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Managing the environmental impact of the dairy industry: the business case for sustainability

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Abstract: Increasingly stringent workplace, food safety and environmental regulations, growing customer expectations, limited resources and climate change mitigation measures are just some of a growing list of pressures currently facing the dairy industry. In order to remain competitive it is becoming increasingly accepted that the entire supply chain needs to explore opportunities to manage and improve resource efficiency and to reduce waste. This chapter looks at eco-efficiency initiatives undertaken on dairy farms and processing sites that have achieved both environmental and economic gains. The authors draw on case studies from around the globe and their own studies in Australia to demonstrate that eco-efficiency really does make good business sense and is an essential component of the industry's long term environmental and financial sustainability.

Key words: eco-efficiency, cleaner production, waste management, waste minimisation, water efficiency, water minimisation, energy management, environmental improvement, dairy waste management.

10.1 Environmental challenges facing the dairy industry

One of the biggest challenges facing food producers and processors today is managing and reducing environmental impacts while also staying viable in an increasingly competitive marketplace. While compliance and environmental legislation have played an important role in setting requirements for managing

environmental emissions, the dairy industry is now actively being encouraged to play a more proactive role in improving its environmental performance. This has included, for example, industry codes such as those for dairy farm effluent management and the development and certification of environmental management systems.

Effective resource management has become critical with pressure worldwide on fresh water supplies and a dependence on non-renewable fossil fuels. In recent years many countries have introduced water and energy efficiency programmes and greenhouse abatement initiatives to encourage more sustainable use of these limited resources. The Kyoto protocol and emergence of emissions trading schemes have provided opportunities for industry to trade carbon permits and invest in green(er) technologies.

In some countries, full-cost recovery regulations for water supply and wastewater treatment have also encouraged not only water efficiency but also product and chemical recovery leading to higher product yields and improved effluent quality. The impact of solid waste disposal has also become a significant environmental issue for the dairy industry, with many manufacturers signing packaging agreements and looking at the environmental impacts of packaging from production through to disposal by the customer. This chapter looks at the environmental impacts of the dairy industry from the paddock to the manufacturer's gate and demonstrates through various case studies how innovative farmers and manufacturers are endeavouring to sustainably manage environmental impacts by adopting the principles of eco-efficiency.

Eco-efficiency is about systematically evaluating existing practices to identify opportunities to minimise resource consumption or waste production. Eco-efficiency not only benefits the environment but is also a 'win-win' business strategy. Cost savings can be made directly from reduced raw material, water and energy usage. Not only is waste a loss of valuable material but its storage, handling, transport, treatment and disposal are also costly. Improved efficiency also often means reduced maintenance and operational costs. There may also be many indirect benefits that are important in today's marketplace such as reduced exposure to risk and liability, improved relations with regulators with the focus being on self-regulation, and even a safer work environment as managers explore less hazardous, environmentally friendly alternatives. In some cases there can also be opportunities for a competitive advantage through product diversification or greater ability to attract investors or customers through promotion of a 'green' image. Thus eco-efficiency demonstrates the 'business case' for better environmental management practices.

10.2 The environmental impacts of dairy farming

10.2.1 Changing soil characteristics

Possibly the first step towards more sustainable milk production involves becoming more aware of the land and its characteristics. Sustainable farming

means having and using soils and other inputs sustainably. As with many eco-efficiency opportunities the best results are frequently achieved by implementing simple, commonsense and often low-cost measures. This is particularly true when it comes to preventing soil compaction, erosion, poor drainage, soil acidity and nutrient deficiencies on dairy farms. Using monitoring and mapping techniques to identify the major soil types, rivers, streams, dams and drainage on the site (including wet soils and other drainage systems) is an effective method to highlight areas requiring varying farm management regimes.

Soil compaction

Soil compaction by cattle hooves and cultivation practices can destroy the soil structure and restrict the movement of air, water and roots through the soil. When looking at eco-efficiency opportunities it is always better to reduce or eliminate the cause of the impact. Eldridge (2004) suggests a number of good farming practices to prevent or fix soil compaction:

- Minimising tillage, e.g. sowing pastures using direct drilling (deep ripping of paddocks may be required if the soil is already compacted)
- Slashing and mulching pasture to add organic material to the soil rather than burning it
- Growing deep-rooted pastures to help break up compacted soil
- Cultivating the soil only when the soil moisture content is suitable
- Using fences to separate wetter areas from drier locations so stock and vehicles can be kept off these areas during wet periods
- Installing feeding pads and breaking up the herd by installing a number of watering and shade areas
- Confining cattle traffic to established and raised laneways (Eldridge, 2004).

Case Study 1

A dairy farm in New South Wales, Australia, established a network of gravel laneways, gully crossings and a bridge to reduce erosion and soil compaction and to improve access during wet periods. Watering troughs were also located in all paddocks to reduce the impact of stock on the riparian zones. Apart from the many environmental benefits including less pugging (hoof depressions) and erosion, the redirection of nutrients in the runoff from the laneways into the paddocks and improved river water quality, the infrastructure has allowed the farm to increase its herd size from 130 to 300 head. Table 10.1 shows the direct financial savings resulting from this work (NSW Department of Environment and Conservation, 2004).

Table 10.1 Direct financial savings (AUS\$) from soil conservation work

Works implemented	One-off costs	Areas where savings were made	Estimated savings (AUS\$)
<i>Laneways</i>		Reduced labour	4,200
Gravel for the lanes	75,000	Tractor savings	2,200
Laneway contractor	75,000	Motorbike savings	5,500
Bridge	25,000	Reduced mastitis (10%)	300
Culverts	10,000	Nutrient recovery	1,800
<i>Stock watering system</i>		Reduced land width	3,000
Pipework and tank	24,000	Total savings per year	17,000
Pumps	3,000	Productivity gain per year	75,000
Troughs	18,000	Total cost-benefit per year	92,000
Total one-off costs (includes estimates to complete the work)	230,000	Payback period: 3–5 years	

Source: NSW Department of Environment and Conservation (2004).

Soil and river bank erosion

During the last 40 years about 30% of the world's arable land has become unproductive with around 75 billion tons of soil being lost every year worldwide. As it takes on average around 500 years to replace 25 mm of soil, erosion has now become a huge global concern (Pimentel, 2006). Again, efficient management practices can help prevent the loss of this vital resource.

Rotational grazing, where livestock are moved between paddocks, can help to maintain healthy pasture cover essential for soil health. This good farming practice requires subdividing the land into paddocks, providing access to water, and constant monitoring, including grazing durations. The US National Sustainable Agriculture Information Service has produced a guide with further resources to assist farmers interested in implementing a rotational grazing system (National Sustainable Agriculture Information Service, 2004). Decision support software is also available to help producers determine stocking strategies or even to test the benefits of rotational grazing before making capital investments. For example, the Australian software 'PaddockGRASP' simulates pasture growth within individual paddocks up to 12 months in advance. The model, of course, requires the input of information such as soil types, tree cover, terrain and pasture cover as well as historical climate data and any existing land degradation issues (MCV, 2007). Case study 2 illustrates financial benefits in adopting a rotational grazing scheme for a US farm.

Riverbanks are an area of prime environmental concern as erosion is not only dangerous for stock but results in a loss of valuable nutrients and

Case Study 2

The Scherping family managed a 200-acre dairy farm in Minnesota for 15 years by ploughing soils and growing corn crops that required both fertilisers and herbicides. By 2000 the farm had totally moved away from planting up cornfields to instead utilising permanent pastures, which were grazed on a rotational basis. In 2000 the farm was compared with 564 other dairy farms in Minnesota. The expenses were 50% of gross income compared to ‘confined corn fed’ dairy farms where higher production costs were about 75% of gross income. Table 10.2 shows the financial savings made (RTC, 2005).

Table 10.2 Financial savings (US\$) from rotational grazing

Farm	Gross income	Direct costs	Overhead costs	Annual profit
Scherping dairy	125,000	54,000	8,000	63,000
Confinement farms	180,000	107,000	9,000	54,000

Source: RTC (2005).

farmland. Once unstable, the river bank is more susceptible to flood damage and noxious weeds, Key management strategies to prevent or repair riparian erosion include fencing waterways to exclude or restrict stock, maintaining riparian buffer zones, building dedicated stock crossings, locating watering points and shelter away from waterways and replanting native vegetation on eroded waterways. Often the placement of water points away from the waterways has helped producers better utilise the paddocks (Jansen and Robertson, 2001).

Loss of soil fertility

It is important that nutrients leaving the farm in the form of milk are replaced. Computer software is available to producers, such as ‘Dairybal’, which is a whole farm nutrient and water mass balance spreadsheet (Queensland Department of Primary Industries and Fisheries, 2008). The program can calculate the waste output from a dairy herd according to the rations they are fed and types of pastures or crops on which they graze. It then apportions the waste between the milking shed, the yards, the feed pad and up to six paddocks. Such software can determine whether the effect of current or proposed cropping or pasture management practices on nutrient loading is sustainable. It also identifies areas where inorganic fertilisers may be required, thereby avoiding the detrimental environmental impacts of over-fertilising. Case study 3 demonstrates how a 210-cow farm in New Zealand reduced its fertiliser use by conducting a nutrient balance.

Case Study 3

Louis and Barbara Kuriger from the North Island of New Zealand undertook a nutrient budget. Based on 2002 fertiliser application rates, they were able to reduce their phosphate rate from 71 kg P/ha/yr to 48 kg/ha/yr, saving around NZ\$5000 in phosphate application alone. The impact of reducing annual fertiliser application was analysed in 2004 against previous soil tests and showed that the soil phosphate level had remained constant despite constant farm production (Dairy New Zealand, 2005).

Along with the benefits discussed previously, rotational grazing can also help to ensure that manure and urine are returned to where the feed was initially grazed. Also around 8–10% of a dairy cow's manure and urine can be recovered from the milking yards (Hopkins, 2004). If well managed, this effluent can be a valuable resource that can improve pasture production and reduce fertiliser use. Various methods are available, including direct return to fields and composting.

Case Study 4

Rosenholm Farm in Wisconsin has used the organic solids remaining after dairy manure has been flushed, together with bedding material, to produce compost for the commercial market for over 14 years. The dairy spends about 10% of what it would take to haul and land-apply all their manure. Only lagoon liquids are used on farm (National Dairy Environmental Stewardship Council, 2005).

A US study on the feasibility of composting for small to medium-sized farms suggests it can be economically viable if farmers use existing equipment, rented machinery and hired help or are part of a cooperative arrangement between a number of farms (Center for Integrated Agricultural Systems, 1996). The article provides cost comparisons between manure handling methods. Organic solids separated from the manure can even be utilised as bedding with some systems (Johnson, 2007).

Returning dairy effluent to paddocks or pastures is an effective way to help restore the nutrient balance. As much as 90% of the nutrient value (nitrogen, phosphorus, potassium, sulphur and trace elements) in the effluent can be retained in a well-designed system and management plan (Dairy Insight *et al.*, 2007). Tables 10.3 and 10.4 give an indication of the value of effluent for two feeding schemes. However, as in all intensive practices, care must be taken not to overload the paddocks with nutrients or to create nuisances.

Table 10.3 Dollar value (NZ\$) of effluent from 100 cows on an all grass system

Nutrient	Solid fertiliser equivalent	Dollar value
N	13 t urea	650
P	0.7 t superphosphate	130
K	1.1 t MoP	450
Mg	0.2 t MgO	70
Total dollar value		1300

Source: Dairy Insight *et al.* (2007).

Table 10.4 Dollar value (NZ\$) of effluent from 100 cows fed maize on a feed pad

Nutrient	Solid fertiliser equivalent	Dollar value
N	2.3 t urea	1080
P	1.3 t superphosphate	250
K	2.1 t MoP	830
Mg	0.3 t MgO	100
Total dollar value		2300

Source: Dairy Insight *et al.* (2007).

10.2.2 Water contamination and consumption

Besides the good farming practices outlined above, there are other opportunities to reduce the impact of effluent generated on dairy farms. Reducing the volume of water used in the dairy and yards will reduce the amount of effluent generated. The amount of water used per cow can vary considerably. An Australian study, for example, showed that in the south-west of Victoria the most efficient dairies used less than 2000 L per cow annually, while the least efficient used 38,000 L per cow (Victorian Environmental Protection Agency, 2007). Dairy Australia (2008) suggests how producers can improve water efficiency and effluent quantity and quality through:

- sweeping or scraping floors and yards before washing to reduce the solid content in the effluent;
- periodic damping of yards and the use of scrapers (including gate scrapers with blade or chain), which can reduce the amount of water needed for final cleaning;
- design of yards to reduce cleaning requirements e.g. good slope and drainage and weeping walls or solid separators to remove solids;
- using non-stick coatings for dairy walls and floors;
- allowing the cows a few minutes in the paddocks in the early morning so manure falls in the paddock before moving them to the shed;
- installing a barrier foot bath or using sawdust to reduce the amount of material brought into the yards to reduce cleaning requirements;

- harvesting of rainwater to supplement water supplies that can assist in effluent digestion;
- recycling effluent from a multiple pond system for washdown;
- using harvested rainwater for plate coolers and then storing and reusing cooling water for yard washing or return to stormwater dams;
- using recycled effluent or plate cooler water for flood washes as this method requires large volumes of water;
- correctly sizing plate coolers and interlocking water and milk pumps so water is going to the plate cooler only when milk is flowing (water flow can be further optimised by installing a variable-speed drive on the pump on more sophisticated systems);
- dry cleaning and considering reducing the size of hoses;
- checking and repairing nozzles and hoses regularly;
- making sure hoses have trigger nozzles and are not excessively long;
- turning off cup and platform sprays in rotary sheds after milking;
- making sure milking machines capture final rinse water for the initial rinse and that the volumes of water used for rinsing are not excessive;
- recycling wash water to recover not only water but also detergents;
- considering air injection on older milk lines, which can reduce water used for pipe cleaning by 20–30%;
- checking vat cleaning matches manufacturer's requirements and ensuring spray heads are checked and cleaned regularly;
- for larger farms, considering the dietary intake of cows. Adjusting feed without compromising stock health can have an impact on phosphate and nitrogen levels in the effluent stream (McDonald, 2006);
- not allowing clean stormwater to mix with effluent.

The UK Milk Development Council has produced an excellent guide called 'Effective Use of Water on Dairy Farms' that can assist farmers to evaluate how efficiently they are using water on their farms and that includes three detailed farm audits (MDC, 2007).

Fertiliser should be applied under the optimum conditions (i.e. not when heavy rain is expected or when water tables are very high) and when plant uptake is greatest. Soil and effluent testing can help to ensure that nutrient applications are not in excess of the plants requirements and best practice application methods to protect riverbanks and streams should be used (Watschke, 1998).

Excluding stock from riverbanks and saturated soils as discussed previously is not only essential to prevent erosion but also avoids nitrogen from urine and phosphorus from manure that can cause algae growth. Riparian vegetation not only takes up nutrients for plant growth but also filters surface runoff and denitrifies groundwater (Hoorman and Cutcheon, 2005).

10.2.3 Air emissions and energy consumption

Greenhouse gases absorb the sun's heat and make the atmosphere warmer. The three main greenhouse gases released during dairy farming and production are

carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄). Nitrous oxide is characterised as having 296 times more global warming potential than carbon dioxide, and methane as having 23 times more global warming potential than carbon dioxide (Energy Information Administration, 2003). All three greenhouse gases are produced during combustion of fossil fuels in production of electricity; however, there is significantly more impact due to enteric emissions of methane, i.e. that which is produced by microbes in the cow's rumen during digestion. Around 80% of the methane emissions come from enteric fermentation and 20% from manure management (Vergé *et al.*, 2007). Nitrous oxide is also produced by microbes in waterlogged soils converting nitrogen from cow urine, fertiliser or legumes into nitrous oxide. Producers can calculate methane, nitrous oxide and carbon dioxide emissions using tools developed in Australia: 'GrassGro' and 'DairyMod' (Victorian Department of Primary Industries and University of Melbourne, 2008).

Methane emissions can be reduced by running fewer cows and managing them more productively through improved genetics and nutrition to achieve the same yields. Matching animal feed to efficiency (milk yield) makes good business sense, reduces waste and optimises outputs. The Queensland dairy industry, for example, was able to reduce methane release by 6% between 1988 and 1996 by dropping cow numbers while improving milk production from 2924 L per cow in 1988 to 4046 L per cow in 1996 (Davidson, 2000).

Research is being undertaken to find additional technologies to reduce ruminant methane production. These include the following:

- Addition of unsaturated fatty acids such as coconut, linseed, canola and cod liver that act as a sink for hydrogen (New Zealand Ministry of Agriculture and Forestry, 2003).
- Antibiotics such as monensin, which encourages growth of *Streptomyces* spp. The National Research Council (2001) found increases in milk production, better feed conversion efficiency and reduced acidosis, ketosis and bloat; however, it appears the effects decrease with repeated use (O'Mara, 2004; Davidson, 2000).
- Organic acids such as malate, fumarate, citrate and succinate that will use the hydrogen gas, thereby starving the methane microbes. While they are effective they may be costly as a feed supplement (O'Mara, 2004). Breeding high malate or fumarate forages may be an alternative (Eckard and Hegarty, 2004).
- Bacteria called acetogens that convert carbon dioxide and hydrogen to acetate rather than methane. These acetogens occur naturally in ruminants, humans and wood-eating termites but their activity needs to be promoted (Davidson, 2000).
- A vaccine against methanogens is being investigated by the CSIRO in Australia.
- Secondary metabolites used for the manipulation of rumen fermentation by selective inhibition of a microbial group, e.g. ethanol extract of soapnut seed pulp administered during regular milking to remove protozoa (Kamra *et al.*, 2006).

Nitrous oxide emissions can be reduced by not applying nitrogen fertiliser at high application rates or before heavy rainfall is predicted. To ensure maximum uptake, nitrogen fertiliser should also only be applied when the pasture is actively growing. Producers should avoid applying fertiliser or overstocking paddocks with waterlogged soils. Recent research trials by the University of Melbourne in Australia for the Pastoral Greenhouse Gas Research Consortium show that nitrification inhibitors (substances that slow or stop the conversion of soil ammonium to nitrate) have the potential to reduce nitrogen losses by up to 60–70% (PGGRC, 2006).

Producers can also reduce carbon dioxide emissions and energy costs by reducing electricity use and investigating renewable energy options. Electricity usage on dairy farms can range between 200 kWh and 400 kWh per cow per annum (MDC, 2005).

Heating water accounts for around 40% of electricity use on farms (Dairy SA, 2008a). As discussed previously, reducing water consumption for cleaning is the best way to reduce heating requirements. Other opportunities include using other options to pre-warm the water. A reduction in greenhouse gases of 139 g per 100 L of water is possible for every 1°C increase in water temperature that can be achieved before it enters the electric hot water service (Dairy SA, 2008a). Preheating options include solar heating, heat recovery from the refrigeration unit, heat capture from cleaning wastewater or the heat in the milk itself as it passes through the plate cooler, a heat pump, or even alternatives such as geothermal sources.

Case Study 5

The O'Regan family manages 630 cows on their Awarua Farm at Tahuna, New Zealand. The farm's milking machine was allowing relatively hot cleaning water to go to waste. By installing a heat exchanger to recover heat from wastewater to preheat incoming water, the farm achieved an annual energy saving of 30% (2245 kWh) or a reduction in CO₂ emissions of about 1 tonne per year (EECA, 2007).

When looking at the actual electric hot water system, producers should ensure the water is heated only when it is needed, that the storage tank and pipes are insulated and that the thermostat is set correctly, i.e. is not overheating the water. A study by the Farm Energy Centre showed an uninsulated tank will lose about 50% of its energy over a 17-hour period while only 5% will be lost from a tank that is well insulated (MDC, 2005).

Cooling milk on average uses around 30% of the dairy farm's total energy consumption. A reduction in greenhouse gases of 37.5 g per 100 L of milk is possible for every 1°C decrease in milk temperature that can be achieved before the milk enters the vat (Dairy SA, 2008b).

Energy savings may also be possible by improving the efficiency of vacuum and milk pumps. Opportunities include installing variable-speed drives that adjust pump speed according to the demand rather than having the pump operating at a constant speed. Water pumps and pipes should be correctly sized for the load with no unnecessary bends or elbows. Energy-efficient new electric motors should replace old ones, including turn-off standby features when the cluster is not milking. Other opportunities include installing energy-efficient equipment and lighting, which should be task specific (e.g. general lighting for laneways and holding yards and specific lighting for office and veterinary areas) and maximum use should be made of natural lighting through the use of skylights.

10.2.4 Farm wastes and chemicals

Dairy farms produce solid non-biodegradable wastes such as containers, packaging, scrap metal and drums along with plastic silage wrap. Biodegradable wastes include milk and deceased stock. In many cases there will also be waste chemicals or chemical residues. The waste hierarchy should be considered when dealing with waste, i.e. first eliminate, then reuse or recycle, recover, and lastly dispose as the least preferred option. Disposal of all waste must be in accordance with relevant legislation or advice from relevant local authorities.

Waste milk can be fed to animals if the farm has suitable storage facilities (up to 10 L per day per cow). A less preferable option is to apply it to the land away from watercourses at a rate of 1:10 milk to water (only during dry periods) or to dispose milk to effluent ponds (only possible for one or two days) (Dairy Australia, 2003).

Poor management of deadstock can lead to disease, odour and the contamination of groundwater. Carcasses can be composted if a dedicated area is set aside and the producer has a sound knowledge of the composting process, otherwise it is preferable to have them removed by a knackery. Deep burial in areas with a low water table or burning are the least preferable options (Dairy Australia, 2003).

Solid non-biodegradable wastes such as food wastes and green wastes can be composted and materials such as timber and wire reused. Lead batteries, scrap metal and oil (sump, engine, gear and hydraulic oil) can be recycled and plastic containers and drums returned if possible to the supplier or a recycler collection point. In some areas recycling is an option for silage wrap and baling twine (Central Murray Regional Waste Management Group, 2008). Recycling can significantly reduce the cost of sending material to landfill.

Solid waste will be reduced through the use of best practices in the design and operation of the dairy process, from field to parlour, including applied eco-efficiency, optimisation of yield, benchmarking, modern milking and dairying practices, and herd management, including selection of calving times for optimum yield and feed efficiency.

10.2.5 Loss of habitat and biodiversity

Biodiversity is the natural variety of native wildlife together with the environmental conditions necessary for their survival. It is acknowledged that most dairy farms use land that has been extensively farmed for many years; however, it is possible for the dairy farmer to manage for biodiversity and enhance the natural habitat as well as improving the farmed land. A recent study of dairy farmers in South-west Victoria, Australia, examined a range of biodiversity issues. Eighty percent of farmers in the study were looking for practices which provided them with a productivity return and were unlikely to use specialist environmental indicators to monitor resource states. They would, however, use information that has both a production and an environmental benefit such as soil tests. Thirty percent of farmers wanted indicators that can help them to benchmark their environmental performance against farmers similar to themselves. Twenty percent of the farmers were thinking of the next generation and placed a high value on biodiversity practices (Parminter and Nelson, 2003).

Dairy farmers can help in biodiversity conservation in many ways, such as by improving farm management practices by, for example, conserving and restoring native vegetation and providing protected areas, managing feral animals, improving vegetation levels, using conservation methods and best-practice grazing and tilling, restoring eroded or saline soils and managing water on site effectively.

10.3 The environmental impacts of dairy processing

10.3.1 Consumption of non-renewable fuel and greenhouse gas emissions

The transport of milk from the farm to the processing plant and from the plant to distribution outlets consumes energy (usually non-renewable fuels) and releases greenhouse gas emissions. Global trade also means more milk products are travelling even further distances. The transport sector accounts for 15% of global carbon dioxide emissions and 31% of ozone released into the atmosphere (Butler, 2008). Tim Lang developed the concept of 'food miles', which looks at the ecological as well as social and economic consequences of food production to help consumers make judgements about which products they purchase (Woodhouse, 2007). Food miles, however, can be misleading and a lifecycle approach is a better tool for consumers to evaluate food systems as it includes production as well as transport and distribution. For example, a report produced by Lincoln University in New Zealand compared the efficiency of dairy production in Europe and New Zealand. The findings claim that because New Zealand animals graze on grass all year round rather than eating feed concentrates, they are twice as energy efficient, even with export transport costs included (Woodhouse, 2007).

An Australian life cycle study by Lundie *et al.* (2003) indicated that around 49% of total energy use is associated with milk manufacturing, 43% with

production on-farm and 8% for milk transport. In processing, energy is consumed for refrigeration, the operation of machinery and general lighting and air-conditioning (cooling and heating). Typically the main sources for this energy are non-renewable fossil fuels such as natural gas, coal, oil, LPG (liquid petroleum gas) and electricity.

Energy management

Good energy management is an important key in identifying the end uses of energy and opportunities for improvement. This may involve the formation of an energy team and the installation of steam, gas and electricity sub-meters to track energy use across the site.

Evaporators and driers

A wide range of energy efficiency opportunities exists through optimising the operation of energy-consuming equipment. For example, evaporators that are used to concentrate milk can be single or multiple-stage (effect). By increasing the number of effects, significant efficiencies can be obtained. Some large factories in Europe have been able to increase the number of effects up to seven (ETSU, 1998). In some cases evaporators may be replaced with membrane units where the equivalent level of concentration can be attained depending on viscosity, etc.

Case Study 6

A whey processing plant in the Netherlands uses a nanofiltration unit to concentrate and desalinate whey instead of an evaporator and ion exchange unit. The unit increases the solid content from 5.5% to 17% and removes 70% of the salt content from the permeate. Overall energy consumption has decreased by 70% of the original consumption, largely due to a reduction in steam production, in addition to water and chemical savings from reduced cleaning requirements. The payback period was 1.3 years (CADET, 1999).

Usually used in conjunction with evaporators, spray driers deliver milk droplets into a chamber of hot air to dry product to 50–90% solids content. Considerable savings can be made by maximising the solids content of the milk input. For every 0.5% increase in milk solids, energy consumption is reduced by 2% (ETSU, 1996). Energy may be recovered from drier exhaust streams.

Boilers

The efficient operation of boilers will reduce both energy and water consumption. Having optimum ratios in the boiler of air to fuel will ensure the optimum mix of flue gases. Insufficient air causes incomplete combustion while excess air leads to heat loss in the boiler stack. Installing an oxygen trim control on boilers can lead to considerable fuel savings, as shown in Table 10.5.

Table 10.5 Fuel savings from installing online oxygen trim control

Boiler capacity (MW)	Fuel savings (GJ/yr)	Fuel savings (AUS\$/yr)	CO ₂ emissions (t/yr)	Payback period (yr)
0.5	318	3,816	19	2
1	635	7,620	37	1
2	1,270	15,240	75	0.5
4	2,540	30,480	150	0.2
6	3,810	45,720	224	0.2
8	5,080	60,960	299	0.1
10	6,350	76,200	374	0.1

Assumptions: gas costs AU\$12/GJ; boilers operating 24 h/day, 350 days/year; installation cost of the boiler.

Source: SEAV (2004).

Table 10.6 Effects of soot and scale on heat transfer

Build-up (mm)	Heat loss (%)	Increased fuel consumption (%)
<i>Soot</i>		
0.8	12	2.5
1.6	24	4.5
3.2	47	8.5
<i>Scale</i>		
0.8	8	2
1.6	12	2.5
3.2	20	4

Source: Spielmann (n.d.).

Other typical boiler efficiency measures include monitoring the stack gas temperature regularly. A major variation is an indicator that either the boiler tubes need to be cleaned or the air-to-fuel ratios need to be adjusted. The accumulated soot or scale acts as an insulator and can inhibit effective heat transfer, as shown in Table 10.6.

Boilers should be operated at design working pressure. If lower pressures are required, pressure-reducing valves should be employed. The boilers in many dairy processing plants have a steam supply potential far in excess of the site's actual needs, to cater for short peaks in demand. Good communication between the boiler operators and the end users can help reduce fuel wastage.

It is important to ensure minimal heat losses from the system. Opportunities include recovering boiler condensate and preventing the loss of live steam by repairing leaks and faulty steam traps and promptly replacing damaged insulation. For example, failure to repair 1 m² of un-insulated surface carrying steam at 700 kPa will lose around 225 MJ in a 24-hour period. That is approximately 81,000 MJ of natural gas or 2 tonnes of fuel oil per year (SEAV, 2002).

Case Study 7

Murray Goulburn in Victoria, Australia, saved AUS\$180,000 annually (1536 tonne reduction in greenhouse emissions) by improving coordination between the boiler house and the operations team. Before the initiative the boiler attendant was only aware of the need for steam about 40% of the time compared to 95% after steps were made to improve communication (Industry, Science and Resources, 2003).

Regular checking and maintenance of steam traps are important. If traps fail to close, uncondensed steam and heat will escape, while if a trap fails to open the system becomes waterlogged and system performance is reduced. The insulation of steam and condensate return lines can reduce heat loss by up to 90%, as Table 10.7 illustrates.

The layout of steam lines also affects heat losses. Where possible, rationalise the length and sizing of the steam pipework, avoid excessive pressure drops and ensure pipes are sloping to ensure condensate drains to steam traps. Boiler efficiency can be further improved by installing heat recovery equipment such as economisers and recuperators. Economisers are air-to-liquid heat exchangers that recover heat from flue gases to preheat boiler feed water, while a recuperator is an air-to-air heat exchanger that recovers heat from flue gases to preheat combustion air.

Refrigeration

Refrigeration can consume up to 20% of a dairy processing plant's total energy costs (ETSU, 1998). Dairy processors typically use the vapour compression cycle refrigeration system consisting of a fluid called a refrigerant (usually ammonia). Optimising the system can save considerable amounts of energy (and money) (EEBPP, 2000).

There are several ways to increase evaporating temperature (pressure) and decrease condenser temperature:

- Not setting the thermostat in cold rooms and freezers lower than necessary.
- Sizing the evaporator and compressor to match the refrigeration load. A small

Table 10.7 Heat losses from insulated and uninsulated steam lines

Level of insulation	Heat loss (MJ/m/h)	Steam loss (kg steam/m/h)	Equivalent fuel cost (gas) per 50 m pipe per year (AUS\$)
Uninsulated	2.83	1.0	3396
Insulated with mineral fibre	0.14	0.05	165

Assumptions: 125 mm steel pipe at 150°C; natural gas costs AUS\$0.012/MJ; boiler operating 8 hr/day, 250 days/year.

Source: Prasad *et al.* (2004).

evaporator may mean a lower initial capital outlay; however, running costs may be greatly increased by the need for a larger compressor to cope with the greater load. A condenser that is too large, on the other hand, can actually cause sub-cooling where the refrigerant starts to vaporise.

- The evaporator should be kept clean and defrosted when necessary to prevent the build-up of ice on the coil affecting the heat transfer. Hot gas from the outlet of the compressor can be used to defrost freezers if controls are accurate. The defrost water can then be used elsewhere in the plant.
- Condensers should be cleaned regularly to promote efficient energy transfer, and air-cooled condensers should have unrestricted airflow.

Reducing the load on the compressor is fundamental as it usually consumes 80–100% of the system's total energy use. The efficiency of the system is measured by the coefficient of performance or COP. This is the ratio of cooling output (kilowatts) compared with energy input (kilowatts), thus the higher the COP, the more efficient the system. The Australian Dairy Processing Engineering Centre has software available called 'Coldsoft' for plant personnel to review and improve the performance of refrigeration systems (DPEC, 2003).

It is important that the compressor capacity matches the load, as operating at partial loads will cause the compressor to stop and start frequently. The use of multiple compressors with a sequencing or control capability to match the load may help. Also ensure that the suction lines into the compressor are insulated. Case study 8 demonstrates how an effective control system and the temperature of the suction air can affect compressor efficiency.

Case Study 8

A Nestlé ice cream plant in Victoria, Australia, uses about 13 GWh annually (or approximately AUS\$960,000) for refrigeration. A study showed that the compressor was operating under no load and stopping frequently because the suction temperature was 9°C above the design temperature due to incorrect valve selection. The condenser pressure was also being maintained at around 1000 kPa even over winter months. By upgrading the computer control system the site was able to improve the valve selection, enabling the suction temperature to drop to 3°C. The compressor now operates at a higher load, which has minimised stopping. The study also suggested reducing the condenser pressure to 750 kPa. The project saved AUS\$100,000 annually in electricity costs, and compressor start-ups have been reduced by 92%. There was also a 20% overall reduction in plant maintenance. The project cost AUS\$59,000 and took four months to install (SEAV, 2002).

While many of these opportunities can be costly, there are also many simple good housekeeping practices that can reduce the load on refrigeration systems.

For example, up to 10% of the power consumption in refrigeration plants occurs from heat ingress through doorways. Automatic self-closing doorways, swinging doors or plastic strips are possible options for entrances frequently left opened. Lights and fans can also add heat to the system. Consider sensors or timers on lights, appropriate low energy consumption lighting and variable-speed drives that can cycle off fans and refrigerant feed during low-load times.

There are examples of some dairy plants using absorption chillers, which cool using low-grade heat produced elsewhere in or near the plant, e.g. low-grade steam, incinerated garbage, hot water, exhaust gas or solar energy. While the COP of absorption refrigeration is low, less than 0.8 kW of refrigeration for 1 kW of energy for a single-effect system, they can be a viable option if a reliable waste heat source is available.

Case Study 9

Honeywell Farms is a milk processing plant in the USA that uses a lithium bromide absorption chiller to cool the liquid refrigerant of the main refrigeration system below its saturation point. The system uses waste heat from a compressor driven by a natural gas engine. The system reduces the load on the compressor by 8–10% and saves US\$90,400 annually. The payback period was 3.8 years (CADET, 1996).

Compressed air

Around 10% of a dairy processing plant's total energy use is for compressed air used for purposes such as cleaning and operating filling and packing machines (ETSU, 1998). Again, compressed air systems are typically only 10–20% efficient, losing most of the electricity input in the form of waste heat. Because they are so inefficient it is important to select the correct type of compressor for specific applications. If the compressor needs to operate at variable rates, consider installing a control sequencing system or multiple compressors. Air receivers are another option to consider if the compressed air system needs to cope with occasional spikes. Installing a variable-speed drive may also be ideal for compressors that are oversized or operate at variable loads.

Other opportunities to reduce energy consumption in compressed air systems include identifying and repairing leaks using ultrasonic detectors, and simple methods such as soapy water on pipework or shutting the plant down and listening. Table 10.8 illustrates the cost of compressed air leaks.

There are many technical options to optimise compressor systems and as energy costs continue to rise these opportunities become more valuable – leaks, pressure drops, too-high set points, isolated equipment with long lines, dirty filters, etc., can all be managed with good maintenance and attention to detail. An interesting, easy-to-apply saving is to ensure the inlet air into the compressor is as cool as possible so that less energy is required to compress it. It is estimated

Table 10.8 Cost of compressed air leaks

Equivalent hole diameter (sum of all leaks)	Quantity of air lost per single leak (m ³ /yr)	Cost of single leak (AUS\$)
Less than 1 mm	12,724	153
1 to 3 mm	64,415	773
3 to 5 mm	235,267	2,823
Greater than 5 mm	623,476	7,482

Assumptions: 700 kPa system operating for 4000 h/yr, electricity cost of AUS\$0.08/kWh.
Source: SEDA (2003).

that every 3°C drop in inlet air temperature decreases electricity consumption by 1% (SEDA, 2003).

Heat recovery from compressors for both refrigeration systems and compressed air may be viable if a potential application exists close to the heat source. A heat exchanger that recovers heat from compressor lubricating oil can heat water up to 90°C without adversely affecting compressor performance. For example, a 37 kW single-stage oil-injected rotary screw compressor unit attached to a heat recovery unit can produce 36 L/min of 73°C hot water (Atlas Copco, 2003).

Other opportunities

Lesser opportunities to reduce energy consumption in dairy processing plants include lighting and air-conditioning optimisation. Simply turning off lighting when not needed and installing energy-efficient lighting can provide easy savings, together with task lighting, occupancy sensors and natural lighting.

Some dairy companies are now also considering other alternative sources of energy, for example biofuels such as methane gas from anaerobic digesters, or sludge from wastewater treatment processes or separators. Table 10.9 illustrates the savings made by one ice-cream plant in New South Wales, Australia, which utilised methane gas from a lagoon digester. If there are opportunities, a regional

Table 10.9 Sample methane and energy yields from biogas digestion for an ice cream factory in New South Wales

	Low rate digestion of effluent
Material available for digestion	3060 kg COD/day
Organic load available	0.34 kg COD/m ³ /day
Methane conversion rate	0.352 m ³ /kg COD removed
Organic removal rate	70%
Methane yield	754 m ³ CH ₄ /day
Energy yield	27,000 MJ/day
Equivalent natural gas savings	AUS\$324/day @ AUS\$12/GJ

Source: UNEP (1999).