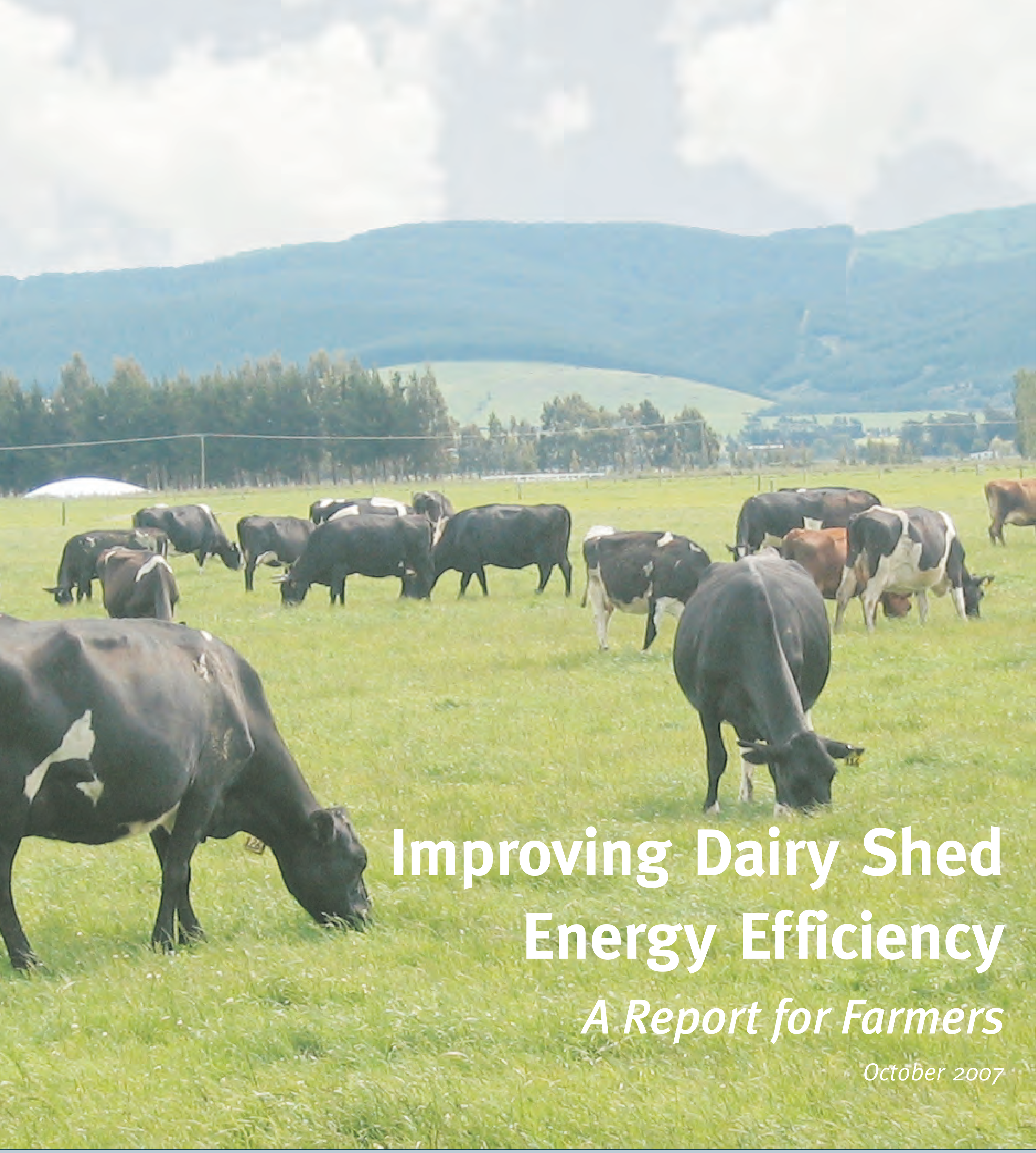
www.cowshed.org.nz



Improving Dairy Shed Energy Efficiency

A Report for Farmers

October 2007

CAENZ

Venture Southland
Enterprise, Tourism & Community Development

Sustainable Farming Fund
Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Dairy InSight

Preface

The *Energy Efficiency in Dairy Sheds* project provides dairy farmers with a robust and objective view on ways, with good practice, that they can significantly improve energy efficiency and operating costs for all types of dairy sheds. This report is also for other farmers planning a conversion, potential new dairy farmers, and other interested persons.

Equipment trials were carried out on five Southland dairy farms during the 2006/07 dairy season. The trials examined the performance and effects of various pieces of equipment including a heat pump, heat recovery units, a solar water heater, vacuum pump variable speed drives, milk pump variable speed drives, a milk vat insulating wrap and a chilled water milk cooler.

Based on real time energy monitoring and independent assessment, the project has provided a much-needed information source for farmers who have been wary of making energy management decisions based on incomplete information and claims made within sales literature.

The key focus in this project has been to identify ways in which energy use in the dairy shed can be reduced and to measure the energy savings possible under practical conditions as applied to existing dairy sheds. There are of course two factors that need to be taken into account when considering investment in new technologies: cost effectiveness and overall energy use. These are interrelated and need to be considered together, not separately.

For example, there are there are immediate gains to be made from better tariff options – specifically the use of night rate. Moving electrical demand to night time does not save energy, but it does make better use of the national and local infrastructure for the production and transmission of electricity.

This study has found many critical points for the dairy sector to consider in improving energy usage.

One example is the overall importance of gaining efficiencies in water heating and hot water storage. It has been shown that there are many options available and the performance of these systems and devices is, in most cases, very close to the claims made by the manufacturers and suppliers.

The study has demonstrated that any farm seeking a best practice approach to energy efficiency will need to focus on approaches to designing the dairy shed and the specification of best-in-class equipment. Additional electricity meters are needed as part of an energy management programme that provides for checking temperatures, flow rates and pressures, and recording electricity use.

This collaborative study has identified a number of related issues which merit further investigation. There is an obvious need to work with equipment suppliers to ensure that farmers can measure their energy consumption easily and accurately. Further investigation is needed into opportunities for improving energy efficiency enabling technologies.

In the long term, a clear set of standards is required for the performance of dairy sheds and their design. The findings from this study suggest that without the adoption of national design standards or best practice guidelines it is unlikely that significant gains will be made in energy efficiency across the industry.

Reference to the *Energy Efficiency in Dairy Sheds – Technical Report* is recommended for detailed technical information on which this report is based. This is available at www.cowshed.org.nz, along with other reports written during the project, and the cost calculator decision tool, a major output of this study.

R J (George) Hooper, Executive Director
New Zealand Centre for Advanced Engineering

Contributors to this report are Dr Ken Morison, Warren Gregory, Don Mackenzie and Scott Caldwell. The contributors would like to particularly acknowledge the advice and oversight of Robin McNeill, Venture Southland, during the course of this project.

Published October 2007 by the New Zealand Centre for Advanced Engineering, University of Canterbury Campus, Private Bag 4800, Christchurch.

1 Background

Electricity is a significant cost for the dairy sector and a major factor in rural energy demand growth. Technologies have been developed to improve energy efficiency in New Zealand dairy sheds but a lack of independent assessment and easily-accessible information has meant that many farmers have remained unaware of potential efficiencies, or have been unwilling to commit time and investment into this area.

Energy Efficiency in Dairy Sheds was a collaborative project – its aim was to identify cost-effective measures that will improve dairy shed energy efficiency based on practical trials on working dairy farms in Southland. These results and cost-effective measures should be helpful for similar sized dairy properties in other locations in New Zealand.

The project was facilitated by Venture Southland and was funded by Dairy InSight and the Ministry of Agriculture and Forestry's Sustainable Farming Fund, with field work and analysis carried out by the New Zealand Centre for Advanced Engineering (CAENZ).

The findings and trial results reported here provide the means for dairy farm owners and managers to make informed decisions relating to the selection of equipment and best practice in the dairy shed. They also provide equipment designers and suppliers with objective performance measures which will help to inform product development and innovation.

The project focused on opportunities for reducing electricity use and cost by:

- Changing operating practices.
- Improving maintenance.
- Improving the efficiency of equipment operation.
- Using energy sources that are cheaper than electricity.

Cost-effectiveness was evaluated using standard economic decision making tools and most often the 'simple payback method' – how many years of savings it takes to equal the initial cost. The report writers' view is that in most cases a dairy farmer would be unlikely to make a change to an existing arrangement unless the payback period was five years or less. However for new installations longer payback periods may be acceptable.

Cost savings were based on August 2007 electricity prices, with some rounding for ease of comparison. For farms buying electricity on an 'anytime' pricing plan, the typical average price was 15 c/kWh (after deducting any discounts and before adding GST), but this includes the fixed daily charge. In valuing savings, a marginal cost of 14 c/kWh was used. However, where a night-rate pricing plan is used this lower rate needs appropriate consideration.

For the purpose of this report a typical dairy farm in Southland is taken as a farm producing a peak of 15000 litres of milk per day and using 1000 litres per day of hot water. The vacuum pump is a water ring pump without a variable speed drive, water heating is by electricity on the 'anytime' plan, milk cooling is with primary cooling by dairy shed water, and milk storage is in vats without insulation (see Figure 1.1). Electricity costs are in the order of $15,000 annually.

Electrical energy used for different functions in a typical dairy shed (without energy saving equipment) is shown in Figure 1.2.

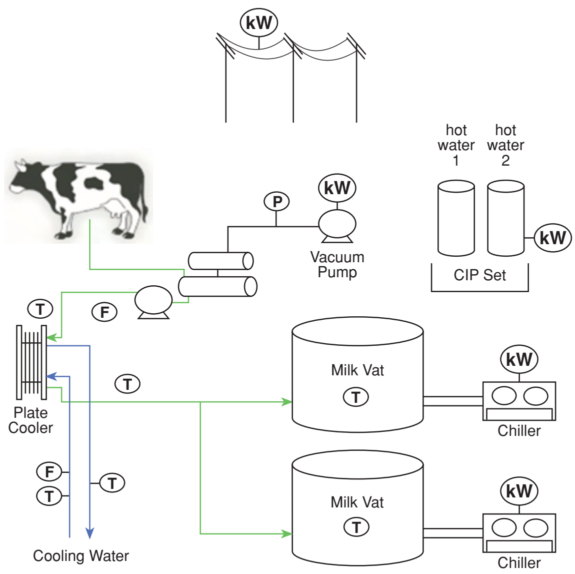


Figure 1.1: Processes in a typical dairy shed (T = temperature; F = flow rate; P = pressure)

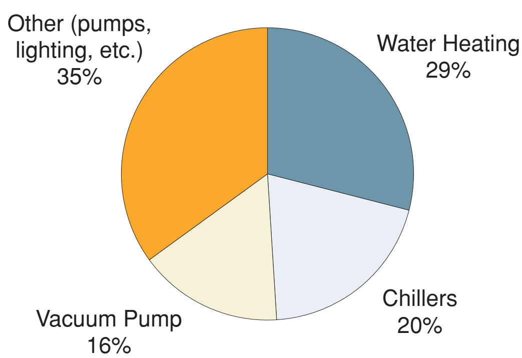


Figure 1.2: Typical percentages of electrical energy use in a Southland dairy shed

2 Vacuum Pumping

Introduction

The vacuum pump is the heart of the milking machine and is also a significant consumer of electricity. As an example, a water ring vacuum pump used to operate a 50 bail rotary milking machine might consume 16% of the total electricity used in the dairy shed. Over a season, the cost of this electricity will be approximately $2,500.

Three main types of vacuum pump are in common use:

- the water ring pump;
- the positive displacement or rotary lobe blower commonly referred to as a 'blower'; and
- the rotary vane pump.

No dairy sheds in the trial had a rotary vane pump already installed at the start of the project, but one was installed later as a trial.

Each of the three types of pump has advantages and disadvantages as shown in Table 2.1. These must be weighed up when deciding which type to install. In addition to energy efficiency and suitability for variable speed operation, other factors to consider include initial cost, maintenance requirements, noise and cleanliness (oil lubricated pumps can be messy).

Options for Improving Energy Efficiency

There are two main options for improving the energy efficiency of the vacuum pumping system:

- Use the most energy-efficient design of pump.
- Use a variable speed drive to control the pump speed.

Vacuum pump efficiency

The three commonly-used designs of vacuum pump have different energy efficiencies:

- water ring (lowest efficiency);
- lobe rotor; and
- rotary vane (highest efficiency).

Choosing a lobe rotor or rotary vane pump instead of a water ring pump will lower the energy used for vacuum pumping.

Variable speed drives

An alternative to the traditional 'air bleed' vacuum regulator is to fit the vacuum pump with a speed controller that will vary the pump speed automatically to maintain a constant vacuum line pressure.

The main advantage of speed control is that as the pump speed reduces, the power required to drive it reduces also. Most dairy vacuum pumps have a considerable amount of spare capacity at

Figure 2.1: An installed rotary vane vacuum pump

Water ring	Lobe Rotor	Rotary vane
Advantages • milk or wash water can pass through without damaging the pump • quieter than other designs	*Advantages* • no lubrication required • well-suited to speed control • higher energy efficiency than water ring pump • no water required	*Advantages* • highest energy efficiency • no water required
Disadvantages • least energy efficient • least well-suited to speed control • require a continuous supply of good quality water	*Disadvantages* • noisy • can be damaged if milk or wash water passes through	*Disadvantages* • requires oil lubrication • can be damaged if milk or wash water passes through • limits on maximum and minimum speed

Table 2.1: Advantages and disadvantages of three different vacuum pump designs

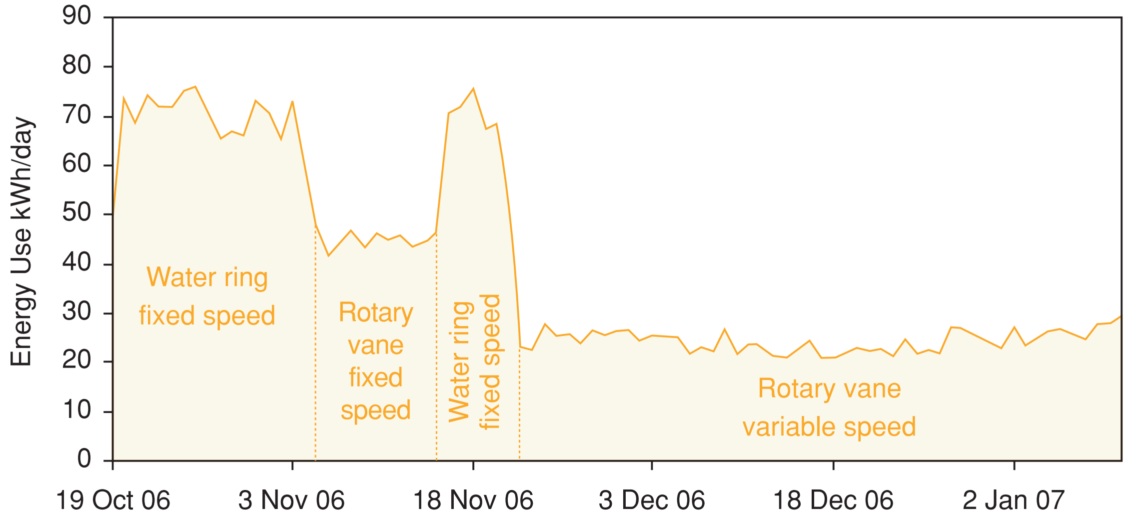


Figure 2.2: Daily energy use for vacuum pumping in a trial using a rotary vane vacuum pump with and without variable speed

their rated speed and controlling the motor speed results in significant energy savings.

As well as being installed in new dairy sheds, motor speed controllers can also be retro-fitted to the vacuum pumps in existing sheds.

Vacuum pump trials and CSL variable speed control trials were carried out at three farms.

A rotary vane vacuum pump (Supervac 7) was installed alongside the existing water ring pump with piping arranged so that either pump could be selected (see Figure 2.1).

Energy Efficiency

There is a significant range in the power requirement of vacuum pumps, and energy savings can be made by using an energy-efficient design.

In a trial, the use of a rotary vane pump in place of a water ring pump reduced energy use of the vacuum pump typically from 71 to 44 kWh/day (38% reduction), and it is estimated that this will save 6750 kWh over a year. The fall in daily energy use for vacuum pumping is shown in Figure 2.2. Although a lobe blower was not trialled, it is estimated that in the same application it would reduce energy use by 22% - 30%.

A further reduction in pumping energy requirements can be achieved with the addition of a variable speed drive system such as a Varivac to an existing pump. The energy savings achieved when a Varivac system was added at three farms are shown in Figure 2.3.

Combined savings can be achieved if a water ring pump is replaced with a rotary vane or lobe pump with variable speed drive. A saving of 61% for the lobe pump is expected and 64% for the rotary vane. A 64% saving represents a reduction to nearly one third as shown in Figure 2.3.

Other matters

Vacuum control

It is claimed that in some cases variable speed control can improve vacuum control. This was checked at three farms using pressure measurements made in the vacuum line at a point as close as practicable to the milk receiving can.

From these results there is no evidence that vacuum control was improved by the use of variable speed control on the vacuum pump. However, the control achieved was satisfactory.

The vacuum line pressure data showed that the

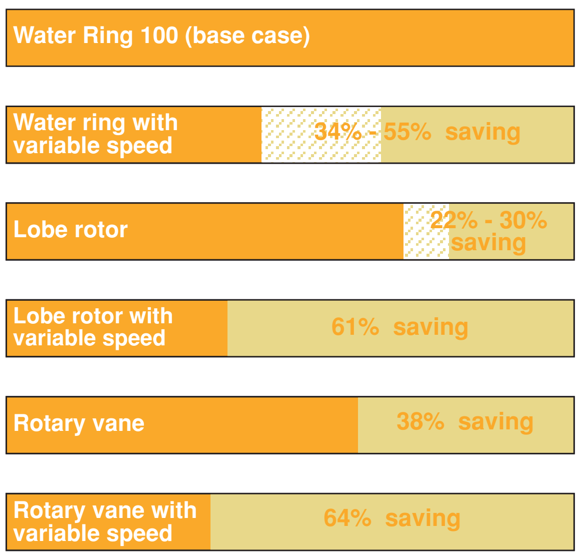


Figure 2.3: Energy savings comparing vacuum pumps with and without variable speed drives

conventional air bleed system can work well. If a farm is having control problems the existing vacuum control system should be checked.

Somatic Cell Count

For all three farms, there was also no obvious change in the somatic cell count of the bulk milk sent to the Fonterra processing plant.

Figure 2.4 shows the somatic cell count in the bulk milk collected over the 2005/06 and 2006/07 seasons for one farm. It also shows the periods in the 2006/07 season when the Varivac was on and off. It was beyond the scope and technical expertise of the study team to determine what factors have influenced the somatic cell count. It is possible that reduction in noise and vibration in the milking equipment contributed to the changes but this was not tested.

Milking time

Data for milking time was analysed to see if there was any change following the implementation of speed control. There was no measurable evidence that the milking time was reduced.

Noise

All vacuum pumps are noisy, but sound level data does not appear to be readily available. Anecdotal evidence from suppliers is that water ring pumps are the quietest and lobe pumps the noisiest.

Transfer of vacuum pump noise into the dairy shed can be minimised by:

- locating the pump in a separate room or acoustic enclosure;
- fitting a silencer to the exhaust line; and
- positioning the pump exhaust so that it points away from any work area.

While running in variable speed mode, the water ring vacuum pumps were noticeably quieter than when running at fixed speed. One farm manager noted that dairy shed staff were pleased with this.

The noise from the rotary vane pump was more annoying than the noise from the water ring pump. This was particularly so when the pump was operated at variable speed and the pitch of the sound varied with the pump speed. In a permanent installation, it is likely that the noise could be significantly reduced by means indicated above.

Maintenance

Because of the relatively short length of the trials, no information was obtained on maintenance costs. However, oil leaks from the lubricators and associated pipework were a problem during the rotary vane pump trial. This type of pump requires continuous lubrication and dairy shed staff need to regularly check lubricator oil levels and add oil when required.

Water Use

Water ring vacuum pumps require a continuous flow of water to make up for the water carried out of the pump with the exhaust air. The water supply arrangement typically seen in Southland is the 'once through' system where the water carried over is drained to waste. A water ring vacuum pump with a 'once through' water supply consumes about 5 litres per minute which compares with about 100 litres per minute for milk cooling.

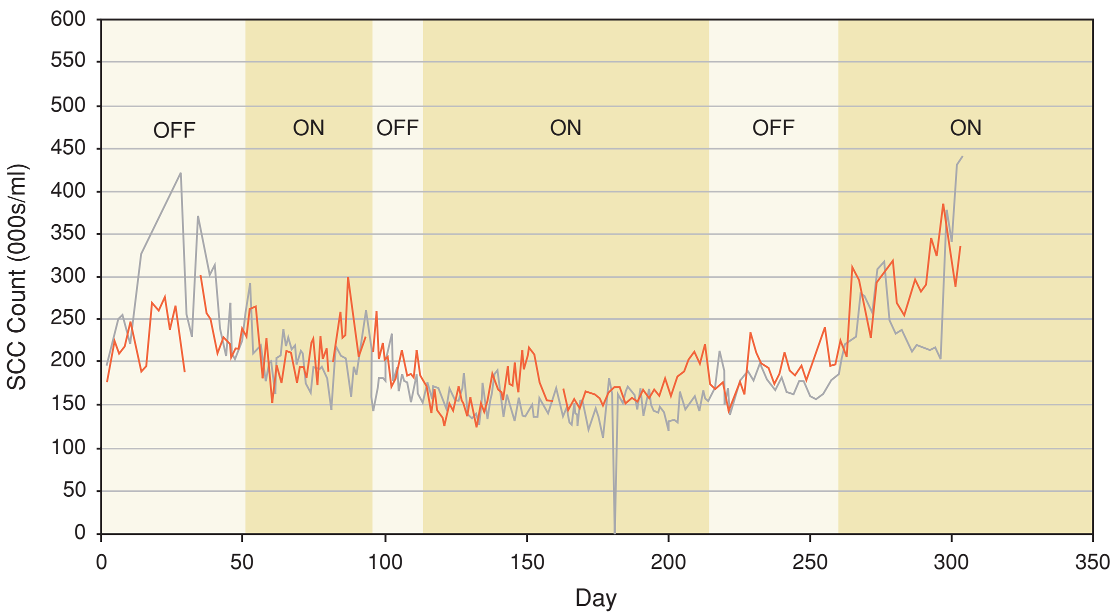


Figure 2.4: Somatic cell count in the bulk milk collected during the 2005/06 and 2006/07 seasons

Cost savings and economics of investment

Vacuum pump type selection

The cost of electricity to run each of the three different vacuum pump types for a year is shown in Figure 2.5 for a range of electricity prices. These costs are based on a pump of 4000 litres per minute capacity (the size required for a 50 bail shed) operating for 1900 hours.

At a marginal electricity price of 14c/kWh, the annual electricity costs are:

- water ring pump $3500
- lobe rotor pump $2700
- rotary vane pump $2500

A vacuum pump cannot be selected on energy efficiency alone however – other factors such as noise and maintenance requirements have to be considered.

The use of a rotary vane pump rather than a water ring pump saved an estimated $945 per year (38%) for a 38-a-side herringbone shed. It is estimated that a lobe rotor in the same application would save $550 - $750 per year (22% - 30%). The influence of electricity price on these figures is shown in Figure 2.6.

Using a 5-year simple payback period as the criterion, changing from a water ring pump to a more efficient rotary vane pump for this example is only justifiable if it can be done for $5000 or less.

Variable speed drive

At a marginal electricity price of 14c/kWh, the estimated annual cost savings when a variable speed drive such as the Varivac is fitted to an existing pump are:

- water ring pump $1800 (Site 1)
- water ring pump $900 (Site 2)
- lobe rotor pump $850
- rotary vane pump $750

The estimated cost savings will vary with electricity price as shown in Figure 2.7.

The current CSL Varivac prices are about $7800 for 15 kW and $6500 for 11 kW plus installation of $600. To achieve a 5-year payback period, annual savings of $1680 for a 15 kW system and $1420 for an 11 kW system would be required. Varivacs were trialled on water ring pumps at two farms, but the savings achieved at only one of these was large enough to justify the necessary investment.

Combination of efficient pump and variable speed drive

Further savings can be achieved by replacing the

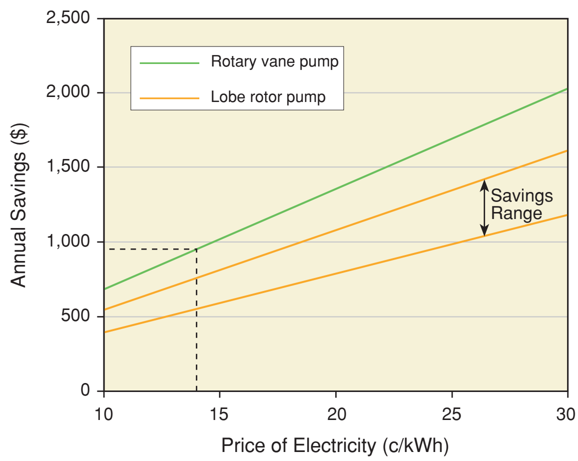


Figure 2.6: Estimated annual cost saving when replacing a water ring pump with an alternative pump type in a 38 cluster dairy shed

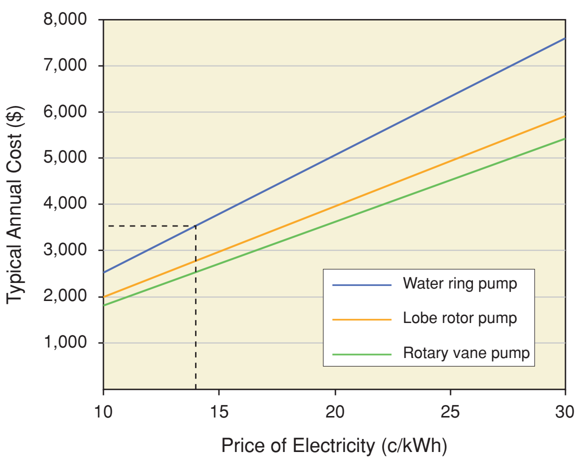


Figure 2.5: Annual electricity cost for a 4,000 litre/minute vacuum pump

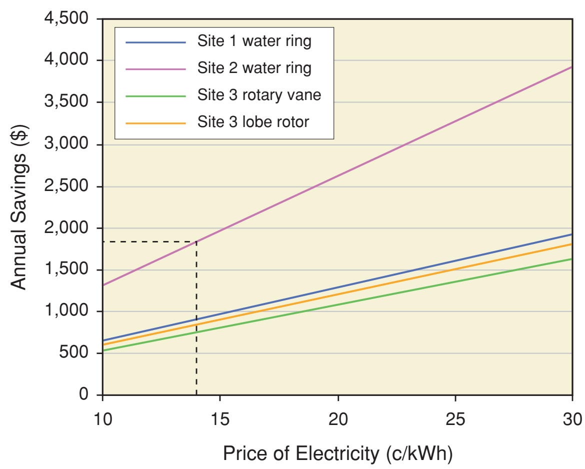


Figure 2.7: Influence of electricity price on the predicted savings from fitting a variable speed drive to each of the three types of vacuum pumps

Bails	Design flow rate [L/min]	Saving when using lobe rotor with variable speed	Saving when using rotary vane with variable speed
20	1600	$870	$910
30	2400	$1300	$1370
40	3200	$1730	$1820
50	4000	$2170	$2270
60	4800	$2600	$2730

Table 2.2: Annual savings using a new lobe rotor or rotary vane pump with variable speed drive in place of a water ring pump

old pump with a more efficient one that has a variable speed drive. Table 2.2 predicts the savings achievable when this is done.

Figure 2.8 shows the influence of electricity prices on these predicted savings.

Again using a 5-year pay back period, an additional investment of $13,000 - $14,000 for a rotary vane or lobe pump with variable speed control would be justified on a 60 bail farm.

Summary

For new installations, energy use will be minimised by installing an energy-efficient pump (lobe rotor or rotary vane) and a variable speed drive.

For existing installations, replacing a water ring vacuum pump with a lobe blower or rotary vane pump in order to reduce energy use is unlikely to be justified by energy cost savings. Adding a variable speed drive to a water ring pump will provide savings, but may not always achieve a five-year payback. Section 9 shows how to check the likely savings and make the decision on the worth of this investment.

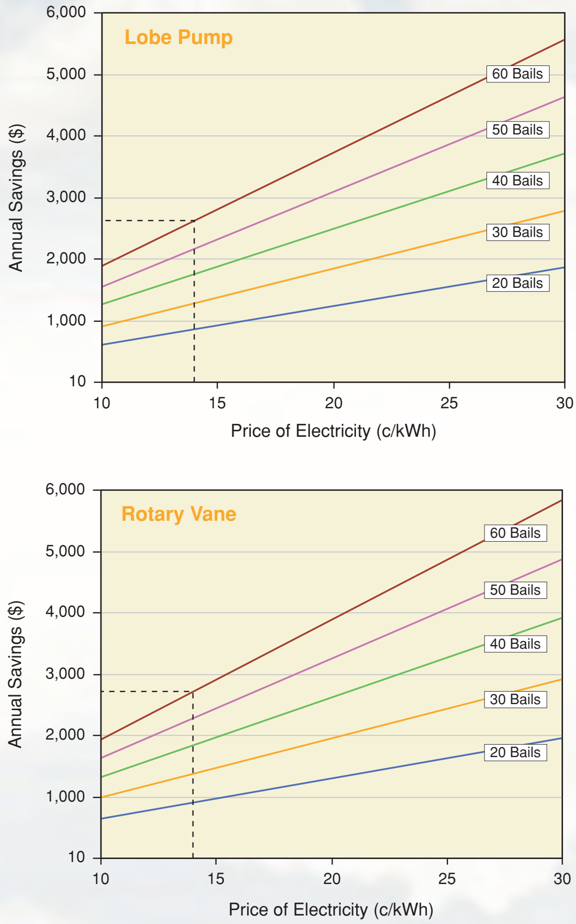


Figure 2.8: Influence of electricity price on predicited savings for a lobe rotor pump and a rotary vane with variable speed drives

3 Water Heating

Introduction

Cleaning Requirements

Hot water is used in the dairy shed for cleaning the milking plant and the milk storage vat. The New Zealand Food Safety Authority (NZFSA) code of practice 'NZCP1: Code of Practice for the Design and Operation of Farm Dairies' provides practical guidance on most matters related to dairy shed hygiene including cleaning. It recommends the use of hot water for cleaning and in Section 15.4.1 says:

> *'The minimum quantity of hot water available shall be 10 litres per set of cups and 2% of the vat volume with a minimum volume for vats of 120 litres.'*

As an example, a farm with 50 sets of milking cups and a milk vat of 25,000 litres would require at least 1000 litres – 500 litres for the plant wash and 500 litres for the vat wash.

Energy used for water heating

The amount of energy used to heat water in a dairy shed depends on:

- how much hot water is used;
- the temperature range through which the water is heated; and
- the efficiency of the water heating and storage system.

Typical practice is for water to be heated to 85˚C so that there is sufficient residual heat (for the operation losses) to keep the washing water above 60˚C to remove milk fat.

A 50 bail dairy shed typically uses about 1,000 litres of hot water each day but this figure could rise to 1,500 litres if the cleaning procedure requires the milk lines to be washed twice with hot water. On-farm monitoring has shown that the amount of energy (usually electricity) required to heat this water from 10˚C to 85˚C and to hold it at this temperature is about 0.1 kWh per litre in a conventional electric water heater.

Considerably less energy is required by the water heater if there is some means of pre-heating the water, e.g. a heat recovery unit on the refrigeration system.

Most dairy sheds in Southland use electricity for water heating. A dairy shed using 25,000 kWh per year for water heating can therefore expect to pay between $2,000 and $3,800 for water heating depending on the cost of the electricity used (see Section 7, Electricity).

Options for Water Heating

The options for improving energy efficiency and reducing the cost of water heating include;

- Improving the efficiency of existing electric water heating systems;
- Using alternative technology to heat water; and
- Reducing the cost of electricity.

Improving existing systems

Measurements made during the project trials show that hot water usage varies significantly from shed to shed and so there is scope for better management of hot water. Measurements also showed that there are significant energy losses from the typical dairy shed water heating system and that these can be reduced by simple, low cost measures.

Alternative heating systems

Many alternative heating systems are possible including using:

- fuels such as wood, coal, oil and gas;
- biogas from an 'on-farm' digester;
- electricity from a wind or hydro-powered generator;
- waste energy recovered from other dairy shed equipment; and/or
- a solar water heating system.

See the full technical report for information on heating systems that have not been discussed in this report. The most cost effective are the systems that recover heat from the milk vat refrigeration system, pre-heating the cold water before it goes into the electric heaters for final heating and storage. The heat energy in the milk (initially at 38˚C) is many times that required in the hot water (target 85˚C). Transferring this heat using a heat pump is an effective use of electricity.

Reducing the cost of electricity

Reducing the purchase price of the electricity used in an electric water heating system will save money but won't reduce energy use. Ways of reducing the electricity price are discussed in Section 7 of this report.

Trials

During the project, the performance of the water heating systems at five dairy sheds was monitored. In addition, three alternative heating systems were set up and monitored:

- DTS heat recovery unit — heat recovery from the condenser of the milk vat chiller unit.
- Heat pump (Mahana Blue) — heat recovery from the condenser of the milk vat chiller unit.
- Solar water heating system - with 12 m^2 of collector.

Energy efficiency

Reducing hot water use

An obvious way to reduce the cost of water heating is to use less hot water but this must not be done at the risk of affecting shed hygiene and milk quality. An annual cost saving of $2,000 would be quickly lost if a load of milk was downgraded as a result of inadequate cleaning of the plant or vat.

Ways to minimise hot water use include:

- Ensuring that only the required amount of hot water is used for each wash. Some dairy sheds use significantly more hot water than others of similar size and could benefit from a careful review of washing practices.
- Eliminating losses from dripping taps or overflowing cylinders. A dripping hot tap is an obvious source of energy loss but often goes un-checked. During the project, the flow rate from a leaking valve was measured and found to be the equivalent of 144 litres per day. Assuming the leaking water to average 70°C, the system was losing 9 kWh of energy per day. If left unchecked for the whole 300 day season, this drip would have wasted 2,700 kWh of electricity.

Reducing the frequency of hot washing

Hot water use can also be reduced by reducing the frequency of hot water washes. Based on the normally recommended hot water quantities, a farm with 38 sets of milking cups and a milk vat of 18,000 litres would require at least 740 litres – 380 litres for the plant wash and 360 litres for the vat wash.

If such a farm reduced hot washing of the plant from once a day to once every two days (and retained a daily hot wash of the vat), the number of hot washes of the plant would reduce from 280 to 140 per season. Allowing for daily hot washing of the plant during the first 8 weeks of the season while calving cows are producing colostrum, the required number of hot washes is 168. Therefore 112 hot washes might be saved over the remainder of the season.

Each hot wash requires approximately 33 kWh of energy. Over one milking season the possible saving in electricity for this shed is about 3700 kWh and at the marginal electricity price of 14 c/kWh, this is worth $520. A smaller shed using 240 litres of hot water per wash would save 2400 kWh ($330) and a larger shed using 600 litres would save 5900 kWh ($820).

The value of these energy savings at different electricity prices is shown in Figure 3.1.

Changing to a programme of reduced hot washing requires a change in detergent. A suitable detergent has been approved by the New Zealand Food Safety Authority (NZFSA) for use in a reduced frequency wash programme. It is reasonable to assume that an approved product used in accordance with the manufacturer's instructions will not adversely affect milk quality.

In the example given above, the electricity cost saving is $520 per year before taking account of any difference in detergent cost. The website www.deosan.co.nz provides an 'on-line' calculator. The results produced by this calculator were checked and appear correct.

There is no capital investment required to change to reduced frequency hot washing and it is certain that there will be some saving in electricity use due to reduced usage of hot water.

The $520 per year electricity cost saving quoted above was based on purchasing electricity at a marginal cost of 14 c/kWh. The cost of water heating can be lower than this if using night rate electricity or an alternative heating system (e.g., a heat pump). In such cases, the electricity cost saving will be reduced and the economics of reduced hot washing should be carefully checked before proceeding.

'Just in time' control

Many dairy shed managers leave the electricity supply to the water heaters turned on at all times

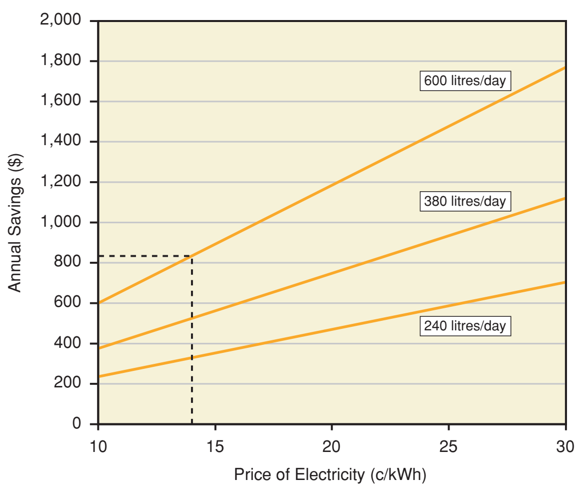


Figure 3.1: Estimated annual savings from reducing the number of plant hot washes on a farm from 280 to 168

and this means that heating starts as soon as the heater is filled with cold water.

A water cylinder that is reheated immediately after morning milking will normally be up to temperature by 2pm. If the hot water is not required until 8 am the following morning, a significant amount of electricity will be used to hold the water at 85˚C over the intervening 18 hours. This is illustrated in Figure 3.2.

From 2pm until 8 am the following day, the elements switched on at regular intervals to make up heat losses and keep the water up to temperature. During this period, the heater consumed 7.8 kWh. If this was repeated every day of a 300 day season, the annual energy loss would be 2,300 kWh. In a shed with two water heaters, the annual energy loss could be twice this amount.

This energy loss can be greatly reduced if the heating is delayed until nearer the time the hot water is required. If the hot water is needed only at morning milking, a time switch should be used to switch the heater on at about 11pm. Heating at this time will not only reduce the energy loss but is also ideal for making use of cheaper night rate electricity. On a large farm, changing to night rate water heating may reduce electricity costs by about $2,000 – see Section 7.

If the hot water is needed at afternoon milking, the best time to heat the water depends on the electricity purchase plan. If the electricity price is the same both day and night then turning the heater on five to eight hours before the water is needed will be best because losses will be minimised. If night rate electricity is available however, it will always be much cheaper to use this to heat the water at night and accept that throughout the day there will be a significant heat loss from the hot cylinder. In this case, it is likely to be worthwhile improving the insulation of the hot water system to minimise the losses.

Insulation

Based on measurements made during the project, the average rate of heat loss from nine dairy water heaters and their associated piping when operating at their maximum temperature (typically 85˚C) was calculated to be 440 watts (W).

An independent trial was carried out to measure the heat losses from a hot water cylinder in a controlled indoor environment. This showed that a well-insulated cylinder with well-insulated pipework might be expected to have a loss rate as low as 150 W.

The amount of energy lost over a day will depend on how long the heater and pipework are kept hot and adopting 'just-in time' heating will significantly reduce this loss.

To minimise losses when the heater is at operating temperature, consider the following:

- Location – cylinders and their piping that are exposed to air movement will have substantially greater heat loss than those in still air. Locate new cylinders indoors in a sheltered location. Existing cylinders and piping that are exposed to draughts will benefit from being enclosed or otherwise shielded from draughts.

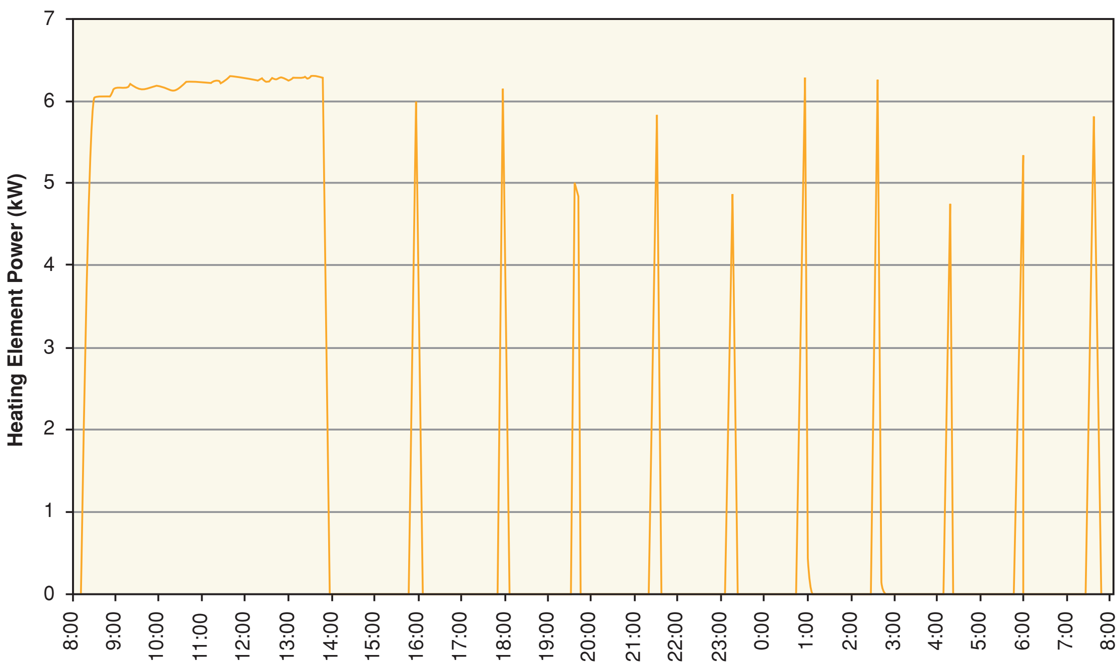


Figure 3.2: Power requirement of a typical 400 litre water heater that is refilled immediately after use for the morning 'lines' wash

- Pipe insulation – insulate all warm or hot pipework.
- Cylinder insulation. A modern cylinder in good condition will not benefit greatly from having a cylinder wrap added - insulating the pipework is a better investment.

  Older cylinders or those that are exposed to the wind will benefit more from a cylinder wrap.

The cost saving that would be achieved by reducing the loss rate from 440 W to 150 W would be $195 per year per cylinder. This figure is based on a marginal electricity price of 14 c/kWh and assumes the cylinders are at temperature for 16 hours a day, 300 days a year. Based on a 5 year payback, expenditure of $1000 per cylinder would be justified to achieve this saving.

Cost savings at other electricity prices are shown in Figure 3.3.

Thermostat setpoint

Faulty water heater thermostats or thermostats set at too high a temperature are also a source of unnecessary electricity use. A thermostat that fails to open will cause the water to overheat and boil. Usually this will be obvious to the shed manager but not always. Any signs of steam discharging from the overflow pipe should be a signal to suspect a faulty thermostat.

Having the thermostat set above 85°C also results in unnecessary heat loss from the water cylinder and pipework. The water temperature should be checked periodically (using an accurate thermometer) when the wash tub is being filled.

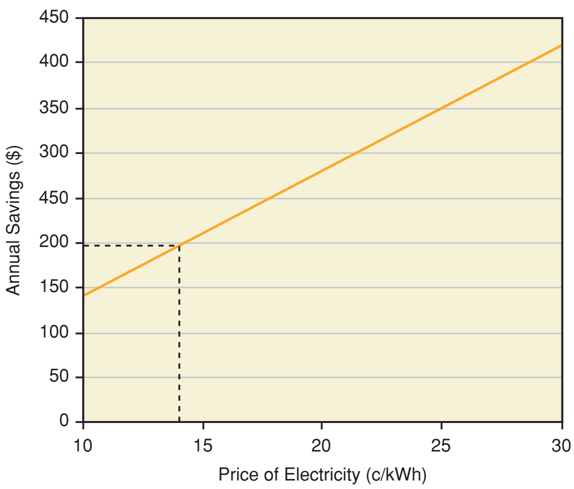


Figure 3.3: Annual saving that would be achieved if the rate of heat loss from water cylinders on the monitored farms was reduced to the level achieved in the workshop trial

Alternative heating systems

Direct heating with the condenser of the milk vat chiller unit

Most milk vat refrigeration systems reject the heat extracted from the milk through an air-cooled condenser. By adding a refrigerant-to-water heat exchanger between the compressor and the condenser, a portion of this heat (the superheat) can be removed. This superheat can be used to pre-heat the water for the dairy shed hot water system. The heat exchanger in this system is sometimes referred to as a 'de-superheater' or more simply as a 'heat recovery unit'. Two systems have been reviewed.

The DTS heat recovery unit system has a small brazed plate heat exchanger fitted into the refrigerant circuit of the milk vat cooler. The cold feed to the water heater passes through this heat exchanger and into the water heater. A float valve in a stainless steel cistern stops the water flow when the water heater is full. This is a 'once through' system and so the water flow has to be kept low so that it reaches an adequate temperature (see Figure 3.4).

The PE Heat Minda system has a similar (but larger) heat exchanger used in conjunction with a pump and an extra hot water storage tank. This system has the added feature of storing the hot water and recirculating it to maximise the heat recovery. When the refrigeration unit is running, water from the tank (which typically has a 1000 litre capacity) is circulated through the heat exchanger and back to the tank. This pre-heated water is then used to automatically re-fill the water heaters through an insulated make-up tank (see Figure 3.5). The Heat Minda system was not trialled.

Based on the measurements made during the trial of the DTS heat recovery unit, it is estimated that over a full season the trial dairy shed was using 32,000 kWh of electricity for water heating. Note

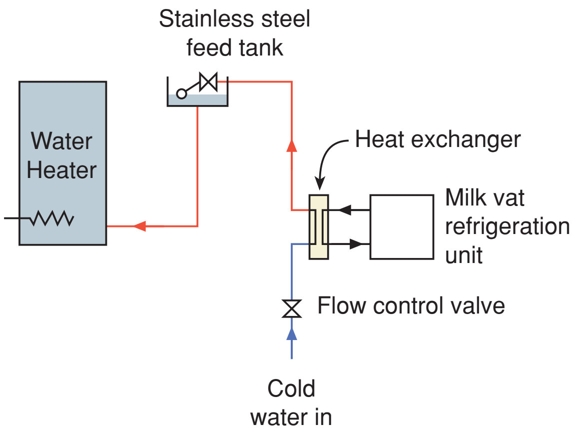


Figure 3.4: Diagram of the DTS heat recovery unit

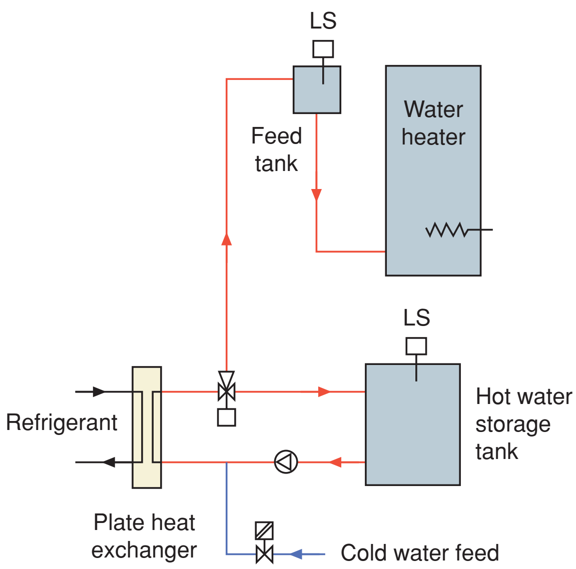


Figure 3.5: Diagram of the PE Heat Minda system

that this is higher than normally expected for a 50 bail shed and is due to higher than normal hot water usage.

Because of the way the water flow was controlled, the heat recovery unit did not perform as well as predicted. The water flow was often too high and this limited the amount of useful heating obtained. When operating well, it pre-heated the water to a temperature of about 35˚C and gave savings equating to 8,500 kWh per year (26% of total use).

At a marginal rate of 14c/kWh, this saving has a value of about $1200. Figure 3.6 shows the saving at other electricity prices.

Based on a total installed cost of $2,600, the DTS heat recovery unit has a simple payback period of about 2 years.

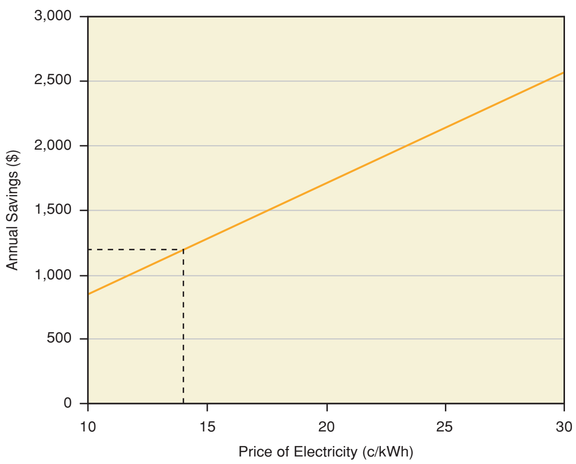


Figure 3.6: Estimated annual savings when installing a DTS heat recovery unit. Savings based on an annual reduction of electricity for water heating of 8,500 kWh.

The performance of this unit would have been better if a manual flow control valve had been used instead of an automatic valve.

A further improvement would be to feed the water into a well-insulated hot water header tank that would later be used to re-fill the water heaters as is done with the PE Heat Minda system. This would enable water to be produced at up to 65˚C and it would enhance the flexibility of the system.

Heat pump (Mahana Blue)

The Mahana Blue heat pump also connects to the refrigerant circuit of the milk vat cooling system. Whenever the refrigeration unit is running to cool the milk, the heat pump can be used to heat a small flow of water which can then be used to re-fill the dairy water heater.

An important difference between this device and the DTS heat recovery unit is that the heat pump can generate water at 85˚C temperature, but it requires electricity to operate. This means that the water needs very little additional heating before use.

Figure 3.7 is a simplified diagram of the piping arrangement used in the trial.

Based on the measurements for a typical mid-season day, use of the Mahana Blue reduced water heating electricity usage from 88 kWh per day to 39 kWh per day – a saving of 49 kWh (56%). It is estimated that the Mahana Blue heat pump would reduce annual electricity use by approximately 13,700 kWh. At the marginal rate for 'anytime' electricity of 14 c/kWh, this saving is worth $1,900 per year. Figure 3.8 shows the estimated savings at other electricity prices.

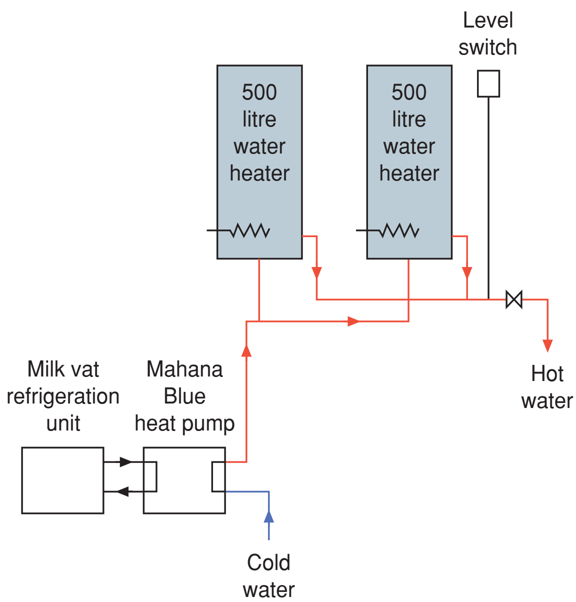


Figure 3.7: Diagram of Mahana Blue heat pump piping installation

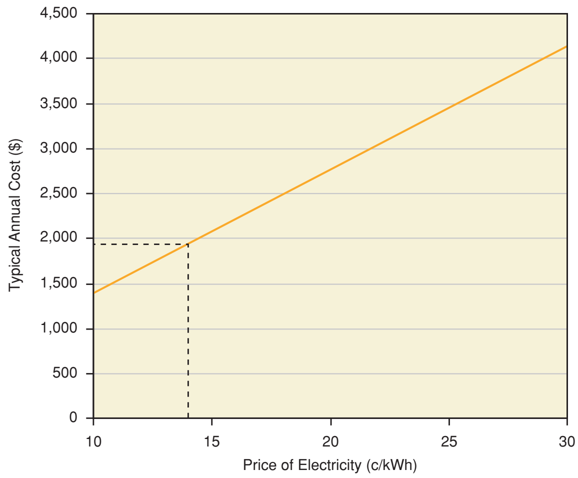


Figure 3.8: Estimated annual saving when installing a Mahana Blue heat pump. Savings based on an annual reduction of electricity for water heating of 13,700 kWh.

The Mahana Blue heat pump was installed with minimum difficulty and has performed well for seven months.

The estimated saving is a little lower than the 60% expected. There is no doubt that under more carefully controlled conditions, a greater saving could be made but the purpose of this trial was to find out how the unit performed in a normal installation.

Solar water heating

A typical large dairy farm requiring 1000 litres of 85˚C water each day for cleaning purposes uses 25,000 kWh of energy each year to heat this water.

In Southland, a solar water heating system with 12 m² of collector area can be expected to provide between 8,000 and 10,000 kWh of the total required energy. From the trials, the experience has been that a system retrofitted to existing water heaters performs at the bottom of this range.

A system with more than 12 m² of collector area will contribute more energy but will also cost more. The 12 m² is considered to provide a reasonable balance between capital cost and electricity saving potential.

The electricity cost saving potential for a system with a 12 m² collector is $1,000 to $1,400 per year assuming the alternative heating source is electricity costing 14 c/kWh. The saving potential is only $500 to $700 if night rate electricity is the alternative. Consequently, a five year payback will only be achieved if the system can be installed for $7,000 (or $3,500 if night rate electricity is being used).

It is feasible to use solar water heating in a Southland dairy shed but any farmer contemplating this should consider the following:

- solar water heater suppliers do not seem to be very experienced in designing systems for dairy sheds;
- only a few solar water heater suppliers are established in Southland and they and their installation contractors are still building up experience;
- suppliers don't seem prepared to make a site visit and provide an all-inclusive quotation; and
- the savings case for solar water heating in a dairy shed is not compelling. For most dairy sheds there are more cost-effective ways of saving money on water heating, e.g. by using night rate electricity or a heat recovery system.

Summary

There are several steps that can be taken to reduce water heating energy use and the associated electricity cost.

Firstly, the current system should be checked to see if any simple changes can be made to improve efficiency. The obvious measures to be taken include adding insulation to any part of the hot water system that is warm to the touch, fixing water leaks and reviewing washing procedures to see if hot water use can be reduced.

Heat losses can also be reduced significantly by adopting a 'just in time' approach to water heating i.e. installing a time switch to turn the water heater on to coincide with the appropriate full heat-up period, typically ranging from five to eight hours before the hot water is required. However, this will not be a good idea in a dairy shed using night rate electricity for water heating if it means heating water during the day.

These low cost actions can reduce energy use in a typical 'two cylinder' water heating system by between 2000 and 4000 kWh per year and save $300 to $500 per year in electricity cost.

Further improvements can be made using one of the range of techniques listed below. Usually, only one of the options listed can be chosen as the implementation of one should result in a sufficient reduction in heating costs to make all other options uneconomic.

Options investigated in this report are listed below. These are ranked in order of capital expenditure, not cost savings:

a) Heat at night to take advantage of cheaper off-peak tariffs (see Section 7).

b) Change detergent and use fewer hot washes.

c) Add a heat recovery unit — heat recovery from the condenser of the milk vat chiller unit.

d) Add a heat pump to heat water, e.g., Mahana Blue.

e) Install a solar water heater.

A comparison of retrofit water heating options for a typical dairy shed in Southland is shown in Table 3.1.

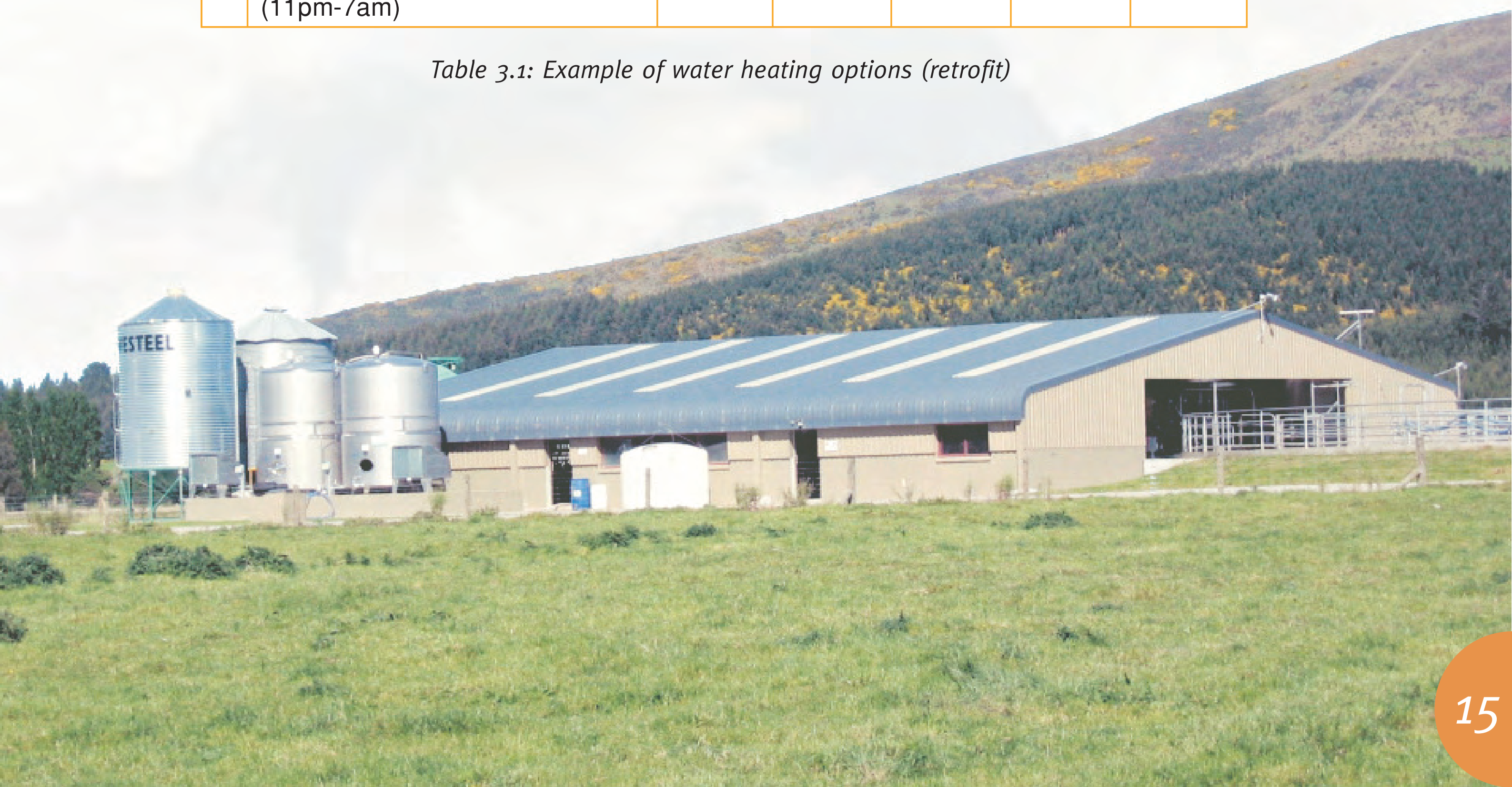
For a particular dairy shed study, it is recommended that the computer-based calculator available at www.cowshed.org.nz be used.

This table is based on a 'typical' dairy shed with a 50-bail rotary platform using 1000 litres of hot water each day. The figures in the table were calculated using the 'Dairy Shed Energy and Electricity Cost Calculator' which is available on the project website http://www.cowshed.org.nz

Annual energy cost excludes the fixed costs (daily charge) and is based on a marginal electricity price of 13.6c/kWh. The savings shown are based on implementing one action only. To get savings from taking more than one action requires recalculation because the savings are not additive.

	Action	Capital cost [$]	Annual energy use [kWh]	Annual energy cost [$]	Energy saving [kWh]	Energy cost saving [$]
1	Base case – 'typical' dairy shed	0	28,040	3,810	0	0
2	Reduce hot water use by hot washing milk lines every second day instead of daily	0	23,470	3,190	4,570	620
3	Reduce heat losses from the water heating system by 'just in time' heating	1000	23,950	3,260	4,090	560
4	Reduce heat losses from the water heating system by improved insulation	500	25,440	3,460	2,600	350
5	Add a heat recovery system	2,700	19,630	2,670	8,410	1,140
6	Add a heat pump, heat recovery system	9,700	12,900	1,750	15,140	2,060
7	Add a solar heating system with 12 m^2 of collector area	14,600	20,990	2,850	7,050	960
8	Heat water at night using night rate electricity, at 6.5c/kWh (11pm-7am)	1,000	23,980	1,570	4,060	2,250

Table 3.1: Example of water heating options (retrofit)



4 Milk Cooling

Introduction

Milk inside a cow has a temperature of about 38˚C but it usually drops to about 35˚C once it passes through the collection can and some pipe work. This warm milk has to be cooled to ensure that bacteria don't affect its quality.

The current requirements for cooling (NZCP1) are:

> *"Unless used immediately for further processing, milk shall be:*
>
> - *primary cooled after filtering, refer to section 13.1 for further primary cooling requirements;*
> - *cooled to 18˚C or less at the completion of every milking;*
> - *cooled to and maintained at 7˚C or below within 3 hours of the completion of milking and kept at or below 7˚C until it is collected or the next milking."*

It is understood that in some other milk-producing countries (e.g. Australia), storage at 4˚C is the norm. It is possible that for marketing reasons, New Zealand dairy farms may have to reduce the maximum milk storage temperature from 7˚C to 4˚C at some time in the future.

Milk cooling equipment

The milk cooling equipment usually includes a primary cooling system (pre-cooling) and a refrigeration system. See the page 3 for a schematic diagram.

On most Southland dairy farms, primary cooling is carried out by passing the milk through a plate heat exchanger and using the dairy shed water supply as the coolant. Desirably, the plate cooler will reduce the milk temperature from 35˚C to 18˚C although based on measurements made at two farms as part of this project, 18˚C is not usually attained.

The further cooling of the milk from 18˚C to below 7˚C is commonly carried out inside the milk storage vat using a direct expansion refrigeration system. A cooling pad attached to the floor of the vat is supplied with refrigerant from a refrigeration unit located nearby. The refrigerant evaporates inside the cooling pad and absorbs heat from the milk as it does so. To prevent the milk freezing, the vat has a motor-driven agitator that continuously moves the milk across the base of the vat.

In Southland, most dairy farms are suppliers to the milk processing company, Fonterra. The normal arrangement is that Fonterra owns the storage vat (or vats) and the dairy farm owns the refrigeration unit.

Energy use and cost

The refrigeration unit on a farm producing 15,000 litres of milk per day at peak season operates at a power of about 10 kW and typically runs for 10 hours per day at peak periods thus consuming about 100 kWh of electrical energy. Over a full season, energy use is likely to be 20,000 kWh – about 20% of total dairy shed electricity use.

At the marginal electricity price of 14 c/kWh, a milk vat refrigeration unit costs about $2800 per year to run.

Options for improving milk cooling

The options for improving the energy efficiency of milk cooling are fewer than they are for vacuum pumping and water heating. Those identified were:

- increasing the efficiency of the pre-cooling system;
- ensuring that the milk vat refrigeration unit is operating at normal efficiency; and
- insulating the milk vat.

Reducing electricity cost (but not usage) by shifting cooling load to the night hours was also identified as a possibility.

Trials

Measurements and trials were carried out at two farms. At both sites, the performance of the pre-cooler and the milk vat refrigeration units was monitored.

At one site, a Corkill Systems milk pump speed controller was installed and its effect on the performance of the pre-cooler measured. Also, the farm manager added additional plates to the pre-cooler and increased the cooling water flow by cleaning the pump. The effect of these changes was also measured.

At the other site, an insulating wrap was fitted to one of the milk vats and a chilled water cooling system was trialled.

Energy efficiency

Pre-cooler

The lower the temperature of the milk leaving the pre-cooler, the lower will be the milk vat refrigeration unit electricity use. On a farm producing 15,000 litres of milk per day at peak and with an efficient refrigeration unit, each 1°C reduction in the temperature of the milk leaving the pre-cooler will save 860 kWh per year.

The difference between the milk outlet and water inlet temperatures is normally referred to as the 'temperature approach' of the pre-cooler and for best efficiency, should be as low as possible. In theory, the temperature approach can be as low as 2°C but neither pre-cooler was able to achieve this.

At one site the bore water temperature was low (10°C to 13°C) throughout the season and yet the temperature of milk leaving the cooler rarely fell below 20°C. Pre-cooling was improved following the implementation of milk pump speed control, increasing the surface area of the heat exchanger and increasing the water flow. As a result of all three actions, the temperature of the milk leaving the cooler was reduced by 8°C. This 8°C reduction is expected to reduce annual electricity use by 6,900 kWh.

At the other site, cooling water is supplied from a surface stream and so rises above 20°C in mid-summer. Despite this, the pre-cooling was effective with the milk temperature getting to within 4°C of the cooling water temperature in mid-summer.

Milk vat refrigeration unit

In milk cooling, the main electricity user is the milk vat refrigeration unit that this is normally an energy-efficient piece of equipment. The Australian Cowtime website (www.cowtime.com.au) says "Direct expansion is the simplest and most energy efficient way of cooling milk to the required storage temperature".

It is a feature of the mechanical refrigeration cycle that the heat energy removed from the milk exceeds the electrical energy required to run the refrigeration unit. The ratio of the energy extracted from the system to the energy used to run the unit is known as the 'coefficient of performance' (COP). The higher the COP, the more energy-efficient the refrigeration system is.

When running as designed (COP in the range 2.7 to 2.9), there is little that can be done to improve the energy efficiency of these refrigeration units.

In the trials, one unit was found to have a COP in the expected range (2.7 average) but the COP of the other units was much lower than expected (1.7 average). If the observed average COP of 1.7 could be increased to 2.7, this would save 9000 kWh per year of electricity.

Possible causes of the poor performance include a cooling pad that is too small, poor installation of refrigerant lines to the vat, or a faulty refrigeration unit.

If the milk cooling time is getting longer and the vat refrigeration unit is suspected of poor performance, call a refrigeration serviceman to check the unit. One good indicator of problems is the sight glass in the liquid refrigerant line which should appear clear. If it shows a lot of gas bubbles in the refrigerant, this is a sign that the refrigerant charge is too low and performance will be sub-standard.

Improvement of the refrigeration system does not require new technology but just maintenance or improved installation of current technology.

Milk vat insulation

The heat gains from the sun and air into un-insulated milk vats were measured at up to 6 kW on warm, sunny, breezy days.

Based on weather data the average heat gain into one vat was estimated to be 2.1 kW. It was estimated that the insulating wrap reduced this heat gain by approximately 80% and that over a year this would save 2,850 kWh of electricity.

Other matters

Water use

The pre-cooling system uses a large amount of water - typically fives times as much as the milk it is used to cool. Much of this water passes through the cooler when the milk pump is stopped and does little useful work. In most dairy sheds, the water from the cooler is stored and usefully re-used for shed cleaning but if cleaning systems that used less water were developed, there may be a surplus running to waste. Variable speed control of the milk pump will lower the maximum milk flow rate and might allow a lower cooling water flow rate. There may also be scope to develop other pre-cooling systems that use water more efficiently e.g. by using an automatic control valve to vary the water flow according to the need for cooling.

Milk cooling time

To ensure good milk quality, the milk cooling system must be capable of meeting the milk cooling times and temperatures specified by NZCP1. Meeting this requirement is usually the main driver for improving the efficiency of existing cooling systems and energy savings are a welcome by-product.

Meeting the cooling standard becomes more difficult in warm and windy weather when heat gains of up to 6 kW can occur in the milk vat. Milk vat insulation can cut this gain significantly and potentially avert the need to replace the refrigeration unit.

Cost savings

Pre-cooler

On a farm producing 15,000 litres per day at the peak and with an efficient refrigeration system (COP = 3), every 1˚C drop in milk temperature from the cooler will save about $120 per year in electricity costs. For an inefficient refrigeration system (COP = 2), the saving is $180.

It is estimated that the installation of the variable speed drive on the milk pump resulted in a reduction of 5˚C in the cooled milk temperature which is sufficient to justify the investment of $3,000 in the milk pump speed controller.

To decide if variable speed milk pump control is justified, a farmer needs to estimate the temperature approach of the plate cooler. This can be estimated from the external temperatures of the relevant pipes but not all farmers have equipment to do this:

- temperature approach less than 6˚C
  – unlikely that cooling will be greatly improved by a pump speed controller
- temperature approach greater than 12˚C
  – a controller might be economic for a farm processing at least 15,000 L/day.

If the temperature approach is more than about 6˚C and if the milk is not being cooled quickly enough in the vat, then a milk pump controller is likely to assist in reducing the cooling time.

Milk vat refrigeration unit

Although refrigeration units are normally very energy-efficient, cost savings are possible if a unit is operating below normal efficiency. Based on measurements and calculations it was estimated that if the average COP of the inefficient refrigeration system could be increased from 1.7 to 2.7, this would save 9000 kWh per year of electricity worth $1300.

Milk vat insulation

Insulation of the milk vat was estimated to save $400 per year in reduced electricity costs. For a 5-year payback, insulation would be a worthwhile investment if it cost no more than $2,000.

It was estimated, using the weather data, that if the average air temperature was 7˚C higher (as might occur in warmer parts of New Zealand), the savings would increase to about $600 per year and justify an investment of $3000.

Cooling with chilled water

Instant cooling of milk using chilled water is less energy-efficient than the normal in-vat direct expansion cooling system. Shifting the cooling load into the night hours and using night rate electricity can save money but not nearly enough to make it economic to invest in a chilled water plant (or ice bank) simply as a cost saving measure.

The installation of a chilled water system might be considered to solve a milk cooling problem, but not to reduce electricity usage or cost.

Summary

The opportunities for reducing energy use and electricity cost in the area of milk cooling are considerably fewer than in the areas of vacuum pumping and water heating.

Three opportunities for reducing energy use are;

a) optimising the operation of the pre-cooling system including the installation of a milk pump speed controller to give a more even flow of milk through the cooler;

b) Improving the performance of under-performing refrigeration units; and

c) insulating the milk vat.

The electricity costs savings associated with these can be low and so significant capital expenditure is not usually warranted.

5 Water and Effluent Pumping

Introduction

A typical dairy shed is likely to have pumps for

- circulating water through the milk cooler (cooler pump);
- supplying water to the shed washdown hoses (washdown pump);
- pumping water to the drinking troughs on the farm (farm pump); and
- pumping effluent from the holding pond to an irrigation system.

Normally these pumps are fitted with electric motors of sizes ranging from 1 to 18.5 kW. The effluent pump usually has the largest motor and is typically 15 kW or 18.5 kW.

The annual water usage for two dairy sheds monitored as part of this project is shown in Table 5.1 below. These figures are for the dairy shed only and exclude stock water.

	38-a-side herringbone	60 bail rotary
Total water use	13.2 million litres	17.9 million litres

Table 5.1: Water usage on two farms in the 2006/2007 Dairy Season

The majority of this water ends up in the effluent sump and is pumped to the spray irrigator for disposal.

Options for Minimising Energy Use

The main options for minimising energy use in water and effluent pumping are to:

- reduce fresh water use (and hence effluent;)
- size water and effluent piping correctly; and
- select pumps and motors that are energy efficient.

Sizing pipelines

For farm installations, selecting a pipe diameter that gives a pipeline velocity in the range of 1 to 2 metres per second (m/s) is likely to give the best balance between initial cost and operating cost. Acceptable flow rates are shown in Table 5.2.

The cost of energy to operate the pump will not vary much if the water velocity is within this range but at higher velocities, there will be a significant increase in energy required.

The chosen pipe diameter should be used for the full length of the pipeline and all fittings should be matched to this diameter.

Pipelines operating with a water velocity greater than 3 m/s are likely to require too much pumping energy and should be replaced. Farm owners/managers should check this by measuring (or estimating) the flow rate in a pipeline and then comparing it with the values shown in Table 5.2.

Pipeline inside diameter (mm)	38	50	65	80	100
Acceptable flow rates (m^3/h)	4-8	7-14	12-24	20-35	30-55
Flow rate at 3 m/s velocity (m^3/h)	12	21	36	54	85

Table 5.2: Pipeline diameters and flow rates

If the flow rate is greater than shown in the table, replace the pipeline to get lower pumping costs.

Water pumping

The energy used by a water pump depends on the efficiency with which the pump converts the input mechanical energy into useful pumping energy. This is determined by the pump design and also by the condition of the pump – a worn pump will be less efficient than a pump in good condition.

Most pumps used in the dairy shed are centrifugal pumps with a pumping efficiency in the range of 50% to 70%. This means that 50 to 70% of the power put into the pump does useful pumping work. Most of the remaining 30 to 50% is converted to heat and lost.

As an example of the amount of energy used by a typical pump, a dairy shed cooler pump operating at 50% efficiency and pumping 10 m^3/h at a head of 15 m for 7 hours per day will consume 1,800 kWh in a 270 day season. If a pump operating at 70% efficiency could be found, this would reduce energy usage by 530 kWh per year – a saving of $80 in electricity. While this is a worthwhile saving it may not be justification for replacing an existing pump that is otherwise performing satisfactorily.

There will also be some inefficiency in the electric motor. Electric motors sold in New Zealand since 2002 have been required to comply with minimum energy performance standards (MEPS) and these standards were upgraded in 2006. As a result, most motors purchased after 2002 will be reasonably efficient. It is unlikely that there are significant savings to be made in a dairy shed by replacing pre-2002 motors with motors of higher efficiency. Whenever possible however, failed motors should not be repaired but replaced with new motors that comply with the latest (2006) MEPS.

Effluent pumping

The amount of energy used for effluent pumping is closely related to the quantity of effluent that is pumped. Minimising the use of washdown water and diverting stormwater away from the effluent system will help to reduce the cost of pumping.

Traditionally, centrifugal pumps such as the Reid and Harrison Yardmaster design have been used to pump the effluent from the holding pond through a reticulation network to the irrigator. Some Southland farms have replaced these pumps with a more efficient progressive cavity design (Mono brand). This pump typically has a 4 kW motor compared with 11 kW, 15 kW or even 18.5 kW on the normal effluent pump.

The Mono pump was not trialled in this project but theoretical calculations indicate that energy savings of 3,800 to 5,700 kWh per year may be possible. This saving is worth $500 to $800 per year at a marginal electricity price of 14 c/kWh.

The cost to replace the pumping system in an existing pond is likely to be at least $17,000 and more elaborate upgrades may cost $25,000 or more. Expenditure of this magnitude cannot be justified by electricity savings alone and the decision to upgrade is usually based on achieving several benefits including improved environmental performance, reduced maintenance, and reduced energy use.

Summary

Energy usage in the dairy shed can be reduced by designing pumping and piping systems to be as energy efficient as possible. In the case of an existing dairy shed however, the saving in electricity costs is unlikely to be sufficient to encourage replacement of existing pumps or pipelines for that reason alone. In the case of a new shed however, it is well worthwhile considering the energy efficiency of each pump and piping system at the time of design and installation.

The dairy shed effluent pump is likely to have the largest motor and to consume the most electricity and should be the starting point when looking at saving pumping energy. Effluent pumps with significantly lower power requirement than the traditional centrifugal pump are in use on some farms already and are worthy of consideration for new installations.

6 Efficient Lighting

Introduction

In a typical modern dairy shed, electricity used for lighting accounts for 1% to 2% of the total electricity use. In some sheds however, this figure may rise to 5% if incandescent light fittings are still being used. Although lighting is not a major cost, it is one that can be reduced quite easily.

One of the ways to reduce the energy used for lighting is to design the dairy shed to make maximum use of natural light. This can be done by building orientation and by the inclusion of translucent sections in the roof and wall cladding.

The energy used by artificial lighting can be reduced in two main ways - minimising running hours and choosing energy efficient light fittings.

Running hours can be minimised by switching off lights when they are no longer required. Where lights are switched manually, it is very likely that they will be left on for longer than necessary and savings can be made at no cost simply by making a conscious effort to turn off un-needed lights. Light switches that sense light levels and movement can be used to automate the switching.

Energy use for lighting can also be minimised by choosing energy efficient light fittings. In existing dairy sheds this may require the replacement of inefficient light fittings and, in new sheds, it may require extra investment to pay the higher first costs of energy efficient fittings.

Maintenance of light fittings is also important. Light output will deteriorate with time unless the fittings are regularly cleaned and lamps replaced.

Case study

The following information is theoretical but is based on the lighting systems installed in a 38-a-side herringbone dairy shed.

The shed has:

- 22 x 200 watt incandescent lamps over the milking area (i.e. 4.4 kW)
- 3 x 500 watt quartz halogen floodlights in the yards (i.e. 1.5 kW)

At the milking pit, replacing the 22 incandescent lights with 10 twin tube fluorescent fittings would give increased light output and cut the power from 4.4 kW to 1.3 kW – a saving of 70%.

In the yards, replacing the three 500 W quartz halogen floodlights with three 150 W high pressure sodium (or metal halide) floodlights would give increased light output and cut the power from 1.5 kW to 0.5 kW – a saving of nearly 70%.

Table 6.1 shows the estimated annual energy use for milking pit and yard lighting before and after the change to energy-efficient light fittings.

The total saving in energy use is 4,620 kWh. At the marginal electricity cost of 14c/kWh, the annual cost saving is $650. The annual cost saving at other electricity prices is shown in Figure 6.1.

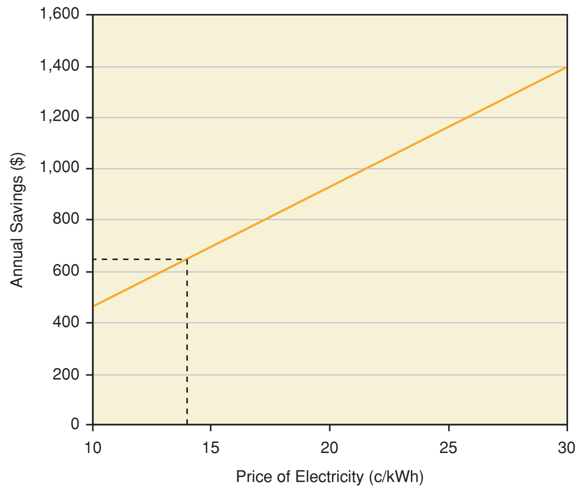


Figure 6.1: Electricity cost savings after change to energy-efficient light fittings

In addition to the saving in energy use, there will also be a reduction in the cost of replacement lamps. Although the fluorescent and high pressure sodium lamps are more expensive initially than the incandescent lamps they replace, they also have a much longer life. Over a period of 5 years, the total cost of lamp replacement will be lower.

	Milking pit		Yard	
	before	*after*	*before*	*after*
lighting power (kW)	4.4	1.3	1.5	0.5
estimated running hours	1200	1200	900	900
annual energy use (kWh)	5280	1560	1350	450

Table 6.1: Estimated annual energy use for milking pit and yard lighting before and after the change to energy-efficient light fittings

Summary

Energy use for artificial lighting can be minimised by making maximum use of natural light to light the dairy shed and by turning off the artificial lighting as soon as it is no longer needed.

Fluorescent lighting provides cost-effective general lighting for most dairy sheds and is particularly suited to herringbone sheds where the low roof doesn't permit the use of metal halide fittings. Where incandescent lamps (the traditional light bulb) are still in use, they should be replaced with compact fluorescent lamps or new linear fluorescent light fittings installed. Changing from incandescent to fluorescent lighting will reduce lighting electricity usage by 70% and will also reduce the cost of replacement lamps.

Metal halide light fittings are suitable for rotary platform dairy sheds where they can be mounted high enough above the floor.

In the yard, flood lights with quartz halogen lamps are often used. While these fittings are cheap to buy, the lamp life is short and they are not energy efficient. A 150 watt high pressure sodium or metal halide floodlight will provide more light than a 500 watt quartz halogen light and uses 70% less energy.

For a new dairy shed or a major lighting upgrade in an existing shed, a lighting specialist can provide a suitable design and estimate the savings that can be achieved by using energy efficient light sources. The use of automatic (time or motion or light intensity based) switching should also be considered.

Lighting Options

The table below is based on information taken from the Australian CowTime Project website with some added comments. In this table, the least energy-efficient light fittings are at the top and the most energy-efficient are at the bottom.

Fluorescent light fittings are particularly suited to dairy sheds. The fittings are cheap and the triphosphor tubes commonly used in modern fittings are very energy efficient. They also have good colour rendering characteristics and instant re-start.

In dairy sheds still using incandescent lights, compact fluorescent lamps can be used as a direct replacement for the existing lamps. Compact fluorescent lamps are now available in high wattages and substituting a 45 watt lamp for a 200 watt incandescent lamp will cut energy use by almost 80% while still providing the same light output.

Incandescent (the traditional lightbulb)	Best used in areas where lighting is only required for brief periods. These lights are cheap, easy to replace, and produce light instantaneously. However, they are energy inefficient and the lamps have a short life span.
Halogen	Designed to provide high intensity light in a specific direction. Inexpensive to purchase but expensive to operate because of low energy efficiency. These are often seen in dairy shed yards.
Fluorescent	The most cost-effective general lighting for a dairy shed. Tubes need to be cleaned annually and replaced every 4-5 years to maintain the light output.
Mercury vapour (high pressure)	A high output light suited for general lighting in larger areas with high roofs. They are fairly inexpensive and the lamps have a long life. Disadvantages are that they take several minutes to reach full brightness after being turned on and emit a slightly pinky-blue-white light
Metal halide	Metal halide lights have similar uses and operation to mercury vapour lights. They are twice as energy efficient as the mercury vapour light and emit white light.
High pressure sodium	Pinkish orange light. Very energy efficient and with a long lamp life. Best suited to outdoor floodlighting.

7 Electricity

Introduction

The primary source of energy in most dairy sheds is electricity supplied by a retailer (e.g. Meridian Energy or Contact Energy) via the distribution network that covers most of the country. Until the last few years, New Zealand has had a reliable supply of electricity available at a relatively low price. The country has entered a new period of energy supply and pricing. Wholesale prices for electricity have increased significantly and are projected to further increase.

An alternative to purchasing electricity is to generate it on the farm. There are a number of ways of doing this but none that is currently economic for a farm that has easy access to a supply of electricity from the national grid. For a brief consideration of methane from biomass, generation of electricity from wind, and small-scale hydro generation of electricity, see: www.cowshed.org.nz/index.cfm/3,77,235/dairy-flyer-june-07-red.pdf

This section reviews the current cost of electricity delivered to Southland farms. It also looks at the way in which electricity prices vary according to time of day and season and how different pricing plans might be utilised to achieve energy cost savings as opposed to gains in energy efficiency.

Options for Minimising Electricity Costs

Options for minimising electricity cost include:

- reducing the quantity of electricity used;
- using the best purchasing plan; and
- changing to a cheaper supplier.

Reducing electricity use

To reduce electricity use while still producing the same quantity of milk, it is necessary to improve the energy efficiency with which the electrical equipment in the dairy shed operates. Cost-effective ways of doing this are discussed in the other sections of this report.

Choosing the best purchasing plan

It is possible to minimise the cost of electricity by selecting the best purchasing plan but this is not an easy task as there is a wide choice. Most plans have two main price components –a fixed daily charge and a charge based on the quantity of electricity used and options in both areas further complicate the issue.

The most commonly used purchasing plans encountered in this study were the 'anytime' plan and the 'day/night' plan. Some farms also used the 'anytime' plan in conjunction with a 'controlled' or 'night' supply for water heating.

Prices for the Contact Energy 'anytime' and 'day/night' plans for a typical 50 bail dairy shed with a 50 kVA supply are summarised in Table 7.1.

Prices exclude GST and assume the prompt payment discount of 10% is applied. An Electricity Commission levy of 0.142 c/kWh is also payable.

The daily fee of $4.40 reduces to $3.32 if the load is classified by the power company as 'off peak'. Night energy use must be at least 25% of total use to qualify.

In a typical dairy shed where no special effort is made to shift electricity usage into the night hours, the night usage is likely to be about 20% to 25% of total usage. In this case, there is little difference in the total cost of electricity on either plan.

Worthwhile cost savings can be made by using the 'day/night' plan and maximising night time usage to take advantage of the lower cost at night.

Another option made possible by modern metering systems is to use a 'time of use' purchasing plan.

A 'time of use' meter records electricity use for each half hour period and the electricity is charged at different rates depending on the time of day and whether it is a normal business day.

This option is not widely promoted for dairy farms but may be worth investigating for very large dairy sheds where the high fixed charges associated with the metering equipment can be more easily absorbed.

	Anytime plan	Day/night plan
Daily fee	$4.18	$4.40*
Variable charge – day (7am to 11pm)	13.6 c/kWh	15.5 c/kWh
Variable charge – night (11pm to 7am)	13.6 c/kWh	6.5 c/kWh

* Reduces to $3.32 if classified as 'off peak'

Table 7.1: Contact Energy electricity prices for a dairy shed with 50 kVA supply

Reducing cost by using more electricity at night

The availability of lower-priced electricity at night is advantageous for dairy farms for two reasons.

- For farms milking twice a day, much of the morning milking can be completed before 7am when the price rises.
- Water heating can be shifted from day to night hours to take advantage of the lower prices.

Table 7.2 shows the annual electricity costs for a typical farm that changes from an 'anytime' to a 'day/night' purchasing plan (with 'off peak') and increases night usage from 20% to 40% of total by shifting all water heating to the night hours.

This shows that a total saving of approximately $2000 per year is possible by changing to a 'day/night' plan (with 'off peak') and maximising the night usage by shifting all water heating into the night hours.

The risk and challenge for the farmer is to move as much as can be managed onto night use with certainty. A simple, fail-safe control system seems essential. Relying simply on staff remembering to reset is unlikely to be successful.

Changing supplier

Five electricity retailers operate in the Southland area and it is sometimes possible to save money by changing to another supplier.

Table 7.3 shows the annual cost of electricity purchased from each of the five retailers and using the 'anytime' and 'day/night' purchase plans. It is based on the following farm profile:

– connection capacity – 50 kVA

– total annual energy usage – 100,000 kWh

– fraction of energy used at night (11pm to 7am) – 25%

– fraction of energy used in 'summer' (1 October to 30 April) – 70%

Based on the pricing plans current at 1 April 2007, the difference in annual electricity cost between the dearest and cheapest supplier is about $1,200. Note however that suppliers change prices at frequent (and irregular) intervals and it is impossible to be sure that any cost saving will be long lasting.

One significant difference between the retailers is that Meridian Energy uses different prices in summer (1 October to 30 April) and winter (1 May to 30 September). This suits a dairy farm well as the majority of electricity use is in the summer period when prices are lower.

Summary

Electricity can be purchased under a variety of purchase plans from a number of competing retailers. Selecting the best option requires individual consideration for each dairy shed but the main opportunity for reducing costs lies in making maximum use of cheaper electricity available at night.

Care is particularly required when concurrently reducing energy use and selecting a purchase plan.

	Anytime pricing plan		Day/night pricing plan	
Total annual energy use (kWh)	100,000	100,000	100,000	100,000
Day usage (kWh)	80,000	60,000	80,000	60,000
Night usage (kWh)	20,000	40,000	20,000	40,000
Total of variable charges ($)	13,558	13,558	13,700	11,921
Total fixed charge ($)	1,526	1,526	1,606	1,210
Total cost ($)	15,084	15,084	15,306	13,131

Table 7.2: Annual electricity cost for a typical farm using alternative pricing plans

	Contact	Genesis	Mercury & RD1	Meridian	Trustpower
Date of last price change	1 Apr 07	4 Sep 05	Nov 06	1 Dec 06	27 Jul 06
Anytime plan	$15,226	$15,287	$14,724	$14,070	$15,147
Day/night plan	$14,621	$14,218	$14,793	$13,695	$14,556

Table 7.3: Annual cost of electricity from five retailers

8 Practical Advice

Some of the experiences and practical lessons learned from the project are summarised below.

Installation Issues

Planning

- Adequate Time: Suppliers and installation contractors can provide better (and possibly cheaper) service if they are given adequate time to plan a job.
- Reduce Travel Costs: Travel costs can be a significant part of the total installation cost. Minimise travel costs by ensuring that the contractor can complete all required work at one visit.
- Coordinating Trades: In many cases, energy saving equipment for a dairy shed will require more than one type of tradesman to install it. In most cases, the organisation supplying the equipment is able to organise the necessary installation contractors and usually this is the best arrangement. Farmers wishing to use their 'normal' plumber or electrician may find that problems arise with coordinating the work.
- Quotations: Ideally, a fixed price should be obtained for any project being contemplated. For a straightforward project that the contractor is very familiar with, it may be possible to obtain a price without having the supplier visit the site. For a project involving less common technology, a site visit is essential. Wherever possible, the quotation should include the total cost of getting the equipment installed and running properly.

Correcting Defects

- Correcting faulty installation work: Some of the equipment installed may require one or more return visits from the supplier and/or installation contractor to correct faults. While most contractors will accept that this re-work is done at their expense it is probably worthwhile for a customer to make this point clear at the beginning of the job. The supply and installation of a piece of energy-saving equipment should include all the work necessary to commission it and get it operating as the supplier intended.
- After sales service: Some suppliers ensure that their equipment is installed and performing correctly and make a site visit to check this. If possible, a purchase contract should include at least one after-sales inspection visit by the equipment supplier. Some suppliers also offer good telephone support via a free phone number and this can be a valuable service.
- Watching for defects: Farmer managers and their staff should be on the lookout for any sign of problems around new equipment. This might include checking the vacuum gauge reading, temperatures, operating times and inspecting for signs of water and refrigerant leaks (A low refrigerant level is indicated by bubbles in the sight glass on the refrigeration unit).

Staff Training

As dairy farm operations grow in size, farm owners often employ a farm manager and other staff to handle the day–to-day running of the farm. Although many dairy sheds are similar in design, there will often be important differences in equipment between sheds. Any efficiency measure that relies on a person for its success is at risk if that person is inadequately trained for the job.

Staff turnover can also have a negative effect on dairy shed efficiency. If a new manager or new shed staff are not well trained by former staff then energy efficiency may be a casualty.

For best energy efficiency, farm owners need to ensure that their manager is fully informed of all energy saving systems installed and how to use them to best effect. The manager in turn needs to ensure that the shed staff are also fully informed. This includes any relief or casual staff.

Information

Owners and managers can't manage energy use effectively without good information and most dairy sheds are not adequately equipped with instruments to provide this.

- Meter Reading: Farm owners and managers would learn useful information about the efficiency of their shed by reading the main electricity meter at regular intervals (monthly, weekly or even daily) and charting the total shed energy use.

  Electricity meters are readily available at reasonable prices and there is a good case for dairy sheds to have their own sub-metering on the main loads (water heaters, vacuum pump and refrigeration unit).
- Temperature: The milk vat temperature gauge is useful for gauging the efficiency of the milk cooling system and on an energy efficient farm, additional temperature gauges should be considered (water cylinder temperatures, temperature of milk leaving the plate cooler).

9 Decision Making

Investment decisions fall into three distinct areas: (1) Vacuum pump and variable speed control, (2) Water heating and electrical tariff selection, and (3) Milk pre-cooling and chilling. These are best considered in the order shown as the first decision can be made independently of subsequent decisions.

1 Vacuum Pump & Variable Speed Control

New pump or old pump replacement

Check Table 9.1. Based on the number of bails, find the additional capital expenditure justified for a rotary lobe with variable speed drive.

Obtain quotes for a water ring pump and a rotary lobe with variable speed drive. If the extra cost of the rotary lobe is less than the amount shown in the table as justifiable, purchase one of these, otherwise the water ring pump is appropriate.

Bails	Design Flow Rate (L/min)	Annual Savings	Additional Capital Expenditure Justified
20	1600	$870	$4,300
30	2400	$1,300	$6,500
40	3200	$1,730	$8,600
50	4000	$2,170	$10,800
60	4800	$2,600	$13,000

Table 9.1: Annual savings using a new rotary lobe with variable speed drive, compared with a water ring pump

Existing pump – Variable Speed Drive Retrofit

If you have a rotary lobe pump, adding variable speed control is likely to reduce the vacuum pump electricity use by enough to pay back the cost of the controller in 5 years or less, but only if the herd size is 650 or more.

For a water ring pump, use the following calculations.

Power (fixed speed) = power rating of motor x 0.9

Power (variable speed) = number of bails x 0.13

Power reduction (kW) = power (fixed speed) – power (variable speed)

Annual Saving ($) = power reduction x maximum number milking hours per day x 240 x 0.14 ($/kWh)

Note: The factor of 240 is based on observations that the annual vacuum pump running hours were approximately 240 times the hours on a peak day.

Multiply the annual savings by 5 to get the maximum investment with a simple 5 year payback. If the cost of a variable speed system is less than this, then it is worthwhile.

2 Water heating

Quick Savings

To save energy costs due to heat loss, insulate any parts of the hot water system that are warm to touch and fix any hot water leaks. This could easily save up to $500 per year with very little investment.

Investment to save costs

Also consider doing any one, but only one, of the following. These are ranked in order of capital expenditure, not savings:

a) Change to night time hot water heating and day/night rate.

b) Change detergent to use more cold washes.

c) Add a heat recovery unit to heat water from the chiller condenser.

d) Add a heat pump to heat water, e.g. Mahana Blue.

e) Install a solar water heating system.

A decision flow chart for achieving affordable energy cost savings in water heating is given on page 27.

Because these options require different amounts of capital they can be compared by calculating the value over 10 years of operation. The calculation of net value takes into account energy savings, interest payments, depreciation and tax, and is made for a farm producing a peak of 15000 litres of milk per day and using 1000 litres of hot water.

a) Change to night time hot water heating and day/night rate. Over 10 years the net value of savings is estimated to be over $20,000. This option provides economic benefit to the farm and electricity distribution company.

b) A cold wash system gave a range of savings that were very farm specific. The net value of savings after 10 years is approximately $7000.

c) The DTS heat recovery unit had a net value of savings after 10 years of about $8300. When the hot water usage is about 350 litres per day this saving drops to about $2000. Other systems are available, or are proposed.

d) Heat pump. The Mahana Blue system net value of savings after 10 years was estimated to be $7000. For a farm using 900 litres per day this

To assist decision making on your own property, use the 'Dairy Shed Energy and Electricity Cost Calculator' which is available on the project website at www.cowshed.org.nz saving reduces to $5300. There is no significant payback once the daily hot water consumption falls to about 600 litres.

e) The cost of a solar heating system for one hot water cylinder was $9300. The cost for enough panels for two hot water cylinders is estimated to be $14,500. The best possible performance based on weather is that a solar system might provide 65% of the required hot water energy. In this best possible case the net value of savings after 10 years is negative.

3 Milk Chilling

If a chiller system is running efficiently the cost of running the system is not easily reduced.

Pre-cooler

Each two degrees reduction of milk temperature out of the pre-cooler reduces chilling costs by $240 per year on a farm producing 15000 L/day and justifies about $1400 of investment.

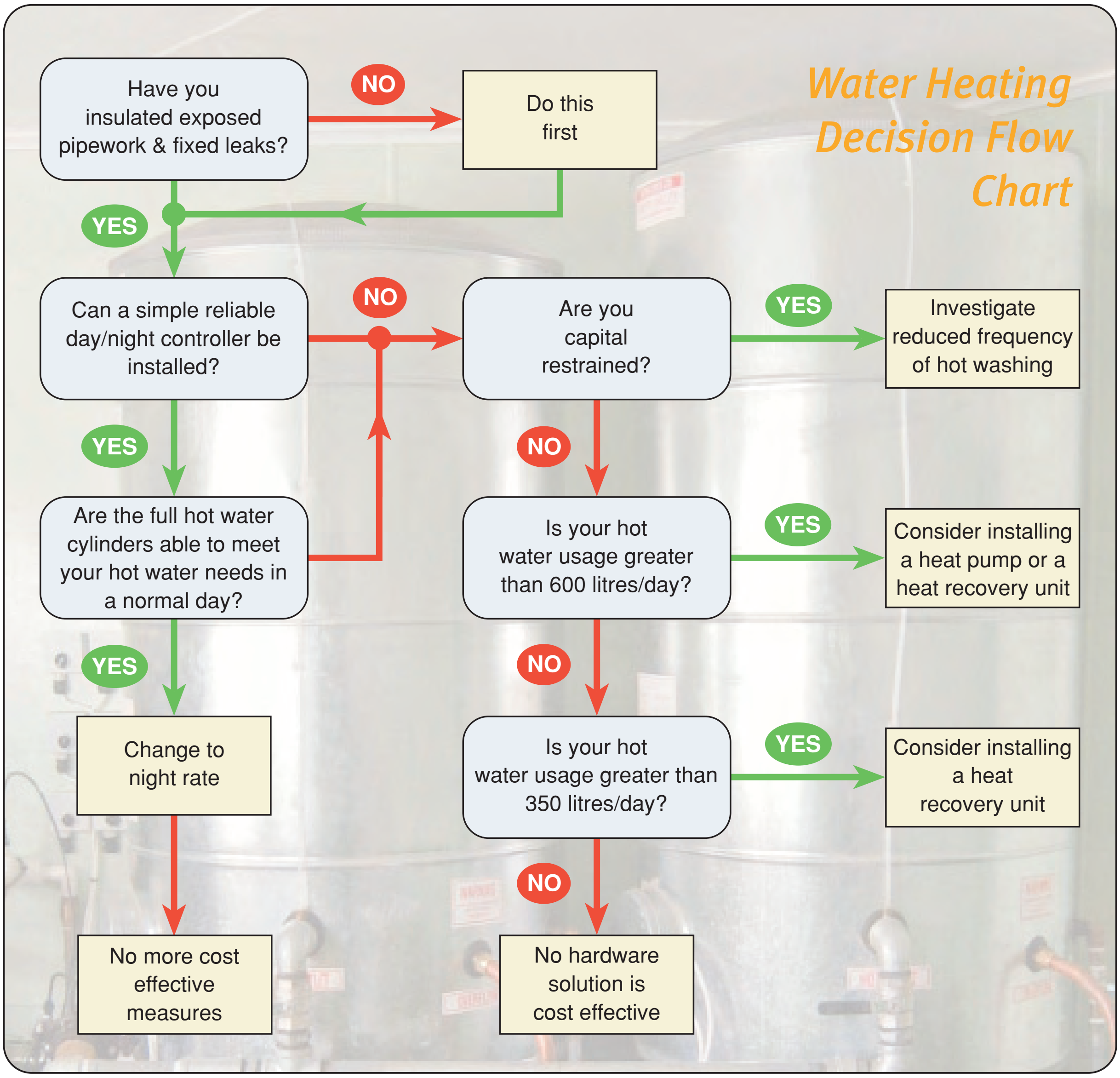
An efficiently operating pre-cooler should reduce milk temperature to within 3 degrees of the water temperature, but those tested did not. Greater investment is only justified if a shorter cooling time in the vat is required.

Variable speed milk pump

The installation of a variable speed drive system on the milk pump can reduce the milk temperature from the pre-cooler by smoothing the milk flow. Use the costings above to estimate investment limits.

Heat Gain and Milk Vat Insulation

Milk vat insulation reduced heat gains (as opposed to energy usage) by milk vats by up to 80%. The annual saving is about $400, which justifies an investment of approximately $2000. If milk chilling is satisfactory on calm, cloudy days but not on warm, sunny, windy days then heat gain into the vat is the likely problem. Vat insulation is probably the most cost effective solution.



Check list

Items for consideration	Basic	Good	Better	Best
Vacuum Pump				
– existing water ring	✓			
– add variable speed drive		✓		
– or, replace by rotary lobe or rotary vane			✓	
– or, for new, as above with variable speed drive				✓
Water Heating				
– review insulation, fix leaks, review washing procedures	✓	✓	✓	✓
– select ONE of a) Heat at night (off-peak tariffs)	✓			
b) Change detergent/use fewer hot washes		✓		
c) Add a heat recovery unit			✓	
d) Add a heat pump (Mahana Blue)				✓
Milk Cooling				
– optimise pre-cooling		✓		
– add milk pump speed controller			✓	
– improve refrigeration performance (COP) - check		✓	✓	✓
– insulate the milk vat		✓	✓	✓
Lighting				
Lighting upgrade – replace incandescent		✓	✓	✓
Lighting upgrade – replace quartz halogen		✓	✓	✓
More day-lighting in shed design				✓
Other Items				
Other pumps & piping – review performance and replace with more energy efficient equipment				✓
If changing to a night rate – install a suitable control system	✓			
Install three extra kWh meters to monitor use		✓	✓	✓

This check list is intended as a simple 'guideline summary' of what is a whole system of interacting components that need detailed study to determine appropriate 'solutions' for each dairy shed and the corresponding management systems. As a guideline, there will be different interpretations of what may be considered as Basic, Good, Better or Best. Best is more likely to be a target for new dairy sheds. The listings are simply based on expected energy efficiency and energy savings, not 'return on capital' as has been highlighted earlier in this report. The selection of equipment and processes for the reduction in energy use may depend on how long a view is taken for the life of the investments.

About the Project Partners

Venture Southland

Venture Southland is a joint committee of the Invercargill City, Southland District and Gore District Councils, with responsibility for regional tourism and economic development. In 2003 Venture Southland commissioned the Southland Regional Energy Assessment, which included a number of observations relating to the growth of energy demand from the dairy sector. *Energy Efficiency in Dairy Sheds* was initiated as an immediate follow-up project.

Sustainable Farming Fund

The purpose of the Sustainable Farming Fund is to support projects that will contribute to improving the financial and environmental performance of the land-based productive sectors. It aims to help the land-based sectors solve problems and take up opportunities to overcome barriers to economic, social and environmental viability.

Dairy Insight

Dairy InSight is the independent farmer-owned organisation responsible for making investments into dairy industry research, development, extension and education projects and activities. It funds and co-ordinates these industry-good activities to improve dairy farmer profitability and ensure the long-term success of the dairy industry.

CAENZ

CAENZ is an independent think-tank and research facilitator with links to the University of Canterbury, Auckland University, and the engineering profession. Established in 1987, CAENZ plays a strong integrating role within New Zealand's engineering and technology sectors, by building collaborative frameworks, advancing solutions and progressing knowledge. A key focus is the development of technology platforms for critical infrastructure and the built environment.

ISBN: 978-0-908993-43-7