FOODSA

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PUMPING
ENERGY EFFICIENT EQUIPMENT TOOLKIT

CONTENTS AND PARTNERS

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Australian Government
Department of Resources, Energy and Tourism

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Zero Waste SA

INTRODUCTION

Pumping systems serve many applications, including the transportation of product, refrigeration and cooling water, hot water, and wastewater; receiving; pressing; and bottling and packaging. They comprise pumps, motors, pipe networks, and controls. Pumping systems contribute 10-30% of the total site energy use, usually as electricity.

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.

MAINTAINING PUMPING SYSTEMS

In the food manufacturing sector pumping requirements vary widely. Because of this, general statements on how to use pumps for best energy outcomes are of limited use.

MAINTENANCE SCHEDULE

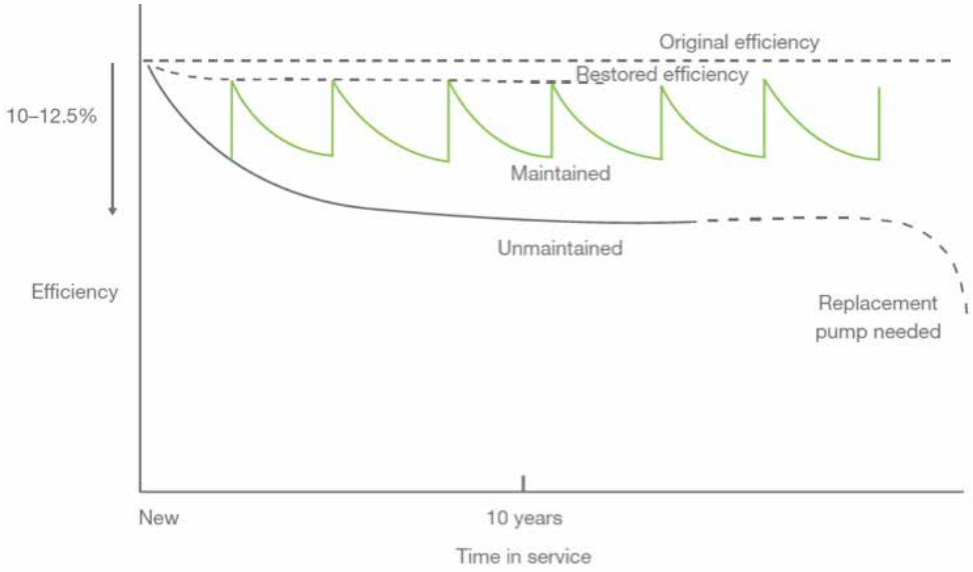
Constant maintenance and inspection of the site's pumping systems can lead to improvements in energy efficiency. Regular maintenance avoids losses in efficiency and capacity, which can occur long before a pump fails.

The main cause of wear and corrosion is high concentrations of particulates and low pH values.

Wear can create a drop in wire to water efficiency of unmaintained pumps by around 10–12.5%. Much of the wear occurs in the first few years, until clearances become similar in magnitude to the abrading particulates.

The main areas to look for pump wear are:

- Cavitation or internal recirculation
- Pump impellers and casings that increase clearances between fixed and moving parts
- Wear rings and bearings
- Packing adjustment on the pump shaft



Average wear trends for maintained and unmaintained pumps

REARRANGE PIPE NETWORK

Rearranging the pipe network, especially installing larger-diameter pipes, is best suited for new or replacement networks due to the capital cost required.

MINIMISE THE PRESSURE DROP OF THE PIPE NETWORK

A pump usually needs to generate fluid flow at a rate and pressure that both meets the demands of the end-use (the end point where the substance being pumped is needed) and overcomes any friction and gravitational flow losses (pressure drop) in the pipe network.

You can reduce pressure drop through the following improvements to the pumping system:

- Smooth pipes have much less friction than rough pipes and can therefore transport substances more efficiently. Internal pipe roughness depends on the material and finish, and the amount of fouling and corrosion
- A small increase in pipe diameter will lead to a relatively large reduction in friction, and therefore, help to reduce flow losses. Pipe friction for circular pipes is inversely proportional to the fifth power of internal pipe diameter
- Pipe friction increases with increasing length. Pipe networks can be unnecessarily long due to bypass loops, bend components, and the location of the pumps and end-uses
- Each pipe component adds friction. Reduce loss of pressure by eliminating bends or smoothing out any sharp bend, keeping inlets rounded and constrictions gradual and using minimal valves and restrictors. Throttling valves should be eliminated. Even a fully open valve can add 70 kPa of pressure drop
- Positioning the pump higher than the end-use eliminates pressure drop due to gravity. The higher end-use above the pump, the greater gravitational loss. A gravity feed arrangement can eliminate the need for a pump altogether

For water distribution, mains pressure might be sufficient if the pipe network losses are low, eliminating the need for a pump. This arrangement might require pressure sensors and controls to control water distribution.

The decision about which of these features to include should account for the combined costs of the pipe network, pump, and energy.

POTENTIAL ENERGY SAVINGS

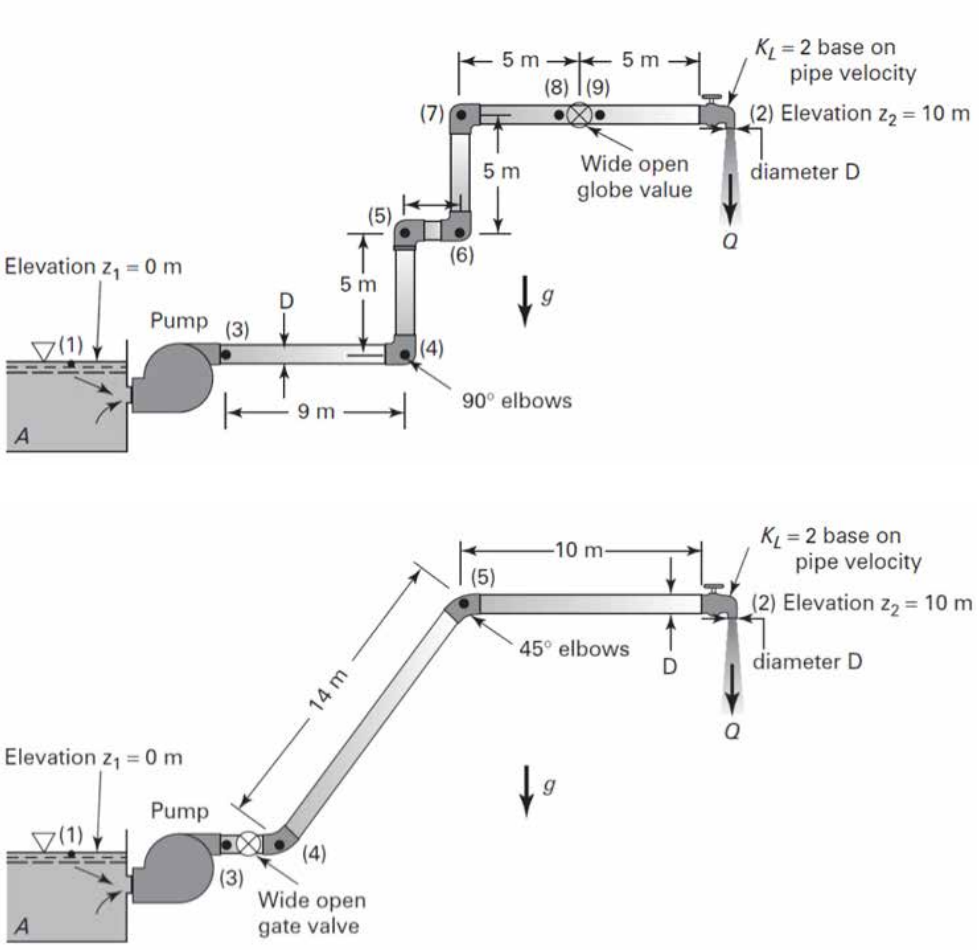
- Savings can be 5-20% of pump power use (from changing to larger diameter pipes only)w

OTHER BENEFITS

- Lower capital cost for pumps as smaller sizes can do the task
- Lower maintenance costs
- Longer operating life of pump system equipment

EQUIPMENT/MATERIAL

- Variable depending on choices made



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

REPLACE PUMP COMPONENTS

Reduce pump power use by installing a smaller impeller or trimming the existing one, but take care to choose the right size for your system.

TRIM OR REPLACE THE IMPELLER

Note: Replacing or trimming a pump impeller is a specialised task that should be performed by a competent supplier.

The flow generated by a pump impeller (a rotor working with the pump to increase pressure) decreases with the impeller's diameter. A smaller impeller is suitable only if the diameter is reduced by less than 20%. If the impeller is too small, the pump efficiency decreases due to recirculation within the pump.

POTENTIAL ENERGY SAVINGS

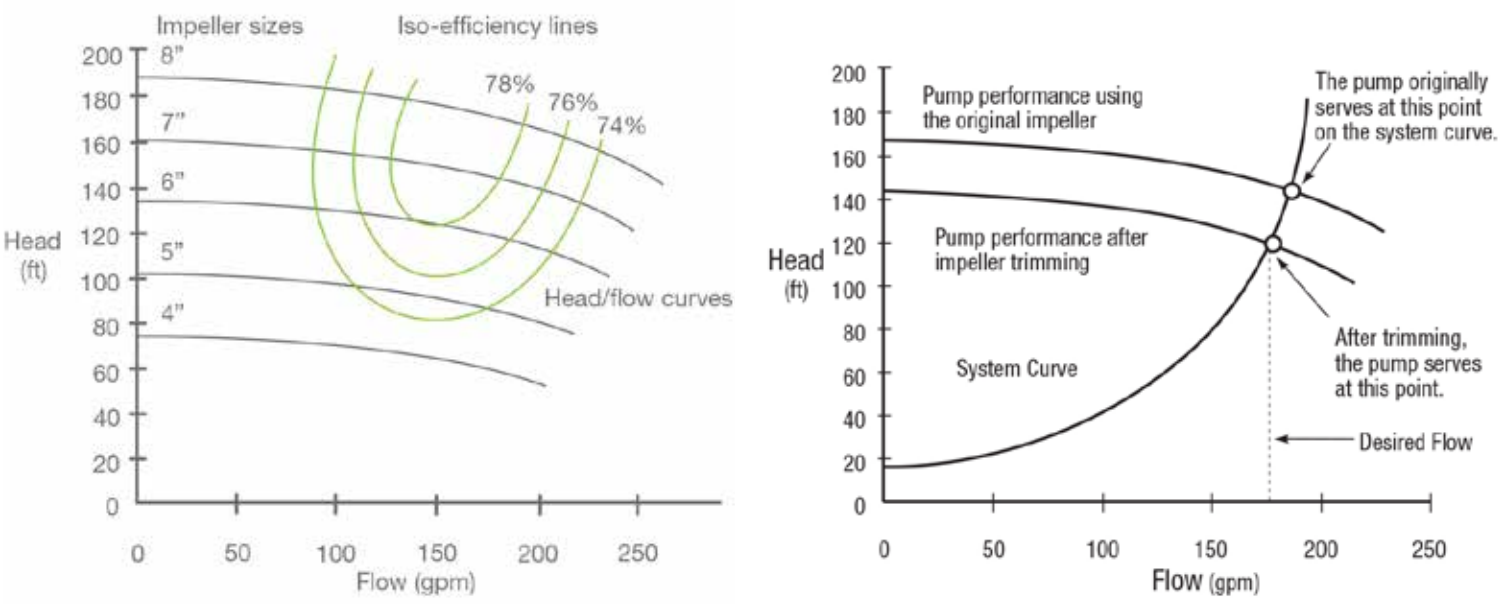
- Savings vary depending on choices made

OTHER BENEFITS

- No other significant benefits identified

EQUIPMENT/MATERIAL

- Purchase, if required, and installation by a professional



Impellor trimming can result in reduced energy consumption for oversized pumps – the left-hand image describes to optimum efficiency for different-size impellors; the right-hand image describes how the reduction in impellor size results in a reduction in pumping energy (head)

INSTALL NEW PUMP COMPONENTS

Smoother internal pump components generate flow more efficiently than rough components.

APPLY PRECISION CASTINGS, COATINGS, POLISHING

Improve pump efficiency by applying castings, coatings, or polishing on smaller pumps.

POTENTIAL ENERGY SAVINGS
- Savings can be 2-3% of pump power use

OTHER BENEFITS
- Longer operating life of pumps due to slower degradation

EQUIPMENT/MATERIAL
- Purchase and installation

Pumps use energy even on standby.

INSTALL CONTROLS TO OPERATE PUMPS ONLY WHEN REQUIRED

Reduce pump power use by installing automatic control systems or time switches to turn pumps off when they are not required for long periods (such as outside of business hours).

POTENTIAL ENERGY SAVINGS
- Savings vary depending on choices made

OTHER BENEFITS
- Lower maintenance costs
- Longer operating life of pump system equipment

EQUIPMENT/MATERIAL
- Purchase and installation

Constant speed drives (CSDs) are well suited to oversized pumps with a constant load.

INSTALL CONSTANT SPEED DRIVES

CSDs use gears to reduce the speed of the pump impeller.

Capital cost is $0.12 per kWh of power consumed by the pump that will use the CSD (2013).

POTENTIAL ENERGY SAVINGS
- Savings can be up to 20% of motor power use

OTHER BENEFITS
- Capital cost associated with replacing oversized pump with smaller pump is avoided through installation of a CSD to reduce the speed of the pump impeller

EQUIPMENT/MATERIAL
- Purchase and installation

(Table 1) Useful indicators of over-sized pumps (and the need for CSDs).

CHARACTERISTICS OF AN OVERSIZED PUMP	DESCRIPTION
Excessive flow noise	Oversized pumps can cause flow-induced pipe vibrations, resulting in excessive noise and increased damage to pipework (including flanged connections, welds and piping supports)
Highly throttled flow control valves	Pumps tend to remain in more restrictive positions in systems with oversized pumps; this increases backpressure, further decreasing efficiency
Frequent replacement of bearings and seals	Increased backpressures from increased flow rates creates high radial and thrust bearing loads as well as high pressures on packing glands and mechanical seals
Heavy use of bypass lines	A system that heavily uses bypass lines indicates that the system has either oversized pumps, is not balancing properly, or both
Intermittent pump operation	Pumps being used for purposes such as filling or emptying tanks that run very intermittently indicate oversizing and hence suffer increased start/stop inefficiencies and wear, as well as increased piping friction

INSTALL NEW PUMP COMPONENTS *CONT.*

Direct drives work well with pumps working at constant loads.

INSTALL A DIRECT DRIVE ON PUMPS

They couple the motor shaft directly to the pump impeller. They transmit power with 100% efficiency, causing the impeller speed to match the motor speed. Other drives, such as belts, gearboxes, and chains, lose at least 1-3% of power, and even more if not properly fitted and maintained.

POTENTIAL ENERGY SAVINGS
- Savings can be 1-3% of motor wpower use

OTHER BENEFITS
- Lower maintenance costs
- Longer operating life of pump system equipment
- Higher equipment reliability due to less wear and tear than typical drives
- Lower safety hazard due to fewer moving and exposed parts

EQUIPMENT/MATERIAL
- Purchase and installation

Variable speed drives (VSDs) are well suited to pumps that operate at part-load for up to 95% of the time.

INSTALL A VARIABLE SPEED DRIVE ON PUMPS

At full-load, VSDs are about 3% less efficient than constant speed drives and should be avoided in situation where full loads are required most of the time.

VSDs continually adjust the motor speed to match the pump output to the load profile. Even a small reduction in speed will lead to a relatively large reduction in power because pump power is proportional to motor speed cubed (speed x speed x speed).

The soft start features, available on some VSDs, gradually ramp up the motor speed, which can decrease energy consumption when loads are constant, but can increase consumption when loads vary frequently.

A VSD eliminates the need for flow-control devices, such as valves and bypass loops. As a flow-on benefit, pressure drop in the pipe network can then be reduced by removing unnecessary flow-control devices.

VSDs only reduce pump power as well as the controls implemented. To find the best control method, you need an appropriate control signal and an iterative procedure to find the optimal settings.

Capital cost is about $200-$500/kW (2013), about the same as the motor.

POTENTIAL ENERGY SAVINGS
- Savings can be 10-60% (20% average) of motor power use depending on size, number, and use patterns of the motor

OTHER BENEFITS
- Lower maintenance costs
- Longer operating life of pumps system equipment

EQUIPMENT/MATERIAL
- VSD for each pump
- Sufficient programming capability in the control system

Variable speed drives

Multi-speed motors use a different set of windings to operate efficiently at each speed.

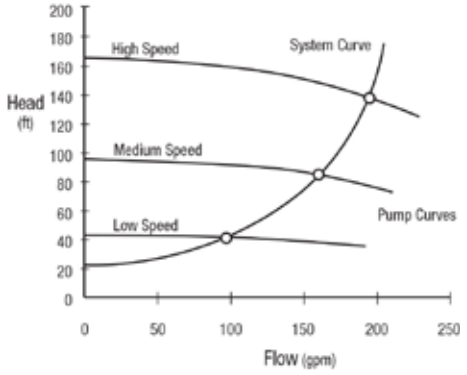
INSTALL A MULTI-SPEED MOTOR ON PUMPS

They are well suited to pumps for which VSDs are too expensive and to pumps that operate at a particular loads for long periods.

POTENTIAL ENERGY SAVINGS
- Savings vary depending on choices made

OTHER BENEFITS
- No other significant benefits identified

EQUIPMENT/MATERIAL
- Purchase and installation



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

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			
	Maintain constant maintenance schedule of pumping systems			

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
	Rearrange pipe network			
	Minimise pressure drop of the pipe network			
	Replace pump components			
	Trim or replace the impeller			
	Install new pump components			
	Apply precision castings, coatings, polishing			
	Install controls to operate pumps only when required			
	Install constant speed drives			
	Install a direct drive on pumps			
	Install a variable speed drive on pumps			
	Install a multi-speed motor on pumps			

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 PUMPING SYSTEMS

CHECK THE FOLLOWING END-USES

Tick those that apply to your business

- ○ Receiving
- ○ Pressing & liquid transfer
- ○ Mobile pumps
- ○ Refrigeration/cooling circulation
- ○ Bottling/packaging
- ○ Hot water
- ○ Wastewater (if water is treated onsite)
- ○ Other

COMPILE A PUMP SYSTEM INVENTORY

COMPILE A LIST OF THE FOLLOWING EQUIPMENT

Tick those that apply to your business

- ○ Pumps: number, make, model, type, power rating (kW), flow rate (l/s), speed (rpm), head (m; kPa), number of pump stages, and time in use (h/y)
- ○ Motor (if it is a separate unit): number, make, model, type, power rating (kW), efficiency (%), speed (rpm), and time in use (h/y)
- ○ Pipes: diameter (m)
- ○ Valves: number, make, model, type
- ○ Other

CHOOSE AN APPROACH TO ESTIMATE TIME IN USE

Tick those that apply to your business

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

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).

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ESTIMATE THE PUMPING REQUIREMENTS

COMPILE A LIST OF THE FOLLOWING INFORMATION FOR EACH END-USE

Tick those that apply to your business

- ○ Fluid: name, temperature (°C), viscosity (Pascal-seconds, or Pa-sec), solids concentration (%) and particle size (m), and density (kg/m3) or specific gravity
- ○ Flow rates (l/s) and head (m; kPa) required now
- ○ Flow rates (l/s) and head (m; kPa) required in the future
- ○ Location of end-use
- ○ Operating times or events that require pumped fluid
- ○ Reason the end-use requires pumped fluid

THIS LIST ENABLES YOU TO:

- Identify the end-uses that dominate the pumping requirements (kW)
- Identify wasteful and unnecessary uses of pumped fluid
- Estimate the base and peak pumping requirements (kW), and the variation in pumping requirements (kW), now and in the future

ESTIMATE THE EFFICIENCY OF YOUR EXISTING PUMP SYSTEMS

MEASURE THE FOLLOWING PARAMETERS

Tick those that apply to your business

- ○ Flow rate (l/s)
- ○ Head (m; kPa)
- ○ Electrical energy use (kWh)

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ Traditional approach: for permanent monitoring, install pressure tappings (connections that do not interrupt the main flow) on either side of the pump, away from regions where pipe components disturb the fluid flow. For critical pumps, consider continuous monitoring by installing ammeters on the motor, pressure gauges on the pump inlet and outlet, energy meters on large pumps, and a flow meter. Also consider electronic data-logging
- ○ Thermodynamic approach (pump): install temporary pressure probes and sensitive temperature probes at the pump inlet and outlet to determine the energy losses (energy not converted to flow and pressure) (kWh). Calculate the flow rate (l/s) by also measuring the power (kW) used by the pump
- ○ Thermodynamic approach (single pump system): install meters to measure the motor input power (kW). Install a flow meter at the pipe outlet to determine the flow rate (l/s). Install a pressure probe at the pipe outlet to determine the fluid pressure (kPa). Calculate the fluid power (kW) using the pressure (kPa), flow rate (l/s), and specific weight (kN/m3). Calculate pump efficiency (%) by taking the ratio of the fluid power (kW) and the motor input power (kW)

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.

DETERMINE THE BUSINESS PARAMETERS OF THE PUMPING SYSTEM

QUANTIFY OR QUALIFY THE FOLLOWING VALUES

Tick those that apply to your business

- ○ Energy price(s) ($/kWh; $/l petrol/diesel/fuel)
- ○ Capital budget ($)
- ○ Targets for running costs ($/y)
- ○ Required level of redundancy in the system
- ○ Acceptable payback period or return on investment
- ○ Acceptable level of risk for new technologies
- ○ Equipment constraints, such as: specific brands of motors or pumps; 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.

DEVELOP A MODEL OF THE PUMPING SYSTEM

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ Software (most common): requires pump system design software, which provides a list of suitable pumps and is usually linked to a particular pump manufacturer
- ○ Manual: requires calculations and graphs

Use data about the fluid, and pumping system components and configuration to calculate friction losses (kW), resistance curves of the system, and running costs ($/y).

This process enables you to compare the current operating points of the pump with the peak-efficiency point (rpm).

REVIEW MANUFACTURER DATA

REVIEW THE FOLLOWING DATA

Tick those that apply to your business

- ○ Pumps: pump manufacturers supply graphs of 'pressure versus flow rate' at various speeds (rpm), which includes efficiency curves. Pump efficiency (%) varies widely with speed (rpm). It usually peaks near the middle of the range of speeds (rpm)
- ○ Variable speed drives: VSD manufacturers supply information about the load characteristics for which their VSDs are designed. VSDs are most effective when installed on a pump that is designed for the same load characteristic. Most pumps are designed for a specific quadratic load

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 PUMP SYSTEM PERFORMANCE

CHECK THE FOLLOWING CONDITIONS

Tick those that apply to your business

Tick those that apply to your business

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

SELECT A SERVICE PROVIDER

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

Tick those that apply to your business

- ○ Measurement and analysis of the pumping requirements profile, and power (kW) of pumps and end-uses
- ○ Reporting on equipment and process performance
- ○ Optimisation of the pumping system, including: optimisation of the control system, flow rates (l/s), and head levels (m; kPa); management of fluid leaks; and minimisation of the pumping requirements at end-uses
- ○ Design of a pumping system that aims to minimise losses from the end-use to the pump
- ○ Supply, service, and installation of pumping system equipment (e.g. pumps, pipes, and valves) 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
- ○ 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 *Pumping* 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

Lawrence Berkeley National Laboratory: BEST Winery Guidebook – Benchmarking and Energy and Water Savings Tool for the Wine Industry

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US Department of Energy (2006), Improving Pumping System Performance: A Sourcebook for Industry, Section Edition US Department of Energy – Energy Efficiency and Renewable Energy and Hydraulic Institute

US Department of Energy (2007) 'Energy Tips – Pumping Systems', Tip Sheet 10: 'Energy Savings Opportunities in Control Valves'. Industrial Technologies Program, Energy Efficiency and Renewable Energy

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