FOODSA

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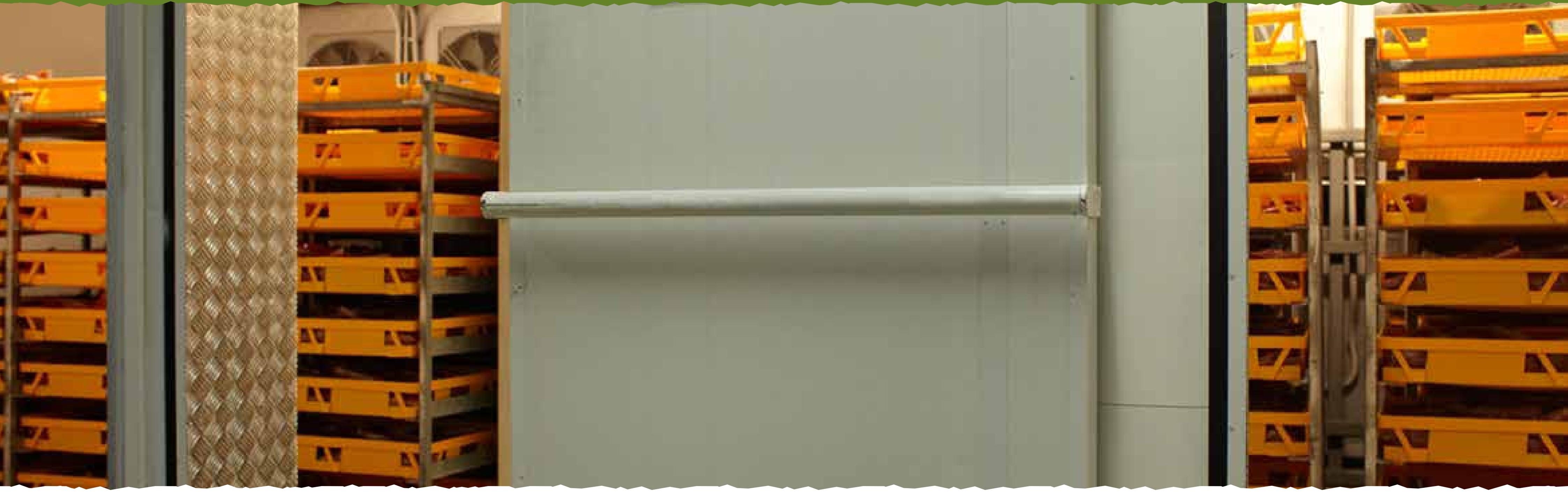
REFRIGERATION
ENERGY EFFICIENT EQUIPMENT TOOLKIT



CONTENTS AND PARTNERS

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INTRODUCTION

Refrigerator systems serve many applications, including the chilling, freezing, and cold storage of food product; and the cooling of water for end uses. They comprise compressors, condensers, evaporators, pumps, fans, pipe networks, and controls. Refrigerator systems contribute 30-80% of the total site energy use, usually as electricity. About 90% of this energy use is by the compressor.

EQUIPMENT & PROCESSES

By using your equipment settings more efficiently you can reduce your energy consumption.

UPGRADE EQUIPMENT

You can evaluate what energy reduction benefits your organisation could gain from upgrading to more efficient equipment and/or adjusting combinations of equipment. Consider adopting a selection of the following opportunities according to available resources.

SELECT & PRIORITISE

Learn how to get the best from your equipment and processes and whether you need to upgrade.

COLLECT & CHECK

Learn how to collect data and engage with your suppliers.

OPTIMISE OPERATING CONDITIONS

By using your equipment settings more efficiently you can reduce your energy consumption.

USE MAXIMUM SAFE TEMPERATURE SETTING

Power use in refrigeration decreases when you increase the evaporation-temperature setting. Use the highest acceptable temperature setting (based on the demands of your product), especially during non-critical periods of production.

POTENTIAL ENERGY SAVINGS
- Refrigeration power use decreases by 2-4% with each 1°C increase in temperature

OTHER BENEFITS
- More cold air capacity available for other uses
- Lower maintenance costs and longer operating life of the equipment due to reduced load on the refrigeration system

EQUIPMENT/MATERIALS
- None needed

Chiller flow should match the load.

CONVERT TO VARIABLE CHILLER FLOW

The chiller uses less power if the flow of primary refrigerant can be varied or if a constant flow of primary refrigerant works with a variable flow of secondary refrigerant. Decrease chiller power use by converting the refrigerator system to *variable flow*.

POTENTIAL ENERGY SAVINGS
- This offers a reduction of 5-20% of chiller power use. To estimate energy savings, consider how efficient the chiller is when part loaded, its reliance on bypass flow control and its load profile

EQUIPMENT/MATERIAL REQUIREMENTS
- None needed, assuming refrigeration system can enable variable flow

Be sure that your equipment is working as well as it can.

SEAL DOORS WELL AND MANAGE THEIR USE

Heat infiltrates refrigeration system though unsealed and open doors, increasing the energy needed to keep the storage cool. Electricity consumption (to maintain cooling load) can increase by 10% due to faulty door seals and by a further 10% due to doors left open by staff. Avoid 75% of this infiltration by:

- Installing tight seals and plastic strip curtains
- Installing automatic door closers or alarm systems
- Implementing proper door management through staff training

POTENTIAL ENERGY SAVINGS
- Savings of up to 15% of power used for refrigeration; will depend on the number of cold stores and how frequently the cold stores are accessed

OTHER BENEFITS
- Increased refrigeration cooling capacity/effectiveness by up to 15%

EQUIPMENT/MATERIAL REQUIREMENTS
- Door seals
- Automatic door closer or alarm system

Door seals

COOL THE PRODUCT BEFORE REFRIGERATION

You can evaluate what energy reduction benefits your organisation could gain from upgrading to more efficient equipment and/or adjusting combinations of equipment. Consider adopting a selection of the following opportunities according to available resources.

PRE-COOLING

By cooling product before refrigeration (pre-cooling) you can reduce the peak load on the refrigerator. The best options are usually evaporative cooling and ice storage. Evaporative cooling is most effective in the hot weather. Ice storage (sometimes referred to as 'ice banks') uses spare refrigerator capacity to make ice that is then used to make chilled water to cool the product.

Using spare cooling capacity to make ice allows the refrigerator to run continuously at a constant cold temperature with a stable load, rather than inefficiently cycling on and off to meet a variable load. Using cool tap water or heat exchange (using cool product to cool hot product) can also be effective options.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on the choices made

OTHER BENEFITS

- Lower peak load allows smaller capital cost for the refrigerator/s

EQUIPMENT/MATERIAL

- Variable depending on choices made

INSULATE REFRIGERATOR EQUIPMENT

We all know the importance of good insulation. Savings can be made by considering all of the opportunities for insulation.

INSTALL INSULATION ON REFRIGERATORS AND PIPE NETWORKS

Insulation can be a very cost effective way to reduce energy wastage. It prevents heat transfer into the cooling fluids. A list of insulation types and uses is provided in Table 1.

Check the insulation on:

- Suction lines and other pipes
- Heat exchangers
- Pumps
- Tank doors
- Valves
- Flanges and other fittings
- Cold store walls and roofs
- Areas of thermal bridging, such as bolts and brackets

POTENTIAL ENERGY SAVINGS

- Savings can be up to 10% of refrigerator power use

OTHER BENEFITS

- Insulation reduces the cooling load
- On suction lines it also reduces the suction temperature, which improves compressor efficiency

EQUIPMENT/MATERIAL

- Insulation
- If needed, a thermographic camera to help find areas of degraded insulation

Tank insultion including spray-on, foil and foam are cost effective ways to reduce energy waste.

INSTALL INSULATION ON TANKS

The three main types of tank insulation are:

- Spray-on insulation (used for large applications)
- Foil over bubble wrap
- Rigid foam with an outer shell

POTENTIAL ENERGY SAVINGS

- Savings can be 20-33% (25% average) of refrigeration power use

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Insulation

Thermographic camera

Decrease heat lost through cold store wall by installing PIR (polyisocyanurate) insulation boards.

REPLACE INSULATION ON COLD STORE WALLS

POTENTIAL ENERGY SAVINGS

- PIR insulation boards insulates up to 40% better than the polystyrene typically used on cold stores walls. The PIR insulation boards can be installed exposed to the interior of the cold store without a thermal barrier

EQUIPMENT/MATERIAL

- PIR Insulation

Foil-over bubble wrap insulation

PIR insulation panels

(Table 1) Low-temperature insulation materials & their typical applications.

TYPE OF MATERIAL	MAXIMUM TEMPERATURE (°C)	APPLICATION
Insulation		
Polyethylene	80	Internal and external locations (joints sealed)
Synthetic rubber	105	Internal and external locations (joints sealed)
Ball blankets		
Polypropylene	110	Metal treatment tanks
High density polypropylene	230	External freezing prevention, UV stabilised

REARRANGE REFRIGERATION CIRCUIT

The length and shape of the refrigeration circuit affects power use.

MINIMISE THE PRESSURE DROP OF THE CIRCUIT

Pressure drop is the difference in fluid pressure measured between the inlet and outlet of the refrigerant distribution network.

The bigger the pressure drop, the more energy is required to pump the refrigerant to the outlet at the appropriate pressure. You can reduce the pressure drop to reduce the energy used to circulate refrigerant around 'the field'.

- Even a small increase in pipe diameter will lead to a relatively large reduction in friction. Replace small diameter pipes with large diameter pipes (including heat exchangers). Thinner pipes place more friction on the refrigerant. This means more power is used to push the refrigerant through the system
- Consider replacing pipes that have rough surfaces with smooth surface pipes, and/or remove corroded pipes. Maintain cleanliness. Fouling, corrosion and rough materials create a rough internal surface that increases friction. Smooth pipes (including in heat exchangers) create less friction and the refrigerant can move through more easily, which improves efficiency
- Pipe friction increases with increasing length. Identify areas where pipe length could be reduced and make the necessary adjustments. Bypass loops, bend components, and the location of the refrigeration unit and cold stores affect the length
- Each pipe component adds friction (see diagrams). Reduce loss of pressure by eliminating bends or smoothing out any sharp bends, keeping inlets rounded and constrictions gradual, and using minimal valves and restrictors

POTENTIAL ENERGY SAVINGS

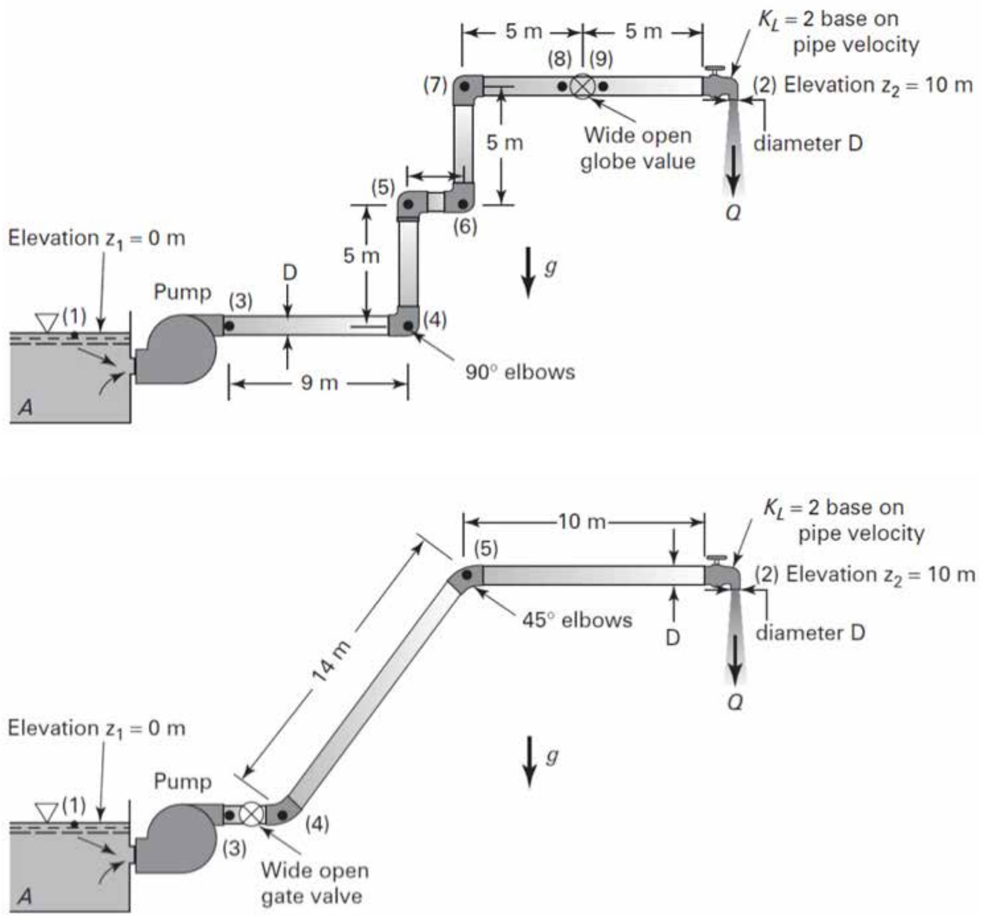
- Savings vary depending on both the reduction in pressure drop and any energy savings resulting from resizing the pump to suit the pressure demands of the rearranged circuit

OTHER BENEFITS

- In a refrigerator that uses a direct expansion system, the compressor operates most efficiently when the suction pressure is high. Keeping pressure drop to a minimum increases compressor efficiency
- If a chiller type is used, a variable flow of refrigerant to match the load will reduce the power needed by the chiller. Variable flow of refrigerant is difficult to achieve when suction pressure is constantly low from pressure drops

EQUIPMENT/MATERIAL

- Variable depending on the choices made



An example of pipe network rearrangement to reduce bends. Top – existing network; Bottom – rearranged network)

REARRANGE REFRIGERATION CIRCUIT *CONT.*

Deliver the primary refrigerant to the end point where the cooling occurs (for end-uses requiring continuous cooling).

PRIMARY REFRIGERANT

This strategy is appropriate for continuous cooling, but is not as efficient for periodic high cooling systems.

For systems using continuous cooling from heat exchange such as food storage, cooling by heat exchange with the primary refrigerant, such as R717 (ammonia) or R22, is more efficient than cooling with a secondary refrigerant, such as brine or chilled water. Primary refrigerants remove more heat per unit mass than secondary refrigerants, and therefore use less energy to achieve the same level of cooling.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on choices made and the current system in place

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Variable depending on the choices made

Deliver the secondary refrigerant to the end point where the cooling occurs (for end-uses requiring periodic, high-cooling)

SECONDARY REFRIGERANT

The use of a separate, secondary refrigerant circuit enables the refrigerator to simultaneously meet many different cooling loads.

This strategy is appropriate for end-uses that require short periods of high cooling. It also enables a high evaporator temperature, reducing the temperature lift and the load on the compressor. Brine and chilled water are common secondary refrigerants. Carbon dioxide is emerging as a good secondary refrigerant.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on choices made and the current system in place

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Variable depending on the choices made

A second brine tank allows for pre-cooling of the warm, returned brine before it gets to the chilled brine tank.

INSTALL A SECOND BRINE TANK

It also increases the store of brine that can be chilled using cheaper off peak energy and overnight cooling.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on the current system in place

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Purchase and installation

Compressors operate more efficiently in cooler surroundings, and condensers expel heat more efficiently to cooler surrounding.

RELOCATE REFRIGERATOR

Increase refrigerator efficiency by locating refrigerator units in areas that are cool, well-ventilated, and out of direct sunlight (shaded, enclosure with reflective paint, or underground).

POTENTIAL ENERGY SAVINGS

- Savings vary depending on where the refrigerator is currently positioned versus where relocation is planned

OTHER BENEFITS

- Lower maintenance costs
- Longer operating life of refrigeration equipment

EQUIPMENT/MATERIAL

- Depends on location and choices made

REPLACE INEFFICIENT REFRIGERATOR COMPONENTS

Technology offers some energy efficient alternatives to some refrigerator components.

REPLACE INTERNAL COOLING WITH EXTERNAL COOLING

The cooling of screw compressors is more efficient with external oil coolers than with liquid-injection oil cooling (the direct injection of high-pressure liquid refrigerant into the compressor). Liquid-injection oil cooling can decrease the efficiency of screw compressors by up to 5-10%.

External oil coolers usually remove heat through the use of water or a refrigerant (usually ammonia) in a shell and tube heat exchanger on the oil circulation system.

Capital cost is typically between $15,000 and $20,000 for external oil cooler (2013).

POTENTIAL ENERGY SAVINGS

- Savings can be 3-15% of refrigeration power use depending on the size of screw compressors

OTHER BENEFITS

- Increase in the refrigeration capacity of the compressor by 5-10%
- Increase in discharge temperature from 50°C to around 70°C, which provides a waste heat temperature that is more cost-effective for heat recovery systems

EQUIPMENT/MATERIAL

- A water or refrigerant/thermosiphon oil cooler
- For cooler using refrigerant/ thermosiphon, a refrigerant liquid-and-vapour return pipe between the liquid receiver and the oil cooler
- For cooler using water, a cooling water pipe between the evaporative condensers and the oil cooler

With this option it is important to control the quantity of refrigerant efficiently.

INSTALL AN ELECTRONIC EXPANSION VALVE

Thermostatic expansion valves can cause problems under conditions of varying pressure. Liquid refrigerant can return to the compressor to cause damage or failure. If the refrigerator uses a direct expansion evaporator and experiences varying pressure, include balanced port or electronic valves, such as *electronic expansion valves* (Tx valves).

POTENTIAL ENERGY SAVINGS

- Savings can be up to 20% of refrigeration power use

OTHER BENEFITS

- Extended compressor life
- Less downtime

EQUIPMENT/MATERIAL

- Purchase and installation

Axial fans are suitable for air-cooled and evaporative condensers, which do not usually require the high pressure air generated by centrifugal fans.

REPLACE CENTRIFUGAL FANS WITH AXIAL FANS IN CONDENSERS

Axial fans use up to 50% less energy than centrifugal fans and should be installed for air-cooled and evaporative condensers.

POTENTIAL ENERGY SAVINGS

- Savings can be up to 50% of condenser fan power use

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Purchase and installation

External oil-cooler for compressor

Electronic expansion valve

Centrifugal fan vs axial fan

INSTALL NEW REFRIGERATOR COMPONENTS

There are some new technologies that can boost the energy efficiency of refrigeration systems.

INSTALL FLOW ENHANCERS

In cold stores, air flow is not uniform. Heat transfer from food products is less effective in dead zones (areas of low or no air flow). Baffles and other air flow enhancers can redirect air flow to these areas to improve cooling efficiency.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on refrigeration and product conditions. For example, one manufacturer of frozen sardines reduced power use by 12% by installing baffles and lowering the ceiling of its blast freezers

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Purchase and installation

Examples of blast freezers

Some food products need a lot of cooling.

INSTALL A BLAST FREEZER

A blast freezer operates at full cooling load. It can cool the product before it is placed into the main refrigeration unit. This allows the refrigeration unit to maintain more constant temperatures, which may result in reduced overall energy consumption. Keep in mind however that blast freezers still use a lot of energy to chill food rapidly, so a proper assessment to compare energy use of your current system versus a blast freezer should be undertaken.

POTENTIAL ENERGY SAVINGS

- Savings vary depending on refrigeration and product conditions

OTHER BENEFITS

- Increased productivity/throughput of product, as the product can be cooled rapidly
- Improve food product quality resulting from rapid chilling

EQUIPMENT/MATERIAL

- Purchase and installation

Clean refrigerant and a clean condenser are more efficient.

INSTALL AN AUTOMATIC PURGER

Purging increases refrigerator efficiency by about 1% for every 1% of contaminant removed. Simple purgers are often inadequate to remove all contaminants, but automatic purgers remove contaminants (air, nitrogen, waste refrigerant, other non-condensable gases, oil, water) that circulate with the refrigerant and accumulate in the condenser.

Three general types of automatic purgers are available:

- Automatic air purgers remove most gases but not water vapour. Automatic purgers are usually cost effective on refrigerators of capacity greater than 500kW
- Water purgers (ammonia anhydrators) remove water vapour
- Some more-expensive purgers remove air and water vapour

An air purger costs around $20,000. Water purgers cost around $11,000 (2013)

POTENTIAL ENERGY SAVINGS

- Using an automatic purger can save 5% of refrigerator power use, or 10-50% of chiller power use

To estimate energy savings, consider:

- The effectiveness of existing contaminant removal and prevention procedures
- The load profile of your equipment
- The contaminant content (this can be difficult to estimate)

OTHER BENEFITS

- Reduced wear-and-tear on the refrigeration system (due to removal of contaminants), leading to reduced maintenance costs and longer equipment life

EQUIPMENT/MATERIAL

- Purchase and installation

Automatic air purger for refrigeration compressors

INSTALL NEW REFRIGERATOR COMPONENTS *CONT.*

Variable speed drives (VSDs) are useful where part cooling loads are common.

INSTALL VARIABLE SPEED DRIVES (VSDS)

In situations where full cooling load is almost constant, they are less efficient (by about 3%) than constant speed drives. VSDs are well suited to components that operate at part-load for up to 95% of the time.

On evaporator fans VSDs also reduce the cooling load.

Variable speed drives continually adjust the motor speed to match the component's (compressor, condenser fan, or evaporator fan) output to the load profile. Since component power is proportional to the speed of the motor cubed (that is, speed x speed x speed), slowing the motor speed a small amount reduces power consumption quite a lot.

Some VSDs include soft start features, which gradually ramp up the motor speed. Soft start can decrease energy consumption when loads are steady, but can increase energy consumption when loads vary frequently.

Of course VSDs only work as well as the controls that are implemented on them. To find the best control method, you need an appropriate control signal and an iterative procedure to test and find the optimal settings.

To get the best from your VSD on fans, also consider:

- Condenser fans need to operate only when the compressors operate. You can improve performance if you couple control of fans with compressors
- If evaporator fans are off for too long, the air in the cold store forms a warm layer above and a cool layer below and this, of course, affects cooling. Optimise power use by running the evaporator fan regularly
- For flooded and recirculated evaporators, run the fan for a while after the solenoids are turned off to drain the refrigerant

Capital cost is $200-$500/kW, about the same as the motor. Capital costs depend on the size (the cost per kW decreases as motor size increases), the number, and the motor's patterns of use.

Variable Speed Drives

POTENTIAL ENERGY SAVINGS

Savings can be:

- 10-60% (20% average) of motor power use
- 4-5% of refrigeration power used for fans

Savings depend on:

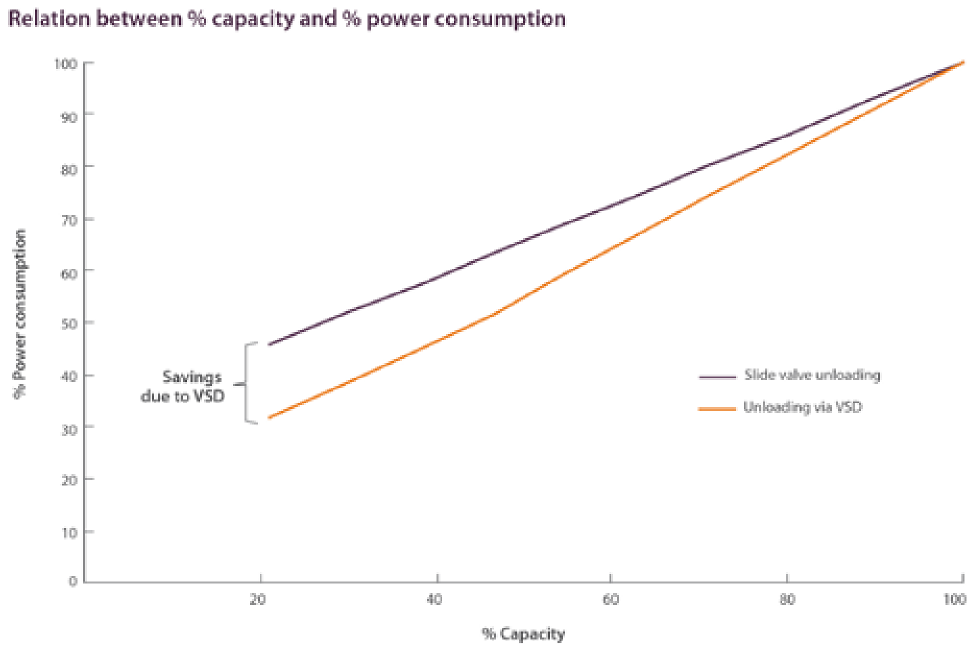
- The size, number, and use patterns of the motor
- The number of cold stores

OTHER BENEFITS

- Lower maintenance costs
- Longer operating life of refrigeration equipment
- Eliminates the need for flow-control devices that can increase pressure drop in the circuit

EQUIPMENT/MATERIAL

- VSDs for each group of components (some components have multiple fans that require only one VSD)
- Sufficient programming capability in the control system (check with supplier)



Energy savings from a variable speed drive

INSTALL NEW REFRIGERATOR COMPONENTS *CONT.*

If VSDs are too expensive for you or your cooling load is more constant, consider multi-speed motors that use a different set of windings at each speed to increase fan efficiency.

INSTALL A MULTI-SPEED MOTOR ON FANS

Multi-speed motors have higher capital costs than single-speed motors. Although single-speed motors are more efficient at their single optimal speed, multi-speed motors have many speeds at which they are very efficient.

POTENTIAL ENERGY SAVINGS

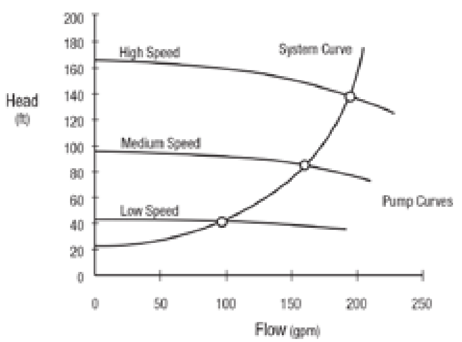
- Savings vary depending on the required motor speeds, and comparison between existing motor set-up

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Purchase and installation



Multi-speed motors can operate efficiently at different set-speeds

Compressors are more efficient when running at full load than at part load.

INSTALL AUTOMATED COMPRESSOR STAGING AND CAPACITY CONTROL (FOR MULTIPLE COMPRESSORS)

If the load varies, consider using multiple, smaller compressors so that all compressors can be used together at peak load, but a selection of compressors can be used at lesser loads. This strategy is suitable when the load is consistently above 50%.

Having compressors of different capacities allows you to match the compressor capacity with the required cooling load.

An automatic controller can turn compressors on and off as needed, usually resulting in only one small compressor operating at part-load. However, consider start up and shut down efficiency losses too. Ideally the logic used to control the compressors should be optimised, that is, set and fine-tuned across the full range of cooling loads and environmental conditions.

Capital cost for an automatic controller is approximately $100,000 (2013).

Capital costs depend on the:

- Number of compressors
- Number of compressors that require VSDs

POTENTIAL ENERGY SAVINGS

Savings vary:

- 5% when installed on a previously partly-optimised refrigerator (most common)
- 15% when installed on a refrigerator that has not previously been optimised

Savings depend on:

- Load profile
- Number, size and condition of compressors

OTHER BENEFITS

- Longer operating life of compressors

EQUIPMENT/MATERIAL

- A suction pressure transmitter
- A slide valve potentiometer, connected to the automatic controller, for each screw compressor
- Capacity control solenoids for reciprocating compressors, connected to the automatic controller
- VSDs on compressors
- Control hardware and software capability (to define the logic)

Example of a compressor-staging controller

REPLACE REFRIGERATOR AND COMPONENTS

Replacing old refrigerators with newer, more efficient models can save significant power use.

FULL REPLACEMENT

New refrigerators are usually cost effective if the existing refrigerator is more than 10 years old.

Assess cooling applications to determine whether central refrigeration (a single large system) or satellite refrigeration (many, small systems distributed throughout the site) is most appropriate.

Select a system that is designed for high efficiency at the most common part load but can meet peak load. Select condensers and evaporators that provide a low temperature lift. Every reduction in temperature lift of 1°C can reduce power use by 2-4%. Select the most efficient combination of compressor and refrigerant for the application.

POTENTIAL ENERGY SAVINGS

- 30-40% of refrigeration power use

OTHER BENEFITS

- Lower maintenance costs

EQUIPMENT/MATERIAL

- Purchase and installation

How efficient chillers are varies widely.

INSTALL AN EFFICIENT CHILLER

Chillers are designed for specific applications (such as air-conditioning or chilled glycol/water). Efficient chillers are also designed for specific operating temperatures and load profiles. If fluid temperatures (refrigerant fluid) are non-standard, then order a special chiller to suit. If the chiller is used during winter, when ambient temperature is low, then seek a chiller that can operate at low condensing temperatures. Such a chiller can use 30-50% less power.

Chillers often run at part-load. Good chillers are more efficient at part load than at full load. The efficiency of chillers is measured by a Coefficient-of-Performance (COP). In the case of chillers, this COP is a measure of the ratio of actual chilling to the amount of energy used to create that result. High efficiency chillers can have a COP up to 6 at full load and 12 at part load, while low-cost chillers may have a COP of less than 4 at full load and less than 2 at part load.

POTENTIAL ENERGY SAVINGS

- Savings can be 10-50% of chiller power use. Depending on the application the most effective high-efficiency chillers use 20-75% less power than the least effective low-cost chillers

OTHER BENEFITS

- Lower maintenance costs

EQUIPMENT/MATERIAL

- Purchase and installation

Generally, large evaporators are more efficient than small evaporators, but some evaporators achieve higher efficiency through specific design features.

INSTALL AN EFFICIENT EVAPORATOR

Many types of evaporators are available, some of which are suited to specific applications such as:

- Direct expansion coolers are preferred for air conditioning. The refrigerant in the evaporator coil draws heat out of the passing air or product
- Pumped liquid air coolers are more efficient than direct expansion coolers, but need more refrigerant. The refrigerant can draw out more heat because it is continually in contact with the entire surface
- Shell and tube liquid coolers are preferred for large refrigeration and central air conditioning systems
- Plate heat exchanger liquid coolers are more efficient than direct expansion coolers. The plates have a larger surface area in contact with passing air or product. They are easy to clean, cheap to make and can be used as structural components such as shelves and walls
- Baudelot liquid coolers are not damaged by frozen product. The refrigerant draws heat out of the passing air or product, cooling the air or product down to within 0.5 degrees of freezing

POTENTIAL ENERGY SAVINGS

- Savings vary depending on choices made

OTHER BENEFITS

- Lower maintenance costs

EQUIPMENT/MATERIAL

- Purchase and Installation

Refrigeration evaporator

REPLACE REFRIGERATOR AND COMPONENTS *CONT.*

Generally, large condensers use less energy than small condensers for the same job because they produce lower-temperature cooling fluid for the chiller.

INSTALL AN EFFICIENT CONDENSER

However large condensers use greater cooling fluid flow (air or water). Best practice aims to balance water and energy use.

Select a condenser that will work efficiently with your most common load as peak cooling load is usually intermittent and it is better to have high efficiency for the most frequent use.

Three types of condensers are most common, each of which has specific performance, efficiency, and equipment:

- Air cooled condensers, which use a fan
- Water cooled condensers, which use a circulating pump and, usually, a cooling tower
- Evaporative condensers, which use a fan and a pump

POTENTIAL ENERGY SAVINGS
- Savings vary depending on choices made

OTHER BENEFITS
- Lower maintenance costs
- Possible reductions in water use

EQUIPMENT/MATERIAL
- Purchase and Installation

Refrigeration condenser

Ammonia (R717) is currently the dominant refrigerant for industrial refrigeration in Australia.

USE AN EFFECTIVE PRIMARY REFRIGERANT

It is the cheapest of the common refrigerants, has good properties, and is thermodynamically 3-10% more efficient than some HCFCs (R22, R134a). In some cases ammonia use can use 30-50% less power in summer and 50-60% less power in winter than HCFCs (R134a, R407C, R404A, R507).

Carbon dioxide (R744) is once again emerging as a good refrigerant and is substantially cheaper than ammonia. Propane has similar efficiency to ammonia.

HCFCs are affected by carbon price due to the level of greenhouse gas emissions, but propane, ammonia and hydrocarbons (R600a, R290, R1270) as refrigerants are not.

If your refrigerators suffer from high leakage, select the most biologically benign refrigerants.

POTENTIAL ENERGY SAVINGS
- Savings can be up to 50% of refrigerator power use

OTHER BENEFITS
- Potential reductions in greenhouse gases and contamination concerns depending on choices

EQUIPMENT/MATERIAL
- Purchase and installation

ALTERNATIVES TO REFRIGERATORS

As well as equipment options, you can also use non-mechanical methods to reduce your energy consumption and ongoing costs.

OVERCOOL THE PRODUCT AT NIGHT

This strategy requires continuous monitoring and control of the cold store temperature. Where practical, cool the product to the minimum allowable temperature at night. At night both ambient temperatures and electricity costs are low and this will delay the need for active refrigeration during the day. The low condenser temperature overnight saves power. Every reduction in condensing temperature of 1°C can reduce power use by 2-4%.

Capital cost is $5,000-$10,000 for initial set-up installation plus extra for optimisation. Capital costs depend on the size of the refrigerator and cold store.

POTENTIAL ENERGY SAVINGS

- Savings can be up to 5% of refrigeration power use

OTHER BENEFITS

- Lower capital costs due to lower peak load

EQUIPMENT/MATERIAL

- Temperature sensors
- A modern computer

Underground cool rooms ('caves') provide an excellent climate for aging and storing beverages and cheese; almost-constant temperatures of about 15-16°C throughout the year, and humidity of 80-90% can be achieved.

INSTALL AN UNDERGROUND COOL ROOM

Since underground cool rooms avoid active cooling, they also avoid the active humidification sometimes associated with mechanical refrigerators.

Capital cost to dig an underground cool room is approximately $100 per square foot. Concrete masonry block buildings can be $91 per square foot and super-insulated butler buildings can be $66 per square foot (2013). This offers a payback period of about 7 years or better depending on whether the cool room is a new facility or a replacement facility (slower payback period).

POTENTIAL ENERGY SAVINGS

- Savings can be100% of refrigeration power used for cold storage

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Variable depending on the choices made

EQUIPMENT AND PROCESSES

Use the following table to select which energy efficiency opportunities your business would be interested in pursuing, as well next steps in terms of actions and responsibilities.

Tick the box if you plan to pursue an Energy Efficiency Option.

X	ENERGY EFFICIENCY OPTION	NEXT STEPS & TIMING	WHO RESPONSIBLE	NOTES
	Optimise operating conditions			
	Use maximum safe temperature setting			
	Convert to variable chiller flow			
	Repair refrigerator components			
	Seal doors well and manage their use			

UPGRADE EQUIPMENT

Use the following table to select which energy efficiency opportunities your business would be interested in pursuing, as well next steps in terms of actions and responsibilities.

Tick the box if you plan to pursue an Energy Efficiency Option.

X	ENERGY EFFICIENCY OPTION	NEXT STEPS & TIMING	WHO RESPONSIBLE	NOTES
	Pre-cooling			
	Cool the product before refrigeration			
	Insulate refrigerator equipment			
	Install insulation on refrigerators and pipe networks			
	Install insulation on tanks			
	Replace insulation on cold store walls			
	Re-arrange circuit			
	Minimise the pressure drop through the circuit			
	Deliver the primary refrigerant to the end point where refrigeration occurs			
	Deliver the secondary refrigerant to the end point where refrigeration occurs			
	Install a second brine tank			
	Relocate the refrigerator			
	Replace inefficient refrigerator components			
	Replace internal cooling with external cooling			
	Replace thermostatic expansion valve with electronic expansion valve			
	Replace centrifugal fans with axial fans in condensers			

UPGRADE EQUIPMENT *CONT.*

Use the following table to select which energy efficiency opportunities your business would be interested in pursuing, as well next steps in terms of actions and responsibilities.

Tick the box if you plan to pursue an Energy Efficiency Option.

X	ENERGY EFFICIENCY OPTION	NEXT STEPS & TIMING	WHO RESPONSIBLE	NOTES
	Install new refrigerator components			
	Install flow enhancers			
	Install an automatic purger			
	Install variable speed drives (VSDs)			
	Install a multi-speed motor on fans			
	Install automated compressor staging and capacity control			
	Replace refrigerator and components			
	Full replacement			
	Install a blast freezer			
	Install an efficient chiller			
	Install an efficient evaporator			
	Install an efficient condenser			
	Use an effective primary refrigerant			
	Alternatives to refrigerators			
	Overcool the product at night			
	Install an underground cool room			

CHECKLIST TO ENGAGE WITH SUPPLIERS

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

DETERMINE THE END USES OF YOUR REFRIGERATOR

Tick those that apply to your business

- ○ Chilling/freezing
- ○ Cold store
- ○ Cooling water pumping/circulation
- ○ Other

COMPILE A REFRIGERATOR INVENTORY

COMPILE A LIST OF THE FOLLOWING EQUIPMENT

Tick those that apply to your business

- ○ Compressors: number, make, model, type (screw or reciprocating), power rating (kW), efficiency, flow rate (l/s), speed (rpm), and number of pump stages
- ○ Condensers: number, make, model, type (air cooled, water cooled or evaporative), and age (y)
- ○ Pumps: number, make, model, type, power rating (kW), efficiency, flow rate (l/s), speed (rpm), and number of pump stages
- ○ Fans: number, make, model, type, power rating (kW), efficiency, flow rate (l/s), speed (rpm), and number of pump stages
- ○ Pipes: diameter of main high-pressure refrigerant liquid line (m)
- ○ Refrigerator: time in use (h/y)
- ○ Other

CHOOSE AN APPROACH TO ESTIMATE TIME IN USE

Tick those that apply to your business

- ○ Record readings on hour-run (h) meter at regular intervals
- ○ Divide the hour-run meter reading (h) by the total time (h) that the refrigerator has been installed
- ○ Compare the energy (kWh) and power readings (kW) (if the system has an electricity meter)
- ○ Examine electricity meter load profiles (kW)
- ○ Use existing control systems and manual procedures
- ○ Check control settings (if the system has controls)

CHECKLIST TO ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

ESTIMATE THE COOLING LOAD

COMPILE A LIST OF THE FOLLOWING INFORMATION

Tick those that apply to your business

- ○ Major end-uses (which comprise at least 70% of the total cooling load (kW))
- ○ Specific cooling requirements (temperature (°C) and cooling time (h)) for each end-use

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ For an initial estimate of theoretical cooling requirements (kW), review equipment manuals and process specifications
- ○ If budget and time allow for a more-accurate estimate of actual cooling requirements (kW), which include undesirable heat gains (kW), install metering and monitoring equipment, such as data-loggers. For this procedure, collect the following data at the end-uses, for either the secondary refrigerant or the product, to calculate the heat removed
  - ○ Volumetric flow rate (m3/s) (measure)
  - ○ Temperature rise (°C) (measure)
  - ○ Specific heat capacity (kJ/kg°C) (look up data sheet or estimate)
  - ○ Fluid: refrigerant/product

THIS LIST ENABLES YOU TO:

- Estimate the cooling load (kW), including the base load (kW) and peak load (kW)
- Identify the end-uses that dominate the cooling load (kW)
- Identify the end-uses that can be rescheduled from peak times to off-peak times
- Group together end-uses that require similar cooling temperatures (°C)

CHECKLIST TO ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

ESTIMATE THE REFRIGERATOR PERFORMANCE

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ For an initial estimate, measure the following parameters, and compare them to their design values:
  - ○ Condensing temperature (°C) at the inlet
  - ○ Condensing temperature (°C) at the outlet
  - ○ Evaporator temperature (°C) at the inlet
  - ○ Evaporator temperature (°C) at the outlet
  - ○ Compressor pressure (kPa) and temperature (°C) at the inlet
  - ○ Compressor pressure (kPa) and temperature (°C) at the outlet
  - ○ Power to the compressor (kW)
  - ○ Ambient temperature (°C)
  - ○ Brine temperature (°C)
- ○ For a more-accurate estimate, perform an energy consumption assessment. For this procedure, log the energy use of the refrigerator and/or specific components against the ambient temperature (°C) and cooling load (kW), and then compare these graphs to the design values
  - ○ Refrigerator
  - ○ Compressors
  - ○ Pumps
  - ○ Fans
  - ○ Other

THESE INDICATORS ENABLE YOU TO:

- Identify inefficient equipment and processes
- Assess the effectiveness of the energy efficiency measure implemented
- Monitor for unexpected changes in the performance of equipment and processes

DETERMINE THE BUSINESS PARAMETERS OF THE REFRIGERATOR

QUANTIFY OR QUALIFY THE FOLLOWING VALUES

Tick those that apply to your business

- ○ Energy price(s) ($/kWh)
- ○ Capital budget ($)
- ○ Targets for running costs ($/y) (including cost of refrigerant)
- ○ Required level of redundancy in the system
- ○ Acceptable level of risk for new technologies
- ○ Acceptable payback period or return on investment
- ○ Equipment constraints, such as: specific brands of equipment, specifications for electrical wiring, compatibility with existing infrastructure or floor space. and adaptability to future upgrades

If the existing equipment needs to be replaced, then calculate the payback period (y) based on the extra (rather than total) costs ($) (if any) of the efficient equipment.

CHECKLIST TO ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

CONFIRM REFRIGERATOR PERFORMANCE

CHECK THE FOLLOWING CONDITIONS

Tick those that apply to your business

- ○ The refrigerator meets the peak cooling load (kW)
- ○ The refrigerator is optimised for the most common cooling loads (kW)

SELECT A SERVICE PROVIDER

SELECT A REFRIGERATION SERVICE PROVIDER THAT CAN PROVIDE THE COMBINATION OF SERVICES THAT YOU SEEK

Tick those that apply to your business

- ○ Measurement and analysis of the cooling load profile (kW), and power (kW) of the refrigerator and end-uses
- ○ Reporting on equipment and process performance
- ○ Optimisation of the refrigerator system, including control system, pressure levels (kPa), temperature levels (°C) and flows (l/s), management of refrigerant leaks, and assessment of heat recovery potential
- ○ Supply, service, and installation of refrigerator components (e.g. compressors, evaporators, filters, and pipes) for optimal energy efficiency (%)
- ○ Supply of spare parts, including shipping/transport
- ○ Guarantee of minimum efficiency (%) of the proposed system
- ○ Guarantee of maximum running costs ($/y) of the proposed system
- ○ Technical support and after sales service
- ○ In-house repairs and onsite service
- ○ Emergency service
- ○ Remote monitoring
- ○ Appropriate removal and disposal of old equipment
- ○ Other

NEGOTIATE A CONTRACT

DETERMINE YOUR PREFERRED TYPE OF CONTRACT

Tick those that apply to your business

- ○ Service contract - the supplier performs certain actions for a fixed price ($)
- ○ Energy performance contract - the supplier performs certain actions that meet certain levels of energy reduction (kWh) for a lower upfront price ($) and a share of the cost savings ($/y)

REFERENCES

The following references were used in the development of the *Refrigeration and Chilling* section of the Food SA BCEEE toolkit. We encourage you to access these references as they may provide additional useful information for your business in evaluating energy efficiency opportunities.

Food SA's Your Guide to Sustainable Business in Food

Carbon Trust: Food and drink processing

Department of Resources, Energy and Tourism: Energy Efficiency Exchange

Lawrence Berkeley National Laboratory: Energy Efficiency Improvement and Cost Saving Opportunities for Breweries

Lawrence Berkeley National Laboratory: Energy Efficiency Improvement and Cost Saving Opportunities for the Fruit and Vegetable Processing Industry

Lawrence Berkeley National Laboratory: Energy Efficiency Improvement and Cost Saving Opportunities for the Dairy Processing Industry

NSW Office of Environment and Heritage: Technology Report: Industrial refrigeration and chilled glycol and water applications

PDH Engineer HVAC Chilled Water Distribution Schemes

Stasinopoulos, P. et al (2010) Whole system design: an integrated approach to sustainable engineering, Earthscan Publishing

Sustainability Victoria: Energy Efficiency Best Practice Guide – Industrial Refrigeration

Sustainability Victoria: Energy Efficiency Best Practice Guide – Pumping Systems

US Department of Energy: Improving Pumping System Performance - A Sourcebook for Industry

Working Group for Cleaner Production: Eco-Efficiency Resources for the Queensland Food Processing Industry