some states however still do not reward customers for improving their power factor (e.g. Queensland and parts of Victoria). However, with increasing network capacity constraint issues in Australia, that trend is rapidly changing with an increasing shift towards KVA demand tariffs.

One common problem with many plants is that after installing capacitor banks, the performance of the new equipment is not monitored and often there is no service agreement with contractors to check the condition of capacitors.

It is advisable to understand local network tariffs, as well as plant's power factor in order to assess costs and benefits of power factor correction.

Example:

Depending on the local electricity network service provider's tariffs, there could be cost saving opportunities through power factor correction by installing capacitor banks.

For example, assuming a small plant has a Max Demand (MD) of 1,000 kW and a power factor of 0.75 (i.e. 1,333 kVA demand), the annual network charges at $96/kVA/annum under a kVA tariff from the local utility will be close to $127,968 p.a.

Improving power factor from 0.75 to 0.95 will reduce the MD to 1,053 kVA and annual costs to $101,088 p.a. resulting in annual savings of over $27,000 p.a. as well as additional capacity as shown below:

1,000 kW MD/0.95 (new Power Factor) =1,053 KVA (reduced kVA demand)

Savings: (1,333-1,053 kVA) *$96/kVA/Yr=$26,880/Yr

For an estimated capacitor bank size of 550 kVARs, and estimated installed cost of $65/KVAR capacitor costs, a pay back period of 1.3 year may be expected.

Note however that not all utilities reward their customers for improved power factor. Understanding your local network tariffs and your site's power factor would be the first step for evaluating cost savings from power factor correction.

Source: Cap Tech Capacitor Technologies

Photo: A 250 KVAR Power Factor Correction System

6 Compressed Air

Compressed air is a convenient and safe source of motive power widely used in the meat industry to operate hand tools, actuators and other tools. However, the greatest demand for compressed air in meat processing operations is usually associated with pneumatic systems for material transfer.

While electric motors and other direct means of motive power and material transfer offer more energy efficient alternatives, pneumatically operated equipment are likely to remain a major part of the meat processing industry.

Compressed air in the meat industry is generally provided at around 700 kPa gauge pressure.

Single stage reciprocating or screw compressors are most commonly used in the meat processing industry.

Below is a list of common energy saving opportunities in compressed air production and distribution:

- Compressed air distributions systems should be sized and designed for the most efficient operation and minimum pressure losses
- Entrained water from condensed moisture in the compressed air should be effectively collected and removed.
- Filters need to be regularly checked for partial blockages (degree of filtration should also match the application to minimise pressure drops)
- Avoid air intakes from heated areas such as boiler houses (a 10 ˚C rise in intake air temperature can result in at least 3.5% increase in energy consumption)
- The greatest losses in a compressed air system are usually associated with leaks and unplanned losses of air in the system. To prevent these inefficiencies, periodic auditing and checking of the reticulation system is required.
- Incorrect sequencing and low part-load performance of screw compressors is also a major source of inefficiency, although VSD fitted compressors are increasingly being used as the trim compressors during upgrades and compressor replacements.

6.1 Compressed Air Audits

Compressed air energy surveys conducted in over 200 industrial plants have revealed that the average leak/loss rate of compressed air in a compressed air system is about 20% (Speciality Air Pty Ltd). In most of those plants up to 13% of the total electrical energy was used to generate compressed air.

Those surveys also identified that the savings achievable through control systems was about 10% mainly through elimination of short cycling of compressors. Typically a further 10% saving could be achieved through elimination of leaks.

Appendix A-3 presents guides for conducting the following two compressed air audits:

Survey 1: Air Flow & Energy Demand Survey
Survey 2: Ultrasonic Leak Survey

7 Lighting

Unnecessary operation of lights in chillers (and other refrigerated areas) has a double penalty of energy consumption by the lights, as well as, the added heat load which has to be removed by the refrigeration system (See Section 4.1.4).

It is also common for some areas such as stores and plant rooms to be over lit. It is therefore recommended that regular monitoring be carried out using a light intensity meter (lux meter) and compare the lighting levels with the minimum requirements set out in AS1680.

Another common issue in most plants is the lack of daylight penetration, either through building design that had not incorporated windows or through restriction of daylight transmission due to dirty translucent panels or sky lights. It is therefore important to have a regular cleaning program to increase natural lighting.

It is also important to give serious consideration to the installation of an integrated electric lighting system equipped with dimmers, and a natural lighting system, including roof lighting, when planning a new single-storey building or renovating an existing building.

7.1 Lighting Control

Correct control of the lighting system will ensure that energy is not wasted while lighting and safety standards are maintained. Correct control involves matching the lighting to the occupancy requirements of each area.

The type of control device should be decided before the installation commences as the cost of installing a more suitable device at a later stage may exceed savings.

7.1.1 Manual switches

The first and most inexpensive control device is the common single pole switch. Manual switching is simple to operate but relies on human behaviour to operate efficiently. A flexible and zoned switching arrangement in any area is essential for efficient operation of lights. A small group of lights operated from one switch is preferred to a whole floor area operated from one switch.

7.1.2 Time switches

Certain areas require some form of lighting at a time when the staff are not normally present. This could be security lighting, building flood lighting, or advertising signs. Time switch control enables these requirements to be met by switching lights on and off at set times.

7.1.3 Photoelectric (PE) switches

PE cells activate an on/off relay by sensing daylight. The main use of these switches is for security lighting where lighting is required throughout the hours of darkness. Sometimes the PE switch is used in series with a time switch to control lighting that is required to switch on at dusk and turn off during night times. In other cases they may be used in series with an occupancy sensor, operating lights only when people are present and there is no daylight.

7.1.4 Occupancy sensors

Occupancy sensors use infra-red or ultra-sonic detectors to operate lights when people are present. Stores, meeting rooms, and some external and security lighting (in combination with a PE cell) are common areas of occupancy sensor applications.

7.1.5 Time delay switches

Time delay switches are pre-programmed to switch off at a set time after being switched on. In areas of limited use such as meeting rooms, the lighting could be programmed to turn off after a set time period. This overcomes the problem of people leaving and forgetting to turn the lights off.

7.1.6 Programmable time-of-day switches

These devices take over the control of the switching cycle. They are usually micro-processor based storing the switching program for a variety of equipment on the premises. Before determining the switching cycle, an accurate survey of the occupancy patterns of the area is required. The lighting requirement is then programmed into the device for each day up to one year in advance.

7.1.7 Dimming controls

Dimming switches in combination with a PE cell can adjust lighting levels depending on the available daylight to reduce lighting energy consumption.

Fluorescent lights require rapid-start electronic ballasts before effective dimming is achieved. Other types of ballasts introduce problems of unstable operation at low levels and often result in poor life characteristics. High intensity discharge lamps such as mercury vapour, high pressure sodium and metal halide can be dimmed, providing the circuit and hardware are compatible.

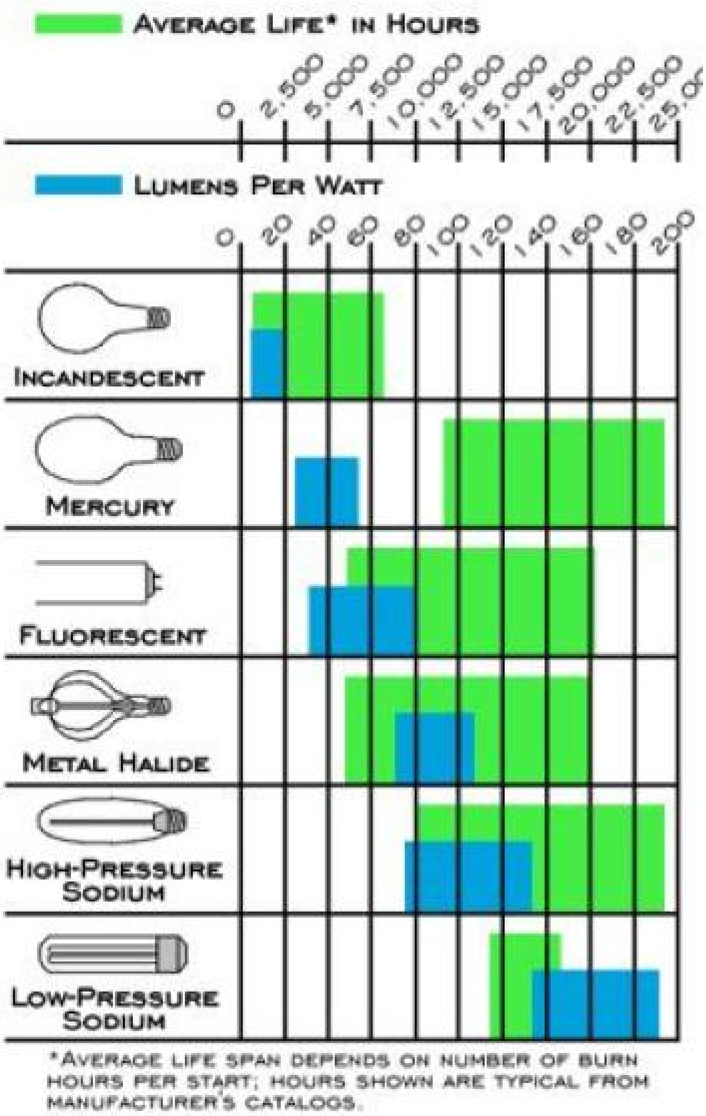
> Overall, the experience has shown that with a lighting program controller, energy savings of up to 33% can be achieved. Using a program controller as well as day lighting, energy savings of up to 46% are achievable.

7.2 Efficient Lamp and Fittings

Use of the most efficient lamp and fitting types should always be considered during new developments and refurbishments. In continuously lit areas, lamp and fitting replacements may also be justifiable on energy efficiency and light level improvements.

Replacement of incandescent lights with compact fluorescent lights, and older fluorescent tubes with more efficient tubes can be carried out in the normal course of lamp replacement. However use of more efficient lamps such as T5 fluorescent tubes or High Intensity Discharge lamps would require replacement of the luminaires (light fittings) as a whole. Use of low loss electronic ballasts and more effective reflectors are other benefits of efficient luminaire designs.

Figure 15 below illustrates the significant variations in lamp life and lamps *luminous efficacy* which is measured in lumens output per Watt of electricity input.



Source: Tri-State Generation and Transmission Association **http://tristate.apogee.net/**

Figure 15-Lamp life and efficacy for common lamp types

As can be seen from Figure 15 above, High Intensity Discharge (HID) lamps such as High Pressure Sodium and Metal Halide lamps offer very good efficiency, and in case of Metal Halide also good colour rendering.

Low pressure sodium lamps with the highest luminous efficacy, shown in Figure 15, have the disadvantage of having a poor colour rendition and their use is limited to areas such as car parks where colour distortion is not a major issue.

8 Thermal Energy Use in Meat Processing Plants

Thermal energy use varies significantly from plant to plant depending primarily on whether or not there is an on-site rendering plant. The type of rendering method, age of the plant and equipment, and extent of heat reclaim are also important factors in thermal energy use.

The absence of steam sub-metering in the surveyed plants does not allow an accurate apportioning of thermal end use. However Table 9 and Figure 16 below show the main components of thermal energy end use in a plant with 150 t HSCW/day production using data used in Eco-Efficiency Manual (2002).

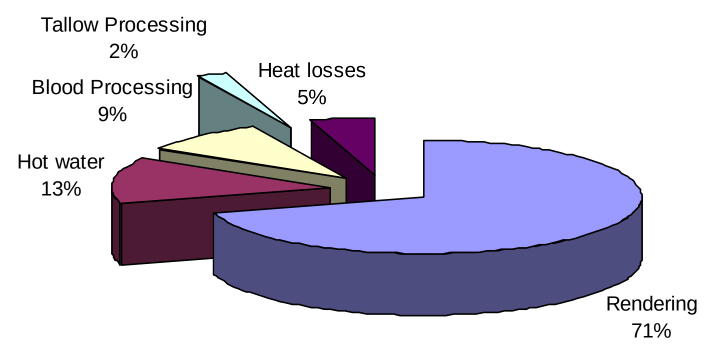
Note however that the average thermal energy index for the surveyed sites was much higher at 2,390 MJ/t HSCW as discussed in Section 2. The *relative* portions of steam use (rather than the magnitudes) shown in Figure 16 are similar to the audited sites.

Steam Use	Tonne Steam/day	MJ/Day	MJ/t HSCW
Rendering	54	150,000	1,000
Hot water	10	28,000	187
Blood Processing	7	20,000	133
Tallow Processing	2	5,000	33
Heat losses	4	10,000	67
Total	**77**	**213,000**	**1,420**

Source: Eco-Efficiency Manual for Meat Processing, MLA 2002

Table 9 Relative portions of steam use in a 150 t HSCW/Day plant

As can be seen from Figure 16, plants with on-site rendering use 70% or more of their total energy use in their rendering plants. Significant heat reclaim opportunities exist at those plants for using cooker's vapours, condensate and flash steam heat recovery for hot water heating.



Source: Eco-Efficiency Manual for Meat Processing, MLA 2002

Figure 16- Main thermal energy users in a typical meat processing plant with on-site rendering

Thermal energy in the form of steam and hot water is usually produced in boilers fuelled mainly by natural gas or coal. Use of coal for generating steam in boilers has a significant effect on the carbon footprint of the plant. Carbon dioxide emissions from combustion of coal are close to 93 kg of CO_2-e per GJ, compared to natural gas emissions of 57 to 70 kg CO_2-e per GJ for the full fuel cycles.

Steam is used in meat processing plants for rendering and generating hot water (82˚C for sterilising, 60˚C for cleaning and 43˚C for hand washing).

For steam systems there are energy saving opportunities during:

- steam *generation*,
- steam *distribution*, and
- steam *usage* as discussed below.

8.1 Steam Generation in Boilers

One of the first steps in improving steam generation efficiency is to pay sufficient attention to combustion analysis, and tuning of burners on regular bases to maintain optimum combustion efficiency.

8.1.1 Improving combustion efficiency of steam boilers

Major losses in any boiler plant are represented by the hot gases discharged to the atmosphere through the chimney stack.

If combustion is good (near complete combustion), there will only be a small amount of excess air intake. The exhaust gases will contain a relatively large percentage of carbon dioxide and only a small amount of oxygen.

However, if combustion is poor, with a lot of excess air, then the increased weight of the exhaust gases will carry a lot of heat up the stack. The exhaust gases will contain a reduced percentage of carbon dioxide and increased amounts of oxygen.

It is important to maintain the correct fuel / air ratio entering the boiler to maximise boiler efficiency. Measurement and monitoring of carbon dioxide or oxygen in flue gases, (together with temperature), will enable the flue gas losses to be calculated. That is the most common method of monitoring boiler efficiency.

Photo: Regular combustion analysis and tuning of burners can ensure boiler operation at optimum combustion efficiency

Better combustion efficiency could be achieved when the boilers are operating close to their rated capacity or on high fire. That is because of better mixing of gas fuel and combustion air, due to higher turbulence, and also due to higher temperatures. Under such conditions, the burner can operate at a lower excess air level and hence lower oxygen level in the combustion gases.

Efficiency of the burner operation is indicated in the lower carbon monoxide levels at lower oxygen levels. Since there is a legal limit on the carbon monoxide level in the combustion gases, the carbon monoxide level becomes a limiting factor in achieving higher efficiency. More oxygen in the combustion gases means more air in the combustion gases and hence higher energy wastage.

The *Burner Tuning Calculator* attached, will enable initial estimates of energy savings from burner tuning of a natural gas boiler.

Example:

Regular combustion analysis and tuning of burners can result in significant savings in annual fuel costs at little or no capital outlay.

For example, in one plant, a 10MW boiler was operating with oxygen levels in the flue gases at:

- 9.7% on high fire,
- 9% on mid fire, and
- 13.3% on low fire.
-

Burners in steam boilers normally could be tuned to operate with:

- 3% oxygen on high fire,
- 5% on mid fire and
- 7% on low fire.

Oxygen level of 13% indicates an excess air level of about 150%. The study revealed that savings up to $17,000/annum and 300t of CO_2/annum could be achieved by tuning burners.

Tuning of burners needs no capital investment and could be considered as a good housekeeping measure.

Boiler maintenance service providers provide combustion analysis reports from their five-weekly inspections of unattended steam boilers. However, little attention is usually given to the combustion analysis parts of the tests.

Boiler maintenance service providers usually focus on reliability of appliance and not on the efficiency of operation as their performance is usually measured on the reliability of steam supply only. Therefore, plant personnel need to include appliance efficiency as one of the key criteria in maintenance contracts.

Given the reduced cost and improved accuracy of modern combustion analysers, it is recommended that plant owners keep a combustion analyser on-site, and carry out combustion analysis and burner tuning regularly.

A deeper understanding of boilers' operating parameters would also be helpful across the industry. Industry courses covering boiler air-to-fuel ratios, boiler blowdown in relation to boiler drum water TDS levels, condensate recovery and economisers can benefit most plant personnel at shop floor and supervisory levels (Ref. Training Section 7.7 below)

8.1.2 Boiler blowdown

Even with the best chemical pre-treatment programs, boiler feedwater will contain some impurities such as suspended solids and particles. These solids enter the boiler and will remain behind when steam is generated. During operation of the boiler, the concentration of solids increases and can cause 'carry over' and inefficiency problems. To avoid these problems, water must be periodically discharged or 'blown down' from the boiler to control the solids concentration in the boiler.

Insufficient blowdown can lead to sludge build-up in the boiler, decreasing the steam generation efficiency. Excessive blowdown wastes energy, water and treatment chemicals. Thus, boiler blowdown needs to be properly managed to operate the boiler efficiently.

There is therefore a need for plant operators to focus on maintaining the correct boiler drum water TDS (Total Dissolved Solids) levels as shown in the example below.

Example:

Excessive boiler blowdown results in waste of energy, water, and water treatment chemicals. Maintaining correct water TDS levels should be the basis for boiler blowdown intervals.

For example, one plant was maintaining the boiler drum water TDS level at 1800ppm instead of 2500ppm. Reducing blowdown rate by increasing the TDS level to 2500ppm, the savings potential was estimated to be as high as 2,600 kL of water per annum, plus $6,600 in gas costs, and 79 tonnes of CO_2-e per annum (in addition to savings in chemical treatment cost).

The *Blowdown-TDS saving calculator* attached, will enable initial estimates of energy savings from reduced boiler blowdown.

8.1.3 Blowdown Heat Recovery

The blowdown water has the same temperature and pressure as the water in the steam boiler; hence it contains a significant amount of thermal energy. This energy can be recovered and reused in the boiler or for process heating.

The study in one plant revealed that the savings that could be achieved with boiler blowdown heat recovery could be as high as $30,000 and 350 tonnes of CO_2-e per annum. None of the twelve surveyed plants had any blowdown heat recovery in place

The *Blowdown-Heat Recovery* calculator attached will enable initial estimates of energy savings from heat recovery with boiler blowdown.

8.1.4 Capturing heat from boiler exhaust gases (Economiser)

Typically, around 15 -18 % of the energy used in a steam boiler is carried away with the exhaust gases into the atmosphere. The function of an economiser is to recover some of this energy from the flue gases and utilise it for heating the feed water to the boiler.

An economiser is a heat exchanger, placed in the passage of flue gases, in between the exit from the boiler and entry to the stack. By fitting an economiser, fuel consumption of the boiler can be lowered thus increasing the efficiency.

An economiser installed on the exhaust gas stack of a steam boiler generating 10 bar steam should be able to increase the feed water temperature by about 25°C. An increase of 6°C in boiler feed water temperature can increase the boiler efficiency by about 1%.

Example:

Economisers can help with reducing fuel consumption by reclaiming some of the waste heat in exhaust gases and by transferring that heat to feed water entering the boiler.

For example, an economiser installed on a boiler stack of one plant was estimated to improve performance of the boiler by heating the feed water from 90°C to 115°C. This was expected to result in a saving of around 4,700 GJ of gas or $26,000 per year (for gas at $5.5/GJ). The corresponding greenhouse emissions were estimated to be close to 312 tonnes of CO_2-e per annum

A new economiser was estimated to cost around $50,000, giving a simple pay back period of 2 years.

The *Economisers Savings Calculator*, attached, will enable estimates of energy savings from installing an economiser.

8.2 Steam Distribution

In most industrial plants, there is often insufficient attention given to the steam reticulation system. Steam leaks, and poor insulation, are therefore common to many meat processing plants.

In some plants, pressure reducing stations installed for supplying steam to cookers in rendering plants are not being utilized properly. In one plant for example, operators used the bypass valve of the pressure reducing station to increase supply of steam to cooker. In other instances cooker performance had been adversely affected by leaving the bypass valves of steam traps open. Some common steam distribution issues are discussed in further detail below.

8.2.1 Pipe sizing

The objective of the steam distribution system is to supply steam at the correct pressure to the point of use. However, there is always some pressure loss due to friction in the pipes. Proper sizing of the piping system is very important to minimise losses and costs. Friction losses in the pipes depend on the velocity of steam, pipe material, diameter and length. There will always be a balance between pipe sizes, pressure losses and costs, and therefore proper pipe sizing should be conducted by a specialist engineer.

Oversized pipework means higher costs for pipes, valves, fittings, installation, maintenance and insulation. Also, a larger pipe surface area means greater heat losses. Undersized pipework on the other hand, may limit the pressure in the system, increase steam velocity which can in turn increase erosion, water hammer and noise.

In most plants the boiler house is often located next to the rendering or the by-products plant hence pipe sizing is not a serious issue. However in some plants heat exchangers generating hot water from steam are located at some distance from the boiler house with extended lengths of steam pipes. Locating heat exchangers next to steam boilers and reticulating hot water as an alternative is likely to save energy as well as cost.

Photo: Locating heat exchangers close to the boiler house and repairing damaged insulation will reduce heat losses and fuel consumption.

8.2.2 Pipe Insulation

Steam leaving the boiler often carries moisture with it.   Moreover, it begins to condense as soon as it starts on its journey and will get wetter with every meter of travel through the mains. The wetter the steam, the poorer its quality and heat transfer ability in process equipment. Uninsulated pipes result in a relatively large heat loss, which increases the amount of condensate in the steam.

Formation of water or condensate in the steam distribution pipes can be reduced by insulating or lagging the steam distribution pipe-work. Special attention should be given to flanges and valves as the heat loss from a pair of flanges is equivalent to heat losses from 0.3 m of plain pipe.

Most lagging relies on the effectiveness of minute air cells in the lagging material which form an effective barrier to escaping heat. The lagging can become ineffective if those air cells are filled with water or are crushed.

Most of the lagged steam pipes are exposed to water and so these must be suitably protected and frequently checked. Another common issue with insulation in most plants is that once insulation works are damaged, they are rarely repaired.

8.2.3 Pressure reducing valves

Steam is usually generated and distributed at relatively high pressures. However, most steam consuming equipment are operated at a lower pressure than the main steam supply pressure. In such cases pressure reducing valves are required to lower the steam pressure.

This pressure reduction has the added benefit of improving the quality of the steam for the processes. In the main steam distribution network, there will be some ‘wetness’ or condensate in the steam, which is not ideal for the steam using equipment and heat exchangers. When a quantity of high pressure steam is suddenly reduced to a lower pressure in a pressure reducing valve, there is a gain of heat energy to quickly evaporate the ‘wetness’ in the steam to produce good, clean, dry saturated steam.

8.2.4 Steam traps

Steam traps are essential in steam distribution networks. They are used to separate steam and condensate in distribution pipework and process equipment. If a steam trap fails, it can account for a large amount of steam wastage and thus energy wastage in a plant.

Steam traps have two noticeable failure modes, which are *failed closed* (passing no condensate or steam), and *failed open* (passing live steam). If a trap is failed-closed, condensate will backup into the system thus preventing heat transfer to take place in a heat exchanger. If failed-open, a steam trap can potentially pass a significant amount of steam which becomes an energy loss to the system. Leaking traps are also a common failure mode.

To prevent unnecessary steam wastage, regular checking of steam traps is essential. A steam trap leaking steam is a serious concern and must be identified quickly. Observing plumes of steam from vent pipes of condensate recovery tanks can indicate leaking steam traps. Temperature measurement of trap discharge is generally only useful with traps that have failed in the closed position. Listening to the sound of trap operation is also useful with the thermodynamic types, although considerable expertise is required in interpreting the sounds. A 15mm steam trap has the capacity to pass 11 kg/h in the failed mode.

Leaks in steam traps, joints and valves can incur significant steam wastage and loss. Even a 3mm diameter hole can discharge as much as 30 kg/hour of steam at 10 bar gauge, which represents a waste of approximately 660 GJ of gas over an 8400 hour working year. Elimination of visible leaks is obviously reasonably straightforward. It is the invisible steam leaks through faulty steam traps that present a far more taxing problem.

8.2.5 Flash steam recovery

Plumes of flash steam from vents of hot wells in the boiler houses are a common sight in most plants. Only a few plants recover energy from the condensate released from cooker prior to discharging it to the hot well. This practice can minimise flash steam generation at the hot well.

When hot condensate under pressure is released to a lower pressure, its temperature must quickly drop to the boiling point for the lower pressure. The excess heat is utilised by the condensate and causes some of it to re-evaporate into steam. This is known as 'flash steam'. The existence of this flash steam is often regarded as a nuisance. However, the proper collection and use of this steam can considerably improve the overall plant efficiency. Flash steam can be recovered and used to generate hot water, preheat boiler feed water, or preheat combustion air. A flash vessel is the normal means of separating the steam from the residual condensate.

Example:

The excess energy in hot condensate (reduced from steam pressure to atmospheric pressure) quickly boils a portion of the condensate which is released as flash steam.

For example if one kilogram of condensate at 14 bar (1400 kPa) gauge pressure is discharged to atmosphere (zero bar gauge), 0.18 kg of flash steam will be released.

828 kJ/kg (enthalpy of condensate at 1400 kPa) - 417 kJ/kg (enthalpy of condensate at atmospheric Pressure)=411 kJ/kg (excess energy)

411/2258 kJ/kg= 0.18 kg of evaporated condensate (flash steam) per kg Condensate

For a plant with 110 tonnes of steam production per day and 90% condensate recovery, the daily energy wastage through flash steam would be:

110 tonnes per day* 0.9*1000 kg/tonne*411 kJ/kg= 40.7 GJ/Day

40.7 GJ/Day * 250 days/Yr /0.8 Boiler efficiency*$7/GJ gas**=$89,000/Yr**

Water losses:

110 tonnes per day* 0.9*1000 kg/tonne*0.18 kg/kg= **17.8 tonne/Day**

17.8 tonne/Day * 250 days/Yr=4450 tonnes (KL) per year +Chemical treatment of equivalent feed water

The *Flash Steam Recovery Calculator*, attached, will enable estimates of energy and emission savings from flash steam recovery.

Photo: Plumes of flash steam from condensate tanks may be indicative of attractive heat and water recovery opportunities.

8.2.6 Condensate recovery

A number of plants surveyed did return condensate from cooker and hot water heat exchangers to the boiler house. None of the plants returned condensate from tallow tank trace heating. Reasons for not returning condensate included the location of tallow tanks and smaller volumes of steam being used in these tanks. Some plants have had foaming issues with steam boilers due to condensate carrying tallow into boiler drum. None of the plants used hot water for tallow heating.

Hot condensate can be recovered from steam distribution and process equipment and can be fed into the feedwater tank in place of cold water from town mains. The hotter the feed water can be supplied to the boiler, the less gas is needed to generate steam.

Returned condensate will also save chemical treatment cost and fresh water demand.

A 6ºC rise in temperature of feed water can save about 1 % in gas demand.

Example:

Maximising condensate return to the boiler should be one of the primary goals of both energy and water conservation in a plant.

For example in a plant where 110 tonnes of steam per day is generated in a boiler at 10 bar gauge pressure using 100% feed water at 10°C, nearly 10% of the annual fuel cost would be spent on raising the feed water temperature to 70 °C.

If this cold feed water is replaced by hot recovered condensate at 70°C, a saving of 10 % in the cost of gas alone can be achieved.

At an estimated 27.63 GJ/day savings and a boiler efficiency of 80% and gas cost of $7/GJ, daily energy savings would be close to $242 or $60,440/Yr

The corresponding water savings would be 110 KL/day or 27.5 ML per year (plus chemical treatment of that amount of feed water)

8.3 Steam Usage

Steam is used in meat processing plants for rendering, and generation of hot water (82˚C for sterilizing, 60˚C for cleaning and 43˚C for hand wash), as well as heating of tallow tanks and in blood dryers for blood coagulation.

8.3.1 Rendering Operation

Since the rendering plant uses most of the steam generated, it is important to monitor steam consumption by the rendering operation against the production on daily basis. This would enable plant operators to minimise any wastage occurring due to failures of steam traps and pressure reducing stations.

Since rendering operation is a major electricity user as well, it is also recommended that the electricity consumed by the rendering processes be monitored against production throughput.

Cooker

The energy efficiency survey revealed that there is room for improvement in cooker operations in most plants. However, there is need for more focus on benchmarking, and staff training on steam and use of steam.

There is a need for monitoring of the energy performance indicators in MJ/t of product on daily basis with anomalies addressed. Experience with similar operations indicates that up to 15% of those energy intensity indicators could be reduced with simple good housekeeping measures. For example, it was found that in some cases operators forget to close the by-pass valves of the steam traps after they were opened to release the condensate from the system during a cold start. Such practices not only waste valuable energy, but also affect the throughput rate of the cooker and product quality.

The study also found that there is a tendency for the cooker operators to open the by pass valve of the pressure reducing station believing that this would improve cooker performance. Again, such practices will not only reduce the efficiency of the cooker, but also affect the cooker output.

Cooker performance depends on two major factors:

- quality of steam fed to the cooker and
- how efficiently the heat is extracted from the steam fed into the cooker.

Quality of steam fed into the cooker depends on the dryness of steam. Performance of the cooker depends on the heat transfer efficiency from steam to the product going through the cooker. Heat transfer from steam is most effective when steam is dry saturated. When steam is wet, more steam is required to perform the same duty than when steam is dry.

Efficiency of steam usage by the cooker depends on two factors, pressure of the steam and the performance of steam traps.

Pressure of the steam fed into the cooker should be decided based on the process temperature.

Performance of the steam traps is the most crucial of all the operating factors. Leaking steam traps allow live steam to pass through as discussed above. The heat transfer from steam to product takes place through the heat released as enthalpy of steam while condensing. Leaking steam traps do not allow condensing of steam to take place and energy is lost with the live steam escaping back to feed water tank.

Increased recovery of condensate and flash steam are also important areas of energy efficiency in most rendering plants.

Use of waste heat from condensing cookers vapours can also offset a large portion of most plant’s hot water heating demand.

8.3.2 Blood Dryer

Blood dryer is often the only other natural gas user on site in addition to the steam boiler. It is used to produce blood meal from the blood collected from the slaughter floor. A small volume of steam is used to coagulate the blood prior to drying.

The use of old and inefficient blood dryers is still common in the industry. Reasons for lack of investment in more modern and efficient equipment has been the historical low demand for and low price of blood meal.

8.3.3 Hot Water usage

At a combined cost of $3 per kilo litres (KL) or higher for supply and disposal of water, most water conservation measures in meat processing plants are attractive options on their own. In the case of hot water, the added energy cost savings can make water conservation options even more cost effective.

Example:

Energy savings are the added benefits for water conservation projects aimed at reducing hot water consumption in meat processing plants.

For example, the additional cost of raising the temperature of 1 kilo litre of water from 15°C to 95°C would be equivalent to 0.42 GJ/Kl at Boiler efficiency of 80%.

1000 l *4.187 kJ/kg Deg C*(95-15)/0.8/1000,000=0.42 GJ/kl

At $7/GJ gas, the cost of water heating: $2.9/Kl

The combined savings water supply, disposal and heating costs for conserving one kilo litres of hot water therefore will be close to $6 /KL.

Calculating Hot Water Energy Input

The following simple equation can be used to estimate thermal energy input for raising hot water.

*Energy input in GJ=4.187*q *ΔT/1000,000*

Where:

*Specific heat capacity of water (kJ/kg K @ 14 **°C**)*	*4.187*
mass (volume) of water in kg (or Litres)	*q*
*Temperature Rise (e.g. from 15 **°C** to 85**°C**)*	*ΔT*

Source: AIRAH Handbook, Australian Institute of Refrigeration, Air-conditioning and Heating, 2000

Example:

Plant X uses 500 KL of hot water at 85**°C** raised from ambient temperature of 15**°C** using a gas boiler with 80% combustion efficiency. To calculate the annual cost of hot water for a gas price of $7/GJ the following formulae can be used:

500,000 L/day*4.187*(85-15)/0.8/1000,0000 =183.2 GJ/Day

183.2GJ/day*250 working days*$7/GJ=$320,567/Yr

Combined Water and Energy Conservation Opportunities

There are many examples of water saving options in a meat processing plant including sensor control of apron wash, thermostatic control of flow to sterilisers, sensor control of hand wash taps and others.

A reduction in water use is also possible for cleaning process in most plants where initial dry cleaning, and higher pressure 60°C water can be used to reduce hot water use. Hot water at high sterilising temperatures can in fact result in baking of protein to plastic surface making cleaning process even less effective.

The use of double skin sterilisers or thermostat control of flow can contribute to both water and energy conservation.

Example:

60 sterilizers in a plant were estimated to use 190 kl of water per day. Assuming a halving of that flow through installation of double skin sterilisers, the resulting energy savings can be estimated as:

190,000*0.5*4.187*(90-15 °C)/1000,000= 30 GJ/day
For 250 days/Yr, 80% boiler eff, and $5.5/GJ gas: $51,563 p.a.)

A complete discussion of water conservation opportunities is outside the scope of this manual. Part 2 of Eco-Efficiency Manual for Meat Processing (2002) can be used a reference for a range of water conservation opportunities in meat processing plants.

Heat Recovery from Waste Water

The higher temperature of waste water discharge is an issue for most plants. Installation of a heat exchanger to preheat hot water use can have a double benefit of reducing the discharge temperature of waste water, as well as reducing energy costs for hot water heating. To ensure food safety however the risk of feed water contamination must be minimised in such installations.

Example:

The waste water stream from sterilisers and hand washers at a plant is believed to be at 36.5 °C and 8 l/s flow. Transferring 70% of that heat to incoming water at ambient temperature of 15.5 °C would be equivalent to reducing 13,336 GJ of gas in a hot water boiler of 80% efficiency. That is equivalent to 17% of current gas usage of the site or $66,743 p.a.

8 l/s* 4.187 KJ/kg Deg K*(36.5-15.5)*0.7/0.8=615 kW

615 kW *(3.6/1000)*16hrs/day*250 days*$7.5/GJ=$66,472

Photo: A heat exchanger preheating the incoming cold water with outgoing Sterilisers waste water

9 Biogas Recovery

A large number of meat processing plants have issues with odour emissions from anaerobic ponds. Most plants have partly addressed the odour issue by allowing a crust to form on top of the anaerobic digestion ponds. However, the majority of the plants will still be required to include methane emissions from the ponds in their greenhouse and energy reports as part of the new National Greenhouse Gas and Energy Reporting Scheme (NGERS).

Meat processing plants are large users of water. The 2003 industry benchmark by MLA was 10.6 KL of raw water/t HSCW. Because of the large use of water, there is also a large amount of wastewater generated. That is an industry average of10 kl/tonne HSCW (MLA 2003).

The wastewater from meat processing plants typically has a high biological oxygen demand (BOD) and chemical oxygen demand (COD) which need to be reduced before disposal.

One of the simplest methods of treatment is to send the wastewater to anaerobic ponds where the anaerobic digestion process reduces the BOD and COD of the wastewater and in the process generate biogas which is mostly composed of methane (CH_4) and carbon dioxide (CO_2).

9.1 Potential for capturing biogas from anaerobic digestion ponds

The biogas generated in anaerobic digestion ponds normally escapes from the ponds into the atmosphere. The biogas is mostly composed of methane, a strong greenhouse gas that is 21 times more potent than carbon dioxide (CO_2). Biogas also has an unpleasant odour which can affect neighbouring properties.

Biogas from anaerobic ponds can be captured by covering the ponds with membrane structures as shown below:

Source: PMP Environmental http://www.pmpenv.com

Photo: Anaerobic pond cover as part of a biogas utilisation facility

The biogas captured from anaerobic ponds can be flared or used for combustion in a boiler or in a gas engine to generate electricity.

The simplest use of biogas (instead of flaring) is co-firing along with natural gas in boilers to displace some of the plant's natural gas use and reduce gas purchases and emissions associated with the gas use.

Example:

In a medium sized plant, 8,000 KL/week of waste water with an average BOD of 2,430 mg/l is discharged into an anaerobic pond where 83% of BOD is removed, releasing an estimated 257 tonnes of methane into the atmosphere.

The greenhouse gas emissions will be equivalent to 5,395 tonnes of CO_2-e as Methane is 21 times more potent than CO_2 as a greenhouse gas. (Assuming a family car has an annual emission of 3 tonnes, the methane release from that pond would be close to emissions from 1,800 cars each year).

Capturing the biogas from anaerobic pond can simultaneously remove a major source of emissions at the site, and also displace demand for natural gas or electricity, resulting in further emission savings.

Based on the assumption of 0.7 m^3 of biogas production for every 1 kg of BOD removed, and based on an estimated calorific value of 22 MJ/m3 for biogas, an estimated 12,920 GJ of gas p.a. can be captured from the above anaerobic pond using a membrane cover.

The captured biogas can be burnt along with natural gas in existing boilers displacing an estimated cost of $96,900 p.a. (at $7.5/GJ).

The reduced emissions from displaced natural gas at 65.5 kgCO_2e/GJ (for full fuel cycles) will also be equivalent to a further 846 tonnes of CO_2-e further reducing the emissions footprint of the plant.

Assuming carbon credits can be generated under the proposed Carbon Pollution Reduction Scheme (CPRS), there will also be carbon credits associated with the reduction of 5,395 tonnes of CO_2 p.a. Assuming those carbon credits have a value of $30/tonne, there will be further benefit of $161,850 p.a.

However it is not yet clear whether carbon credits can be earned by smaller facilities not captured under direct obligations by CPRS. A White Paper outlining facility thresholds, carbon permits, offsets, etc. under CPRS is expected to be released by the Department of Climate Change in December 2008)

9.2 Flaring biogas

Flaring of biogas is the process in which biogas is burned or 'flared' to convert the methane (CH_4) in the gas to carbon dioxide (CO_2). Methane causes a warming effect in the atmosphere which is 21 times stronger than carbon dioxide. When biogas is combusted and converted to carbon dioxide through flaring, a significant reduction of greenhouse gas emissions (by a factor of 21) can be achieved. However the energy content of biogas is not used in this case and while the emission reductions can still earn carbon credits, the full benefits of biogas recovery is not realised.

9.3 Burning biogas in steam boilers

Biogas from rendering plants' effluent ponds can have a methane content of 60-70% which can be co-fired in existing boilers. Boilers can generally operate even on a biogas to natural gas ratio of 70% to 30%.

If the captured biogas is burned in a steam boiler, then the same amount of carbon credits equivalent to flaring may be generated depending on the eligibility of the sites (yet to be determined under CPRS). However, if the biogas is used in a boiler, then natural gas that would have been otherwise purchased can be displaced. In this scenario, the plant can be earning an income from the reduced natural gas use and potentially from reduced emissions liability if that plant is captured under direct obligations by CPRS.

This scenario may only require a small capital cost and minimal alterations to existing equipment as the exiting gas boilers will just be using an extra source of gas and require no major new infrastructure. However, due to the high hydrogen sulphide content and low calorific value of biogas, the conversion of the boiler combustion system should be carried out by specialist combustion engineers.

9.4 Use biogas to generate electricity

An alternative scenario to flaring or using biogas in existing boilers would be to use the captured biogas for combustion in a gas engine to produce electricity. In this case, the plant can generate its own electricity using a renewable energy source; biogas which can potentially earn Renewable Energy Certificates (REC's).

The above electricity generation scenario may involve a significant capital cost for new infrastructure if there is not an existing gas engine at the site. However, the plant will be generating some of its own electricity, resulting in savings from electricity that would have otherwise been purchased from the grid at retail electricity prices. The on-site generation can also reduce the maximum demand charges, provide back-up generation for essential services such as chillers and freezers (preventing expensive product losses during extended black outs), or continuity of production during short outages.

Example:

A 330 kW biogas fuelled generator installed close to a pond generating an estimated 2 GWh of electricity p.a. The generator displaces an estimated $170,000 p.a. in electricity purchases, and earns a further $60,000 p.a. in Renewable Energy Certificates (REC's) earned at an estimated $30/REC (or future carbon credits).

However, at an estimated $700,000 the installed cost of small generators (under 500 kW) are relatively high.

10 Cogeneration

A Combined Heat and Power (CHP) or cogeneration system is another more efficient option for using biogas or natural gas to generate electricity and hot water in a meat processing plant.

Cogeneration is the use of an engine to generate electricity and useful heat simultaneously. More commonly, natural gas is fired in an engine to drive an alternator to generate electricity. A cogeneration option will enable capturing of the waste heat from cooling water and exhaust gases which can be utilised to heat water to be used elsewhere in the plant.

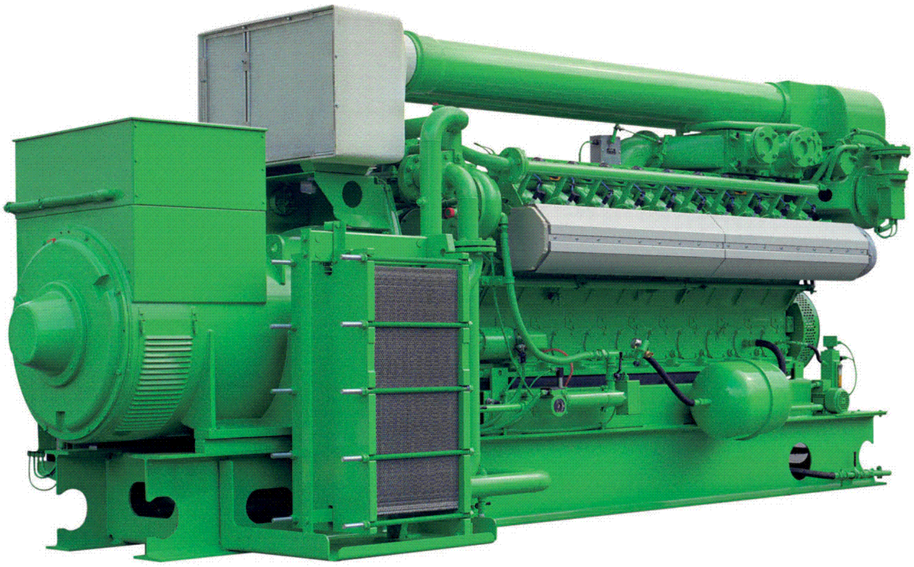
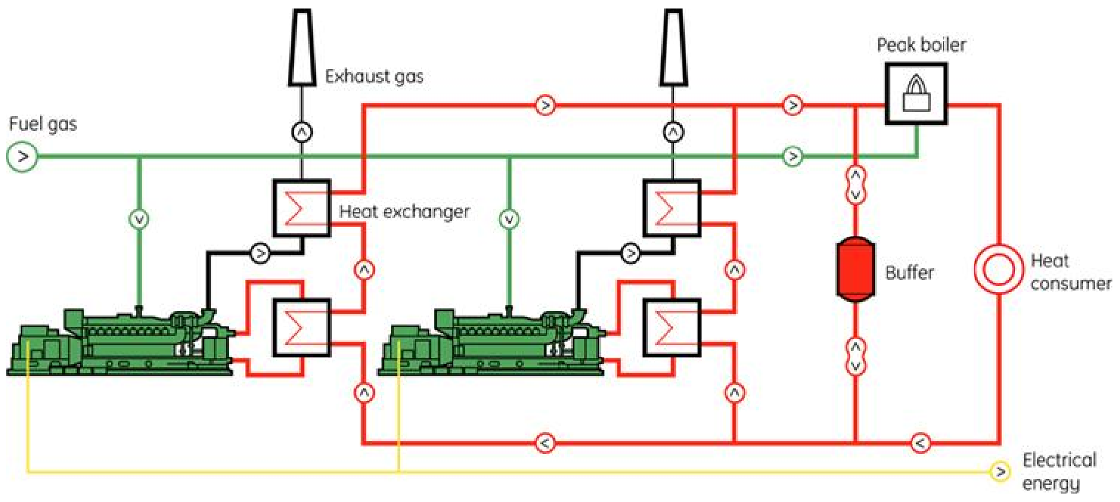


Photo: GE-Genbacher Type 3 Gas engine Courtesy of Clarke Energy



Source: Genbacher.com

Figure 17- Gas engine cogeneration option for combined heat and power (CHP) generation

Whilst a gas engine and generator set can offer average efficiencies of 38% to 43%, capturing the waste heat through cogeneration can increase efficiency of fuel conversion to 85% to 90%.

Note however that for the meat processing plants with on-site rendering facilities, the waste heat from cookers (if captured efficiently) can exceed the hot water heating demand of the plant. In such cases, cogeneration benefits can be reduced to those expected from simple on-site generation (e.g. back-up generation, reduced demand charges, etc.) unless there are additional demands (at the site, or from the neighbouring facilities) for the waste heat produced.

Example:

A 2 MW gas cogeneration unit at an estimated installed cost of $2.1 million was considered for a plant with a suitable base-load and with simultaneous demand for hot water.

The 2 MW cogeneration unit is expected to be operating 24 hrs per day 250 days per year. The electricity and gas prices of 10 cents per kWh, and $4.1/GJ (respectively) were used in the analysis.

The above cogeneration plant was capable of meeting up to 80% of the site's electricity consumption generating nearly 10 GWh of electricity per year, worth nearly $1,000,000 p.a. The waste heat from the unit could also displace 43 TJ of natural gas used for hot water heating, worth $176,000 p.a.

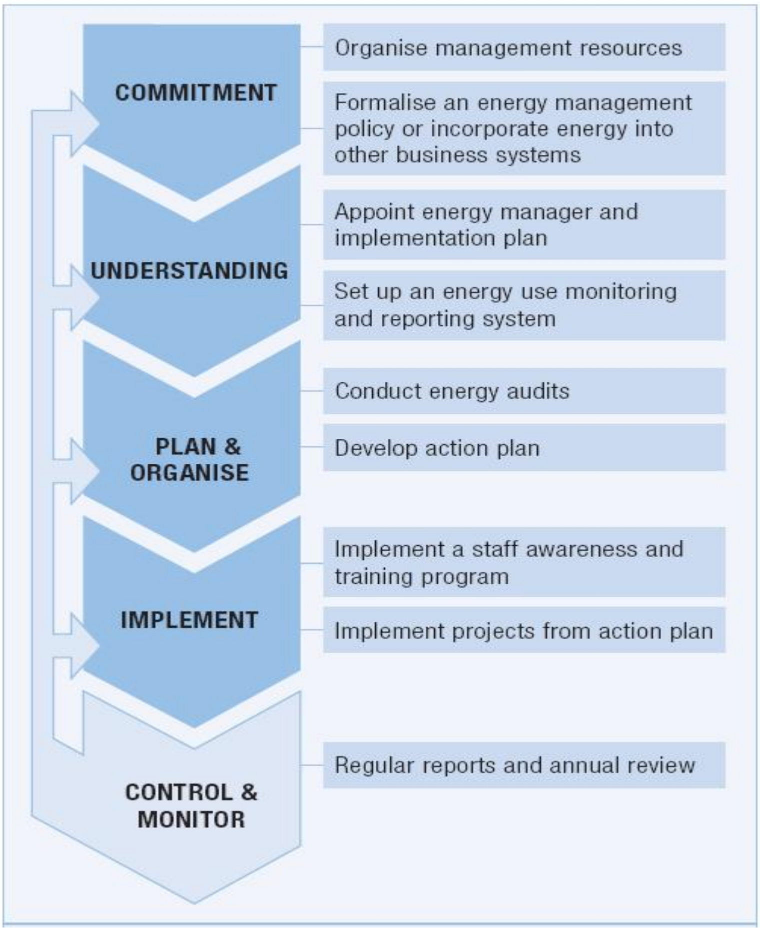
Including the annual fuel cost as well as operation and maintenance costs, the net revenue was estimated to be close to $790,000 p.a. giving a simple pay back period of less than 3 years.

11 Developing an Energy Management System

As for most industrial plants in Australia, few of the meat processing plants audited had an existing energy management system (EMS) in place.

The importance of EMS lies with incorporating energy management into the overall management of an organisation. Leadership and clear energy efficiency policy, appointed energy manager, KPI's and targets for energy efficiency and adequate resource allocation, are among the main elements of an EMS

Figure 18 below illustrates the main elements of an EMS described in detail in *Developing an EMS-Module 4* (accessible from /www.sustainability.vic.gov.au). An EMS can provide the framework for implementing a sustainable energy efficiency program, as opposed to ad-hoc energy audits or single energy efficiency projects.



Source: Sustainability Victoria (www.sustainability.vic.gov.au/resources/documents/Module4.pdf)

Figure 18- Energy management system flow chart

11.1 Monitoring Energy Use

The adage 'you can not manage what you can not measure' applies directly to the success or failure of an energy management program.

Monitoring energy use and setting targets could enable the industry to save up to 15% of its overall energy consumption through good housekeeping measures and changes to controls and operations.

It is therefore important to define Energy Performance Indicators (EPI) for the total plant, as well as individual operations. In case of the total plant, the EPI could be kWh, GJ, kL of water, kg $CO_{2\ \text{equivalent}}$, per head, or tonnes of HSCW. On a sub plant level EPI's such as MJ/tonnes of meat meal or other appropriate EPI's can be used.

Tracking EPI's for different months of the year and for different production levels can highlight plant efficiencies at different throughput rates or different seasons.

For example, Figure 19, below, shows potential savings from increased throughput for a typical plant. As can be seen, lower EPI's are achieved during the periods of higher production rates, despite those periods being in summer months where refrigeration demand is expected to be at its highest.

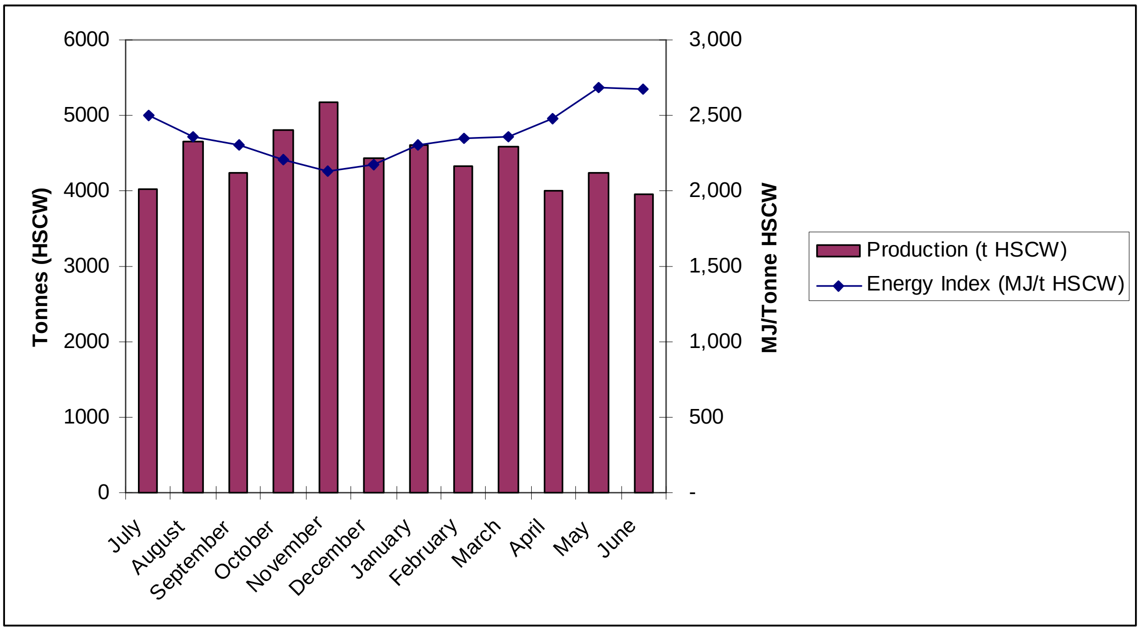


Figure 19- Energy performance indicators (EPI's) vs. production rates for a typical plant

EPIs need also to be defined and monitored for each individual operation or sub plant where plant operators have control over the use of energy in that operation. An example of such operation is the by-products or the rendering plant. The majority of the plants keep records of the weight of meat meal produced in tonnes or kilograms on daily basis but do not keep energy use records.

Rendering is the main user of steam in a meat processing plant. It also uses a considerable quantity of electricity. If both electricity and steam consumed by the operation are metered, then the above EPIs could be calculated on a daily basis. Discussed in further detail below is one barrier to calculating such EPI's-the absence of sub-metering in most plants.

11.2 Improving Sub Metering

A common feature of all sites audited was the absence of sub-metering. Whilst the electrical and thermal energy use owing to their different supply source could be separated, that was often the extent of energy sub-metering available at most plants.

Absence of sub-metering makes determination of EPI's for sub plants and assessment of energy saving measures difficult. *(You can not manage what you can not measure!)*

Use of existing SCADA systems can be one option for monitoring the main meters and any number of sub meters. Existing compressor current readings can also be combined to give a combined refrigeration load history using the existing SCADA system.

There has been significant advancement in the field of metering and data communication over recent years. Instead of having a dedicated software and computer to monitor individual meters, web enabled monitoring is now available as a more cost effective options. Plants subscribing to such services can have their own web page with alarms set to notify of unusually excessive energy usages or other specified parameters.

Wireless web based monitoring would enable any number of authorized personnel to monitor various aspects of the plant's energy performance. Such measurement services are offered by some of the electricity retailers and a range of other metering and energy service providers.

Use of low cost data loggers might also be another option for gaining a snap shot of main energy users.

11.3 Conducting an Energy Audit

In its simplest terms an energy audit is the process of balancing the energy purchases with energy expenditures within a site. AS 3598 Energy Audits describes three levels of energy audits:

-Level 1 or Walk Through audits
-Level 2 Audits
-Level 3 or Detailed Audits

Whilst there are energy management engineers specialised in energy auditing for different industries, an initial self-audit of the plant can reveal significant energy and cost savings. It can also enhance plant operators' awareness of the main energy users and energy efficiency opportunities at the site

Step 1- Desk top Audit

To conduct a self audit, it is always helpful to start with a desk top audit gathering and analysing all main energy bills for the previous 12 or preferably previous 24 months.

Plotting monthly energy demands against monthly production will give useful bench marks for the site's overall energy use, which can be used as a baseline for future improvements. Whilst the benchmarks presented in Section 2 of this manual can be used as a comparison, given the significant variations between meat processing plants, the most useful benchmarking is against a plant itself.

The desk top analysis of the site's historical energy use can also highlight variations in annual or monthly energy use

Step 2- Conducting a walk through audit

Having established the total energy purchases (incomings), the second part of an audit is to understand where those energy imports are used within the site.

However, given the large number of energy users in a typical plant, and given the absence of sub-metering in most plants, establishing energy expenditures is often very difficult unless it is carried out as part of a detailed energy audit.

A walk-through audit is a less formal approach where focus is on large energy users and the obvious areas where energy efficiency can be made. Most plant operators already have many ideas about improving energy performance of the plant.

Checklists and calculators in Appendix A while aimed for a more detailed energy audit may be used as part of a walk through audit to focus on large energy users and estimate potential efficiency gains. Individual topics discussed in this manual could also be evaluated for each plant as part of a self audit.

Professional energy auditors with relevant experience can also be engaged to conduct more detailed energy audits. AS3598 requirements can be used for specifying requirements for an energy audit depending on the level of details required.

Use of Graduate Engineer programs offered by MLA can also be considered for bringing a systematic focus on energy assessments and savings when internal resources are limited.

11.4 Setting Targets

Having established the plant's Energy Performance Indicators (EPIs), and its potential for energy savings, through an energy audit, energy reduction targets can be determined. Those targets could be in total energy use (e.g. 10% reduction in annual energy use), or a reduction in energy intensity (e.g. 10% reduction in MJ/t HSCW) for a plant with variable production.

Given the significant energy efficiency opportunities in the industry, it is possible to set ambitious targets.

Setting targets and measuring and reporting against those targets are essential components of a successful energy management program.

11.5 Implementing Energy Efficiency Projects

Despite the financial attractiveness of most energy efficiency opportunities, there are many barriers to implementation of such projects. Such barriers include the industry's focus on core business, limited human and other resources, perceived interruption to process and others.

It is therefore important to have management support at the highest level of the organisation, along with the required resources including time and budget. Clear targets and accountabilities for meeting energy efficiency targets at different levels of the organisation are also essential.

The *continuous improvement* policies in most plants can provide a good platform for promoting energy saving opportunities.

Lack of capital for implementing energy efficiency projects is another barrier in most plants. Setting up a revolving fund for energy efficiency where initial savings from low cost projects or the 'low hanging fruits' can be reinvested into more capital intensive projects such as biogas recovery or cogeneration may provide a compounding financial resource. Use of external energy service providers including Energy Performance Contracting options may also be considered for implementing energy efficiency projects.

11.6 Training

Ideally, it should be an aim for the industry that staff at all levels are trained on energy management principles. Such training should include managers, engineers, supervisors, operators and technicians.

Special energy efficiency courses and technical seminars could help those staff directly involved with the operation and maintenance of main energy consuming plants and equipment. For example, it has been demonstrated that 3-5% saving on boiler fuel can be achieved simply by improving the training of boiler operators.

Celebrating success by communicating the energy efficiency achievements to all levels of the company, and recognition of employees' ideas and contributions can contribute to a culture of efficiency and sustainability.

Cooperation between management and employees could be extended to the home and personal environment. Practical guidance and information in saving energy at home will not only generate goodwill and save employees money, but also develop awareness and positive habits that are likely to be adopted in the work environment as well.

Given the vast distances between meat processing plants in Australia, and the difficulties for participants to attend off-site training courses, the industry could examine a mix of on-site, and on-line training combined with traditional off-site training and seminars to increase energy management capabilities of the industry.

The National Meat Industry Training Advisory Council can facilitate development of such courses. Other institutions such as Australian Institute of Refrigeration, Air-conditioning and Heating (AIRAH), offer short courses on energy management and specific plants such as Ammonia Refrigeration, Energy auditing and other courses which can also be accessed by the industry.

12 Conclusion

The overall energy use index of 3,368 MJ/t HSCW for the 12 participating plants in this study was near identical to a 2003 audit and an earlier 1998 energy indices by MLA. Despite the small sample size, the results may be indicative of a relatively static energy efficiency performance in the Red Meat Processing industry over the past decade.

The energy savings of between 15% to as high as 60% identified as part of individual site audits, reveal significant energy efficiency opportunities for most plants in the industry. Given the rising energy prices across all fuels, and the proposed introduction of Carbon Pollution Reduction Scheme (CPRS) in 2010, those opportunities are expected to be even more attractive in the future.

Through a comprehensive energy management program combining all technical and management aspects discussed briefly in this manual, individual plants can identify their own energy opportunities to not only minimise the impact of energy price rises but also improve their global competitiveness and their environmental footprint.

References

AIRAH Handbook 3rd Edition, Australian Institute of Refrigeration, Air-conditioning and Heating (AIRAH), 2000

ASHRAE Handbook-Refrigeration, ASHRAE, Atlanta, GA, USA, 1994

Copeland Refrigeration Manual, Copeland Corporation, Sidney, Ohio, USA

Developing an energy management system (Module 4), Sustainability Victoria Downloadable from: www.sustainability.vic.gov.au/resources/documents/Module4.pdf

Eco-Efficiency Manual for Meat Processing, MLA, 2002

Environmental Best Practice Guidelines for the Red Meat Processing Industry, MLA, Downloadable from: www.mla.com.au/TopicHierarchy/InformationCentre/Environment/For+processing+plants.htm#Eco-Efficiency

Food & Drink Industry Refrigeration Efficiency Initiative, Carbon Trust Networks Project, Downloadable from: www.ior.org.uk/ior_/images/pdf/general/REI-G5%20Site%20Guidance%20Topics%20-%20Final%20Jul-07.pdf

Industry Environmental Performance Review-Integrated Meat Processing Plants, MLA (2003)

Industrial Refrigeration Best Practice Guide, North West Energy Efficiency Alliance, 2nd Revision, (2007)

Meat Technology Information Sheet: Refrigeration Energy Strategies, MLA Publication (1997, 2006)

Meat Technology Information Sheet (Rendering System (1997, 2006)

Refrigeration Index Training Manual (and Calculator), MLA (2005)

UNEP Working Group for Cleaner Production, The Potential for Generating Energy from Wet Waste Steams in NSW, SEDA (1999).

Abbreviations

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CO_2-e	Carbon Dioxide Equivalent
COP	Coefficient of Performance
EMS	Energy management system
EPI	Energy Performance Indicator
HSCW	Hot standard carcase weight
ISO	International Organisation of Standardisation
kPa	Kilo Pascals
kPa (g)	kilo Pascals (gauge pressure)
KPI	Key Performance Indicator
kL	Kilo Litres
kW	kilo Watts
kWr	kilo Watt Refrigeration
kWh	Kilo Watt Hours (1kWh=3.6 MJ)
MJ	Mega Joules
GJ	Giga Joules (1 GJ=1,000 Mega Joules)

Appendix A

A-1 Calculators

The accompanying Excel Workbook includes the following five calculators:

Calculator # 1-*Boiler burner tuning* – Calculating savings from improved combustion efficiency of boilers.

Calculator # 2-*Flash steam recovery* – Calculating savings from recovering flash steam generated from condensate returns.

Calculator # 3-*Economiser savings* - Calculating the savings achievable through improving or installing an economiser on boiler stacks.

Calculator # 4-*Blowdown Total Dissolved Solids (TDS) savings* – Calculating savings from reduced blowdown rate of boilers by increasing the maximum allowable TDS level.

Calculator # 5-*Blowdown heat recovery* – Calculating savings achievable through heat recovery from blowdown water.

A-2 Other On-line Resources

Energy Smart Toolbox-Calculators

The following four Calculators can be used to estimate:

- financial savings from energy efficiency projects,
- lighting upgrades
- compressed air upgrades, and
- life time running costs of new equipment:

www.energysmart.com.au/sedatoolbox/calculators.asp

Emissions Calculator

Develop an inventory of your Greenhouse Gas emissions using this calculator:
www.greenhouse.gov.au/challenge/members/pubs/emission_sheet.xls

CADDET InfoStore
Enter a keyword in the search engine to find Energy Efficiency and Renewable Energy case studies with technical and financial performance data from around the world www.caddet.org/infostore/index.php

Motor Solutions Online:

www.environment.gov.au/settlements/energyefficiency/motors/index.html

General Energy Audit Checklists

http://www.environment.gov.au/settlements/challenge/members/energyaudittools.html

Greenhouse Challenge-Information Sheets

Available from: http://www.environment.gov.au/settlements/challenge/publications/factsheets/

- Air Compressors
- Energy Performance Contracting
- Going low carbon
- Heating, Ventilation and Air Conditioning (HVAC)
- Hot Water
- Implementing Energy Management in Business
- Lighting
- Maintenance
- Motors
- Office Equipment
- Power factor correction
- Transport
- Waste
- Water Efficiency
- Workplace Design and Layout

A-3 Audit Data Collection Checklists

steam generation	
Boiler capacities	
% of total gas going to boilers & other gas users	
Boiler fuel	
Boiler/steam pressure	
Boiler operation patterns-one boiler running one stand by, two boilers running, lead/lag	
Boilers are fully attended/unattended	
Combustion data (O_2/CO_2 & exhaust gas T) from boiler service provider's five-weekly reports	
Do boilers have economisers on them	
Blow down details (automatic/manual)	
Boiler drum TDS level (ppm)	
Condensate recovery (%), reasons for not recovering 100%	
Boiler feed water/condensate recovery tank temperature (estimate), is it boiling?	
How regularly steam traps are checked/repaired	
Are there condensate recovery pumps? How many? Condition? How many working?	
Is there any flash steam recovery?	
What heat recovery systems are in place?	
Cookers	
How many cookers in operation	
What different types of products (blood- meal/meat meal)	
Product output rates (t/hr, t/day)	
Continuous/batch	
Does the steam supply to cooker go through a pressure reducing station/what is the steam supply pressure to cooker/s?	
Heat recovery systems on cooker operations, condensing cooker vapours, heat recovery from condensate from cookers?	
Product throughput of cookers (t/hr)?	
Effluent	
Effluent flow rate (kL/day etc.)	
BOD/COD values	
Anaerobic digestion ponds/digester?	
Is biogas captured from ponds/digesters	
Is the biogas flared or used & how?	
Air Compressors	
How many Compressors?	
What capacities (kW OR L/sec), Make, age?	
How many compressors run full time?	
Any lead/lag arrangements in running compressors?	
Any compressed air/leak surveys done recently, maintenance programs in place?	
% Loading of Compressors?	
Any VSD fitted Compressors?	

Refrigeration	
Chiller/Freezer insulation/vapour barriers condition	
VSD’s on evaporator fans?	
Evaporator fan control regime?	
Door Openings Regime?	
Compressor drive ratings (kWe) on low and high side	
Sequencing of compressors (part-load performance)	
Screw compressors at low part load? (VSD?)	
Automated Control?	
Condenser drives	
Set point temp. in chillers freezers, and cool stores	
Freezer types (Plate freezers 30-40% more efficient than blast freezers)	
Other main drives	
Defrosting frequency and method (e.g. daily, hot gas or water, etc.)	
Week-end operations	
Back pressure control for defrosting?	
Discharge, suction and intermediate pressures	
Evaporator controls	
Head pressure floated?	
Minimum head pressure set point too high?	
Suction temperature too low?	
Chillers, Cool Stores, Freezers temperature set points	
Ice on the floor and walls of cold rooms? (excessive air ingress)	

A-4 Compressed Air Audit Guidelines

The following two compressed air surveys are recommended to be undertaken at meat processing plants.

Survey 1: Air Flow & Energy Demand Survey

The Compressed Air Flow Survey should be conducted over seven days, preferably inclusive of a weekend or a period when the production plant can be minimised, in order to identify and qualify the volume of leaks.

Following the completion of the survey a full report should be delivered detailing:

- Actual power usage of the compressors – kWh per annum
- Operating cost of the compressed air plant in $ per annum
- Tonnes of CO_2 produced from the compressed air plant per annum
- Efficiency of the compressors current operation
- Establishment of “Best Operating Practice”
- A comparison of “Current” vs. “Best Operating Practices”
- A Gap “Analysis”
- Actual flow rates and flow profiles
- Actual flow rates and flow profiles (kWh/$/litres per second /tonnes CO_2 per annum/Percentage)
- Establish “Baseline”, from which improvements can be measured
- Determine loadings on compressors and review plant demand profile
- Determine loadings on compressors over weekends and after hours
- Determine current compressor sequencing and control
- Review compressor control system vs. optimal control system

Survey 2: Ultrasonic Leak Survey

The Ultrasonic Leak Survey should be conducted over three days, when the production plant is in operation or the compressed air system is fully charged, in order to identify individual leaks on the compressed air reticulation system and plant.

Following the completion of the survey a full report should be delivered detailing:

- Number of individual leaks detected
- Each leak tagged at location
- Photographed for reference
- Leak rated in:
    - Flow Litres per second (l/s)
    - Electricity - kWh
    - Electricity - $
    - Emissions - kg