Energy

Table of Contents

Abbreviations & Acronyms

AGO	Australian Greenhouse Office
COP	Coefficient of performance
COSP	Coefficient of system performance
CO_2-e	carbon dioxide equivalent
EEAP	Enterprise Energy Audit Program
EEBP	Energy Efficiency Best Practice Program
EPA	Environment Protection Agency/Authority
GHG	Greenhouse gas
kg	Kilogram
kL	kilolitre (1000 litres)
kVA	kilovolt-amperes (apparent power)
kVAr	kilovar (magnetising or reactive power)
kW	kilowatt
kWh	kilowatt hour
m^3	cubic metres
MJ	mega joule
MLA	Meat and Livestock Australia
MSM	Multi speed motor
R&D	research and development
SEAV	Sustainable Energy Authority of Victoria
SEPP	State Environmental Protection Policy
SOx & NOx	oxides of sulphur and nitrogen
TDS	Total dissolved solids
tHSCW	Tonne hot standard carcase weight
TWh	Terawatt hour
US EPA	United States Environmental Protection Agency
VSD	Variable speed drive

Environmental Objectives

- Comply with all relevant legislation and regulations
- Efficient consumption of energy resources thereby reducing greenhouse gas emissions
- Demand management to reduce electricity load factor
- Continuous improvement in environmental systems and performance

Possible Environmental Impacts

Energy utilisation at a meat processing enterprise has environmental impacts at both local and National/Global levels.

Local	**National/Global**
• Smoke (visible plume + particulates) from combustion processes including boilers and direct fried driers • Visible steam vapour from process equipment • SOx and NOx from combustion processes • Solids disposal from boilers using solid fuels • Refrigerant release	• Carbon dioxide emissions and greenhouse impacts both directly from in-house combustion processes and indirectly from electricity consumption

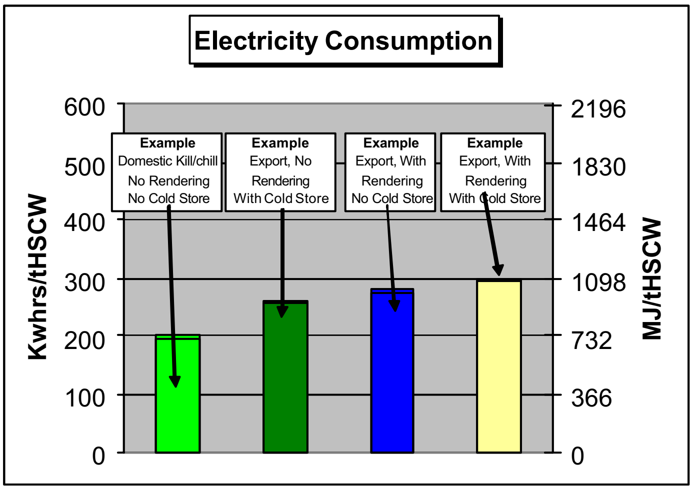
Key Performance Indicators

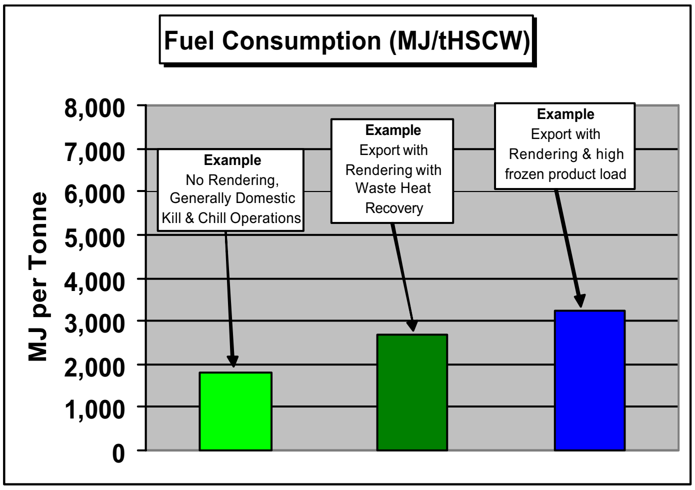
The following table presents a summary of the red meat processing industry energy utilisation in 2003. These averages represent a number of enterprises employing a variety of processes at the individual enterprise level.

KPI	Average	Range	Units
Energy Usage	3390	2000-6000	MJ/tHSCW
	465	100-1000	MJ/head
Greenhouse Gas Emissions	525	250-900	kg CO_2-e/tHSCW
	75	15-170	kg CO_2-e/Head

Source: MLA, Industry Environmental Performance Review 2003

- These KPIs relate to medium to large integrated export abattoir facilities, processing > 100 t HSCW/day.





Further details of the objectives of the pieces of legislation are provided in Appendix 2.

Current Legislation and Regulation	
Commonwealth	Legislative instruments refer to management of energy efficiency and greenhouse gases include: • National Environment Protection Measures (Implementation) Act 1998 • National Strategy for Ecologically Sustainable Development • National Greenhouse Strategy • Greenhouse Challenge Plus All businesses using more than 0.5 petajoules of energy per year will be required to undertake a rigorous energy efficiency opportunity assessment every five years and commencing in 2006. Meat industry data suggests this will only apply to companies processing in excess of 150 thousand tonnes HSCW/annum.
States	There are an increasing number of environmental plans and recommendations coming into place focussing on mandatory targets for high end energy users.
Victoria	In Victoria in addition to management of various air pollutants, SEPP include a Protocol for the Environmental Management of Greenhouse Gas (GHG) Emissions and Energy Consumption (PEM 824 – See Reference 8). EPA Licence holders (scheduled premises) must complete a number of key steps including: • Undertake an Energy Audit including a profile of baseline energy consumption • Prepare a greenhouse emissions inventory • Formulate an emission reduction / improvement plan with quantified savings EPA-Victoria, with SEAV has developed an "Energy & Greenhouse Management Toolkit" which is a useful reference for those companies wishing to establish an energy and emissions management system. (See References 'Energy Management System')
NSW	Draft Guidelines for Energy Saving Action Plans mean that the highest commercial and industrial energy users, as designated by the Minister for Energy and Utilities, will be required to develop and implement Energy Savings Action Plans

Further details of the objectives of the pieces of legislation are provided in Appendix 2.

Environmental Best Practice Overview	
Knowledge of Energy Consumption • Measure & monitor consumption including load profiles (daily, seasonal, annual, etc) in order to compare performance against projections, and balance energy demand over time • Quantify and rank energy using plant & equipment.	**Appropriate Equipment Design & Selection** • Ensure all process equipment is energy efficient and appropriately sized for the load. • Apply energy efficiency principles to minimise energy consumption. • Implement heat recovery and reuse systems (eg hot water generation from rendering operations)
Management Focus on Energy Management • Include all costs including supply, operating and maintenance costs when assessing energy reduction initiatives	**Compliance** • Ensure energy management meets regulatory requirements.

Blast chiller fans

Best Practice Information

The meat industry utilises significant quantities of fuel and electricity. Well designed steam raising, hot water generation, process equipment and refrigeration plant can reduce energy costs and contribute to a reduction in greenhouse gas emissions.

The aim of this document is to assist the meat processing sector to achieve industry best practice for energy management.

Best practice energy management involves:

- Minimising heating fuel consumption
- Minimising electricity consumption
- Maximising heat recovery
- Monitoring and actively managing energy consumption
- Implementing continuous improvement

1.0 ENERGY OVERVIEW

Energy is used in meat processing to provide heating, refrigeration, motive power and lighting. Energy consumption depends on the range of processes conducted by the enterprise. In general:

- Fuel is used to produce steam (sometimes hot water directly)
- Steam is used for process heating and to generate hot water
- Waste process heat is recovered to generate hot water
- Some fuel is used for direct fired drying and on-plant vehicles
- Electricity is used to provide motive power for refrigeration, mechanical handling, size reduction, process machinery, hand tools and lighting.

Thermal energy, in the form of steam and hot water, is typically produced from boilers powered by coal, oil, gas or biomass. Steam is used for rendering, generation of hot water (82^{o}C for sterilising and 45^{o}C for cleaning) and process heat (eg scald tanks, white offal processing, protein coagulation and tank heating).

Waste process heat, particularly from rendering, is recovered for the generation of hot water.

Refrigeration is the largest user of electricity at meat plants. Other large usage areas are the multitude of motors that drive process equipment, pumps, fans, conveyors, and hydraulic systems.

Energy consumption depends upon the:

- age and size of the plant
- processes conducted on the plant
- extent and ratio of product chilling and freezing
- plant capacity utilisation

- plant operating schedules (eg single, extended, multi shift)
- range of products and co-products manufactured.

An estimate made of fuel use in the Meat and Meat Products Manufacturing industry was provided in a report prepared by Energetics for SEAV in March 2004 based on information available from the Australian Greenhouse Office. This information confirms that two thirds of the energy is used as fuel and one third as electricity with a total industry use in the order of 12 Petajoules.

SUMMARY	Percentage	Value (Petajoules)
Fuel	67%	8.3
Electricity	33%	4.1

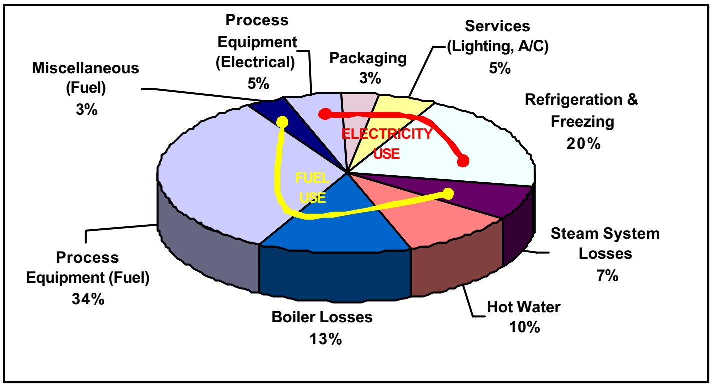
The cost of energy represents in the order of 5% of non-livestock operating costs (approximately $10/head – 2004) with electricity representing 3%-4% and fuel 1% to 2% of costs (ProAnd – Meat Industry Benchmarking Studies).

In the Energetics report, an estimate was also made of the break-up of energy use in the meat processing industry based on energy audit data and industry economic data. These estimates are provided below to provide an indication of the relative importance of energy use components.

Fuel	Equipment Type	Percentage	Value PJ
Electricity	Process Equipment (Rendering, Dressing, Boning etc)	5%	0.6
Electricity	Packaging	3%	0.4
Electricity	Services (Lighting, A/C)	5%	0.6
Electricity	Refrigeration and Freezing	20%	2.5
Gas/Other	Steam System Losses	7%	0.8
Gas/Other	Hot Water	10%	1.3
Gas/Other	Boiler Losses	13%	1.7
Gas/Other	Process Equipment (Rendering, Singeing, Scalding etc)	33%	4.2
Gas/Other	Miscellaneous (Fuel)	3%	0.4
	TOTAL	100%	12.5

Further Information

- *the Energy Efficiency Improvement Potential Case Studies* [1]



The Energetics report identified a series of best practice energy efficiency opportunities for the sector and these are provided in Appendix 1 with comments on current level of adoption by the industry.

2.0 FUEL SELECTION

Fuels are used for a variety of purposes in meat processing including steam raising, direct fired heating (eg pneumatic ring dryers, rotary kiln driers, hot water heaters, etc), process purposes (eg singeing & scalding) and for vehicles (forklifts, trucks, etc).

Fuel Source	Utilisation
Coal	Steam raising
Sawdust/biomass	Steam Raising
Fuel Oil	Steam Raising
Tallow	Steam Raising
Natural Gas	Steam raising, Direct heating, Process
LPG	Steam raising, Direct heating, Process, Vehicles
Butane	Steam raising, Direct heating, Process, Vehicles
Diesel	Direct Heating, Vehicles

An estimate of fuel use based on information available from the Australian Greenhouse Office indicates the total use and relative importance of various fuels in the meat processing sector. Electricity and natural gas represent two thirds of energy consumption.

Further Information

- *the Energy Efficiency Improvement Potential Case Studies* [1]

Fuel	Percentage	Value (Petajoules)
Black Coal	18%	2.3
Wood, Wood waste	5%	0.7
LPG	7%	0.9
ADO	1%	0.1
Fuel Oil	3%	0.3
Natural Gas	33%	4.1
Electricity	33%	4.1
TOTAL	100%	12.5

Oil fired boiler

LPG tanks

General principles in maximising efficiency of process heating includes:

- Maximise efficiency of generation in boiler (boiler efficiency)
- Maximise efficiency of distribution of steam and hot water around the plant
- Maximise efficiency of end use of process heating, by ensuring that:
    - end use equipment uses as little as possible to achieve the desired outcome
    - end use equipment is only running when required.
- Implementation of combination of controls:
    - software – documentation of operating procedures, employee training & awareness, maintenance scheduling
    - hardware – appropriate control equipment, where possible implement automated feedback control.

Boiler efficiencies vary depending on the fuel used. Approximate boiler efficiencies for different fuels are:

Fuel	Boiler Efficiency
Coal	76%
Fuel Oils	79%
Natural gas	80%

2.1 Steam Raising

Steam is raised in the meat processing sector to provide heat for rendering and ancillary processes, and to generate hot water (when there is no on-site rendering) or to supplement hot water generated from heat recovery systems.

Factors affecting boiler efficiency best practice include:

- Maintain steady, continuous load
- Well designed & maintained control equipment
- Regular tuning of burner controls
- Clean heat transfer surfaces and comprehensive insulation
- Good management of condensate return and blow-down to maximise heat recovery
- Appropriate feed-water treatment to minimise scaling and corrosion.

Smaller establishments, where there is no rendering operation, often install hot water boilers.

A comprehensive checklist of factors affecting boiler efficiency is provided in Appendix 3.

Further Information

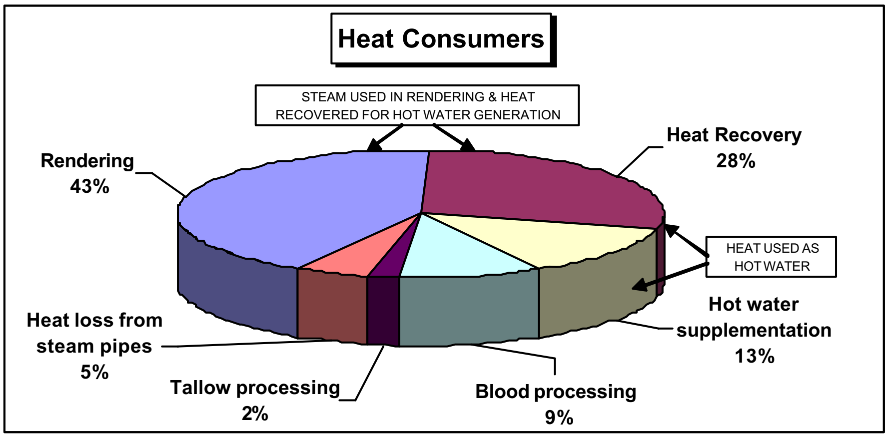
More information is available in the various editions of the following publications, as listed in the Steam Raising References:

- *the Energy Management Brochure For The Meat Processing Industry*
- *Sustainable Energy Authority Victoria*
- *UK Energy Efficiency Best Practice Program, 1994*

Steam vacuum cleaning of carcases

2.2 Steam Reticulation & Use

In a typical integrated meat processing plant with dry rendering, steam is raised to produce process heat for rendering and, from which heat is recovered for hot water generation, supplementary steam is used to generate hot water and for other process uses. An indication of the relative importance of heat users is provided in the following pie-chart. (Note: in wet rendering plants with direct fired driers fuel is used to directly heat dryer air).



Source: Adapted from Reference 2

Rendering plant energy utilisation and heat recovery issues are addressed in Section 2.5 and supplementary hot water heating is most commonly performed through the use of plate heat exchangers (see Section 2.3).

Scald tanks are often heated with direct steam injection in order to quick start up. It is preferable to combine both direct injection for start up and indirect heating for process operating periods.

General principles for sound steam reticulation practices include:

- Monitor steam use by department
- Ensure steam mains are properly sized, laid out, drained and vented, maximising the opportunity for gravity return of condensate
- Minimise steam leaks
- Insulate all steam pipes, flanges and valves and bare process plant surfaces
- Blank off or remove redundant steam piping
- Maintain high process plant loads, and minimise hot idle time
- Ensure process temperatures are well controlled and as low as possible
- Ensure the correct type of steam trap used for each application and that it is correctly installed and regularly maintained
- Maintenance program to detect and repair steak leaks and operation of steam traps
- Where possible increase the amount of condensate recovery and insulate condensate returns.

A comprehensive checklist addressing steam reticulation is provided in Appendix 5 – Steam Reticulation Checklist.

Apron wash

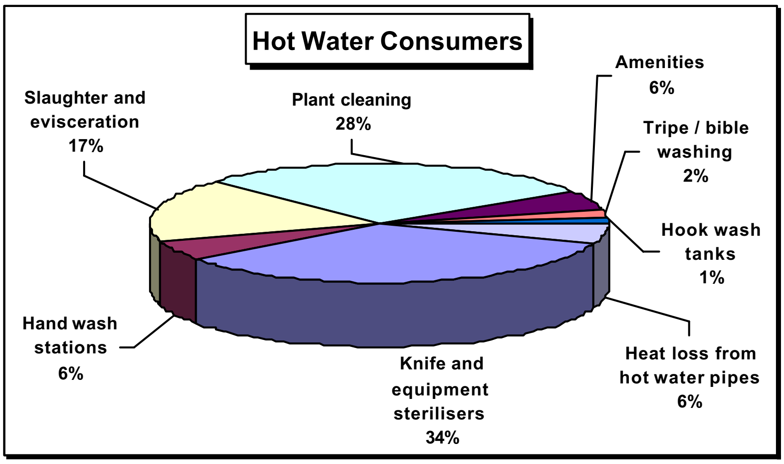
Further Information

- *Refer to the UK Energy Efficiency Best Practice Program* [21]

2.3 Hot Water

Large quantities of hot water are used in meat processing plants. The hot water use is driven by food safety requirements, so all of the suggestions provided must be considered in light of food safety and hygiene requirements.

The following pie chart provides an overview of the major hot water consumption in a typical export meat processing plant.



Source: Adapted from Reference 2

Hot water (82°C and above) is used for sterilising equipment including knives, hooks, viscera tables and hand tools. Approximately 25% of incoming water is used as hot water.

Warm water (approximately 45°C) is used mainly for hand and apron washing and wash-down purposes. Approximately 10% of incoming water is used as hot water.

Water at intermediate temperatures is also used in processing (eg white offal processing systems, scalding operations, etc).

End-of-production wash-down can involve a variety of rinse and sanitation cycles that utilise hot, warm, intermediate and cold water in varying proportions depending on the procedures in place.

Domestic registered processing plants generally use less hot water than export plants.

A hot water boiler is used where waste heat for hot water production is not available

2.3.1 Hot Water Generation

Heat Recovery

- Maximise the recovery of heat from rendering plants to generate hot water
- Recover hot water at as high a temperature as practical, (ie close to 80^{o}C) in order to minimise the discharge of hot water to the wastewater system and loss of energy from the system
- Heat recovery generating hot water at 60^{o}C generates an additional 50% volume compared with 80^{o}C, so consider how to balance heat recovery with hot water requirements to ensure that hot water does not flow to waste.

Hot Water Storage

- Install sufficient hot water storage to take into account any mismatch between the timing of generation from heat recovery and hot water demand
- Insulate hot water storage tanks.

Supplementary Heating

- Install efficient heat exchangers to generate or supplement the heating of hot water prior to delivery to the user Departments. Generally plate heat exchangers are used for supplementary heating and condensate is recovered
- Keep delivery temperatures as low as possible while still complying with hygiene requirements
- Use appropriate water treatment to minimise the accumulation of scale on heat transfer surfaces.

2.3.2 Hot Water Reticulation

Ring Mains

- Install ring mains for hot water supply in order to eliminate end-of-line temperature losses
- minimise distances between hot water generation and end use where practical, avoiding dead legs, long pipe runs and height variations in pipework wherever practicable
- ensure pipework diameter and system pressure is the minimum for the task required
- Insulate ring mains and consider how location of ring mains can minimise heat losses eg avoid elevated outdoor pipe runs if underground culvert is available
- Install and maintain mixing valves to provide intermediate temperature water
- Ensure program of regular of inspection of ring main to detect and repair leaks on a regular basis.

2.3.3 Hot Water Use

Efficient handwash and steriliser operation minimise energy waste

Hot Water General Use

- Ensure all hot water flows cease when they are not required through the use hardware or software eg electronic sensors and timers provide good flow control for intermittent devices
- Control hot water flows to meet and not exceed the required duty eg infra-red sensor or knee operated hand washing stations
- Monitor and maintain hot water flow controls.

Sterilisers

- Replace continuous overflow sterilizers with intermittent devices using infra-red sensors
- Ensure that continuous overflow devices are not overusing hot water by the use of inline flow restrictors
- Consider retrofit of inline flow restrictors for existing sterilisers, to limit maximum flow rate
- Ensure sterilisers are double skin insulated types, to minimise heat loss and reduce potential for worker injury
- Consider whether some sterilisers can be removed.

Hot Water Mixers

- Utilise hot water mixers to balance demand.

Viscera Tables

- Viscera tables are large users of both hot and cold water. Optimise viscera table cleaning operations to produce an acceptable surface cleanliness with a minimum of hot water, including shutting off flow during breaks. Ensure the design of the washing system and nozzles provides acceptable surface cleaning without excess use of water.

General equipment

- On larger floors, consider segregation of water supply to areas, so that flow can be sequentially started or stopped
- Consider installation of motion sensors for flow control
- Consider minimising the amount of carcass and working surface washing, through system automation, improved controls and nozzle design.

Plant Cleaning

- Ensure nozzles on hot water hoses have an efficient spray pattern, adequate but not excessive water pressure and are regularly maintained

- Ensure that hot water hoses cannot be left running unattended, through the use of triggers.

Water Re-Use

- Re-use hot water spent from hygienic operations in Departments that can use hot water that need not be potable. eg recover clean water from sterilizers, hand-wash basins and viscera table washing for use in yards or rendering raw material washing operations, hash washer, gut washing etc.

Further Information

- *Energy Management Brochure For The Meat Processing Industry* [22]

2.4 Heat Recovery

Heat recovery from vapour should be considered if there is a use for the hot water obtained. The advantage of heat recovery is significant and it is well worthwhile making a careful study in any plant where vapour is produced to ensure the hot water generated from heat recovery is maximised, such as cooker vapours in the rendering plant.

Meat processing plants have a large demand for hot water to address hygiene needs and plant wash down. Hot water tanks are required to store hot water in order to match heat recovery timing with hot water demand.

Examples of available heat sources and potential users of recovered heat are:

Potential heat sources	Potential users of recovered heat
Rendering process Screw compressor lubrication oil cooler	Hot water (82ºC) production, Warm water (43ºC)
Refrigeration de-superheater & condenser Condensate return & Boiler blowdown	Pre-heating boiler feed
Carcase singeing	Scald tank heating

Condensers are used to cool rendering vapours to minimise odour emissions and generate hot water for plant use

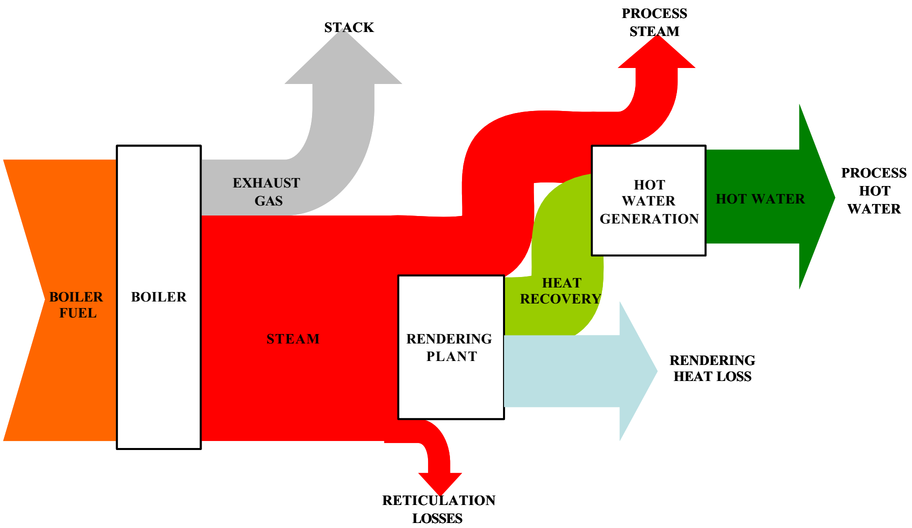
Further Information

- *Energy Management Brochure For The Meat Processing Industry* [23]
- *Heat Recovery, Sustainable Energy Authority Victoria* [24]

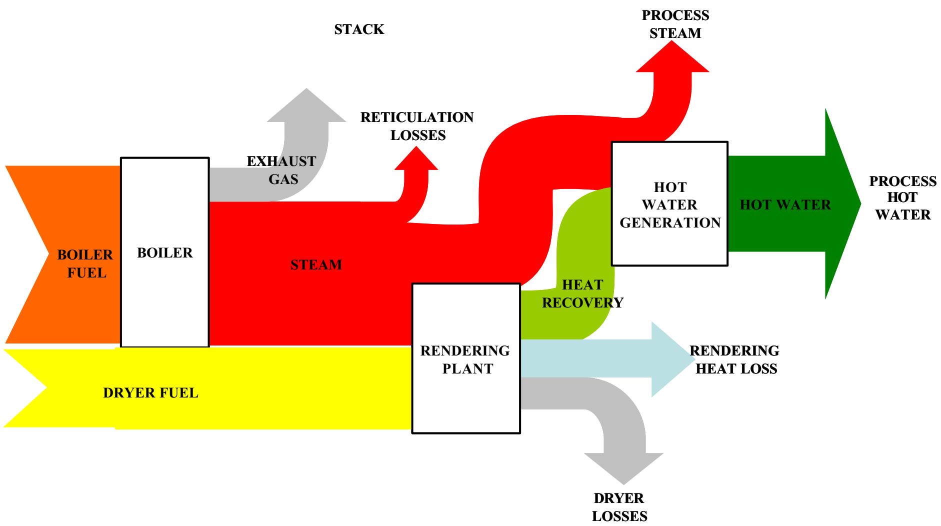
2.5 Product Rendering/Drying

The following figures provide typical Sankey diagrams for heat use in rendering plants. In dry rendering plants heat is recovered from the cooking vapour condensing system. In wet rendering with direct fired drying heat is recovered principally from the dryer.

SANKEY DIAGRAM – TYPICAL HEAT USE DRY RENDERING



SANKEY DIAGRAM – TYPICAL HEAT USE WET RENDERING – DIRECT FIRED DRYING



General principles in maximising the energy efficiency of rendering include:

- Minimise the amount of water entrained in the material entering the rendering plant
- Maximise the amount of condensate recovery in dry rendering systems
- Maximise the amount of heat recovery from cooker vapours
- Insulate equipment such as cookers and driers, to minimise heat loss and improve the working environment.

In order to minimise energy requirements it is important to minimise any added water in the blood or rendering raw material. If washing of the raw material is necessary to obtain satisfactory quality finished meal and tallow or water needs to be added for transport lubrication, then the raw material needs to be drained. In principle raw material should be collected with minimal inclusion of added water, with a preference for screw conveyors rather than pneumatic systems with blow tanks if plant layouts allow.

Further Information

- *Eco-Efficiency Manual for Meat Processing* [2]

One water outlet running at 20 litre/minute can add over 1 tonne of water to the raw material every hour. Rendering plants are generally sized in the order of 5-10 tonne/hour. The effect on the volume of raw material and the subsequent energy demand is significant (10-20% of the load). The energy consequences have a greater impact in evaporating processes such as dry rendering.

Process and storage tank heating should be provided by sufficient heat transfer surface area (eg steam coils) fitted with steam traps and condensate recovery. Tanks should be insulated and have controls installed to operate at the lowest required temperature. Locating the tanks in a sheltered position may also assist with minimising the heat losses (undercover, out of prevailing wind), as can scheduling of loading operations to minimise the heating requirements for the tanks.

2.5.1 Wet Rendering

Continuous low temperature wet rendering systems involve direct injection of live steam into a cooking vessel where the rendering raw material is heated for a short period prior to passing to a centrifugal decanter system to separate the liquid and solid phases.

The solid phase is dried in either a direct heated rotary kiln type continuous drier, or in an indirect (steam) heated disk dryer. Both of these drying systems are normally fitted with heat recovery systems for the generation of hot water for use in the meat processing plant.

While continuous low temperature rendering generally requires less heat input than dry rendering systems as less moisture is evaporated, from an energy point of view there are some disadvantages:

- Condensate return is low due to the use of live steam
- Waste heat recovery efficiency is reduced in direct fired drying systems.

In order to address other environmental issues, a number of wet rendering systems have been retro-fitted with waste heat evaporators to process the stickwater from the primary decanting system.

Water inclusion in the raw material needs to be minimised, condensate recovery should be maximised, and steam lines and hot surfaces of the rendering system should be insulated.

2.5.2 Dry Rendering

Dry rendering involves evaporating the moisture from the rendering raw material in either a batch processing system (batch cookers) or in a continuous dry rendering vessel. Both systems utilise steam for indirect heating/drying of the rendering raw material.

Dry rendering systems are fitted with vapour condensers to recover waste heat for the production of hot water for use in the meat processing plant.

Water inclusion in the raw material needs to be minimised, condensate recovery should be maximised, and steam lines and hot surfaces of the rendering system should be insulated.

2.5.3 Blood Processing

Blood is processed by direct steam injection into an in-line coagulation system, followed by centrifugal separation of solids and liquid. The solids are then dried in a direct fired pneumatic ring dryer.

Due to the low temperature and dust content it is not practical to recover waste heat from the direct fired pneumatic drying system.

Direct steam injection into the coagulator means that no condensate is recovered.

All steam lines and hot surfaces of the pneumatic drier and blood processing system should be insulated.

Modern energy efficient blood processing unit

2.5.4 Summary

In best practice rendering systems, regardless of the system in operation the net energy use should be monitored and minimised. Rendering plants use around 70% of the heat generated on a meat processing plant, of which around 40% is recovered to generate hot water. See Section 2.2.

Steam use in the rendering plant needs to be monitored as does the fuel use in any direct fired drying process. The heat recovered needs to be calculated from the temperature and volume of hot water generated from the heat recovery system.

Different types of energy are used within the meat plants, with different units of measurement (tonnes coal, kWh electricity, m^3 gas, etc.). It is convenient to convert them to a common unit, such as megajoules (MJ). The following calorific values and conversion factors are typical:

Coal	30.7 MJ/kg
Natural gas	39.5 MJ/m^3
Fuel oil	43.1 MJ/kg
LPG	49.6 MJ/kg
Electricity	3.6 MJ/kWh
Steam	2.8 MJ/kg steam
Hot Water (85^{o}C)	280MJ/klitre
Hot Water (45 ^{o}C)	120MJ/klitre

Monitoring net energy use will identify inclusion of free draining water significantly better than monitoring of products yields.

Further Information

- *Energy Management Brochure For The Meat Processing Industry* [25]

2.6 Insulation

In order to reduce heat losses and ensure worker safety both hot and cold surfaces need to be insulated. General principles for good insulation practices include:

- Insulation should be fitted to
  - hot surfaces above 50^{o}C
  - all refrigeration suction lines
  - cold surfaces below 10^{o}C.
- Correct installation, avoiding damage due to impact, weather or wear, and no open joints, is required to maximize the effectiveness of the insulation
- The technical suitability of an insulation system is of primary importance; however availability, service and cost should also be taken into account

(such as clearance around pipes, additional weight, heat losses through conduction to supports)

- Insulating pipes, flanges and valves, with removable jackets to give access where required
- Preventing the ingress of water or chemicals
- The insulation of hot gas ducts and flues for safety and to prevent internal condensation and possible corrosion.

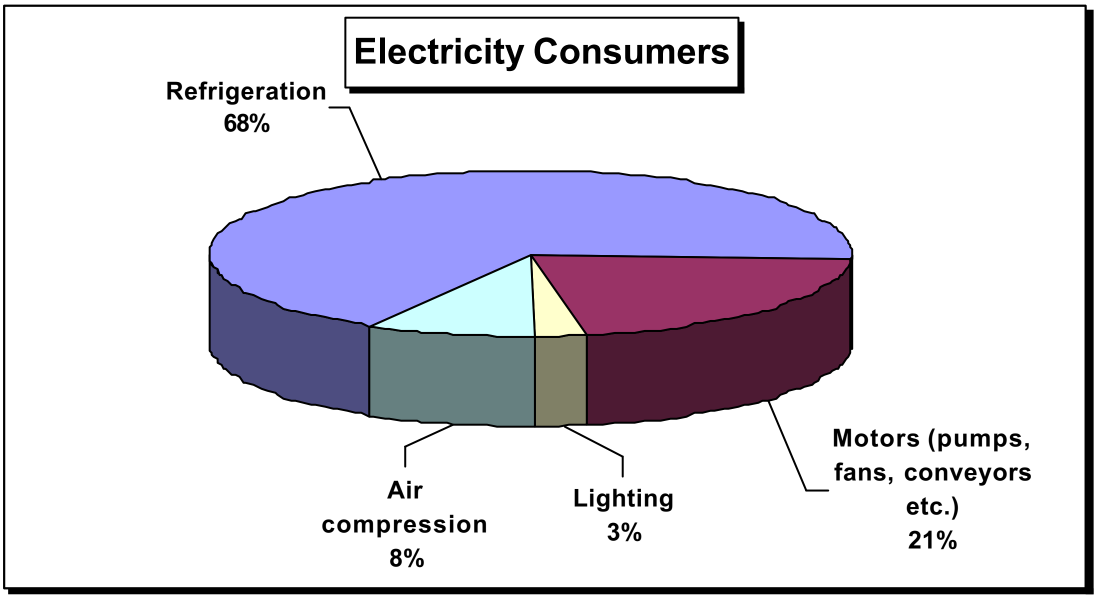
A comprehensive checklist addressing insulation issues is provided in Appendix 4 – Insulation Guidelines.

Further Information

- *UK Energy Efficiency Best Practice Program* [17 / 19]
- *Sustainable Energy Authority Victoria* [18]
- *Insulating steam distribution valves and flanges, CarbonTrust* [20]

3.0 ELECTRICITY USE

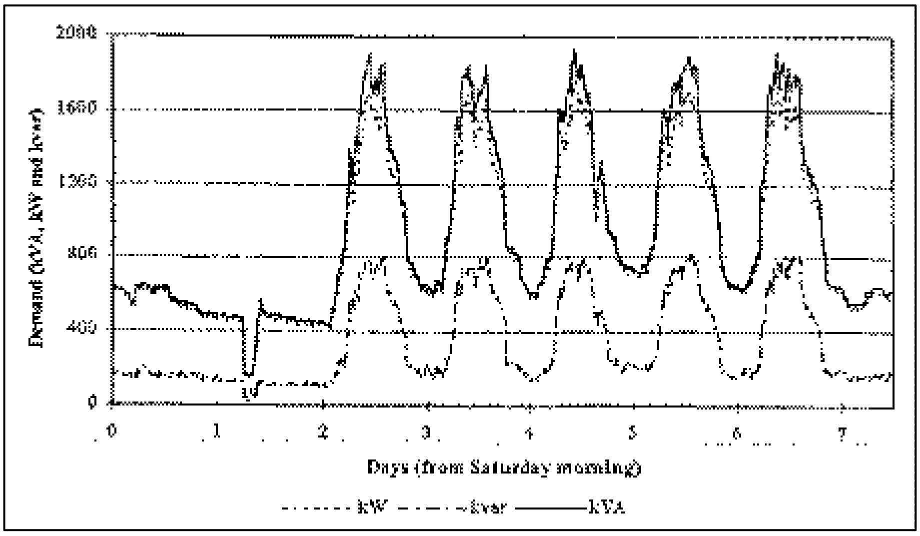
Electricity is consumed to provide power principally for refrigeration, process equipment and lighting. The following pie-chart provides an indicative consumption profile for a typical export meat processing plant with rendering facilities. Significant variation to this profile will occur with different refrigeration requirements (eg domestic operations handling carcases with no boning, absence of rendering, level of mechanisation, etc).



Source: Adapted from Reference 2

The level of electricity consumption will depend upon the factors outlined in section 1.0 Energy Overview.

A typical load curve for a five day single shift operation is shown in the following diagram. As the meat processing industry increases the implementation of extended and double shift operations, the electrical load factor significantly improves.



A series of general principles can be adopted to achieve best practice electricity consumption, regardless of the actual equipment installed and plant operating characteristics.

Electricity charges at consumption levels associated with meat processing almost always include demand and consumption charges. Successful electricity saving projects need to address the benefits of both demand impact and consumption reduction.

These principles include:

- Rescheduling processes to reduce demand coinciding with peak times
- Selecting appropriate evaporating temperatures and maintaining the lowest achievable condensing pressure
- Adopting good door management principles in cold rooms
- Ensure that all electrical equipment (eg lights, conveyors, heaters, etc) is switched off when not in use
- Ensure compressed air is only used when needed and that the system is in good condition with no leaks
- Ensure selection and maintenance of most energy efficient equipment.

The following sections address electrical energy consumption systems in more detail.

Refrigeration compressors are high energy consumers

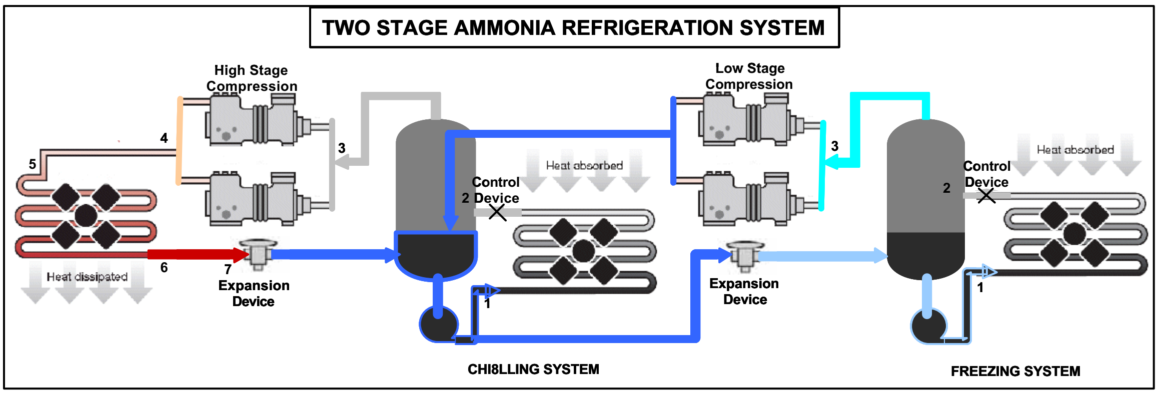
3.1 Refrigeration

Refrigeration accounts for between 60% & 70% of electrical use in meat processing operations. The energy efficiency of a meat processing refrigeration system can be influenced by:

- Reducing the refrigeration heat load
- Reducing the associated electrical use (eg fans, lights, etc), or
- Improving the refrigeration plant coefficient of performance

Best practice meat processing refrigeration systems aim to achieve effective and rapid carcase chilling and plant freezing is a two stage pumped refrigeration system (see following diagram and description). The pumped system (flooded evaporator) is preferred as control of the refrigerated space is improved, particularly under varying load conditions (eg early stage carcase chilling) and evaporator coil surfaces are kept continually wet. Both factors contribute to improved refrigeration efficiency.

Best Practice Meat Processing Refrigeration Cycle



Ammonia refrigerant systems are current best practice in meat processing operations. Typically the energy requirement for freezing in a two stage ammonia refrigeration system is in the order of half that required by alternative HFC refrigerants.

3.1.1 The Refrigeration Load

The cooling load on the refrigeration system determines the size of the refrigeration plant and therefore its power consumption.

The load is usually made up of a number of different components such as:

- Product load
- Heat gains through walls, floor and ceiling
- Heat gains from air changes through doors etc
- Heat from fan motors and lights in the refrigerated space
- Heat from pumps and other electrical devices in the refrigerated space
- Heat from people and handling equipment, such as fork-lift trucks, etc
- Defrosting.

Product load in active chilling and freezing facilities in meat plants is typically 80% of the total cooling load and can only be lowered by reducing production.

It is important to ensure that refrigeration compressors operate at better than 75% of full load. The product heat load varies significantly over time and it is desirable to have a range of compressors sizes installed and system controls that ensure compressors are adequately loaded.

Heat leakage occurs through ceilings, floors and walls and can be reduced by sound insulation design and installation. Insulation properties deteriorate with time and thermal imaging can be used to assess leakage and make repairs.

Air infiltration through doors leads to increased refrigeration load and condensation. A chiller door open to a slaughterfloor could increase the refrigeration load by 33kW. Doors must be easily opened and closed (preferable mechanically operated rapid door technology), and staff encouraged to implement good door management practices.

The fan load dominates electricity use within the active refrigerated space (ie chillers, freezers). Best practice control of refrigerated space involves implementation of refrigeration cycles to suit product requirements, including fan speed control. While high air velocity reduces refrigeration time, a doubling of air velocity requires an eight fold increase in fan power.

While lighting is a relatively small load in refrigerated spaces, energy savings can be made by good lighting design and management.

With implementation of correct temperature setting and controls, defrosting of chilling cycle evaporators is not required. It is important to control air ingress into frozen storage space as air moisture will form ice on the evaporator and freezer structure. Good door management and integrity of vapour seals reduces moisture ingress and therefore defrost requirements.

Internal heat sources impact twice, since heat generated from the evaporator fan motor and lighting must be removed from the cold store by the refrigeration system.

Plate freezer

The energy efficiency of a refrigeration system is expressed as the Coefficient of Performance (COP) and this should be monitored to determine any deterioration in performance. In a typical meat processing plant with both chilling and freezing duties, a good performance COP would be in the region of 2.5 kW refrigeration/kW compressor power.

Further discussion on COP and COSP is provided in Appendix 6. This Appendix also discusses other factors such as compressor selection and impact of refrigerant charge.

3.1.2 System Selection

Selection of the refrigeration systems can have a significant impact on electrical consumption.

Blast freezers require significant electricity to operate the fans installed in the refrigerated space, and the heat generated form these fans adds load to the refrigeration system. Best practice blast freezing involves a 48 hour freezing cycle for standard meat cartons (air speed approx 3m/s) as the energy requirement associated with fan speeds to achieve a 24 hour cycle (air speed approx 10m/s) is excessive.

Plate freezers do not require fans, as freezing is performed by conduction rather than convection. As a result, plate freezer systems have a significantly better COSP and consume less energy per tonne of meat frozen compared to blast freezers. Energy required to freeze product in a plate freezer can be 30% to 40% lower than that required in a blast freezer and freezing can be accomplished in a 24hour cycle.

Chiller design should be optimised to ensure even temperature and air flow throughout the chiller to provide good quality product with minimum shrink loss.

3.2 Drive Motors

There are a large number of motors installed in meat processing plants that drive process equipment, pumps, fans, conveyors, and hydraulic systems. The load characteristics of the motors vary from relatively constant load (eg conveyors and pumps) to significant shock loads (eg some size reduction equipment). Drive motors are invariably supplied with the equipment provided by the manufacturer. When retrofitting equipment or motors, best practice requires specification of duty and starting/control system. The AGO maintains a Motor Solutions Website to assist in the selection of motors.

Further Information

- *www.greenhouse.gov.au/motors*

The following provides a best practice checklist to assess on-site use of drive motors:

Reduce Motor Load

- Optimise the efficiency of the process that the motor is driving
- Ensure that transmission between motor and driven equipment is efficient
- Establish sound monitoring & maintenance programs
- Ensure the control system is effective.

Motor Losses

- Specify higher efficiency motors where feasible
- Avoid using oversized motors
- Check that voltage imbalance, low or high supply voltages, harmonic distortion or a poor power factor are not causing excessive losses.

Motor Speeds

- Due to the cube law applying to pump or fan applications, even a small reduction in speed can produce substantial energy savings
- Use variable speed drives (VSDs) where several discrete speeds or an infinite number of speeds are required. Although often the most expensive option, the many benefits and large energy savings from VSDs make them the usual choice for speed control
- Use multiple speed motors (MSMs) where two (and up to four) distinct duties exist
- Ensure the correct pulley ratio where belt drives are used.

Equipment Redundancy

- Check that changing requirements have not eliminated the need for the equipment altogether.

Switch Motors Off

- Time the switching according to a set program or schedule
- Monitor system conditions, and switch off the motor when it is not needed
- Sense the motor load so that the motor is switched off when idling.

3.3 Electricity – Other

3.3.1 Air Compressors

Compressed air in the meat industry is used by air driven hand tools, pneumatic actuation systems and material transport systems. The compressed air is generally required to be provided at around 700kpa (100psig). Single stage, reciprocating or screw compressors are most commonly used.

Examples of equipment types and free air usage are:

Device	Litre/second
Hide skinning knives	6-7.5
Fat & Bone trimmers	4
Circular breaking saw	13
Large reciprocating saw	25
Small reciprocating saw	13
Small scribing saws	8.5-10
	Litre/cycle
Beef hock cutter	0.5
Smallstock hock cutter	0.1
Smallstock brisket scissors	9

The greatest demand for compressed air in meat processing operations is that usually associated with pneumatic systems for material transfer. These are usually batch systems operated from a blow tank. A typical blow tank system will use in excess of 2.5m^3 of free air per blow cycle.

The following provide details of best practice associated with the operation of compressed air systems in the meat industry.

Air compressors

Compressor selection

- Select or operate compressors at 70 to 80% duty cycle

- Modern screw compressors can have inbuilt VSD's which allows them to efficiently operate over a wide load range.

Good housekeeping

- Turn off compressors during non-productive hours
- Review the air pressure required. If it can be reduced it will reduce consumption and leakage
- If some applications require higher pressures or have longer operating hours than the rest of the system, investigate installing a dedicated compressor
- Compressors operate more efficiently using cool air
- Control/sequence compressors to operate on a "demand-controlled" basis. Compressors use as much as 70% of on-load power when they are idling
- Carry out "out of hours" surveys, to listen for leaks, locate and eliminate
- Isolate redundant piping
- Install an air receiver with volume greater than 10 litres per compressor kilowatt.

Treatment

- Treat the bulk of the air to the minimum level possible, and improve the quality for specific appliances if required.

Use of Compressed Air

- Make sure that air tools are not left running when not in use
- Consider alternatives to compressed air hand tools. Where possible replace air motors with correctly specified electric motors
- Eliminate unregulated compressed air use endpoints (eg quarter-inch pipe instead of correct nozzles).

A detailed checklist is provided in Appendix 7.

3.3.2 Lighting

Lighting Design

- Lighting design must provide conditions for the users to carry out their tasks safely, comfortably and with high productivity. The lit appearance of the building interior is important for example the lumen requirements for inspection zones.
- Select the lamp for the application particularly with regard to its colour performance and its operating characteristics etc. Then select the lamp with the highest efficacy (lumen/Watt). Use the most energy efficient ballast units, with the required control e.g. dimming etc.

Lamp Type	Efficacy lumen/Watt
Incandescent – Tungsten Filament	8 – 12
Incandescent – Tungsten Halogen	12 – 24
Compact Fluorescent	50 – 85
Tubular Fluorescent	65 – 100
Low Pressure Sodium	100 – 190
High Pressure Sodium	65 – 140
High Pressure Metal Halide	70 – 100

Daylight

- The provision of daylight in a building can have important benefits on the productivity of the occupants. It can also have important benefits in saving energy used for lighting. This requires careful design, of the window system, as well as the lighting system. Examples include maximising the amount of daylight in stockyards, slaughter floors, skins sheds etc.

Lighting Controls

- Use occupancy controls to ensure that lights are not left on unnecessarily such as storeroom, meeting rooms, stair wells. This will make for an energy efficient lighting installation and save the user money.
- Good lighting controls, including switches and manual/fixed dimmers, operated either manually or automatically via light and occupancy sensors, provide important benefits in terms of energy efficiency. They must be user friendly and seen by the occupants as an important benefit and hardly noticeable in their operation. Examples include daylight sensors in the stockyards and outside areas.

Ventilation

Meat plants require ventilation for both non-refrigerated and refrigerated spaces.

In non-refrigerated spaces, comfort conditions for the employees provide the basis for the ventilation requirement. Ventilation fans fitted with VSD’s improve control of comfort conditions and minimise energy use.

In refrigerated work-spaces, the ventilation requirement is set by the number of number of employees in the workspace. 5litre/sec of fresh air is required per person. Ventilation air volumes should be reviewed against employee numbers and checked to ensure that required levels are not significantly exceeded.

Aeration

Some meat plants are implementing forced aeration wastewater treatment systems in order to comply with increasingly stringent discharge requirements.

Due to the high biological oxygen demand of meat processing wastewater, the electricity consumption required to provide adequate aeration can be considerable and the system generally runs 24 hours a day seven days a week.

Even for aeration systems following anaerobic digestion, it is common to have in excess of 50kW of aeration installed. This is greatly increased in treatment systems such as Sequenced Batch Reactor and Activated Sludge.

Implementation of aeration control through measurement of dissolved oxygen levels and feedback control of the aerator can reduce the electricity required for aeration.

Switchboards

Thermal imaging of switchboards is becoming common practice in the industry.

The thermal imaging can display unnecessary energy use but is more important to detect poor connections and potential safety hazards.

3.4 Power Factor

Power factor is a measure of how effectively electrical power is being used by a system.

If the Power Factor of a system is low, it uses more power than it needs to do the work. This results in:

- excessive heat being generated
- extra maintenance costs
- the potential for fires in extreme situations

- low voltage conditions which result in sluggish motor operation and dim lights.

Optimise Power Factor

- The use of Power Factor correction equipment in the form of a capacitor bank should be installed as close as possible to the meter point or the equipment that is the main culprit
- A power factor of better than 0.96 is considered best practice for meat plants. Power factor correction systems can achieve power factors better than 0.99.

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Useful Websites

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NSW Department of Energy, Utilities and Sustainability and WA Sustainable Energy Office - The Energy Smart Toolbox provides information, knowledge and resources relating to energy efficiency and energy management.

http://www.caddet.org/links/index.php

This is a good general website that provides links an updates on energy efficiency and renewable energy technologies.

http://www.eere.energy.gov/femp/operations_maintenance/

US Federal Energy Management Program information with advice on operation and maintenance of energy using systems http://www.steamingahead.org/

Steaming Ahead provides advice and solutions to enhance steam systems

http://www.oit.doe.gov/bestpractices/

US Department of Energy – Advice from the US Energy Efficiency & Renewable Energy Best Practice Program

APPENDIX 1

Energetics EEI Opportunities

Energy efficiency improvement (EEI) opportunities in the meat industry identified by Energetics Pty Ltd, “Energy Efficiency Improvement Potential Case Studies – Industrial Sector” (Reference 1)

ELECTRICITY	RECOMMENDED ACTION	COMMENT ON DEGREE OF USE
All Electricity	High efficiency motors	Some as motors are replaced and upgraded
All Electricity	Energy monitoring and control	Increasing as part of supply arrangements
Packaging	Improve operating practices to balance demand & minimise energy waste (e.g. breaks, out of hours)	
Process Equipment (Rendering, Dressing, Boning, Pumps, etc)	Improve operating practices to balance demand & minimise energy waste (e.g. breaks, out of hours)	Increasing as extended and double shift operations are introduced
Process Equipment (Rendering. Dressing, Boning, Pumps, etc)	Variable speed drive control and automation of motors & pumps	Significant use of speed control in some areas
Refrigeration & Freezing	Control of refrigeration equipment in chillers, freezers & cold stores to minimise energy consumption	Majority have a degree of SCADA control implemented
Refrigeration & Freezing	Maintain chillers, freezers and cold storage fully sealed when not required	Mostly practiced
Refrigeration & Freezing	Automate temperature profile control and implement fan speed controls	Mostly practiced
Refrigeration & Freezing	Optimise condenser operation (e.g. pressure reduction using fan speed control, purging operation)	Majority have a degree of SCADA control implemented
Refrigeration & Freezing	Optimise ancillary equipment (e.g. Variable speed drives for cooling tower fans, cooling and chilled water, refrigerant pumps)	Majority have a degree of SCADA control implemented
Refrigeration & Freezing	Optimise compressor performance (e.g. Staging controls, Variable speed drive control, electronic expansion control)	Majority have a degree of SCADA control implemented
Refrigeration & Freezing	Optimise design of blast tunnel fans	Increasing use of plate freezers

		Blast freezers on 48hour cycles
Refrigeration & Freezing	Utilise high efficiency, multiple stage refrigeration plant	Two stage ammonia plant with liquid recycle fitted in most circumstances
Services (Lighting, A/C Boiler)	Implement best practice lighting technology & lighting controls (e.g. in vacant areas, offices, carcass stores)	Mostly implemented as lighting reviewed and upgraded to meet AQIS requirements
Services (Lighting, A/C Boiler)	Optimise heating, air conditioning controls and set points	Some plants have full supervisory control systems implemented

FUEL	RECOMMENDED ACTION	COMMENT ON DEGREE OF USE
All Fuel	Energy monitoring and control	Some implementation
Boiler Losses	Install oxygen trim control	Some implementation
Boiler Losses	Automate blowdown on Total Dissolved Solids and recover heat to boiler feedwater tank	Some implementation
Boiler Losses	Install economiser on boiler flue gas	Limited installations
Boiler Losses	Upgrade to a high efficiency modulating burner with low turn down ratio	Some implementation
Hot Water	Reduce hot water usage using efficient nozzles, trigger action valves, etc	Mostly practiced
Hot Water	Maintain hot tank and line insulation, repair leaks	Mostly practiced
Hot Water	Recovery heat from refrigeration superheat to pre heat hot water	Limited
Process Equipment (Rendering, Singeing, Scalding, etc)	Optimise loading of render plant & balance with hot water heating demand to even steam demand	Mostly practiced
Process Equipment (Rendering, Singeing, Scalding, etc)	Cover surface, insulate and recover heat from all hot water tanks and vessels	Mostly practiced
Process Equipment (Rendering, Singeing, Scalding, etc)	Heat recovery from rendering plant exhaust streams	Almost always practiced
Steam System Losses	Maintain steam traps, optimise condensate return, insulate all valves, flanges, lines, remove dead legs, & repair leaks	Mostly practiced

APPENDIX 2

Legislation

LEGISLATION	OBJECT OF THE LEGISLATION
National Environment Protection Measures (Implementation) Act 1998	The objects of the Act are: • to make provision for the implementation of national environment protection measures in respect of certain activities carried on by or on behalf of the Commonwealth and Commonwealth authorities • to protect, restore and enhance the quality of the environment in Australia, having regard to the need to maintain ecologically sustainable development • to ensure that the community has access to relevant and meaningful information about pollution.
National Strategy for Ecologically Sustainable Development	The core objectives of the NSESD strategy are: • to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations • to provide for equity within and between generations • to protect biological diversity and maintain essential ecological processes and life-support systems. The Guiding Principles are: • decision making processes should effectively integrate both long and short-term economic, environmental, social and equity considerations • where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation • the global dimension of environmental impacts of actions and policies should be recognised and considered • the need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection should be recognised • the need to maintain and enhance international competitiveness in an environmentally sound manner should be recognized • cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms • decisions and actions should provide for broad community involvement on issues which affect them,

National Greenhouse Strategy	The goals of the NGS are: • To limit net greenhouse gas emissions, in particular, to meet our international commitments • To foster knowledge and understanding of greenhouse issues • To lay the foundations for adaptation to climate change.
Greenhouse Challenge Plus	Greenhouse Challenge Plus is designed to • Reduce greenhouse gas emissions • Accelerate the uptake of energy efficiency • Integrate greenhouse issues into business decision-making • Provide more consistent reporting of greenhouse gas emissions levels. All existing members of Greenhouse Challenge, Greenhouse Friendly and Generator Efficiency Standards become members of Greenhouse Challenge Plus on 1 July 2005. For the majority of participants, the decision to join Greenhouse Challenge Plus is voluntary. However from 1 July 2006, participation in Greenhouse Challenge Plus will be a requirement for Australian companies receiving fuel excise credits of more than $3 million. Proponents of large energy resource development projects will also be required to participate in the programme. More information on the mandatory elements of Greenhouse Challenge Plus will be available in 2005
Relevant legislation, policies and programs in the states and territories	Legislation affecting land use and development is the responsibility of the States and Territories and concentrates on processes affecting the consideration of applications for the use or development of land, such as zoning or permit issuing procedures. Legislation in a number of jurisdictions specifies environmental objectives however only limited planning legislation specifically requires the consideration of greenhouse emissions in making planning decisions. In **VICTORIA** in addition to management of various air pollutants SEPP includes a Protocol for the Environmental Management of greenhouse gas (GHG) emissions and energy consumption (PEM 824). EPA Licence holders (scheduled premises) must complete a number of key steps including: • Undertake an Energy Audit including a profile of baseline energy consumption • Prepare a greenhouse emissions inventory • Formulate an emission reduction / improvement plan with quantified savings The policy aims to ensure businesses take up cost effective opportunities for Greenhouse Gas mitigation and integrate GHG and energy issues with existing environmental management procedures and programs. It is likely in future years that other states will adopt similar requirements.

APPENDIX 3

Boiler Efficiency Checklist

Factors affecting boiler efficiency best practice include:

Load Scheduling

- Maintain load requirements that are steady, consistent and continuous
- Minimise periods of no load or low load, and short-term load swings
- Schedule the boilers to match the steam demand
- Eliminate, where possible, the use of boilers on hot standby at full pressure
- Set boiler sequencing controls (when installed in a multi-boiler plant) to adjust the number of boilers and firing rate to suit the load pattern.

Heat Transfer Surfaces

- Maintain clean gas and water side heat transfer surfaces. Cleaning is required if the flue gas temperature increases by 20–40ºC compared with the clean boiler condition.

Radiation Losses

- Maintain boiler insulation in good condition
- Ensure all pipe-work, valves, flanges and fittings in the boiler-house are insulated and replaced after maintenance work.

Boiler Operation

- Maintain all boiler kit in good condition
- Provide superior controls & regular burner servicing to improved fuel to air ratios.

Scaling

- Provide proper feed-water treatment and regular cleaning of the water side of boiler tubes to ensure that any precipitated salts do not adhere to heat transfer surfaces.

Corrosion

- Control pH levels in the boiler to give an alkaline environment in a safe range (pH 8.2–12.5)
- Limit the oxygen concentration in boiler water
- Add neutralising or filming amines to control corrosion in condensate systems when required.

Boiler Water Treatment & Conditioning

- Reducing feed-water TDS reduces blow-down and saves energy
- Maximising condensate return
- Provision of sound chemical control will save money and protect assets.

Blow-down

- Automate blow-down
- Minimise blow-down
- Control TDS limits to minimize boiler blow-down
- Maximise the amount of condensate returned.

Heat Recovery

- Implement blow-down heat recovery.

Burner Management

- Check combustion conditions (flue gas temperatures, flue gas constituents, flame shape, fuel and air trim settings) as a matter of routine
- Minimise flue gas oxygen levels without producing smoke or excessive levels of unburnt carbon.

Variable Speed Drives

- Variable speed drives help to reduce electrical power consumption significantly at low speed operation, reduce average noise levels, provide more flexible control, and improve combustion control on boilers.

APPENDIX 4

Insulation Guidelines

Insulation will reduce heat losses and the following checklist provides best practice guidelines.

General Principles

- Hot surfaces above 60°C and most of those above 50°C should be insulated. The insulation of many surfaces below 50°C will often also be justified, particularly from a cost saving point of view. Surfaces include valves and flanges, in addition to pipes and other plant
- Pipes carrying chilled water and other refrigeration services should be insulated to prevent condensation and heat gain
- Incorrect application can reduce the effectiveness of the insulation.
- It is important when installing insulation to ensure that:
    - the insulation will not suffer subsequent damage due to impact, weather or wear. The ability of the insulation type to withstand the conditions in which it will be placed must be considered
    - removable insulation jackets are used where necessary to give convenient access
    - there are no open joints in the insulation; overlapping of two layer insulation should be carried out if necessary
    - heat losses by conduction to supports are eliminated as far as possible. The use of insulated pipe supports should be considered
    - proper on-site supervision is provided; for example, by using specialised insulation contractors. Insulation is often not as efficient as it could be because it has been applied under poor conditions. If insulation is stored prior to application, care must be taken to avoid physical or weather damage
    - as much work as possible is done off site prior to delivery so that installation times can be minimised and the risks involved can be reduced.

Pipes

- Pipe insulation is the most common form of insulation used in industry
- Flanges and valves need to be insulated. Preformed, easily removable insulation sections tailored to these items of pipe-work fittings are available. Ideally the thicknesses of insulation on flanges and valves should be the same as that on the adjoining pipe; this may be impractical due to space and other limitations
- As an indication of the scale of heat loss from flanges and valves, an un-insulated valve would lose heat equivalent to a 1 m length of un-insulated pipe, and an un-insulated flange will lose half this value

- Pipes also lose heat through their supports, and these should be insulated
- Good insulation can be ruined by the ingress of water or chemicals.

Vessels and large curved surfaces

- When insulating vessels, the need to dismantle associated pipe-work and remove inspection covers should be anticipated. Permanent insulation should end sufficiently far away from flanges and fittings to enable bolts to be withdrawn, with removable sections used to complete the insulating layer. For external applications or where fluid spillages can occur, the permanent insulation should have a suitable finish to prevent fluid ingress when removable sections are not in place
- Special consideration should be given to the support of insulation for vessels and columns subject to wind loads
- Where a vessel containing a hot liquid has an open top, additional heat loss can occur by evaporation. This loss can be minimised by adding a blanket of commercially available floating plastic balls to the surface of the liquid. A single layer of balls which covers 91% of the surface of the liquid would reduce the energy input required to maintain the tank liquid at 90°C by 70%.

Hot gas ducts and flues eg boiler stack, cooker stacks etc

- The insulation of hot gas ducts and flues should be carried out for two main reasons:
    - for safety, because of the high external temperatures
    - to prevent internal condensation, normally caused when internal surfaces fall to a temperature below the dewpoint of the gases being conveyed. Condensation can lead to corrosion, particularly in the exhaust ducts of oil-fired boiler plant where the flue gases are acidic. It is important to ensure that there is no ‘bridging’ in the insulation, which could result in local cold spots. Care should also be taken at access points for temperature and sampling probes and any expansion joints should be adequately insulated to prevent corrosion.

Furnaces and kilns

- Whichever method of insulation is used, heat losses affected by insulation are:
    - the loss through the furnace walls due to conduction, convection and radiation
    - the loss due to the thermal mass of the furnace.
- These losses can be minimised by proper insulation
- In continuously operated furnaces, the heat loss through the walls at full working temperature is much greater than the energy required to heat up the mass of the furnace. Thus in continuously operated furnaces insulation is required to prevent heat loss through the walls and roof
- The insulation of furnaces requires careful consideration of the changes in temperature that may occur during operations.

Boiler plant

- The insulation of boiler plant is normally carried out adequately by the boiler manufacturer, either at the manufacturer's works or during installation on site. The insulation will generally take two forms:
  - mineral fibre slabs fixed to the outer surface of the boiler shell, with an appropriate finish, to inhibit heat losses from the working medium of steam, water or thermal fluid. Damaged mineral insulation should be replaced when necessary, together with the finish, to ensure continued efficient insulation
  - other insulation applied to air-exposed surfaces containing hot gases. For example, combustion chambers and flues.

Safety aspects

- There are many safety factors which must be considered when applying thermal insulation. In all cases where operator/fire safety has to be taken into account, reference should be made to the appropriate health and safety legislation, and to the instructions of the insulation manufacturers
- Where it is not possible to protect surfaces from direct contact, effective guards should be installed, such as wire mesh screens.

Design aspects

- Build adequate insulation into plant at the design stage; retrofitted insulation is often less efficient due to space restrictions, lack of support for the insulation, etc
- It is essential that thermal insulation for plant and equipment is considered early in the design stage, such that an insulation contractor can submit a suitable system that can be incorporated by the plant designer. In retrofit situations, insulation has to be built around the existing plant design and the best solution may not be feasible
- Items that should be considered during design include allowing sufficient clearance around pipes and equipment to fit adequate insulation, and allowing for the additional weight of the finished insulation system
- The technical suitability of an insulation system is of primary importance, although availability, service and cost should also be taken into account.

APPENDIX 5

Steam Reticulation Checklist

The following is a checklist of factors that will allow improved management of steam reticulation

Metering

- Meter the steam used by each department
- Regularly check the amount of steam used by each department.

Operation

- Minimise leaking joints and glands, or leaking valves and safety valves
- Insulate all steam pipes, flanges and valves
- Blank off or remove redundant steam piping
- If practicable pre-heat material with waste heat before processing
- Insulate bare process plant surfaces
- Load the process plant as much as possible and minimise the hot idle time
- Maximise air recirculated in steam heated hot air dryers and avoid excess cold air infiltration
- Ensure process temperatures are well controlled
- Ensure process steam pressures are no higher than they need to be
- Use steam pressures as low as possible when using direct steam injection
- Keep steam supplied to process plant as dry as possible
- If peak loads are inevitable ensure the boiler house is given adequate warning
- If possible stagger peak processes to even out steam demand.

Steam Traps

- Ensure the correct type of steam trap used for each application and that it is correctly installed and regularly maintained
- Protect each trap with a strainer followed by a sight glass
- Fit check valves after the traps when necessary, especially if the condensate is lifted directly to an overhead return
- Only fit by-passes around steam traps when essential and ensure they are correctly used
- Properly vent each steam space for maximum output and even heating
- Where possible improve condensate recovery gravity drainage to a receiver from which a pump can lift the condensate

- Minimise waste flash steam. Use flash steam heat be in low pressure plant, for pre-heating cold material, for heating water or return to the boiler feed tank
- Minimise condensate waste
- Insulate condensate return systems and feed tanks
- Maintain steam traps regularly.

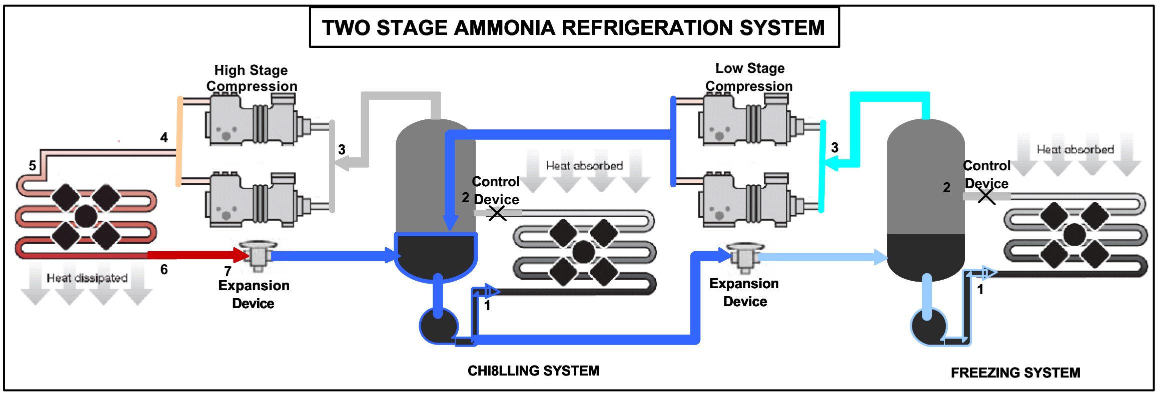
Heat Recovery

- Recover heat from boiler blow-down, hot liquors and contaminated condensate.

Design

- Ensure steam mains are properly sized, properly laid out, properly drained and properly vented
- Allow for expansion
- Install separators be improve steam quality.

APPENDIX 6
Refrigeration



Best Practice Meat Processing Refrigeration Cycle

1 ➔ 2	Intermediate pressure (chilling duty) and low pressure (freezing duty) ammonia (1) in the evaporator absorbs heat energy and changes from a saturated liquid to a saturated vapour. The cooling effect of the evaporator is governed by the difference in temperature between the medium being cooled and the evaporating refrigerant. In chilling duties the evaporator should be designed to minimise chiller shrink loss and improve refrigeration efficiency.
2 ➔ 3	The refrigerant vapour picks up more heat energy between the evaporator and the compressor. This is bad for efficiency and is minimised by insulation.
3 ➔ 4	The superheated vapour enters the compressor where its pressure is raised. There will be a large increase in temperature, because energy of compression is transferred into the refrigerant as heat, thus raising its temperature (superheat). Compressors are the main power users in refrigeration systems. Compressor energy consumption is affected by: • The compressor displacement (m^3/sec) • The difference between the evaporating and condensing temperature – also known as the temperature lift • The temperature of the superheated suction vapour.
4 ➔ 5	The very hot vapour loses a small amount of heat to ambient air in the pipe-work between the compressor and condenser. This is good for efficiency.
5 ➔ 6	The high pressure superheated vapour flows into the condenser. The condenser efficiency is affected by the temperature of the cooling air or water and the size and design of the condenser.

6 ➔ 7	A further reduction in temperature may occur between the condenser and the expansion device. This is good for efficiency.
7 ➔ 1	The high pressure sub-cooled liquid passes through the expansion device. There is no energy loss or gain through the expansion device.

COP and COSP

The energy efficiency of a refrigeration system is expressed as the Coefficient of System Performance (COSP).

$$COSP = \frac{CAPACITY(KW)}{POWER(KW)}$$

The power input is that of the compressor and all other motors (e.g. fan motors and pumps and controls) associated with the system.

Efficiency can also be expressed as COP – this is just the efficiency of the compressor, it does not take into account the power input of other electrical components such as fan motors and pumps.

The COP varies depending on the temperature lift of the system – the temperature lift is the difference between the evaporating and condensing temperatures. The capacity of the compressor increases when the temperature lift reduces;

- the compressor power input decreases when the condensing temperature is lowered
- the compressor power input increases when the evaporating temperature is increased, but the increase in power input is not as great as the increase in capacity (hence the COP still goes up).

The temperature lift reduces if:

- the condensing temperature is lowered; and/or
- the evaporating temperature is raised.

An increase of 1°C in evaporating temperature or a reduction of 1°C in condensing temperature will increase the compressor COP by 2 – 4%. Or put another way: A decrease of 1°C in temperature lift will cut running costs by 2 – 4%.

The condensing temperature will be lower if:

- A condenser with a high basic rating is used (this is usually a larger condenser)
- The condensing temperature is allowed to float down with the ambient temperature. The average ambient temperature in the UK is about 10°C – taking advantage of this rather than holding the condensing temperature artificially high saves a significant amount of energy – probably in excess of 25% for many systems
- Water is used instead of air as the condenser cooling medium (include the fan motors and pumps associated with water-cooled condensers and cooling towers in COSP calculation)
- It is also important that condensers do not become blocked, or their flow of cooling air or water becomes impeded in any other way.

The evaporating temperature will be increased if:

- An evaporator with a higher basic rating is used (this is usually a larger evaporator)
- The evaporator is defrosted when necessary. When the evaporating temperature of an evaporator cooling air is below 0°C, ice will build up on the coil block. This must be regularly removed through an effective defrost procedure. It is also important to ensure the evaporator is clean.

Other Factors

Compressor efficiency

- The efficiency of different compressor types and manufacturers varies, and not necessarily according to price – it is important that the most efficient compressor for a particular application is carefully selected. This depends on the size of the cooling load, the refrigerant used, the temperature of the application and the average temperature of the cooling medium (i.e. ambient air or water).

Refrigerant charge

- The amount of refrigerant has a significant effect on temperature lift – too much or too little refrigerant charge reduces efficiency. Systems that leak refrigerant consume more power than necessary.
- Systems that are overcharged can, in certain cases, also consume more power than necessary and have more refrigerant to lose in the case of a leak.

Refrigerant Type

- The refrigerant type also has an effect on energy use. The variation can be as high as 10%, but this benefit can only usually be achieved when the hardware is optimised to suit the refrigerant chosen. The most efficient refrigerant for an application depends on the compressor used, the temperature of the application and the average temperature of the cooling medium (i.e. ambient air or water). For meat industry operations ammonia is the refrigerant of choice.

Superheat

- The superheat of the suction vapour should be as low as possible – warmer vapour reduces the capacity of the compressor without reducing its power input. On direct expansion systems, this is achieved by correctly controlling the expansion device, and on all system types, by insulating the suction line.

Liquid Sub-cooling

- The amount of sub-cooling of the liquid refrigerant entering the expansion device should be as high as possible – this increases the capacity of the system without increasing power input.

APPENDIX 7

Compressed Air Checklist

The following provides a checklist for compressed air energy efficiency:

Good housekeeping

- Turn off compressors during non-productive hours
- Review the air pressure required. Maintain main compressor discharge pressure under 770kpa (110 psig). If it can be reduced it will reduce consumption and leakage
- If some applications require higher pressures or have longer operating hours than the rest of the system, investigate installing a dedicated compressor
- Compressors operate more efficiently using cool air
- Control/sequence compressors to operate on a "demand-controlled" basis. Compressors use as much as 70% of on-load power when they are idling
- Reduce instances of multiple compressors operating at part load simultaneously
- Minimise compressor operating unloaded for extended periods of time
- Initiate an effective system for reporting leaks. Carry out an "out of hours" survey, to listen for leaks, locate them and tag
- Make sure all redundant piping is isolated
- Check that the condensate collection system is working correctly, and that there is no constant bleed of air. Fit electronically operated condensate traps, which are more reliable
- Install an air receiver with volume greater than 10 litres per compressor kilowatt.

Treatment

- Treat the bulk of the air to the minimum level possible, then improving the quality for specific appliances
- Check the pressure drop across the pre- and after-filters. If it is above 0.4 bars the filter may need replacing
- Measure the dryer inlet temperature. This should not exceed 35°C with the compressors on full load.

Use of Compressed Air

- Over 90% of energy used by a compressor is turned into heat, so consider whether a heat recovery system can be fitted to the compressor(s) and use this heat elsewhere

- Use of higher efficiency nozzles (which entrain free air) can maintain performance, yet reduce the distribution pressure and hence energy consumption
- Make sure that air tools are not left running when not in use
- Check that compressed air is not used for ventilation or cleaning purposes, such as blowing off swarf
- Consider alternatives to compressed air hand tools. Where possible replace air motors with correctly specified electric motors
- When purchasing a new compressor, take into account its energy efficiency, since electricity will be the major running cost
- Eliminate unregulated compressed air use endpoints (eg quarter-inch pipe instead of correct nozzles).

Calculating Compressed Air Leakage

The best way to establish the amount of leakage in a system is by measurement. In the absence of suitable measuring devices, a no-load test should be carried out to establish the percentage leakage from the system. Two possible methods are as follows.

a. For compressors in on/off mode

This applies to compressors that are operated in an on/off load, i.e. when the compressor is on-load it produces a known amount of air.

- Close down all the air-operated equipment
- Start the compressor and operate it to full line pressure, when it will off-load. Air leaks will cause the pressure to fall and the compressor will come on-load again
- Over a number of cycles, make a note of the average on-load time (T) and average off-load time (t)
- Total leakage can then be calculated as follows:

$$\text{Leakage (litres/second)} = \frac{Q \times T}{T + t}$$

where Q = air capacity of the compressor (litres/second), T is the average on-load time (s) and t is the average off-load time (s).

b. For modulating compressors

This test is more difficult, as the compressor output is unknown. The following method can be used if you have a pressure gauge downstream of the receiver.

- Calculate the system volume of air (V) in litres. This can be estimated as the volume of air mains downstream of the receiver isolating valve, including all the pipe-work (25 mm and above) and the receivers

- Pump up the system to operating pressure (P1) and then close the isolating valve
- Record the time (T) for pressure to drop to P2
- Leakage can then be calculated as follows:

$$\text{Leakage (litres/second)} = \frac{V \times (P1 - P2)}{T}$$

where V is in litres, P1 and P2 are in bar$_g$, and T is in seconds.