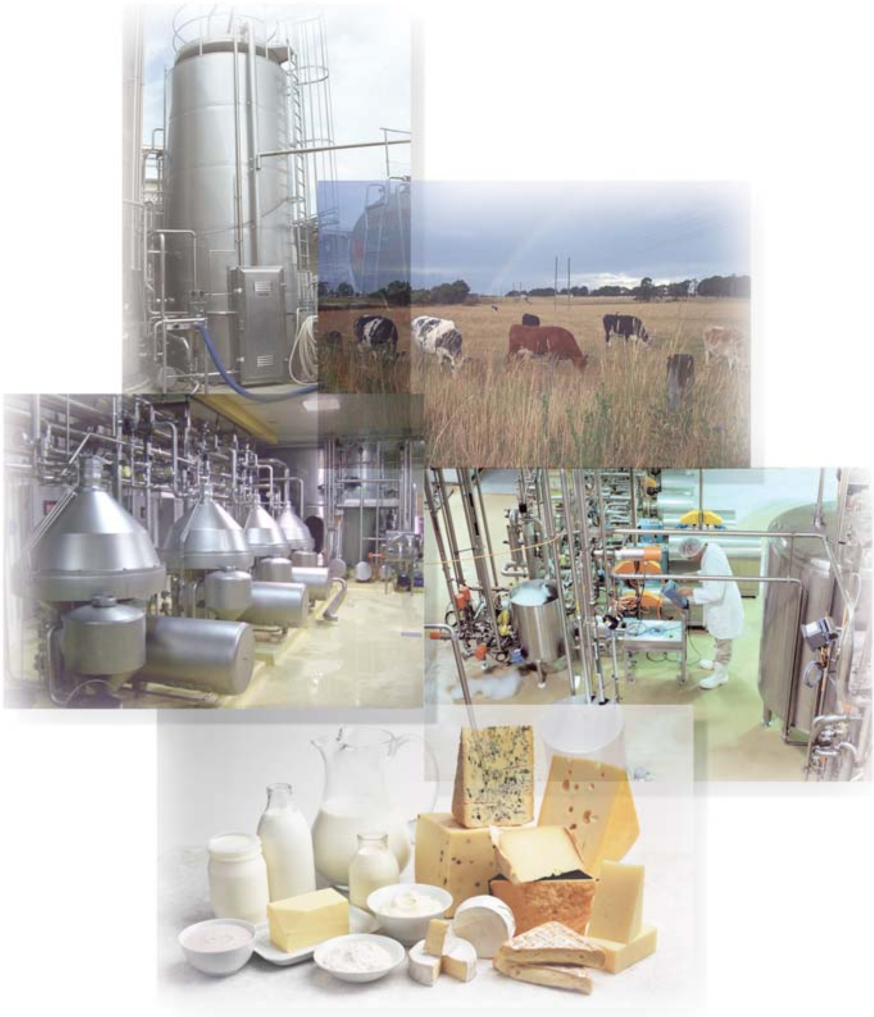
Eco-efficiency

for the

Dairy Processing Industry



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1 Introduction

This manual has been developed to help the Australian dairy processing industry increase its competitiveness through increased awareness and uptake of eco-efficiency. The manual seeks to consolidate and build on existing knowledge, accumulated through projects and initiatives that the industry has previously undertaken to improve its use of raw materials and resources and reduce the generation of wastes. Where there is an existing comprehensive report or publication, the manual refers to this for further information.

Eco-efficiency is about improving environmental performance to become more efficient and profitable. It is about producing more with less. It involves applying strategies that will not only ensure efficient use of resources and reduction in waste, but will also reduce costs.

This chapter outlines the environmental challenges faced by Australian dairy processors. The manual explores opportunities for reducing environmental impacts in relation to water, energy, product yield, solid and liquid waste reduction and chemical use.

1.1 Profile of the Australian dairy processing industry

The Australian dairy processing industry makes a significant contribution to the national economy. In terms of value, processed dairy products are the third-largest exported good in Australia after grains and meat, contributing 12% or $3.27 billion to Australia's exports (DAFF 2003). In 2002–03 the industry had a farmgate value of $2.8 billion with an ex-factory turnover estimated at more than $8.5 billion and a value-added component of $1.6 billion. The entire dairy industry employs almost 200 000 people with 19 000 of these employed in dairy manufacturing (DAFF 2003 and Dairy Australia 2003).

Milk production is concentrated in the south-east corner of Australia, with Victoria, Tasmania and South Australia accounting for 77% of total output, producing approximately 10 300 million litres in 2002–03. The dairy industry can be divided into two distinct sectors: the market milk sector, producing milk for drinking and products with a short shelf-life; and the manufacturing sector, yielding products with a long shelf-life suitable for export. The volume of drinking milk produced has remained relatively static over recent years, accounting for nearly 19% of total milk production. The proportion of market milk to manufacturing milk in the total product mix differs significantly between states, as shown in Figure 1.1.

Figure 1.1 **Milk production by state 2002–03**

Source: Dairy Australia 2003

In Australia milk is processed by farmer-owned cooperatives and by public and private companies. The largest cooperatives — Murray Goulburn Co-operative Ltd, Bonlac Supply Company and the Dairy Farmers Group — account for more than 60% of all milk production and more than 70% of all milk used for manufacturing. Multinational dairy companies operating in Australia include Fonterra, Parmalat, Nestlé, Kraft and Snow Brand. In addition there are public companies such as National Foods Ltd and private companies such as Warnambool Cheese and Butter, and Tatura Milk Industries.

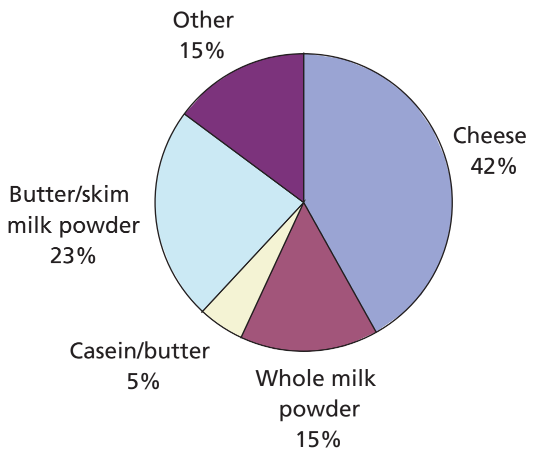
As Table 1.1 shows, there are 70 major dairy manufacturing sites across Australia, 51 of which are in rural areas. The largest cooperative accounts for 30% of Australia's milk production, while there are smaller cooperatives that produce volumes between 100 and 600 million litres (Dairy Australia 2003). Figure 1.2 shows the utilisation of manufacturing milk by major process lines.

Table 1.1 **Major Australian dairy manufacturing sites**

State	No. of sites	
	Capital city	Rural region
NSW	3	9
Vic.	7	24
Qld	3	6
SA	2	4
WA	2	3
Tas.	1	5
NT	1	–
Australia	19	51

Source: Dairy Australia 2003

Figure 1.2 **Utilisation of manufacturing milk 2002–03**



1.2 Environmental challenges

1.2.1 Compliance and legislation

Environmental legislation that regulates Australian dairy processing plants is implemented by authorities such as state environmental protection agencies (EPAs) and local councils. Dairy processors are generally required to have licences for emissions to air and surface waters and the disposal to land of some solid and liquid wastes such as sludge and treated wastewater. Disposal of wastewater to the sewerage system is regulated by local councils or local water authorities.

1.2.2 Water supply and pricing

Over the entire life cycle of dairy manufacture, including milk production on farm, transportation and dairy processing, 99% of the total water consumption can be attributed to the farm (Lunde et al. 2003). For the industry as a whole, therefore, efforts to make major gains in reducing the environmental impacts of water consumption should be focused on the farm. Nevertheless, there are gains to be made by dairy processors in minimising water consumption within factories. Depending on the product mix, dairy processing plants can use substantial volumes of water for equipment cleaning, cooling towers, boilers and other processes. Water supply to dairy processing plants varies according to location, but may be from town water, bores, rivers, dams or irrigation channels. Some factories are required to install large storage reserves to cater for periods of non-supply; for example Bonlac's Stanhope factory must store its entire winter supply to allow maintenance of water channels by the local water board. As increasing pressure is placed on limited water reserves, government bodies and water authorities are actively seeking to promote greater water efficiency and are encouraging water conservation strategies and incentives. For example, Brisbane Water recently introduced a scheme for providing water rebates to large users of water that have developed and implemented water management plans (Cameron Jackson 2004, pers. comm.) and Sydney Water is encouraging large users of water to reduce water consumption through involvement in the 'Every Drop Counts' business partnership program (Sydney Water 2004).

Water supply costs for Australian processors are vary according to the region, ranging between 20c/kL for a North Queensland processor and $1.28/kL for a processor in South-East Queensland. Water supply costs are discussed further in Chapter 3. Many water authorities are now progressively introducing a user-pays charging system to recover the full cost of supplying water to the consumer, in order to encourage water conservation and to cut costs.

1.2.3 Wastewater discharge costs

Wastewater discharge costs vary according to the region, and according to whether the waste is being discharged to land, surface waters or the sewerage system. Plants discharging treated wastewater to municipal sewerage systems face the highest costs. Most water authorities charge on the basis of the organic loads (BOD/COD) and include a separate volumetric charge. However, there are exceptions to this, such as plants discharging to Sydney Water's direct ocean outfalls, where the charging structure is based only on the mass load (in kg) of waste components. Some utility operators have introduced additional charges for nitrogen, phosphorus and sodium loads and these charges are increasing. For example, Ipswich Water in Queensland currently charges 80c/kg for nitrogen and $3/kg for phosphorus. These charges are expected to increase to more than $2/kg and $9/kg over the next few years (Mark Sherson 2004, pers. comm.). Many utility operators also charge for oil and grease content and suspended solids. The charge structure is affected by the processes used by the treatment plants, and by the costs incurred in handling different components of the wastewater. Charging structures can also be used to 'send a message' to customers and encourage measures such as waste minimisation to reduce loads.

Factories that dispose of effluent directly to land generally do not pay disposal charges, but must meet licence conditions for the quality of effluent with respect to components such as mineral content, salt level, BOD or COD, phosphorus, nitrogen, and oil and grease.

Full cost recovery charging has not so far been applied to sewer discharges, but this situation is changing. Many local authorities and water boards, especially those in metropolitan areas, are in the process of formulating charging systems that will progressively increase wastewater discharge fees on a user-pays basis until something approaching full cost recovery is achieved.

1.2.4 Energy and energy supply costs

As with most Australian industries, dairy companies rely on fossil fuels — particularly coal-generated electricity, coal and natural gas — for their energy supply. National greenhouse abatement initiatives such as the Greenhouse Challenge and the Australian Renewable Energy Certificate scheme have been launched in recent years to increase awareness of environmental issues and encourage the more efficient and sustainable use of energy. As yet, only a small number of dairy companies have joined these schemes. Nevertheless, Australian dairy processors appear to be relatively energy-efficient compared with dairy processing companies internationally. A recent survey of Australian dairy processors has shown that energy consumption per unit of production is comparable to, if not better than, energy consumption in European dairies (see Chapter 4, 'Energy'). The dairy manufacturing industry has radically improved its energy efficiency over the last 20 years (in some cases by as much as 50%) through industry-wide upgrading of equipment and the closing of smaller, less efficient factories (Lunde et al. 2003). The industry could further explore the use of renewable energy, and an obvious means is through the use of biogas (from anaerobic digesters) to supplement energy supplies. Cogeneration systems have been investigated but to date have been found not to be financially viable.

The national energy supply market (electricity and gas) has been progressively deregulated over the last decade. Deregulation in the electricity industry began in Victoria in 1994 and has spread to most states, giving dairy companies a choice of retail companies for their supply of electricity. The low cost of energy and the lack of mechanisms to control demand in Australia are seen as among the main factors inhibiting the adoption of more energy-efficiency practices (UNEP 2002). Energy is typically the greatest of all utility costs, despite the low unit cost, so significant savings are possible; it therefore makes economic sense for dairy processors to minimise energy consumption. A medium to large dairy processing site could typically spend $2–3 million on energy costs per year, so a possible 10% reduction in energy costs can be a significant incentive to reduce energy use.

1.2.5 Solid waste management

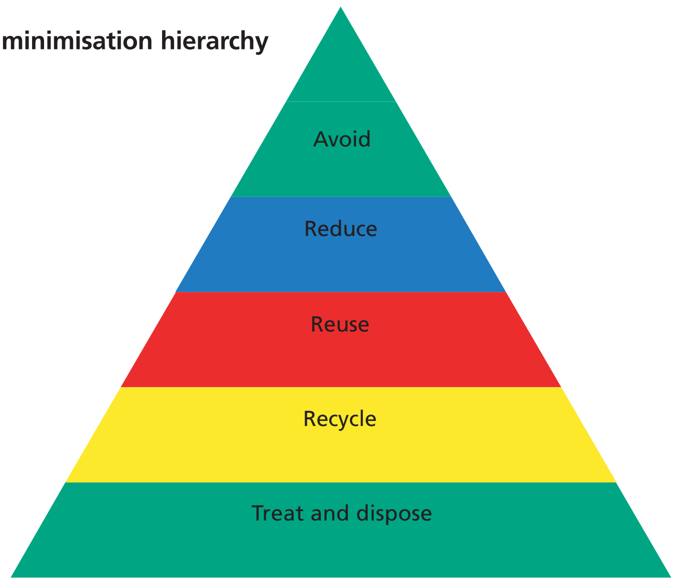
Solid wastes generated by dairy processors include:

- packaging waste such as cardboard, cartons, paper and plastic
- organic waste such as sludge and reject product
- building and maintenance wastes
- office waste.

Dairy processing plants in city areas are generally well serviced by waste disposal and recycling companies, so it is usually more profitable for a company to segregate and recycle wastes than to dispose of waste to landfill. Processing plants in regional areas may experience some difficulties until waste services are developed and expanded. Organic waste is generally disposed of as animal feed, applied to farm land as fertiliser, composted, or digested to produce biogas.

For dairy processors, solid waste disposal costs can be a relatively minor component of total operating costs. It is, however, an area where employees at all levels can contribute and immediately see results, and this can be a good start in encouraging employees to be more environmentally aware and participate in company-wide initiatives. The waste minimisation hierarchy shown below in Figure 1.3 represents a sequential approach to reducing solid waste — with steps to avoid, reduce, reuse, recycle and lastly treat and dispose waste. This is discussed further in Chapter 6, 'Solid waste reduction and value adding'.

Figure 1.3 **The waste minimisation hierarchy**



1.2.6 Packaging

Dairy processors face increasing pressure to develop and use packaging that reduces the consumption of resources, enables reuse or recycling, and minimises landfill disposal. The importance placed on packaging may reflect the strong increase in awareness resulting from the National Packaging Covenant (NPC), launched in 1999. The NPC encourages voluntary actions by signatory companies to reduce packaging waste, and is underpinned by regulation in all states to include non-signatories. In some cases packaging initiatives are driven by the requirements of export customers. Most dairy processing companies are signatories to the NPC.

Eco-efficiency opportunities for reducing packaging waste are included in Chapter 6.

1.3 What is eco-efficiency?

Eco-efficiency is a 'win–win' business strategy that helps companies save money and reduce their environmental impact. Eco-efficiency means increasing process efficiencies and reducing environmental impact, for example by reducing the use of goods and services, enhancing recyclability, and maximising the use of renewable resources. The World Business Council for Sustainable Development has identified a range of ways companies can improve their eco-efficiency (WBCSD 2000). Companies can:

- reduce material intensity of goods and services
- reduce energy intensity of goods and services
- reduce toxic emissions
- enhance material recyclability
- maximise use of renewable resources
- extend product durability
- increase efficiency in the use of goods and services.

Eco-efficiency is often pursued through approaches and 'tools' such as cleaner production, environmental management systems, life-cycle assessment and design for the environment. These tools help companies identify opportunities to improve resource efficiency and reduce environmental impacts.

Eco-efficiency involves systematically evaluating existing practices to identify opportunities for improvement. The ultimate goal is to avoid the use of a resource or eliminate the production of a waste altogether. Failing this, smarter solutions to existing practices are investigated, which aim to reduce, reuse, recover or recycle resources and waste. Eco-efficiency opportunities can usually be categorised into five main groups: housekeeping improvements, product modification, input substitution, process improvements, and onsite recycling.

1.3.1 Reasons for adopting eco-efficiency

There are many reasons for dairy processors to adopt eco-efficiency, including:

- to reduce operating costs and improve profitability
- to reduce energy, water supply and solid waste costs
- to overcome water allocation restrictions
- to reduce wastewater treatment and/or disposal costs
- to reduce the effect of rising wastewater discharge fees in the future
- to comply with tightening air emission standards
- to help in developing waste minimisation plans (e.g. water and waste management plans, National Packaging Covenant or Greenhouse Challenge plans)
- to create an 'environmentally friendly' image and gain competitive edge
- to improve relations with environmental regulators and ensure compliance with regulations
- to add value in the adoption of an environmental management system.

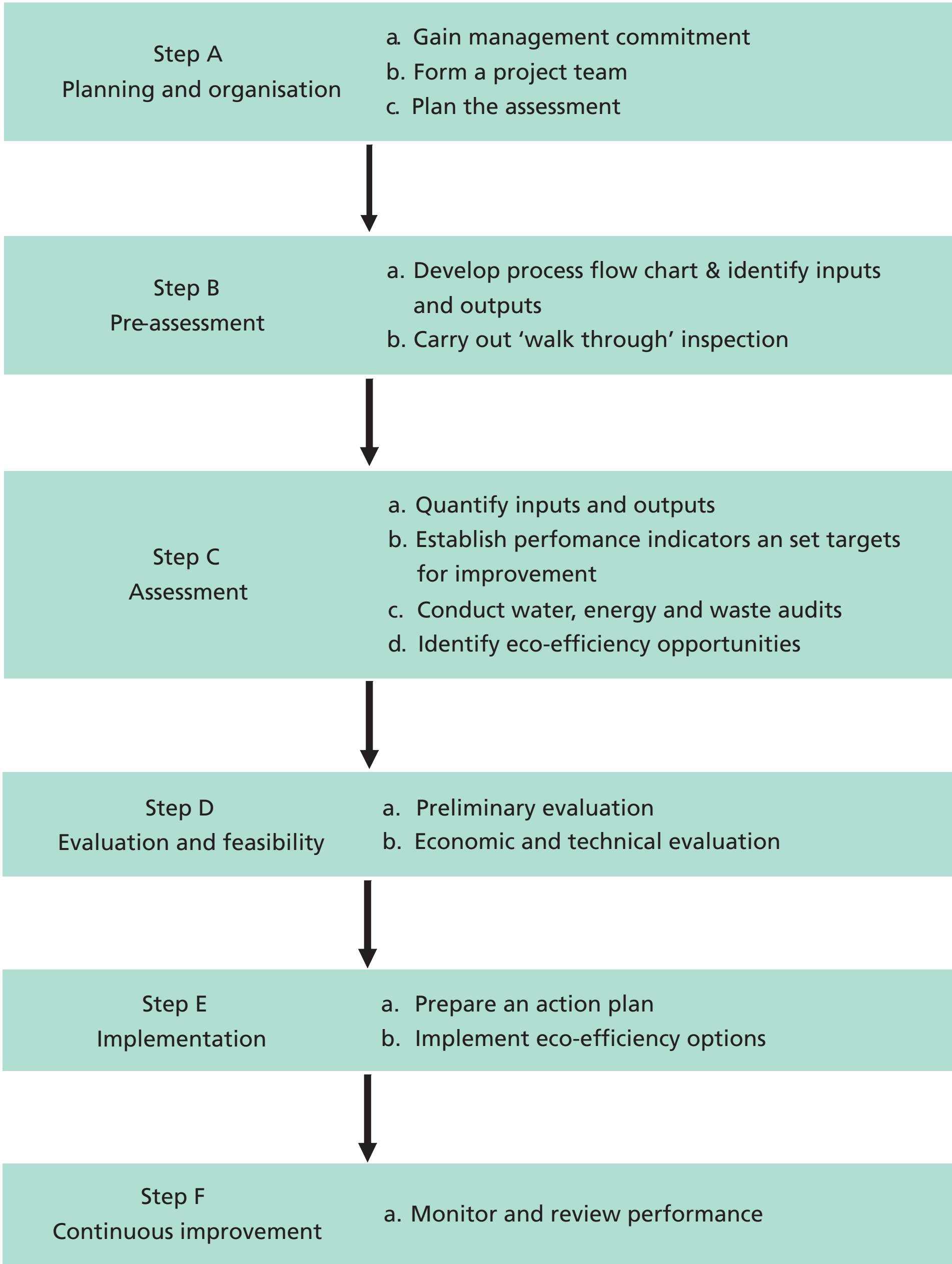
The best starting point for any company that wants to improve its eco-efficiency is to conduct an eco-efficiency assessment. This process is described in the next section.

1.3.2 How to carry out an eco-efficiency assessment

A method for carrying out an eco-efficiency assessment is shown schematically in Figure 1.4. This method has been adapted from the UNEP *Environmental management tools — cleaner production* (UNEPTIE 2003) and outlines six main steps: planning and organisation, pre-assessment, assessment, evaluation and feasibilty, implementation and continuous improvement.

An eco-efficiency self-assessment guide can be found as part of the *Eco-efficiency toolkit for the Queensland food processing industry* (UNEP 2004). There are also dairy-specific publications that describe waste minimisation programs — in particular, *Environmental management tools for the dairy processing industry*, Parts 1 and 2 (Jones et al, 2002).

Figure 1.4 **Method of undertaking an eco-efficiency assessment**



Source: Adapted from UNEP, Environmental Management Tools — Cleaner Production Assessment, 2003

1.4 Eco-efficiency and environmental management

An environmental management system (EMS) is a documented set of procedures that identifies the impacts of a company on the environment and defines how they are managed on a daily basis. It is an ongoing process that demonstrates the company's commitment to ensuring a good standard of environmental management. A company may choose to obtain third-party certification of its EMS to the ISO14001 standard. To date, few Australian dairy processors have an ISO14001-certified EMS; but there are some larger processors, particularly those that compete with export markets, that have gained certification. Some processors have an effective corporate EMS that is not certified.

Like eco-efficiency, environmental management is a process of continual improvement with documented management and action plans. An eco-efficiency assessment identifies those areas of greatest impact and seeks to suggest financially attractive options to control or reduce these impacts. An eco-efficiency assessment should not be undertaken separately from an EMS; instead it should complement it, with the outcomes of the assessment being incorporated into EMS action or audit plans.

1.5 Food safety and HACCP

'Hazard analysis critical control point' (HACCP) is commonly used throughout the dairy processing industry to identify and manage those steps in a processing operation that may pose a risk to food safety and quality. Proactive preventive procedures and controls are established to prevent or manage these risks.

It is essential that any eco-efficiency opportunities that are identified for a dairy company do not adversely affect food safety and quality. Water recycling is an example of an eco-efficiency opportunity where increased risk (or perceived risk) can be a barrier to its adoption. New procedures set in place as a result of an eco-efficiency assessment may need to be included and managed by the HACCP system. Conversely, a HACCP program may identify issues and link in with an eco-efficiency assessment.

1.6 Key performance indicators

Typical eco-efficiency key performance indicators (KPIs) for dairy processors are shown in Table 1.2. The development of benchmarks is an effective way to encourage continuous improvement within or between companies. By comparing one plant's KPIs with those of similar processing plants, it will be possible to identify areas where there is scope for improvement. KPIs for water and energy consumption are outlined in later chapters.

KPIs can be linked to staff incentive schemes and to other management programs. They are a useful, easily understood, spin-off from an eco-efficiency program and can help in prioritising overall efficiency.

Table 1.2 Typical key performance indicators for a dairy processor

Component	KPI
Product yield	kL or tonnes product per kL raw material consumed
Water	kL consumed per kL or tonne product
Water-to-milk ratio	kL water per kL raw milk processed
Water reuse %	kL water reused per kL total water used
Energy	MJ consumed per kL or tonne product
Energy-to-milk ratio	MJ energy per kL raw milk processed
Wastewater	kL generated per kL or tonne product
Solid waste	kg generated per kL or tonne product

1.7 Achieving best practice in dairy processing

Subsequent chapters describe numerous eco-efficiency opportunities that are available to the dairy processing industry. Many of the opportunities described are not new, and could be considered as good operating or engineering practice; and they have been undertaken to some degree by most leading dairy processing companies. Where possible, benchmark figures have been provided for aspects such as water and energy consumption and wastewater volumes and quality. While the question of 'best practice in dairy processing' cannot be directly quantified within the scope of this document, the following points attempt to describe the characteristics of a dairy processing company and operation that is headed towards best practice. Ideally, the adoption of best-practice technologies, procedures and initiatives should be considered during the design and planning stages of a plant. A holistic approach should also be taken in deciding what is the most appropriate technology or plant design. For example, if a factory in a regional area has the option to irrigate, it may not be sensible for it to treat wastewater to potable water standards.

1.7.1 Characteristics of a company that is aiming for best practice

General:

- a multi-use clean-in-place (CIP) system with the use of membranes to recover product, chemicals and water
- integrated process control software that enables trending of key variables and generates customised reports for different purposes; able to be accessed by management from office workstations; and uses programs that interface with accounting, inventory, maintenance and quality systems
- membrane plants for the recovery of condensate, cleaning chemicals and, in some circumstances, whey proteins.

Product yield:

- inline monitoring of key contaminant levels — COD, EC, pH, turbidity, protein, fat
- effectively designed pigging systems for key product lines
- CIP-able bag houses for spray dryers.

Water usage:

- a detailed water balance or model that identifies the volume of water used in each area
- water meters installed at strategic locations through the plant, and a system for regularly monitoring and reporting water consumption
- inline probes to detect product–water interfaces

- segregation of wastewater streams, with appropriate-quality streams reused rather than all streams being sent to the waste treatment process or to effluent; diversion of wastewater streams to different stages of the treatment process as required, using online monitoring of chemical oxygen demand (COD) or other parameter
- in powder plants, a condensate recovery system for 'cow water' that reuses 90–100% of available condensate
- a knowledge of the typical quantity and quality of wastewater streams at all times during processing using online and traditional monitoring techniques
- recirculation or reuse of pump sealing water
- zero discharge of wastewater to sewer for dairy processors in regional areas that have the opportunity to use water for irrigation.

Energy usage:

- a detailed energy balance or model that identifies what quantity of energy is used in each area
- a system for the regular monitoring and reporting of energy consumption
- in powder plants, mechanical vapour recompression evaporators and multi-stage dryers
- high-efficiency boilers with recuperators and economisers for recovery of heat to pre-heat flue gas and boiler feed water
- biogas recovery, with biogas used to supplement energy consumption
- cogeneration plants that export excess electricity to the grid
- efficient demand-management systems, including load shedding, to reduce peak demand
- efficient refrigeration systems that utilise state-of-the-art control systems, variable speed drive (VSD) compressors, heat recovery and ice bank storage where applicable
- high-efficiency motors of at least 90% efficiency
- efficient lighting systems that take advantage of natural light and automatically switch off or dim according to lighting needs
- pinch analysis of dairy factories to identify possible areas for improvement in heating and cooling duties.

Chemicals:

- the use of enzyme-based and chemicals with reduced rates of phosphate and nitrogen
- the holistic use of chemicals with consideration of the impact of wastewater disposal, particularly in regard to irrigation and salinity issues
- clean-in-place systems incorporating chemical recovery.

Future technologies:

- the use of alternative renewable fuels such as solar and wind energy
- the possible use of ozone for the treatment of wastewater streams
- active noise control of spray dryers to control noise pollution.

1.8 Summary

In past years, the dairy processing industry has undertaken various resource management and waste minimisation programs to increase operating efficiencies. These programs have been undertaken on a corporate basis or for individual sites driven by a few motivated managers. Many of the 70 dairy processing plants across Australia are well over 50 years old, with processing operations that have grown in size, with a combination of old and new equipment and technologies, and with workforces of various levels of experience. For these plants, there are numerous eco-efficiency opportunities that can be taken up. These range from simply improving housekeeping through to investing capital to upgrade or replace existing equipment. The chapters that follow describe some of the challenges and opportunities that are available to the industry.

2 Making eco-efficiency happen in your organisation

'Doing more with less' (i.e. eco-efficiency) makes good business sense. No employee or manager would ever successfully argue that they should be doing 'less with more' (i.e. less output from more resources), or that they should be actively working to create more waste! Waste costs money, is detrimental to the environment and is generally bad for business.

The dairy industry has achieved substantial improvements in efficiency over recent years. Yet careful examination still reveals elements of waste — wasted money, wasted resources (such as energy and water) and wasted product.

Although eco-efficiency makes good business sense, there are some barriers that limit its uptake. This chapter discusses those barriers and shows how they can be overcome, through a case study that draws on the experience of Murray Goulburn and its involvement in the Commonwealth Government's Energy Efficiency Best Practice Program — a program that was designed to address internal organisational barriers to change. Although Murray Goulburn's experience was focused specifically on energy, the approaches that were developed can be used to implement each of the eco-efficiency areas highlighted in this manual.

2.1 Barriers to eco-efficiency

'The main barrier to the implementation of most projects identified by others is that of ownership of the problem. Support from senior management is also imperative to ensure success of the project.'

— Ted Isaacs, Murray Goulburn Cooperative, Leongatha

In researching this manual we asked staff what they saw as the key barriers to the implementation of eco-efficiency. Their responses included:

- lack of capital
- lack of time and human resources
- operator awareness and training — particularly when there are many casual staff
- lack of communication
- unsystematic approaches to eco-efficiency initiatives that prevent projects from being implemented, being completed or being reversed at a later time if necessary
- getting senior management and board approval for projects.

There are no simple answers for these and the many other potential barriers that exist within organisations; however, each of them must be overcome if the eco-efficiency project is to be successful.

Here are some of the key points to consider:

- **Develop management awareness, commitment and support for projects.** This is important from the beginning, and throughout projects, to ensure there is time for holding team meetings, performing process trials and implementing solutions.
- **Establish a cross-functional working group.** This should include a range of staff, including cleaners, operators, engineers and managers.
- **Hold regular team meetings**, to keep focus and to ensure continued progress.
- **Determine baseline information on resource consumption and waste generation.** When you achieve savings it is important that you can clearly communicate exactly what those savings are. There must be a clear picture of the situation before the savings were made.
- **Ensure that you develop good business cases** for the eco-efficiency projects that you are trying finance. This should include clearly communicating additional benefits such as positive publicity, improved involvement with the local community, safety, and operational benefits. In some instances you might also explore whether there are alternative approaches that have not been considered.

More detailed information on carrying out an eco-efficiency assessment is available in the UNEP *Eco-efficiency toolkit for the Queensland food processing industry*, which includes a self-assessment guide (UNEP 2004).

2.2 Avenues for supporting the implementation of eco-efficiency

One of the most effective means of implementing eco-efficiency is through site-based cross-functional teams. This is discussed further in the next section, in the context of the Murray Goulburn experience.

Here are some other ways in which dairy processing companies have supported and implemented eco-efficiency projects:

- **The appointment of designated managers and supervisors.** Many dairy processors have appointed managers to work specifically on projects within the company that improve product yield and reduce waste (e.g. Murray Goulburn's Process Improvement Manager or Energy Manager).

- **Partnerships with suppliers and customers to improve production efficiencies and reduce the use of resources.** Some dairy processing companies have formed partnerships with chemical suppliers to optimise clean-in-place systems and reduce chemical use. Partnerships with packaging suppliers have reduced the environmental impacts of packaging, often driven by the National Packaging Covenant. Similarly, partnerships with customers have improved efficiency and reduced waste by solving supply chain management problems.

- **Including eco-efficiency aspects in tender and proposal documents.** If it is specified in tender documents that resource consumption must be considered during the design stages of projects, it can go a long way towards improving process yields and reducing environmental impacts. Examples might include the installation of metering devices during commissioning stages, the selection of less resource-intensive equipment, or improved process layout design.
- **Environmental management systems.** If the company has established an environmental management system (EMS), this can also provide an opportunity to integrate eco-efficiency into the way things are done in the organisation. An EMS provides a management structure that allows for setting targets, clarifying responsibilities, training, and raising awareness to achieve environmental improvement. A focus within the EMS on continuous improvement will allow it to be used to go beyond mere compliance and achieve many of the environmental improvement opportunities discussed in this manual. An EMS can also provide legitimacy within an organisation for a focus on eco-efficiency — particularly where the organisation also has an environmental policy that commits it to a high level of environmental performance.
- **Grants and partnerships with government bodies.** There are opportunities to obtain national and state government grants, which can provide encouragement and financial support for improving efficiency through the use of more efficient technology and research.
- **Support from industry associations.** Organisations such as Dairy Australia, the International Dairy Federation (IDF) and the Dairy Processing Engineering Centre (DPEC) provide valuable resources in the form of publications, training and advice that can be used to support an eco-efficiency program.

Making eco-efficiency happen within your organisation requires support from a range of areas; it is not the sole responsibility of one particular manager or group. It depends on support and encouragement from all levels of your organisation, as well as external stakeholders such as suppliers, customers, industry associations and government.

A good way of getting started is through a site-based team, as described in the next section.

2.3 The Murray Goulburn experience

2.3.1 Building skills, knowledge and support through site-based teams

Site-based teams provide an excellent mechanism for breaking down the many barriers to cross-functional communication that limit the uptake of eco-efficiency improvements. They also build a sense of ownership and awareness of environmental issues at the site level. This is demonstrated by the work of Murray Goulburn's energy team at the company's Rochester site. The Rochester energy team demonstrated that better energy management saves money, reduces waste and helps build links with the local community.

To get a team together, a flyer was put on the Rochester noticeboard, inviting staff involvement. The only requirement was that the team should include a range of staff from different functional areas — operators, maintenance staff, boiler technicians, supervisors and an engineer. The cross-functional make-up of the group was the key to its success. This was demonstrated at the team's first meeting; when it was exploring potential energy-efficiency projects, the members came up with over 50 different opportunities.

Key learning
When you can tap into a cross-section of skills and knowledge from different functional areas the possibilities for improvement are much greater. Why? Because everyone gets the opportunity to share their own perspective. This opens up the possibility of identifying and implementing projects that might otherwise be left alone because of the difficulty of working across functional areas. When people identify problems themselves and are given the opportunity to do something about them, they are also more committed to making them happen.

In order to determine which projects they should focus on, the team carried out a number of activities.

- It reviewed existing onsite energy data and monitoring equipment. The members knew they first had to understand how energy was used and wasted, in order to understand the potential for savings.
- It identified the people who could help or hinder them in implementing their projects (key stakeholders). The members invited their branch manager, a senior engineer and the environmental manager to a meeting, in which they asked questions about the kind of support they could expect for their projects. This group of people also provided valuable input to the technical and organisational aspects of the projects.
- It developed a business plan that mapped out the resources required, the likely financial savings and other benefits that would be achieved, and the people and tasks that would 'make the projects happen'. The business plan was presented to the managing director to get his input, and ultimately his support, for the team's activities.

Key learning
In developing the business plan, the team had learnt a lot about their site, its production process, and the opportunities and challenges of implementing change. Their discussions with key managers across the organisation helped develop support from outside the team, and helped them to be very clear about what they needed to do to successfully implement eco-efficiency.

The first project the team implemented was achieved through improved communication between the boiler house and process operators. It did not require any capital outlay but led to annual savings of $180 000 and 1536 tonnes of CO_2 (which contributes to global warming). The following different perspectives and the team approach contributed in various ways to identifying and implementing this project:

Process operator perspective

Steam is a critical production input. Any time delay in the provision of steam has a direct impact on production. Steam must be available and ready to go at all times.

Boiler operator perspective

Process operators require steam. To ensure that steam is readily available at all times two boilers need to be warmed up and ready to go. Even though it is inefficient to have them idling at 30%, steam must available quickly.

Eco-efficiency perspective

Operating boilers at 30% load is inefficient and expensive, and generates greenhouse gas emissions unnecessarily.

Benefits of a team approach

Because process operators and boiler operators were both part of a team that had a shared goal and commitment to saving energy, it was obvious to both groups that improved communication would allow the boilers to be run more efficiently, while at the same time ensuring that the process operators were not left without steam when they started up a production process. Because they came up with the idea of the project themselves, there was a lot more commitment to implementation and ensuring that the improved communication processes actually worked.

2.3.2 Raising management awareness of the benefits of eco-efficiency

It is critical that both company and site management understand and support eco-efficiency.

Following the work of the Rochester team, Murray Goulburn held a special meeting for all senior and site managers to explore the risks and opportunities that energy management held for the business overall. The workshop included:

- an update on the scientific and political developments of global warming and climate change, and its likely impact on business
- a presentation from representatives of the Rochester energy team, discussing how they achieved $180 000 of energy savings and were on track to achieve more
- an interactive session to identify strategies and actions that would support a more focused approach to energy management across all Murray Goulburn sites.

After the workshop it was agreed that representatives from each of Murray Goulburn's seven sites would attend a two-day workshop to discuss and develop action plans for establishing energy management teams on each site.

Soon after, a new position of Energy Manager was created, and filled by a senior engineer, to ensure that there was a strong link between corporate and site-based energy initiatives.

2.4 Summary

There are some barriers to the implementation of eco-efficiency. The best approach to overcoming these barriers will depend on the nature and priority of each organisation, its culture, and working approaches adopted at each site. The keys to successful implementation of eco-efficiency include:

- developing management awareness, commitment and support
- establishing a site-based cross-functional working group
- involving and obtaining the support of external stakeholders such as suppliers, customers, industry associations and perhaps government
- reporting back to, and discussing eco-efficiency initiatives at, regular team meetings
- establishing baseline information on resource consumption and waste generation
- ensuring that good business cases are developed for eco-efficiency projects.

Environmental management systems can provide an important framework for eco-efficiency, as they supply a structure for setting targets, clarifying responsibilities, training, and raising awareness to achieve environmental improvement.

The work done at Murray Goulburn demonstrates one successful approach to implementing energy efficiency. Consider your own unique circumstances. You can use the ideas presented in this chapter to develop your own implementation plan for eco-efficiency.

3 Water

3.1 Overview of water use

This chapter discusses water use in dairy processing plants. Eco-efficiency opportunities are discussed under the broad categories of reducing demand in processing, cleaning, utilities and amenities, followed by opportunities for recycling and reuse, and finally a brief discussion on wastewater treatment.

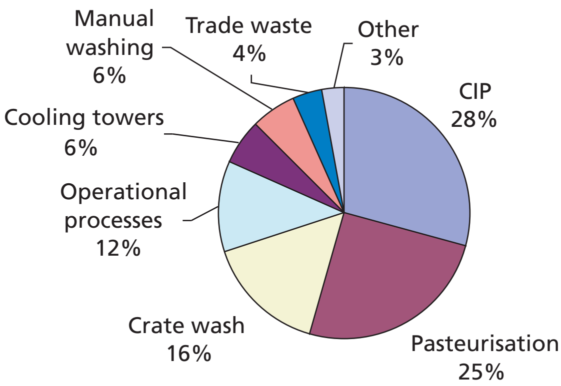
3.1.1 Water use in dairy factories

The total amount of water used by the dairy industry is approximately 3000 GL/yr, which is equivalent to 13% of Australia's total freshwater resources (Lunde et al. 2003). Of this, 99% is attributed to on-farm use, indicating that the main opportunities for reducing water consumption in the dairy industry are to be found in improving the efficiency of milk production at the farm. Nevertheless, there are still gains to be made by dairy processors in minimising water consumption within factories. The source and quality of water is an issue for some processors, depending on their location. Generally they use town water, but other sources include river water, irrigation channel water, bore water and reclaimed condensate. Water shortages in both regional and urban areas are leading processors to review the effectiveness of their onsite water use, both of their own accord and in response to pressure from local authorities.

Dairy factories also produce high volumes of moderate to high-strength liquid wastes (i.e. with high BOD and COD levels). Water and wastewater management can incur costs for dairy processors, and these vary according to the location of the processing plant, the source of water and the requirements for effluent treatment. The location and type of processing plant and the options for effluent discharge play major roles in determining the level of water reuse and recycling, as well as the degree and method of effluent treatment. Factories in regional areas often have the option of using effluent water for irrigation and may therefore not realise the major financial or environmental benefit to be gained from treating and reusing effluent within the factory. Generally, dairy processors who can reduce water use over the broader system (including upstream and downstream of processing plants), without compromising quality or hygiene standards, will benefit from reduced water supply and effluent charges as well as improving the sustainability of the dairy processing industry. HACCP plans play an important role in ensuring that hygiene standards, which are critical to producing a quality product, are met.

Water is used in dairy factories for processing and cleaning, for the operation of utilities such as cooling water and steam production, and for ancillary purposes such as amenities and gardens. Figure 3.1 shows an example of water use in a dairy processing factory that produces market milk.

Figure 3.1 **Breakdown of water use of a market milk processor**



Many dairy processors track the overall consumption of water by monitoring the ratio of water to raw milk intake. Water consumption in Europe has been reported to range from 0.2 to 11 L/L milk (Daufin et al. 2001) with effluent volumes per raw milk intake in the same range. Ratios for Australian processors producing any combination of white milk, cheese, powders or yoghurts range from 0.07 to 2.90 L/L milk, with the average being around 1.5 L/L milk (UNEP 2004).

Table 3.1 shows the range of ratios for factories producing white or flavoured milks, cheese and whey products, and powdered products. For factories that produce powdered products, there is the potential for the majority of water (>95%) to be supplied from treated condensate, also known as 'cow water'. However, the potential for recovering condensate depends on the scale of a particular powder plant and the ratio of supply to demand on a given day. For example, if the production rate is reduced during the off-peak season there will consequently be less condensate available for recovery. The range in water to milk intake ratios indicates there is potential for some dairy processing plants to decrease water consumption significantly.

Table 3.1 **Water to milk intake ratios (L/L)**

	Min.	Max.	Average	No. of plants providing data
White and flavoured only[a]	1.05	2.21	1.44	7
Cheese and whey products	0.64	2.90	1.64	3
Powdered products	0.07	2.70	1.52	10

[a] Excludes UHT milk.

3.1.2 The true cost of water

Water is often viewed as a cheap resource — which is not surprising, considering that Australians pay more for 1 L of milk than for 1000 L of water. Increasingly, however, there is a shift away from this attitude, with an increase in community awareness of the value of water and a trend for local councils and water authorities to move towards full cost recovery for the supply of fresh water and treatment of wastewater. Table 3.2 shows the cost of town water supply for a number of regions where there are dairy processing plants. These costs range from 50c/kL for water supplied from the Goulburn Murray Water Board to $1.28/kL for Ipswich City Council. The relatively low cost of water supply in some regions can be a barrier to implementing water conservation projects when payback periods are considered.

Table 3.2 **Water supply costs in dairy processing regions**

Council	State	City/town	Water supply cost ($/kL)
Sydney Water	NSW	Penrith	0.94
Hunter Water Corporation	NSW	Hexham	0.85
South Australia Water	SA	Mount Gambier	1.00
Gippsland Water	Vic.	Maffra	0.54
Goulburn Valley Water	Vic.	Tatura	0.47
South West Water Authority	Vic.	Warrnambool	0.58
Eacham Shire Council	Qld	Malanda	0.20[a]
Brisbane Water	Qld	Brisbane	1.13
Ipswich City Council	Qld	Booval	1.28
Devonport City Council	Tas.	Devonport	0.70

[a] Water supply from river, not town water

The components making up the total true cost of water for dairy processors are:

- purchase price
- treatment of incoming water
- heating or cooling costs
- treatment of wastewater
- treatment of evaporator condensate for reuse
- disposal of wastewater
- pumping costs
- maintenance costs (e.g. pumps and replacement of corroded pipework and equipment)
- capital depreciation costs.

Table 3.3 provides an example of the full cost of ambient and hot water. It indicates that, while the purchase cost of the water was $0.54/kL, the true cost was actually $2.33/kL for water at ambient temperature and $5.13/kL for hot water. The cost of wastewater discharge in different regions is discussed more fully in Chapter 5, ‘Yield optimisation and product recovery’.

Table 3.3 **Example of the true cost of ambient and hot water ($/kL)**

Purchase	$0.54
Wastewater treatment[a]	$0.75
Wastewater pumping	$0.05
Wastewater discharge (volume charge)	$1.09
True cost of ambient water	**$2.43**
Heating to 80°C[b]	$2.80
True cost of hot water	**$5.23**

[a] Based on assumption of treatment costs for an anaerobic digester

[b] Cost for heating to 80°C using steam produced by a gas boiler

3.1.3 Measuring water consumption

To understand how to manage water effectively it is essential to understand how much water enters and leaves the factory and where it is being used. Understanding water flows will help to highlight where the greatest opportunities for cost savings are. This can be achieved by developing a detailed water model for the site using dedicated software or a simple spreadsheet. The water model should balance the total water entering the factory over a period with the volume of water used in processing and finally disposed as effluent.

There are a number of methods that can help to quantify water use and develop a water model:

- Install flow meters in strategic areas to directly measure water use.
- Use a bucket and stopwatch to estimate flow from pipes or hoses.
- Use manufacturers' data to estimate water use for some equipment and compare with actual water use.
- Use known operational data to estimate water use (e.g. a 10 kL tank fills every wash cycle).

When identifying areas of water use, manual operations as well as equipment should be monitored carefully (e.g. the volume of water used for washing down floors and equipment must be taken into account). It is also a good opportunity to observe staff behaviour (e.g. taps left running or hoses left unattended).

Flow meters

Flow meters on equipment with high water consumption, incoming water inlets and wastewater discharge outlets will allow regular recording and monitoring of water use. Flow meters are also useful for measuring 'standing still' water consumption during periods when equipment is not operating, to detect any leaks. When installing a meter ensure that the meter is tailored to meet the application (e.g. measurement of product wastewater or clean-in-place volumes).The cost of installing or hiring flow meters will vary according to the meter size and functionality. Factors to consider include pipe size, flow rate (L/min), fluid quality (e.g. incoming potable water, wastewater, process water), type of power supply (mains, battery or solar), accuracy required and piping installation costs. It is also particularly important to consider ongoing maintenance and recalibration costs. Often a higher capital cost with lower maintenance costs can result in lower life-cycle costs.

'Every Drop Counts'
Improved water management: Dairy Farmers, Lidcombe
Dairy Farmers in Lidcombe joined the Sydney Water 'Every Drop Counts' water minimisation business partnership. The company installed 27 water meters across the site and worked on developing an accurate understanding of water flow to each area. A water assessment was undertaken over a number of months, identifying savings by preventing cooling tower overflow; recirculating homogeniser water, crate wash water and DAF water; reducing water for cleaning; repairing leaks; and reviewing truck washing practices. The assessment identified total savings in water costs of $300 000/yr with an initial cost of $150 000 and ongoing costs of $26 000/yr.

Improved water management: National Foods, Penrith
National Foods Ltd in Penrith also joined the Every Drop Counts partnership. Additional water meters were installed and these were fitted with pulse unit and data loggers, allowing the daily water usage to be recorded and downloaded to a central system. Water usage for the site was mapped and potential improvements identified, including redesign of the crate wash system, improved maintenance and monitoring, more efficient pasteuriser and bottle washing, collection of rainwater, and reductions in water use for pump seals. Water use for the site was reduced by 22% as a result of the program, reducing water use by 110 kL/day and saving $104 000/yr, with implementation costs of $86 000.

3.1.4 Increasing staff awareness and involvement

The involvement and support of staff is essential in reducing water use. Ideas for involving staff and encouraging water conservation include:

- forming a water management team
- using posters and stickers to promote awareness of water efficiency
- implementing staff suggestion schemes to encourage ideas for reducing water use
- promoting progress by displaying graphs and performance measures
- regularly discussing water efficiency at staff meetings
- considering a staff incentive scheme and including targets in staff job goals.

Involvement of staff, the establishment of clear goals and targets, and prompt implementation of initiatives can help develop a strong water conservation culture.

'It is important to set targets and allow operators active involvement in developing improvements.' *— Adam Carty, Murray Goulburn Cooperative, Kiewa, Victoria, commenting on minimising site water use.*

'One of the main issues is operator awareness and training. With such a large number of casual and seasonal staff, training and awareness has to be maintained so that eco-efficient projects are continually generated from the floor and maintained.' *— Peter McDonald, Murray Goulburn Cooperative Co., Koroit, Victoria.*

Increasing staff awareness: Murray Goulburn
Murray Goulburn Cooperative sites introduced environmental awareness training into their staff inductions. The inductions have a 'two-tiered' approach where staff have a training session which is followed up a few months later to reinforce the earlier message. This has ensured that all staff are aware of the initiatives to minimise water use and are encouraged to generate projects.

Measurement of resources: Peters and Brownes, Balcatta
Peters and Brownes in Balcatta have built a site database of utility usage/production data, which provides 'year to date' usage of electricity, gas and water consumption. Water, electricity and gas usage is metered within strategic locations of the factory allowing resource use to be analysed by area, and the information is available to managers online.

3.2 Reducing demand for water: processing

3.2.1 Optimising rate of water flow

Sometimes equipment operates at water pressures or flow rates that are variable and set higher than necessary (e.g. pump sealing water, homogeniser cooling water, belt filter sprays or carton machine cooling water). By conducting trials to determine the optimum flow for the equipment or comparing the flow rate with manufacturers' specifications, consumption could be reduced. To maintain a constant and optimum flow rate, consider installing a flow regulator.

Optimising homogeniser cooling water: Dairy Farmers, Mount Gambier
Dairy Farmers in Mount Gambier reduced water costs by $10 800/yr, by reducing the flow of cooling water to the homogeniser to the optimum rate. The cost was only $250 for the installation of a flow regulation valve.

3.2.2 Efficient process control

Installing automatic monitoring and control devices in key sites can lower production costs. A wide variety of devices are used in dairy factories to detect operating parameters such as level, flow, temperature, pH, conductivity and turbidity. These are particularly important for detecting the quality of processing and waste streams to enable the maximum recovery of product, chemical and water. Refer to the DRDC publication *Milk processing effluent stream characterisation and utilisation* (DRDC 1999) for information on instrumentation and methods for monitoring and controlling waste streams.

Water sprays are often used in dairy factories for washing, or to lubricate equipment. Water is wasted if sprays are left operating unnecessarily during breaks in production; this can be prevented by linking sprays to conveyor or equipment motors, using automatic cut-off valves. Timers may also be useful for shutting off sprays or taps when not in use.

3.2.3 Leaks

Leaking equipment such as pumps, valves and hoses should be promptly repaired, not only to save water, but also to set a good example to staff on the importance of water conservation and good housekeeping. Equipment that is left leaking over lengthy periods can waste significant amounts of water or product. Table 3.4 gives some examples of the cost of water loss from leaking equipment. For equipment items that use large volumes of water, the cost of installing and regularly monitoring meters to detect leaks can be well justified. If possible, it is a good idea to take supply water meter readings during non-production hours to highlight any unusual water consumption or even leaking pipes. A system for reporting and promptly repairing leaks should also be established.

Taking supply water meter readings during non-production hours can highlight any unusual water consumption or leaking pipes.

Table 3.4 Cost of water loss from leaking equipment

Equipment	Hourly loss (L)	Annual loss (kL)	Water cost ($/yr)
Union/flange (1 drop/s)	0.5	5	12
Valve (0.1 L/min)	6	53	128
Pump shaft seal (0–4 L/min)	0-240	0–2100	0-5103
Ball valve (7–14 L/min)	420–840	3680–7360	8 942–17 885
1-inch hose (30–66 L/min)	1800–4000	15 770–34 690	38 321–84 297

Assumptions: purchase cost of water = $0.54/kL; total cost of water = $2.43/kL (see section 3.1.2)
Table derived from hourly and annual water loss figures in Envirowise 2003.

3.3 Reducing demand for water: cleaning

A large proportion of the water consumed by dairy processors (50–90%) is used for cleaning equipment and surrounding areas of the plant (Envirowise 1999a). There are numerous opportunities for reducing water use for cleaning, as outlined in the following section. The Dairy Process Engineering Centre (DPEC) publication *Performance evaluation guide manual — cleaning systems 98/99* (DPEC 1989/99) is a practical guide for evaluating the effectiveness of a cleaning system and benchmarking current performance. It also includes a worked example and ready-to-use work sheets. Another useful resource is *CIP: cleaning in place* (Romney 1990).

3.3.1 Design and selection of processing equipment and process layout

Criteria for the selection of equipment and the design of process layout should include ease of cleaning. This will minimise the risk of product contamination and spoilage, as well as reducing water and chemical use and the time taken for cleaning. Pipe runs should be designed with minimal bends and dead legs where contamination can occur. Additional valves may be installed in existing pipes to prevent them from acting as dead legs; and pipes should run on a decline to allow for efficient drainage. Floor surfaces should be designed to promote run-off, to reduce the need for hosing of product residues.

3.3.2 Dry cleaning

Dry cleaning not only reduces water and chemical use but also reduces the volume of wastewater and improves its quality. As much product as possible should therefore be removed from plant and equipment by dry cleaning techniques before being washed down. In some cases usable product can be recovered also. Cleaning aids such as squeegees and brushes are used in dairy factories, and care must be taken to ensure they do not become a source of contamination. For this reason, some factories use distinguishing features such as colour coding so that cleaning aids are used only in designated areas.

Scrubber dryers and vacuum cleaners can wet or dry clean and remove gross soiling before washing with water to reduce the amount of wastewater that would normally be discharged to the drain. They are fast and efficient, reduce chemical use, and are suitable for relatively dry areas such as cold stores or warehouses where hosing is unsuitable and there may be large expanses of floor space.

3.3.3 Trigger-operated controls for hoses

Hoses left on unnecessarily waste water. For example, a hose left unattended for a total of one hour each day can lose between 470 kL and 940 kL annually, equating to \$1000–\$2000 every year for each hose.[1] The cost of a trigger gun can range between \$20 and \$200 for a heavy-duty unit.

[1] Assumptions: \$2.43/kL for true water cost; 260 days each year; hose flow rate of 0.5–1.0 L/s

A hose left unattended for a total of an hour a day can waste as much as $1000–$2000/yr.

Reuse of pasteuriser water, and hose water-saving devices: Parmalat, Nambour
Parmalat in Nambour previously sent pasteuriser cleaning water to wastewater. Storage tanks and pipework have now been installed to allow the water to be reused for washing empty milk crates. In addition, water-saving devices have been attached to hoses used for cleaning. This has saved the company 1 kL of water per shift or 260 kL/yr.

3.3.4 High-pressure cleaning systems

High-pressure water cleaners are typically used to clean floors and some equipment. They can use up to 60% less water than hoses attached to the water main (Envirowise 1998). Mobile high-pressure cleaners can have flow rates ranging from 4 L/min to 20 L/min and pressures of up to 500 kPa. In a dairy processing plant, high-pressure cleaners may be useful for cleaning areas such as around wastewater treatment plants, cooling towers and some floor areas. They may not be useful around some processing areas due to the possibility of creating aerosols.

3.3.5 Clean-in-place systems

Clean-in-place (CIP) systems are commonly used in dairy processing plants for cleaning tanks, piping, filling machines, pasteurisers, homogenisers and other items of equipment. A well-designed system minimises the use of water and chemicals; it also saves the labour required for manual cleaning. The most eco-efficient CIP systems are multi-use, where rinse water and chemicals are recovered and stored for reuse. Chemicals and water used in some CIP systems are recovered using membrane filtration.

In most systems, interfaces between product, chemical and rinse water are detected using conductivity or turbidity meters; other systems use timers. The effectiveness of conductivity and turbidity meters compared with timers is a topic of debate. Timers may not provide a consistent or repeatable quality of clean due to factors such as varying flow rates, pressures, and pump or valve wear; meters can fail, causing operating delays or unnecessary loss of product, chemicals or water to the waste stream. In addition, instrumentation can 'drift' out of calibration over time; and timers can be adjusted to compensate for operational factors. Regardless of which system is used, it is important to regularly verify chemical strengths and temperatures as well as carrying out visual checks, if possible, to ensure equipment is clean. These checks may be done every day, shift or clean. It is also important to carry out longer-term monitoring — for example, every 12 months to validate CIP system settings and review timers, chemical concentrations, temperatures and general cleaning effectiveness.

For further reading on CIP systems see AS 1162:2000, Cleaning and Sanitizing Dairy Factory Equipment; and AS/NZS 2541:1998, Guide to the Cleaning-in-Place of Dairy Factory Equipment. CIP systems are also discussed further in Chapter 7, 'Chemical use', which includes information on types of chemicals used and typical concentrations.

'When optimising CIP systems, take one step at a time and don't try to make too many changes at once.' — *Alison Dilger, National Foods, Morwell*

Reuse of water by CIP system: Pauls Ltd, Stuart Park[1]
Pauls in Stuart Park previously utilised a single-use CIP system where all water and chemicals were used once and then discharged to waste. The system has been replaced with a multi-use CIP system that recycles final rinse water for the pre-rinse cycle. All chemicals used in the system are also returned and circulated through holding vats, where temperature and conductivity are monitored and automatically adjusted to meet specifications. The new CIP system saves Pauls $40 000/yr, with a payback period of only one year.

Fine-tuning of CIP system: National Foods Ltd, Penrith
National Foods in Penrith, as part of a regular audit of CIP systems, reviewed the flush time of their pasteuriser. They were able to reduce the flush time by 12 min/day, which resulted in water savings of 15 ML/yr.

Validation of CIP System: National Foods Ltd, Morwell
During the early stages of commissioning the National Foods Morwell plant, there were problems with product quality and cleaning times, and concentrations of cleaning agents were increased. As the quality issues were resolved it was found that many concentrations and times were above recommended levels. These were able to be reduced without compromising product quality, although there were challenges in convincing others that this was the case. The costs of implementing the changes were just the time and tests required to make the changes. Savings were in the order of $100 000 /yr.

Upgrade of major CIP set: Murray Goulburn Cooperative, Koroit
Murray Goulburn's Koroit factory upgraded its CIP system and installed additional tanks for the storage of used and clean caustic. Previously, not all the evaporators had access to the CIP system, so water and chemicals were disposed after a single use. The initiative ensured increased chemical recovery, better quality of chemical supply, reduced effluent volume and less plant downtime; it led to savings of $80 000/yr. The cost of implementation was $90 000.

Optimisation of CIP system: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville incorporated its milk pasteuriser CIP system into the cheese room CIP system, allowing water and chemicals to be reused rather than being sent to drain after a single use. The project outlay was $50 00, with savings of $73 000/yr in chemicals and 16 kL/day of hot water.

[1] Environment Australia 2001

CIP rinse recovery: Bonlac Foods Ltd, Spreyton
At Bonlac Foods in Spreyton large volumes of water are required for final rinsing after CIP of the separators and evaporator. After the chemical concentration has dropped to an acceptable level this water is diverted from the wastewater system to an irrigation dam. Excessive chemical contamination of irrigation water is avoided by the use of conductivity probes.

Burst rinsing

Burst rinsing is becoming more commonly used for the pre-cleaning of tanks and tankers to maximise product recovery before CIP. Depending on the characteristics of the product being cleaned (e.g. its viscosity), a series of bursts rather than a continuous rinse can minimise water use. One disadvantage is that it can add time to a cleaning cycle.

Burst rinsing of tankers: Murray Goulburn, Leongatha
Murray Goulburn in Leongatha routinely rinsed its milk tankers before CIP, flushing out the milk solids and losing them to effluent. Burst rinsing, which has now been introduced, displaces milk solids from the tanker and associated lines without excessive dilution. The milk solids are recovered for processing.

Burst rinsing: Peters and Brownes, Balcatta
Peters and Brownes in Balcatta introduced burst rinsing into the ice-cream CIP after an audit by the factory's chemical suppliers. The initiative required some small program changes to the CIP automation system but resulted in water savings of 15 ML/yr or $20 000. The plant found burst rinsing could not be used for all operations; for example, it added too much time to the cheese processing cleaning cycle where time was critical. Also, burst rinsing was not continued in areas of the beverage plant because there were no savings. The plant is continuing trials in other areas.

Spray balls and nozzles

Spray balls and nozzles are an integral part of a CIP system. Spray nozzles for tank cleaning usually come in three main types:

- fluid-driven tank wash nozzles which are rotated by the reactionary force of the fluid leaving the nozzle
- motor-driven tank washers, controlled by air or electric motors which rotate the spray head for high-impact cleaning
- stationary tank wash nozzles or spray balls which use a cluster of nozzles in a fixed position.

Spray balls and nozzles should be selected to suit the application, particularly with regard to the temperature and corrosive nature of the cleaning fluids. Spray nozzles should be regularly monitored and maintained and their efficiency reviewed as part of a cleaning validation program.

Water-efficient spray nozzles: milk and beverage processor, USA
Schroeder Milk Co. in Minnesota now saves around 20 000 L daily after improving the efficiency of spray nozzles on its carton washer. The company changed from using shower heads and spray bars to smaller nozzles and mist sprays, and now only operates the washer when needed instead of continuously.[1]

[1] University of Minnesota 2003

3.3.6 Scheduling or modifying product changeovers

Efficient product scheduling and planning of product changeovers is an effective means of reducing resource consumption for cleaning and is commonly practised by dairy plant managers. Product changeovers should be optimised so that equipment cleaning is kept to a minimum and productivity is maximised.

'Pigging' systems

Pigging is a method of removing product from pipes; it can reduce the volume of water required for cleaning by minimising residual product left in the system, and therefore reduce rinse times. Pigging systems are discussed further in Chapter 5, 'Yield optimisation and product recovery'.

Effluent volume prediction model: Murray Goulburn, Leongatha
Murray Goulburn in Leongatha uses an Excel-based effluent volume prediction model to monitor and help schedule CIP washes. The model is used to prevent the wastewater system from being overloaded and allows wastewater volumes to be benchmarked and potentially reduced.

3.3.7 Crate washers

Crate washers can use a significant volume of water in a plant producing short shelf-life milk. The breakdown of water consumption in Figure 3.1 shows crate washing as accounting for 16% of the total water used. Crate washers can be prone to leaks and it is important that they are well maintained. Recirculating water in crate washers is a relatively easy method of reducing consumption. Another idea is to investigate adjusting the washer speed and length of cleaning cycles, to achieve the most efficient clean while still meeting hygiene standards.

Redesign of crate wash system: National Foods Ltd, Penrith
National Foods in Penrith redesigned its crate wash system to allow the recirculation of water. The improvement saved 60 kL/day of water and $105 000/yr, based on water supply and discharge costs. The cost of implementation was $50 000.

3.4 Reducing demand for water: utilities

3.4.1 Blowdown in cooling towers and boilers

Blowdown prevents the build-up of dissolved solids deposits in cooling towers and boilers, which reduces operating efficiency. Cooling towers and boilers often operate with a constant blowdown flow, or are timed to release water at regular intervals while some blowdown is regulated manually. In order to minimise the flow of make-up water needed after each blowdown, a conductivity probe can be installed. The probe initiates blowdown only when the conductivity in the water exceeds a set value. It may be possible to reuse boiler blowdown water for non-product uses such as floor cleaning or perhaps ash sluicing (for factories with coal-fired boilers). Blowdown can also be a good source of recovered heat, as discussed in Chapter 4, 'Energy'.

3.4.2 Cooling tower operation

Cooling towers can be a source of microbial contamination, or can use excessive water, if they are not well maintained. A regular maintenance schedule will enhance the tower's efficiency and maximise its lifespan. Requirements for microbial control measures are set out in AS/NZS 3666.1:2002, Air-Handling and Water Systems of Buildings — Microbial Control — Design, Installation And Commissioning, and in guidelines issued by state health departments.

Float valves are used on many cooling towers to control make-up water supply. The valve should be located in a position where it cannot be affected by water movement as a result of wind or water flowing through inlet pipes into the tower basin.

Cooling towers should be regularly checked for leaks and scale build-up.

Overflow of water on cooling tower: Murray Goulburn, Leongatha
Murray Goulburn in Leongatha conducted a water audit, which identified that one of the cooling towers was intermittently overflowing. The leak was measured at 120 L/min, which equated to around 57 000 L/day, assuming the leak occurred 30% of the time.

3.4.3 Equipment sealing water

Some items of equipment, such as vacuum pumps, centrifugal pumps and homogenisers, require sealing and cooling water. Often this water is used 'once through' and disposed to drain after a single use. There can be opportunity for substantial savings by recovering this water for other uses. In the case of pumps, an alternative is to use types that have a dry mechanical seal; however, care must be taken if using dry seals for pasteurised products, due to the possible risk of contamination if product reaches past the seal and cannot be easily removed during cleaning.

Recirculation of vacuum pump sealing water: Murray Goulburn, Koroit
Murray Goulburn Cooperative in Koroit installed a water recirculation system on the powder packing plant vacuum pumps, reducing water use by approximately 10 000 kL/yr and saving $5000 in water supply costs. Wastewater at Koroit is used for irrigation, so there were no additional savings in disposal costs.

Recirculation of vacuum pump sealing water: Murray Goulburn, Leitchville
At the Murray Goulburn Leitchville factory a water recirculation system was installed on the vacuum pump. The water is cooled using an air-cooled radiator. The project was very successful, saving $27 000 in maintenance costs and 1.1 million L/yr in water that was previously sent to drain. The cost of implementation was $15 000, which included a pump, balance tank, pipework and fan.

Recirculation of homogeniser water: Dairy Farmers, Bomaderry
At Dairy Farmers in Bomaderry most of the pumps and homogenisers require water cooling for their seals. Where possible, recaptured condensate water is used on the pump seals. There are three homogenisers on the site, all of which are now fitted with water recycling units; these recycle water used on the homogeniser seals and only require dumping and cleaning once a day. Now around 15 kL of water per day is saved, with mains water costs of $120/day. The cost of the recirculation system was approximately $4500.

3.5 Ancillary water use

Water use in amenities, kitchens/cafeterias and gardens may be a small percentage of a factory's overall water use but there can still be significant savings to be made. Practising water conservation, often by implementing simple and low-cost measures, also sends a strong message to staff. Table 3.5 shows water efficiency ratings and corresponding flow rates of various appliances. A comparison of water-efficient products and non-rated products is shown in Table 3.6, with an indication of potential savings in water volume.

Table 3.5 **Water appliance ratings**

Rating	Level of water	Flow rates for efficiency (L/min)	Flow rates for basin taps (L/min)	Flow rates for showers (L/place setting)	Flow rates for dishwashers toilets L (average flush volume)
A	Moderate	6.0–7.5	12.0–15.0	2.0–2.8	5.5–6.5
AA	Good	4.5–6.0	9.0–12.0	1.5–2.0	4.0–5.5
AAA	High	3.0–4.5	7.5–9.0	1.0–1.5	3.5 -4.0
AAAA	Very high	2.0–3.0	6.0–7.5	0.8–1.0	2.5–3.5
AAAAA	Excellent	Not more than 2.0 with automatic shut-off	Not more than 6.0	Not more than 0.8	Not more than 2.5

Source: AS/NZS 6400:2003, Water Efficient Products — Rating and Labelling

Table 3.6 **Comparison of water-efficient products with non-rated products**

Product	Savings
Taps	Non-efficient taps can use more 12 L/min Efficient AAA-rated taps or taps with a restrictor use only 6 L/min
Shower heads	Non-efficient shower heads can use more than 20 L/min High-efficiency roses can use less than 9 L/min
Toilets	Non-efficient toilets can use 12 L of water per flush High-efficiency dual-flush toilets use 3.6 L per flush (based on 4 half flushes to 1 full flush)
Clothes washers	Non-efficient washers can use more than 36 L per kg of washing Efficient front-loading washers can use less than 9 L per kg of washing
Dishwashers	Non-efficient dishwashers can use more than 3 L per setting (14 place-setting dishwasher) Efficient washers can use less than 1 L per setting
Urinals	Non-efficient cyclic flushing urinals are 30–80% less efficient than demand flushing urinals

3.6 Stormwater

There is potential for dairy processors to supplement water supply through the collection and reuse of stormwater. Stormwater can feasibly be used for non-potable applications in external areas of the processing plant (e.g. pump seal water, floor cleaning, irrigation, garden watering).

Use of stormwater: National Foods Ltd, Penrith
National Foods in Penrith reconnected an existing stormwater collection tank. The stormwater supplements trade waste vacuum pump sealing water, which is also recirculated. The initiative has saved the company 12 kL/day and $4000 in water supply and discharge costs. The initial cost was $2000, with operating costs of $100/yr.

3.7 Water recycling and reuse

Some wastewater streams are relatively clean and can be recycled or reused onsite. If the quality of wastewater streams is not suitable, some form of treatment may be necessary if the water is to be reused. In some cases in may be necessary to segregate wastewater systems to allow for reuse. Generally, water that will be in contact with product must be of drinking water quality and meet the Australian Drinking Water Guidelines (NHMRC & ARMCANZ 1996). Water that is recovered for use as boiler and cooling tower make-up must also generally be of high quality, as excessive organics or salts in the water will become concentrated and cause damage through excessive scaling or corrosion. Conductivity is usually used as an indicator of boiler feed-water quality and a maximum acceptable conductivity of 25 μS/cm has been cited (IDF 1988). Advice on the quality of water that can be reused in boilers and cooling towers should be sought from relevant experts.

Reuse of pasteuriser flush water: National Foods Ltd, Chelsea Heights
National Foods in Chelsea Heights reduced water use by 3 kL/day by recovering water from the pasteuriser flush. Estimated savings per year are greater than 1 ML. The company is planning to implement the same initiative on the remaining pasteurisers.

Reuse of pasteuriser sanitiser water: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville now recovers pasteuriser sanitising water by returning it to the hot water system. The factory collects around 8 kL of 85°C water per day, which was previously sent to drain, saving around 2900 kL/yr and approximately $1000 in water supply costs. Water from the factory is used for irrigation so there were no savings in disposal costs. The cost of installation was $8000 for a double butterfly valve, non-return valve, pipework and programming. The conductivity sensor and divert valve is used to divert water that may be contaminated.

Reuse of instrument cleaning water: Dairy Farmers, Malanda
Dairy Farmers in Malanda reuse water used for cleaning inline instruments that are used for testing quality parameters of incoming water such as turbidity. The instruments need to have a constant flow of water across them. The water is stored and pumped back into the water treatment (clarifier) system, saving 26 ML/yr and $5200 per year in water supply costs (based on a cost of 0.20c/kL).

3.7.1 Condensate recovery

Condensate water can be generated from two areas in dairy processing plants: from drying and evaporation processes used to concentrate milk products or produce powders (vapour condensate); and from boiler and steam supply systems. Recovery of condensate from these areas is discussed below.

Drying and evaporation processes

Condensate recovery systems are widely used in Australian dairy factories and can provide a substantial proportion of total water supplies. Around 87% of raw milk is water, the majority of which (about 85%) may be recovered, to potentially provide up to 100% of total factory requirements. The benefits of condensate recovery can be twofold, with savings in water consumption as well as in the recovery of heat energy. Vapour condensate, also known as 'cow water', can be used in numerous areas of the plant such as boiler and cooling tower feed water, CIP systems, cheese curd wash water, dryer wet scrubbers, indirect heating (via heat exchange) and pump seal water. There are, however, some factors to take into consideration in using condensate:

- It may contain carryover of product.
- It may require cooling.
- It is very low in dissolved solids (measured by conductivity), which can cause corrosion.
- It can be odorous.

The quality of vapour condensate depends on the type of product that is being evaporated, the evaporator installation, the place of extraction, the efficiency of operating personnel and the care they take. For example, it has been shown that the BOD of vapour condensate produced from concentrating acid whey has been almost 14 times that of condensate produced from concentrating skim milk, which can limit the opportunities for reuse: 'In general it has been found that the condensate from the earlier stages (effects) of an evaporator can be used after monitoring as boiler feed water, with that from the later stages being suitable for washing floors and the exterior of plant and vehicles.' (IDF 1988) Generally, without further treatment condensate is classified as non-potable.

The IDF Bulletin 232 (IDF 1988) lists a number of requirements for the reuse of condensate:

- Stable evaporation operation is the most important prerequisite for obtaining a high-quality condensate.
- Continuous inspection and monitoring of the condensate quality is necessary. This is usually done using conductivity and/or turbidity.
- It must be possible to chemically clean all the systems used to collect and convey the condensate.
- Continuous supervision of the evaporation installation and treatment of vapour condensate is important.
- Mixing of condensate with other types of water must be avoided, due to the potential for rapid bacterial growth.
- If disinfection is required, condensate should be adequately and properly dosed with disinfectant, with time allowed for additives to react.

To utilise the maximum available volume of condensate — and depending on the initial quality — further treatment may be needed before use. Methods used for treating condensate include the addition of disinfectants such as silver ions, chlorine and chlorine compounds, and P3-oxonia, as well as technologies such as carbon filtration and ion exchange (IDF 1988). Reverse osmosis is used as a higher level of treatment, to remove unwanted components and produce water that can be reused in most areas of a dairy processing plant. This is discussed further in the next section. Condensate is also often acidic, and may require caustic addition to increase the pH — for example to prevent boiler corrosion if used as boiler feed water.

It has been found that the use of relatively clean condensate for cooling tower make-up water can allow the growth of bacteria despite the use of biocides. This can be explained by the relatively low conductivity of the condensate compared to town water, and its effect on the frequency of boiler and cooling tower blowdown. As blowdown is usually controlled on the basis of conductivity, the low conductivity of condensate leads to less frequent blowdown and higher concentrations of organics, which can encourage microbial growth. This can also increase the level of scaling and build-up in the boiler or cooling tower, decreasing the life of the equipment.

Condensate is a good source of heat energy, and should be utilised. Significant savings in heating costs can be realised by recovering the heat energy for purposes such as pre-heating product or boiler feed water. For best results, condensate recovery should be integrated into the process at design stage to gain maximum economic benefit from energy and water recovery. Further information can be found in Chapter 4, 'Energy'.

For further reading see the IDF Bulletin No. 232/1988, *The quality, treatment and use of condensate and reverse osmosis permeates* (IDF 1998).

Boiler condensate return systems

Water produced from the boiler system in the form of steam condensate should also be recovered wherever possible, to reduce the amount of make-up water required by the boiler. Reducing condensate loss can reduce water supply, chemical use and operating costs by up to 70% (FEMP 2003). A condensate return system also reduces energy costs, because the already hot condensate requires less energy to reheat. Steam traps, condensate pumps and lines should be routinely inspected, while boiler systems should be maintained to reduce blowdown and maintain boiler efficiency. More information on boiler condensate return systems can be found in Chapter 4.

'In sensitive areas of the plant, it was necessary to only use recaptured condensate which has a low or no bacterial load.' *— Peter Ryan, Dairy Farmers, Bomaderry*

'We have an EPA licence to send excess evaporator condensate water to the Hunter River. The odour prevents us from using it in the boilers and other products. We have capital works in progress that will enable us to use all of the condensate water that we produce.' *— Garry Christie, Dairy Farmers, Hexham*

Challenges with recovery of condensate water: Bonlac, Spreyton

Bonlac at Spreyton recovers milk evaporator condensate, which is cooled before being sent to process water tanks with mains water make-up. The water is sanitised by dosing and recirculating with chlorine dioxide. Whey permeate evaporator condensate is recovered hot and used to supplement boiler feedwater or hot water, or is sent to irrigation. The trace organics in milk condensate rule out its use in some product contact applications. It was also found that acidity of recovered condensate plus excess acid from chlorine dioxide dosing has caused corrosion problems in non-stainless steel piping and equipment. It is important to specify corrosion-resistant piping material and provide for pH adjustment.

Recovery of condensate water: Murray Goulburn Cooperative, Koroit

Murray Goulburn at Koroit installed a 1 million litre condensate water recovery tank and automated the water recovery system. The installation has increased water-holding capacity and reduced production downtime, due to having immediate access to a bulk supply of water as opposed to waiting for town water. Downtime was also reduced as one of two condensate tanks could be cleaned without shutting down the plant. Savings were approximately 88 000 kL/yr and $50 000/yr for an outlay of $200 000. Over 90% of water requirements are now supplied by the condensate water. One issue with installation was setting up an appropriate water treatment system to ensure the quality of the water.

Reuse of condensate water: Murray Goulburn, Rochester

Murray Goulburn's Rochester site recovers 190 ML/yr of condensate from the factory's milk and whey powder evaporators for use within the plant. Condensate cannot be recovered from all the evaporators due to occasional product carryover. There are also issues with the low pH of some condensate, which precipitates protein and leads to the growth of thermophilic bacteria. Condensate water is blended with town water which is then chlorinated, filtered to remove chlorine, and passed through an ion exchange bed to remove hardness before use.

Reuse of dryer condensate water: Murray Goulburn, Maffra

Murray Goulburn in Maffra introduced a water recovery and reuse program. Initiatives included using condensate water from dryer air heaters for supplementing boiler and de-aerator feed water; dryer wet scrubbers; indirect cooling in heat exchangers; pump seal water; and external tanker CIP rinsing. Some of the condensate is treated with chlorine dioxide and filtered before reuse. CIP final rinse water is also recovered and used for the first rinse on the next CIP. As a result, fresh water consumption for the factory has reduced by 110 ML/yr and supplementary supplies of town water no longer need to be brought in by tanker. The program has saved the company at least $59 000/yr in water costs, not including tanker transport costs.

Condensate recovery, Dairy Farmers: Bomaderry

Dairy Farmers in Bomaderry are installing additional storage capacity to allow the collection of 60 kL of condensate water per day. Currently 30 kL water of nearly distilled quality is sent to the boiler for feed make-up. The rest of the condensate will be used as make-up water in the operation of the crate washer. Savings in water costs are expected to be approximately $12 000/yr. Additional savings, which could be high as $25 000, will be made from reduced costs to irrigate and dispose of water. Potential problems with using the water are the volatile organic odours and the small amount of dissolved salts coming off the wash cycles of the evaporator.

Discontinued use of condensate for cooling tower make-up: Bonlac, Spreyton

Bonlac in Spreyton previously recovered evaporator condensate for use as cooling tower make-up. The low conductivity of the condensate meant that blowdown was less frequent and traces of organics became more concentrated. Persistent contamination of the cooling tower led to the decision to discontinue using condensate for cooling tower make-up.

3.7.2 Use of membranes for water recovery

Membranes are commonly used within the dairy industry for the recovery of product, chemicals or water. This section looks at the use of membranes to recover and reduce the consumption of water. The use of membranes in dairy processing plants is covered further in Chapter 5, 'Yield optimisation and product recovery'.

Some dairy processing plants use reverse osmosis (RO) to polish evaporator condensate. The filtration process removes trace elements, which can cause corrosion. It also removes traces of product (from carryover), thus improving the quality of the permeate and increasing the possibilities for reuse within the plant. Permeate produced from membrane filtration can be used to supplement process water that is in contact with product; however, it requires further treatment to make it potable quality and is more commonly used for boiler and cooling tower water make-up. RO will not remove all the BOD from the stream, but a 90–95% reduction is normally achieved (PCI-memtech 2000). A barrier to the use of membrane filtration for treating condensate water for reuse is the cost of treatment compared with the cost of using fresh town water. For example, it is estimated that the cost of treatment for one Victorian plant is around 90c/kL, whereas the cost of town water is only 69 c/kL (Matthew McGuiness 2004, pers. comm.).

Membrane filtration is not suitable for recovering water from all waste streams. For example, water recovered from whey permeates by reverse osmosis should not be used in cheese factories because of the risk of bacteriophage, a virus that disrupts the cell membranes of bacteria used in the cheese-making process (Peter Gross 2004, pers. comm.). Bacteriophage infection can reduce the rate of fermentation in cheese-making and lead to lower-quality cheese.

Water recovery using membranes: Murray Goulburn, Rochester
Murray Goulburn's Rochester plant processes around 800 kL/day of whey to produce whey powder and lactose powder. Whey is processed in ultrafiltration, nanofiltration and reverse osmosis plants. The permeate from the RO plant is recycled to the factory as usable water. Over a year the RO plant saves 70 000 kL ($32 000) in reduced water intake.

Challenges with RO permeate chlorinator: Murray Goulburn, Leitchville
At Murray Goulburn in Leitchville reverse osmosis (RO) permeate is chlorinated before being used to supplement cooling tower and boiler water requirements. The reuse of the permeate allowed mains water use to be reduced by 17%; however, the system had to be shut down due to fouling problems with the membranes, which affected the quality of the permeate. The initial cost of the system was $40 000, with a 12-month payback period. The chlorination system is sized to treat 1 million litres of water per day. Challenges include the amount of chlorination required and control of bacteria in the cooling towers.

Novel use of reverse osmosis water: Dairy Farmers, Malanda
Whey proteins are processed in a reverse osmosis plant at Dairy Farmers in Malanda. The company installed pipework to allow water from the RO plant to be used in the laboratory. This eliminated the need to produce 60 kL/week of distilled water (3 ML/yr), and saved $600 in water supply costs. The pipework installation cost $500.

3.8 Wastewater

This section outlines typical wastewater treatment systems used in Australian dairy processing plants. Further information on wastewater management, trade waste discharge costs, yield optimisation and product recovery is presented in Chapter, 'Yield optimisation'.

3.8.1 Treatment of wastewater

The degree of treatment necessary to treat wastewater from a dairy processing plant is determined by the end use and criteria set by regulatory authorities — that is, whether the wastewater is to be discharged to sewer, reused on or off the site, discharged to surface water or used for irrigation. Processes used to treat wastewater fall into three main categories:

- physico-chemical (for primary treatment)
- biological (for secondary treatment)
- disinfection (some forms of tertiary treatment).

This eco-efficiency manual does not attempt to examine wastewater treatment in detail, so it is discussed only briefly in this section.

Primary treatment

Primary treatments commonly used by the dairy industry are screening, equalisation, neutralisation, and dissolved or induced air flotation (DAF or IAF) to remove fats and suspended solids. Other primary treatments that are being trialled at some factories use 'hydrocyclones' which also remove fat and can be used in combination with air flotation units.

Primary treatment systems such as induced air flotation (IAF) are commonly used in the dairy processing industry to remove fats and suspended solids.

Secondary treatment

Secondary treatment may incorporate the removal of organic matter and in some cases nutrients such as nitrogen and phosphorus. It typically uses a series of anaerobic and aerobic biological treatment processes. Secondary treatment relies on micro-organisms consuming and converting organic material in the wastewater into either carbon dioxide or methane (biogas), or into more cell matter (sludge) which can be removed and usually dewatered, stabilised and removed offsite. Further information on biogas and sludge utilisation can be found in Chapter 4, 'Energy' and Chapter 6, 'Solid waste reduction and value adding'.

Tertiary treatment

Tertiary treatments use biological and/or physical and/or chemical separation processes to remove organic and inorganic substances that resist primary and secondary treatment; they produce very high-quality effluent. The most common form of tertiary treatment used by the dairy industry involves the use of membranes, as described in sections 3.7 and 5.8.

3.8.2 Selection of a wastewater treatment system

Selection of a wastewater treatment system will depend on:

- the location of the plant
- capital and operating costs
- available space
- the characteristics of the wastewater, such as types and load of contaminants, volume of wastewater and the variation in the generation of the wastewater over time
- proximity to nearby residents
- effluent quality, as specified by either the local authority or the regulator
- the end use (e.g. is the water to be reused or recycled onsite or given/sold to a third party?)

For dairy processing plants that have the option to discharge waste to the sewer, primary treatment is usually the highest level of treatment required; but plants in regional locations usually treat wastewater by secondary and tertiary methods to a level suitable for irrigation. Soil salinity is an aspect that must also be considered in some cases. Salinity of dairy effluent is affected mainly by the use of sodium hydroxide in cleaning and effluent neutralisation, as well a by the loss of salt during the manufacture of cheese and butter. An eco-efficiency approach to selecting and operating a wastewater treatment system considers:

- the resources consumed by the treatment system, such as electricity, chemicals and oxygen

- opportunities for the system to recover valuable materials contained in the waste stream
- opportunities to reuse water after treatment
- opportunities to recycle biosolids or effluent after treatment
- the ease with which the system can be operated
- the efficiency of the wastewater treatment system in meeting regulatory requirements
- the complexity of the process and risk of system failure.

Where financially viable, wastewater treatments should be selected that enable existing and future opportunities for water reuse, product and energy recovery, and effluent or biosolid recycling. Again, from an eco-efficiency perspective, the most important step is to minimise the volume of wastewater and prevent waste from entering the wastewater stream in the first place. This is discussed in more detail in Chapter 5.

Zero discharge of wastewater: Bonlac Foods, Stanhope
Bonlac Foods in Stanhope will begin reusing 100% of its wastewater for irrigation in a project focusing on the sustainable reuse of water. Previously the water was irrigated to land over summer and to surface waters during winter. The project will involve building new storage and treatment lagoons and preparing more than 250 hectares of land for irrigation.

Recovery of wastewater for ash sluicing: Bonlac Foods, Spreyton
Bonlac Foods in Spreyton uses considerable volumes of water to sluice ash from the coal-fired boilers. A system was installed to recover treated wastewater for this purpose. Treated water is visually clear after treatment by the DAF plant, but has a moderately high dissolved BOD content. The system includes strainers to protect the pump and valves, and has an automatic backup supply of process water. The cost of the system is $34 000, with anticipated savings of $15 000/yr in water and trade waste charges.

3.8.3 Reuse of treated wastewater for irrigation

Some wastewater streams from dairy processing plants in regional areas are used for irrigation. The suitability of wastewater for irrigation can vary according to:

- the concentration of dissolved salts in the water, measured as electrical conductivity (EC)
- the concentrations of specific salts such as sodium, phosphate and nitrates
- soil type (e.g. permeability and how well it drains)
- crop type (e.g. salt tolerance of particular species)
- the climate (e.g. amount of leaching due to rainfall)
- method of irrigation (e.g. whether from overhead sprinklers, because wastewater with high salt levels may cause leaf burn).

Table 3.7 gives a general idea of the suitability of wastewater for particular sets of circumstances.

The uptake of salts by crops and pasture can reduce growth, discolour or scorch leaves, or cause foliage death, so it is essential that the salinity level of wastewater used for irrigation is routinely monitored. A risk assessment that includes a water, nutrient and salt model should be developed to fully assess the hydraulic and nutrient salt loadings of the soil, and the likely impact of irrigation. It is also important to prevent runoff and contamination of waterways, and spray drift onto neighbouring lands. As a starting point, refer to the ANZECC *Guidelines for fresh and marine water quality* for information on quality of water that can be used for irrigation (ANZECC 1992).

Table 3.7 **Suitability of saline wastewater for irrigation**

Concentration of dissolved salts (EC units)	Conditions suitable for use of saline wastewater
1500–2500	For continued use, moderate to high leaching and salt tolerance needed.
2501–5000	Salt-tolerant crops; considerable leaching; and permeable, well-drained soils required for continued use.
5000	Should be used only on salt-tolerant crops, and usually only to supplement rain or low-salinity water.

Source: Goulburn-Murray Water 2001

4 Energy

4.1 Overview of energy use

The dairy manufacturing industry has radically improved its energy efficiency over the last 20 years (in some cases by as much as 50%) through industry-wide upgrading of equipment and the closure of smaller, less efficient factories (Lunde et al. 2003). Dairy factories still use significant amounts of energy, depending on the types of products manufactured. Dairy factories producing mainly market milk use energy for heating and pasteurisation, cooling and refrigeration, lighting, airconditioning, pumping, and operating processing and auxiliary equipment. Factories producing concentrated milk products, cheese, whey or powders require additional energy for churning, pressing, separation, concentration, evaporation and drying.

The sources of energy in Australian dairy processing plants are generally electricity and thermal energy from fossil fuels including coal, oil, natural gas and LPG, while a small number of plants supplement fuel supplies with biogas. In this section, energy use has been analysed for three categories of dairy processing plants: those where the primary product is white or flavoured milk, those that primarily produce cheese and whey, and those that produce mainly powdered products.[1] Table 4.1 shows typical percentages of energy supplied from electricity and other fuels used to produce thermal energy (i.e. steam for Australian dairy plants surveyed during this project).

Table 4.1 Proportions of electricity and thermal energy use

	Electricity (%)	Thermal (%)
Milk only	66	34
Cheese and whey products*	27	73
Mainly powders	21	79

* excluding powders

Table 4.2 shows total use of energy (electrical and thermal) per kL of raw milk intake. As the table shows, these figures vary by around 18% for liquid milk plants and over 500% for plants producing mainly powders. The wide variation for powdered plants is mainly due to the differences in evaporating technology used. The median of these figures is around 45–65% of typical energy consumption in dairies in the UK. The Australian data also compares favourably with figures quoted by the International Dairy Federation. Electricity consumption for a range of plants was 0.22–0.47 GJ/t milk treated, and thermal energy consumption was 2.88–5.40 GJ (Kjaergaard-Jensen 1999); these are significantly higher than the Australian figures. In Canada, average electricity use was 0.61 GJ/kL for a liquid milk plant and 0.36 GJ/kL for a cheese, whey, powder plant, while for thermal use the figures were 1.06 GJ/kL and 1.07–1.38 GJ/kL respectively (Wardrop Engineering 1997); these are closer to the Australian data.

[1] Energy data is based on a survey of Australian dairy processors. Figures are for a total of 17 plants including 5 primarily milk producers, 3 cheese and whey and 9 mainly powder producers.

Table 4.2 **Total energy use — electrical and thermal**

	Australian data, this project					UK data[1]
GJ/kL raw milk intake	Min.	Max.	Median	Variance %	No. plants providing data	Average
Milk only	0.46	0.54	0.47	17%	5	0.82
Cheese and whey products	0.39	0.75	0.63	92%	3	1.44
Mainly powders	0.48	3.03	1.32	531%	9	2.18

[1] ETSU 1998

Figures 4.1 and 4.2 show the typical breakdown of energy costs in two UK dairy processing plants, one producing mainly white milk and the other producing cheese and powders. For a short shelf-life milk plant, energy costs are relatively evenly distributed between refrigeration, general services, processing, clean-in-place, bottling and cartoning. For plants producing cheese, whey and powders, the main energy costs are in drying and evaporating, followed by general services, refrigeration and clean-in-place.

Figure 4.1 **Energy cost breakdown by area — milk plant**

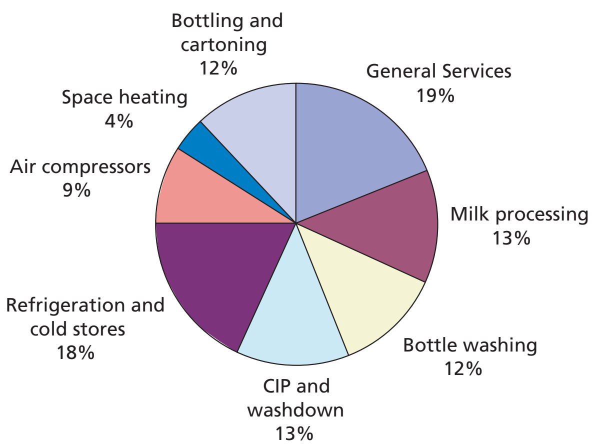
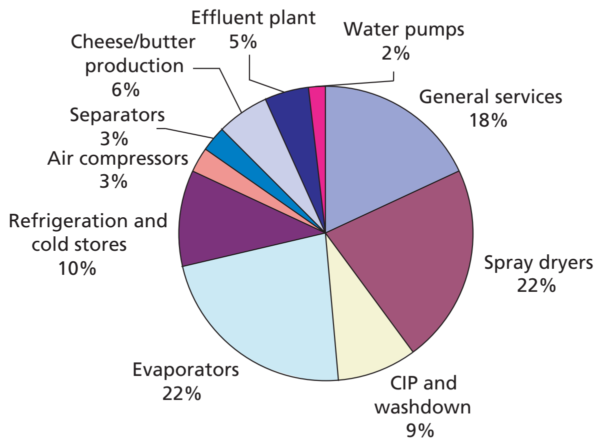


Figure 4.2 **Energy cost breakdown by area — powder, cheese and whey plant**



Source: ETSU 1998

There is scope for Australian dairy processors to reduce energy usage by implementing eco-efficiency initiatives, such as:

- optimising the operations of energy-consuming equipment
- recovering heat energy
- optimising the plant's load requirements with electricity supply demands
- exploring alternative sources of energy
- cogeneration.

4.1.1 The cost of energy

Table 4.3 shows typical costs for the energy sources commonly used in dairy factories, which vary between approximately $2 per GJ for black coal and around $14 per GJ for electricity. It should be noted that there can be some variation in the price paid for fuels and electricity within the industry, depending on the supplier and the negotiating power of the business. Most dairy processing plants consume over 200 MW h/yr, making them eligible to choose their electricity supplier and purchase electricity on the contestable market where this is available.

Table 4.3 Typical costs for primary energy sources

Fuel costs	Calorific value		Typical fuel cost			
			($/quantity of fuel)		($/GJ)	CO_2 emissions kg CO_2 equivalent/GJ[a]
Black coal	27.84	MJ/kg	$55	/t	$1.98	92.7–98.1
Fuel oil	43.1	MJ/kg	$425	/t	$9.86	81.5
Natural gas	39.5	MJ/m3	$0.22[b]	/m^3	$5.5[b]	61.8–70.8
Electricity	3.6	MJ/kW h	$0.05	/kW h	$13.89	281–401

[a] AGO 2004;

[b] Typical cost in Victoria (NB: Typical cost of natural gas in Queensland = $12/GJ)

Table 4.4 shows typical fuel costs for steam production in coal, natural gas and oil-fired boilers. These costs do not include the operating costs of chemicals, labour, maintenance and ash disposal. The fuel costs for producing steam from coal is considerably lower than for gas and for fuel oil. As shown, the cost per tonne of steam is around $6.50 for a coal-fired boiler (85% efficiency) to over $16 per tonne for a natural gas boiler (95% efficiency). (Note: this does not include costs of labour or ash handling.)

Table 4.4 Typical fuel costs for steam production[a]

	Coal boiler (85% efficiency)		Natural gas boiler (95% efficiency)		Fuel oil boiler (90% efficiency)	
Energy content of steam	2.8	GJ/t steam	2.8	GJ/t steam	2.8	GJ/t steam
Fuel energy input	3.3	GJ/t steam	2.9	GJ/t steam	3.1	GJ/t steam
Quantity of fuel	118	kg coal/ t steam	74	m^3 gas/t steam	72	kg oil/t steam
Cost	**$6.47**	**/t steam**	**$16.28**	**/t steam**	**$30.50**	**/t steam**

[a] Based on a system producing steam at 11 bar and 184°C, with a steam enthalpy of 2.8 GJ/kg steam

Hot water is also used for heating and sterilisation. Table 4.5 shows typical fuel costs for water heating.

Table 4.5 **Typical fuel costs for direct heating of water with electricity or gas from 20°C to 84°C[a]**

	Direct water heating			
	Electricity		Gas	
	95% efficiency		95% efficiency	
Heat input required (MJ)	282	MJ/kL	282	MJ/kL
Quantity of fuel/power	78.2	kW h/kL	7.1	m^3 gas/kL
Cost	**$3.91**	**/kL**	**$1.69**	**/kL**

[a] Based on electricity price of \$0.05/kW h and gas price of \$0.22/m^3

Replacement of electric heaters with steam heaters, Murray Goulburn Cooperative, Koroit
Electric dryer bar heaters were replaced with heaters fuelled by steam. Savings in fuel have been estimated at \$156 000/yr (including 1938 tonnes CO_2 emissions) for an installation cost of \$80 000.

4.2 Energy management

A good energy management program will identify uses of energy for a factory and highlight areas for improvement. One of the first steps in an energy management program is to find out where energy is being used across the site, which may require the installation of additional instrumentation such as steam, gas and electricity submeters. Measuring and monitoring energy use will highlight opportunities for savings and in turn reduce greenhouse gas emissions. The formation of an energy management team, involving a wide cross-section of staff, is a proven way of identifying opportunities to reduce energy consumption.

Energy management: Peters and Brownes, Balcatta
Peters and Brownes at Balcatta has improved its energy management by creating a database of weekly operating information. Electricity is analysed by site area and charges are now split into areas. Gas is also metered to allow usage across the site to be analysed.

Energy saving projects: Murray Goulburn, Maffra
Murray Goulburn in Maffra has implemented a number of energy-saving initiatives, which have reduced total energy costs by 12%. Initiatives include:

- forming an energy management team to identify energy issues
- installing energy-efficient lighting
- improving the operation of the refrigeration system compressors
- more closely linking boiler operation to process plant requirements by improving communication between the boiler house and process operators
- benchmarking plant start-up and shutdown times
- tagging and measuring energy consumption of all relevant equipment items
- repairing steam and air leaks and maintaining pipes.

Product scheduling improvements save energy: National Foods, Penrith
National Foods in Penrith, by improving product scheduling and increasing throughput of the factory, has also saved in energy and water for washing the pasteuriser. Operating procedures dictate that the pasteuriser is cleaned every 9–14 hours, depending on the type of product. The product scheduling improvements have reduced the time for which the pasteuriser switches to recirculation mode (effectively not producing product), thereby reducing energy and water consumption per unit of product.

Demand management

There are substantial savings possible through managing the electricity demand of the plant. Demand charges are based on the largest amount of electricity consumed in any single demand period (e.g. 15 minutes) during the billing period. Demand charges can therefore be decreased by managing the operation of equipment to utilise off-peak supplies, load shedding, and staggering the start-up times of large equipment items such as compressors or dryers. Soft starters on motors will also flatten out power demand during start-up.

Reducing power demand: Murray Goulburn Cooperative, Leongatha
Murray Goulburn in Leongatha conducted an electrical energy audit. The survey provided a better understanding of electrical load characteristics, an opportunity to better manage peak loads, and a basis for future selection characteristics for electrical equipment. The audit provided the framework for better managing variable production inputs. Potential savings in demand charges were estimated at $100 000. Challenges include having people underst and the ramifications of their actions when plant is started, and potential costs.

Improved start-up procedures: Murray Goulburn Cooperative, Koroit
A procedure was developed for plant start-up after power flicks at Murray Goulburn's Koroit plant; this resulted in savings due to reduced peak loadings. Large equipment items are now started in sequence, which has reduced the maximum demand of the site.

4.3 Reducing the demand for steam and hot water

4.3.1 Evaporation

Evaporators are commonly used in dairy processing plants to concentrate heat-treated milk from approximately 10% to around 50% total solids. Figure 4.3 shows a schematic of a falling film evaporator typically used by the industry. Evaporators may be single- or multiple-stage (effect) where energy savings are made by using the vapour from the first effect to heat product in the second, and so on. Energy consumption is reduced by increasing the number of effects, up to as many as seven for large factories in Europe (ETSU 1998). Thermal vapour recompressors (TVRs) further reduce energy usage by using a steam ejector to compress the vapour, increasing its temperature and pressure before utilising its evaporative energy. Mechanical vapour recompressors (MVRs), which use a motor or mechanically driven compressor, are even more energy-efficient than TVRs, even though additional electrical energy is required to operate the compressor. The most energy-efficient evaporators use a combination of multi-stage design and mechanical vapour recompression. Table 4.6 shows a comparison of energy requirements for four combinations of evaporators. A study of five Australian milk powder factories indicated that a combination of TVRs, MVRs, multiple-stage evaporators (up to five) and multiple-stage dryers are currently used by the industry (Lunde et al. 2003).

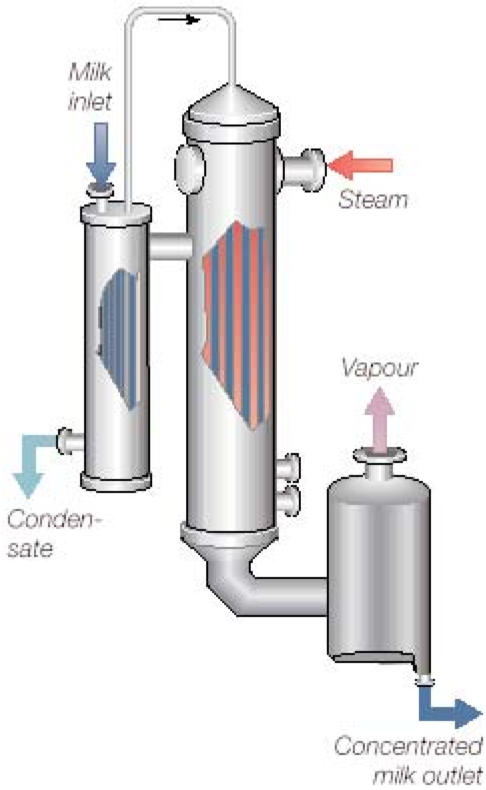


Figure 4.3 **Single-effect falling film evaporator schematic**

Source: Tetra Pak Handbook, 1995

Table 4.6 **Energy consumption of multi-effect evaporators and vapour recompression**

Technology	Typical specific energy consumption
Triple-effect evaporation	0.14 kW h per kg water evaporated[a]
Five-effect evaporation	0.085 kW h per kg water evaporated[a]
TVR + triple-effect evaporation	0.12–0.15 kW h per kg water evaporated[b]
MVR + triple-effect evaporation	0.01–0.02 kW h per kg water evaporated[b]

[a] Joyce 1993

[b] ETSU 1998

Use of mechanical vapour recompression: dairy processor, Japan
Meiji Milk Products in Japan replaced a thermal vapour recompression evaporator (TVR) with a mechanical vapour recompression (MVR) system, and reduced evaporator operating costs by 75%. The MVR was installed on a four-effect evaporator with an evaporation rate of 30 t/h. The TVR had operating costs of US$680 000/yr, while the MVR required only US$175 000/yr. The cost of the new MVR was US$1.5 million compared to US$1.3 million for a new TVR evaporator.

Source: CADDET 1992

4.3.2 Membrane concentration

Membranes are often used to concentrate dairy streams in preparation for further processing. For example, ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) membranes have been used to concentrate whole milk, skim milk, whey and protein streams (Koch 2004; PCI-memtech 2000). Membrane processes are energy-efficient for concentration, with typical energy consumption around 0.004–0.01 kW h per kg of water removed (ETSU 1998), which is significantly more economical than using evaporation methods (Table 4.6). However, there are economic limitations to the level of concentration that can be attained, to the point where it is financially preferable to use traditional evaporation methods. For example, whey is concentrated up to 18–27% because beyond that range process performance is reduced, due to the high osmotic pressure, high retentate viscosity, lactose crystallisation and calcium phosphate precipitation (Daufin et al. 2001). The more concentrated the retentate, the higher is the pressure and the more robust the membranes required for filtration. Membranes have been used to concentrate streams to up 55% total solids (PCI-memtech 2000), primarily determined by viscosity and fouling considerations. Pumping equipment will also be more energy-intensive, which will lead to higher operating costs. Further information on membranes can be found in 'Cost-effective membrane technologies for minimising wastes and effluents' (WS Atkins Consultants Ltd 1997).

Thickening and desalinating whey in the dairy industry: dairy processor, The Netherlands[1]
Before food ingredients can be made out of whey, the original thin liquid must be concentrated and desalinated. A whey processing plant in The Netherlands has installed a nanofiltration unit to perform part of the total thickening process. The membrane filter replaces an evaporator and ion exchanger; this increases the solids content of the whey from 5.5% to 17%, and removes 70% of the salt content with the permeate. Steam consumption for the old system was 436 m^3 natural gas equivalent (NGE) per tonne dry solids, and electricity consumption was 11.5 m^3 NGE/t. Steam use for the new system has decreased to 120 m^3 NGE/t but electricity consumption has increased to 19.2 m^3 NGE/t. Net energy savings are 308 m^3 NGE/t, which equates to around 70% of the original energy consumption. In addition there were savings in chemical and water use for cleaning. The payback period was 1.3 years.[1]

[1] CADDET 1999

4.3.3 Spray drying

Spray drying is used extensively by the dairy industry for producing powdered milk, whey and cheese. It involves atomising the feed into a spray of droplets which are put into contact with hot air in a drying chamber. Spray dryers are usually used in conjunction with evaporators, and dry product from around 50% solids through to 97% solids. The energy consumed in spray drying is reported at around 0.05–0.1 kW h per kg of water removed (ETSU 1998). Dryers may be co-current, counter-current and mixed flow, with sprays produced by a rotary (wheel) atomiser or nozzle atomiser (Schuck 2002). Spray dryers may be single, two-stage or multi-stage, with the latter being the most energy-efficient but also the most capital-intensive. Second and later stages use fluidised bed drying, which is more energy-efficient.

A useful measure of the dryer efficiency is specific energy consumption (SEC), which measures how much energy is required per kilogram of water evaporated from the feed, where:

SEC (kJ/kg) = rate of energy consumption of dryer (kW) / rate of evaporation of dryer kg/s

The evaporative rate, E, in kg vapour/s is given by:

$$E = W_S (X_1 - X_0) \text{ where}$$

W_S = dry solids feed rate and X_1 and X_0 are the moisture contents of the input and output streams defined as a fraction of the dry solids weight.

The rate of energy consumption should be routinely monitored and compared against other similar spray dryers. Tips for the efficient operation of a spray dryer include:

- operating the plant at full design rating
- maximising the solids content of the milk concentrate, to achieve good atomisation at the spray nozzle or atomiser
- minimising the loss of waste heat from the exhaust (It is desirable to use high inlet air temperatures and low exhaust air temperatures, to achieve the required degree of drying. This can be achieved through two-stage drying, where a fluid bed dryer is installed to reduce residual moisture content of the product to an acceptable level, hence allowing the dryer to run with lower exhaust air temperatures.)
- recovering waste heat by installing a recuperator that uses exhaust air to pre-heat the inlet air
- investigating ways of pre-heating the milk concentrate.

There can be problems with recuperating waste heat, due to the presence of particulates in the exhaust air stream and the tendency for fouling, which causes hygiene problems. This technology is no longer in use in Australian dairy factories for this reason. A more detailed discussion on heat recovery systems and the efficient operation of spray dryers can be found in Good Practice Guide 185 of the UK Energy Efficiency Best Practice Programme, *Spray drying* (ETSU 1996).

The energy efficiency of the dryer can be maximised by maximising the solids content of the feed — for example, operating at 40% solids instead of 30% reduces the heat input by 36% (ETSU 1996).

As a rule of thumb, every 0.5% increase in feedstock solids reduces energy consumption by 2%.

ETSU 1996

Improved start-up procedures for evaporator and dryer: Murray Goulburn Cooperative, Rochester[1]

The Murray Goulburn Energy Management Team (EMT) in Rochester identified energy saving opportunities for the Niro evaporation and drying plants at their Rochester (Victoria) branch. By monitoring the amount of steam used during plant start-up, the EMT saw opportunities to reduce steam usage. It was found that too much time was spent heating the evaporator and dryer on start-up. Reducing the heating time reduced the amount of steam used. The EMT estimated potential annual savings of $23 000 from reduced steam usage.

Heat recovery from spray dryer: Tatura Milk, Tatura[2]

Tatura Milk Industries' recently installed milk powder plant has included heat recovery on the gas-fired heater. The spray dryer uses 4.5 t/h of steam, 22 GJ/h of gas and 550 kW h of electricity, to produce 5.5 t/h of whole milk powder.

[1] ITR 2003

[2] Niro 2003

4.3.4 Boiler operation

There are some basic items that should be considered for the efficient operation of boilers; these are discussed briefly below. For expert advice on the operation and maintenance of your boiler, it is best to contact your supplier, maintenance contractor or in-house engineer.

Check the fuel-to-air ratio and compare readings with optimum gas percentages

The efficiency of a boiler can be monitored by measuring the excess air and the composition of flue gas. Insufficient excess air will lead to incomplete fuel combustion, while too much causes a loss of heat in the boiler and a decrease in efficiency. Optimum percentages of oxygen (O_2), carbon dioxide (CO_2) and excess air in exhaust gases are shown in Table 4.7. The ratio of boiler air to fuel can be adjusted to obtain the optimum mix of flue gases, using oxygen trim systems. Table 4.8 shows the potential fuel savings resulting from the installation of online oxygen trim control. Such systems usually reduce energy consumption by 1.5–2%, with a typical payback period ranging from a few months to 2 years (SEAV 2002a).

Table 4.7 Optimum flue gas composition

Fuel	O_2 (%)	CO_2 (%)	Excess air (%)
Natural gas	2.2	10.5	10
Coal	4.5	14.5	25
Liquid petroleum fuel	4.0	12.5	20

Source: Muller et al. 2001

Table 4.8 **Fuel savings from installing online oxygen trim control**

Boiler capacity (MW)	Fuel savings (GJ/yr)	Fuel savings ($/yr)	CO_2 (t/yr)	Simple payback (yr)
0.5	318	3 816	19	2.0
1	635	7 620	37	1.0
2	1270	15 240	75	0.5
4	2540	30 480	150	0.2
6	3810	45 720	224	0.2
8	5080	60 960	299	0.1
10	6350	76 200	374	0.1

Source: Adapted from SEAV 2002a

Assumptions: gas costs $12/GJ; boilers operate 24 h/day, 350 days/year; installation cost of the boiler trim system $7500

Oxygen trim controller on boilers: Peters and Brownes Foods, Roxburgh
Peters and Brownes Foods in Roxburgh is investigating the installation of an oxygen trim controller on its boiler, which is expected to reduce gas usage by 2% and save $10 000/yr for a cost of $30 000.

Regularly record the flue gas temperature

A good benchmark for the operation of the boiler can be established by measuring the stack gas temperature immediately after the boiler is serviced and cleaned. The stack gas temperature can then be regularly monitored and compared with the optimum reading at the same firing rate. It is estimated that there is a 1% efficiency loss with every 5°C increase in stack temperature (Muller et al. 2001). A major variation in stack gas temperature indicates that there has been a drop in efficiency and the air-to-fuel ratio needs to be adjusted, or the boiler tubes cleaned.

Operate the boiler at the design working pressure

It is important to ensure boilers are operating at their maximum possible design working pressures. Operating them at lower pressures will result in lower-quality steam and reduced overall efficiencies. If the system requires lower pressures, use pressure-reducing valves. The general rule is: generate and distribute steam at high pressure and reduce it to the lowest possible pressure at the point of use (Manfred Schneider 2004, pers. comm.).

Monitor and clean boiler tubes to remove scaling

Scale acts as an insulator and inhibits heat transfer. A coating of scale 1 mm thick can result in a 5% increase in fuel consumption, and if the thickness is allowed to increase to 3 mm the fuel consumption can increase by 15% (MLA 1997). So preventing the build-up of scale by treating the boiler feedwater can result in significant energy savings. Not only does scale increase fuel consumption but, if left untreated, it will also reduce the life expectancy of the boiler.

The treatment of boiler feedwater will help to minimise build-up of scale, which acts as an insulator and inhibits heat transfer.

Match steam supply with demand

If the steam production at the boiler house is too high compared to the plant's actual steam demand, the excess may need to be vented, resulting in unnecessary fuel wastage. The use of metering instrumentation (steam, water and fuel meters) will help match steam supply with demand. If appropriate, meter the steam flow to different sections of the plant separately. Improving communication between boiler operators and end users can lead to significant savings in boiler operating costs. It is not uncommon for boilers to be operated inefficiently at low load or on standby ready to meet process demands. Improving communications can allow the boilers to be operated more efficiently at higher loads for the periods required, thereby reducing operating costs. Boilers should be started up as late and shut down as early as possible while still meeting process demands. This is more difficult to manage with solid fuel boilers than with gas or oil, due to the slower response time.

Variable demand during the day, especially when it peaks for short periods (for example when large capacity plant is first started), can be accommodated by using a 'steam accumulator' — a large vessel filled with water that is heated by the steam to steam temperature. Steam that is not needed to heat the water simply flows through it and out to the plant; but when a sudden peak load is imposed a proportion of the water in the tank is 'flashed off' into steam at the reduced pressure, thus protecting the boiler from instantaneous loads. This kind of system can effectively meet short-term demands that are considerably in excess of the boiler's rated output (Manfred Schneider 2004, pers. comm.).

Improving steam-raising efficiency: Murray Goulburn Cooperative, Rochester[1]
Murray Goulburn at Rochester formed an Energy Management Team (EMT) which identified inefficiencies in boiler operation due to communication problems between boiler and process operators. The boilers were operated at low load (and lower efficiency) so they could quickly increase steam supply at any time to meet production demands. The EMT developed new procedures and a communications plan for the site to improve communication. The average load of one boiler was increased from 30% to 60%, contributing to a 4% increase in steam-raising efficiency. The savings on the one boiler are estimated at $180 000/yr, with greenhouse gas emission reductions of 1536 t.

[1] ITR 2003

4.3.5 Steam delivery

Rectification of steam leaks

Leaks allow live steam to be wasted, causing more steam production to be required to meet the plant's needs. As more replacement feedwater is required, more fuel is used for heating and more chemicals are needed for treatment. For example, a hole 1 mm in diameter in a steam line at 700 kPa will lead to a annual loss of 3000 L of fuel oil or 4300 m^3 of natural gas, equating to around $2000 (SEAV 2002b).

Elimination of steam leaks: Bonlac Foods, Spreyton
Bonlac Foods in Spreyton generates steam and distributes it at 4000 kPa — the pressure required for spray dryer air heating. All other duties use steam at 1000 kPa which is produced at four 'letdown' stations located near the points of use. Design faults at the letdown stations allowed continual leakage of steam. The stations were rebuilt with heavy-duty automated isolating valves and improved design. The improvements saved $71 300 in coal supply costs. The cost of implementation was $147 000. The completion of the project was delayed by the difficulty in scheduling windows in the production schedule to allow installation; but the project could have been avoided if the design of the steam equipment had been examined more critically during construction.

Boiler condensate return systems

Boiler condensate (as opposed to evaporator condensate) contains valuable heat energy. It should be returned to the boiler feed tank to save water and utilise this energy, unless it is excessively contaminated with product or corrosive elements. If it is contaminated, the heat it contains could be recovered (e.g. via a heat exchanger to the cold make-up water). If contamination is only a possibility, various contamination detection systems are available (usually conductivity meters) to enable its normal recovery or rejection to waste if contaminated. A 5°C increase in the temperature of the feedwater will save around 1% of the fuel used to raise steam (SEAV 2002a). In addition, the water has usually been chemically treated already, thus saving treatment costs.

Condensate return systems are often designed with flash vessels to allow for the re-evaporation of condensate into steam (referred to as flashing). The flash vessels also remove non-condensable gases such as air and CO_2. If these gases remain in the equipment being heated, the gases form pockets that insulate the heat transfer surface and decrease boiler efficiency (Graham Smith 2004, pers. comm.). The steam in the flash vessels can be used as a low-grade heat source.

Condensate return: National Foods Ltd, Murray Bridge
At National Foods in Murray Bridge a system was installed to recapture condensate from the large steam users and return it to the boiler. This has reduced the running costs of the boiler and reduced the use of boiler chemicals. Challenges included installing the pumps and pipework for the return line to the boilers on an existing system. Condensate return lines should be installed with the boiler, saving time and effort upfront.

Improved condensate return: Murray Goulburn, Rochester[1]
Murray Goulburn in Rochester, as part of the Energy Efficiency Best Practice project of the Australian Government Department of Industry, Tourism and Resources (ITR), identified savings of around $200 000/yr in natural gas costs by improving the efficiency of the condensate return system, repairing steam leaks and improving maintenance of pipes. By insulating condensate return pipes, boiler feedwater temperature could be increased from 45°C to 65°C, thereby increasing the boiler efficiency by 3.3%.

[1] ITR 2003

Maintenance of steam traps

A steam trap is an automatic valve for removal of condensate from a steam system. In the presence of steam it closes, preventing steam from being passed through it and being wasted before it has given up its heat and condensed. In the presence of water it opens, allowing the discharge of condensate. Depending on its type, it may also open to discharge non-condensable gases. Where feasible, condensate removed from steam traps should be returned to the boiler feed tank as previously discussed. Regular testing and maintenance of steam traps and condensate lines saves money and time as well as improving operating efficiency. Traps can be checked by plant staff or an outside contractor. Traps that are losing steam can waste thousands of dollars a year, usually far more than the cost of their replacement or repair (Smith 2004, pers. comm.).

Steam system audit: Murray Goulburn Cooperative, Leongatha
Murray Goulburn in Leongatha undertook a steam system audit to review the efficiency of the many steam traps. It cost the plant $10 000 to eliminate the faulty/leaking traps. Savings have not been quantified.

'Be proactive. The savings are the result of fixing a large number of small out-of-the-way items.' — *Ted Isaacs, Murray Goulburn Cooperative, Leongatha*

Rationalisation of boiler use and steam lines

For some older factories that have progressively expanded over the years, steam supply lines may not take the most direct route from the boiler to the point of use. This results in a greater length of steam pipework than is really required and greater opportunity for heat loss and leaks. Rationalising steam and condensate pipework can lead to savings in boiler operating costs. A review of boiler use may also identify the need for a boiler upgrade or even replacement.

Rationalised steam supply: Peters and Brownes Foods, Roxburgh
Peters and Brownes Foods in Roxburgh reduced gas usage by $10 000/yr and maintenance costs by $15 000 by decommissioning two boilers for the ice-cream plant and using steam from existing beverage plant boilers. The cost of implementation was $65 000, with a payback period of less than 1.5 years.

Insulation of pipes

Uninsulated steam and condensate return lines are a source of wasted heat energy. Insulation can help reduce heat loss by as much as 90%, as shown in Table 4.9. Insulation that is damaged should be repaired and sources of moisture should be removed to prevent insulation from deteriorating. It is estimated that 35% of the heat energy supply is lost during the manufacture and distribution of steam, while approximately 2000 kW h is lost in a year from a 1-metre length of 5cm steam pipe with a surface temperature of 170°C (Kjaergaard-Jensen 1999).

Table 4.9 **Heat loss from 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
Uninsulated	2.83	1.0	$3396
Insulated with mineral fibre	0.138	0.05	$165

Source: Adapted from US DOE 2002
Assumptions: 125 mm steel pipe at 150°C; natural gas cost of $0.012/MJ of boiler operating 8 h/day, 250 days/year.

Insulation of pipes: Murray Goulburn Cooperative, Leitchville
Murray Goulburn in Leitchville made repairs to the insulation of various steam and condensate pipes. The expenditure was $12 000, with a 6-month payback period.

Insulation of steam lines: Dairy Farmers, Jervois
Dairy Farmers in Jervois are planning to upgrade insulation on their steam lines. It is estimated that 30 kW of energy is radiated per metre of pipe, and pipes are approximately 60 m long.

4.3.6 High-efficiency boilers

Boiler efficiency can be improved by installing heat recovery equipment such as economisers or recuperators. An economiser is an air-to-liquid heat exchanger that recovers heat from flue gases to pre-heat boiler feedwater. Fuel consumption can be reduced by approximately 1% for each 4.5°C reduction in flue gas temperature (Muller et al. 2001). Recuperators are air-to-air heat exchangers that are used to recover heat from flue gases to pre-heat combustion air.

Combustion air blower variable speed drives can be retrofitted to continually match the load on the boiler. When replacing or upgrading boilers, many dairy processing companies are also investigating the option of converting to a more efficient and cleaner fuel (e.g. coal or fuel oil to gas). The installation of these energy-saving measures can mean an improvement in boiler efficiency from around 90–94% for a new boiler. The environmental impacts of switching fuels will be reduced (less greenhouse gas emissions), but the disadvantage is the higher cost of natural gas as shown previously in Table 4.4.

Energy-efficiency in boiler design: Bonlac Foods, Darnum Park[1]
Bonlac Foods in Darnum Park increased the efficiency of their four 10 MW boilers by installing economisers, oxygen trim control, variable-speed drives and automatic blowdown control. Around 80% of the condensate is returned to the boilers, utilising heat in the condensate and reducing water consumption, chemical consumption and wastewater generation.

[1] AGO 2002a

4.4 Reducing the demand for electricity

4.4.1 Refrigeration systems

The energy cost of a refrigeration system can approach 20% of the total energy costs in a liquid milk processing plant (Figure 4.1). Dairy processors typically use the vapour compression cycle refrigeration system consisting of a compressor, condenser, evaporator and expansion valve. The most common refrigerant is ammonia.

The efficiency of a refrigeration system is measured by the coefficient of system performance (COSP) which is the quantity of refrigeration produced (cooling output in kilowatts) divided by the total energy required by the system (energy input in kilowatts). The higher the COSP, the higher is the efficiency of the system.

A useful software model, Coldsoft, is available from the Australian Dairy Processing Engineering Centre (DPEC 2003b). The model allows plant personnel to review and improve the performance of dairy site refrigeration systems.

Compressors

The purpose of the compressor is to draw low-pressure refrigerant vapour from the evaporator, and compress it so the vapour can be condensed back into a liquid by cooling with air or water. The compressor is the workhorse of a refrigeration system and usually accounts for between 80% and 100% of the system's total energy consumption (Carruthers 2004, pers. comm.). It is important, therefore, that the system operates under optimum conditions. The amount of energy used by a compressor is affected by the:

- type of compressor
- compressor load
- temperature difference of the system (i.e. the number of degrees by which the system is required to cool).

Compressor selection

There are three main types of compressor used for refrigeration — reciprocating, rotary screw and scroll. Centrifugal compressors are often used for air-conditioning systems. It is important when selecting a compressor to choose a type best suited to the refrigeration duty and one that will enable the system's COSP to be as high as possible.

The compressor is the workhorse of a refrigeration system and usually accounts for between 80% and 100% of the system's total energy consumption.

Compressor load

The compressor's capacity needs to be matched with the load. If a compressor is not required, or is oversized, it operates at only partial load and the energy efficiency may be reduced. The use of multiple compressors with a sequencing or capacity control system to match the load can help to improve efficiency. In some cases, even with a capacity control system an oversized compressor will still be inefficient as a result of frequent stopping and starting. Some compressors are more efficient than others at part load, depending on the method of capacity control, and it is best to ask the manufacturer for a profile of efficiencies at varying load conditions.

Ice banks can be an effective way of meeting peak demands without the need for large compressor capacity. They are best used in applications where there are short to medium peak loads but a much lower average load during a production day. Ice can be formed during the night to take advantage of cheaper off-peak electricity.

Installation of new condenser: Dairy Farmers, Booval
Dairy Farmers in Booval installed a new condenser to reduce the operating head pressure and save on the operating costs of the refrigeration plant. The payback on capital investment was 2 years. Challenges included the selection of a condenser to comply with noise limits.

Minimising temperature difference

Compressors are most efficient when the condensing temperature (and therefore pressure) is as low as possible and the evaporating temperature (pressure) is as high as possible, while still meeting the refrigeration duties.

Increasing the evaporating temperature will increase the compressor efficiency, so the thermostats should not be set lower than necessary. For example, it is cheaper and requires less energy to cool a stream down to 4°C than to 2°C. Less heat energy will be absorbed into the refrigerant, which in turn will reduce load on the compressor. In some cases this may not be possible, due to production temperature and humidity requirements; but do not cool more than is required.

Alternatively, the condensing temperature can be decreased by ensuring that the condenser, which may be a water- or air-cooled cooling tower, is operating efficiently. Condensers should be sized correctly to maintain the optimum condensing temperature within the capabilities of the refrigeration system. If the condenser is too large, however, the refrigerant can actually sub-cool[2] and this will affect the function of the expansion valve.

A refrigeration system with a small evaporator and condenser may require a smaller initial capital outlay; however, running costs may be greatly increased by the need for a larger compressor, so this should be avoided.

An increase of 1°C in evaporating temperature or a reduction of 1°C in condensing temperature will increase the compressor efficiency by 2–4%.

ETSU 2000

Energy management control system: Nestlé, Victoria[1]
A Nestlé ice-cream plant in Victoria uses electricity worth around $960 000/yr. About 13 GW h of this electricity is used by the refrigeration system.

A feasibility study for the refrigeration system showed that the compressors were operating under no load, there were numerous compressor start-ups, and the suction temperature of 12°C into the compressors was far above design temperature of 3°C due to incorrect valve selection. The minimum condenser pressure was also being maintained at around 1000 kPa over the winter months.

The study recommended upgrading the current control system to improved valve selection so that the correct suction gas temperature (3°C) could be recovered, enabling the compressors to operate at higher loading and minimise stopping.

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[1] SEAV 2002b

[2] Subcooling refers to cooling of the refrigerant below its saturation point (the point at which liquid turns into a vapour).

The study also suggested modifying the condenser pressure to operate at a minimum condenser pressure of 750 kPa instead of the existing 1000 kPa.

The project cost the company $59 000 and installation took 4 months. Nestlé now saves $100 000/yr in electricity costs. Compressor start-ups were reduced by 92% and the run hours by 22%. There was an overall reduction in maintenance costs for the refrigeration plant of 20%.

The cost of operating a refrigeration system can be up to around 20% of total energy costs in a dairy processing plant.

Hot gas bypass defrost

Hot gas from the outlet of the refrigeration compressor can be used to defrost freezers, but the control must be accurate. The defrost water may then be used elsewhere in the plant. Once installed and optimised, a hot gas bypass defrost system can ensure frost-free evaporator operation. Once the evaporator is no longer covered in ice its cooling capacity will be increased.

Reducing load on refrigeration systems

Up to 10% of the power consumption in refrigeration plants can be from heat ingress through doorways in coolrooms. Many plants rely on good operator practice to keep doors closed, but this is not always effective. Automatically closing doors or an alarm system could be considered; and plastic strip curtains or swinging doors are useful at frequently opened entrances.

Lights and fans also add to the heat load. Sensors and timers can be used to ensure that lights are used only when necessary. Variable speed drives, coupled with a programmable controller, can cycle off fans and refrigerant feed during low load times.

Cooling water loops using water at ambient temperature have also been used by some dairy processors to pre-cool high-temperature fluids (around 90°C) before chilling, thereby reducing the load on the refrigeration system.

Absorption refrigeration

Absorption chillers allow cooling to be produced from heat sources such as clean fossil fuels, incinerated garbage, biofuels, low-grade steam, hot water, exhaust gas or even solar energy, usually using a lithium bromide and water refrigerant (Broad Air Conditioning 2004). The COP of absorption refrigeration, however, is relatively low compared with vapour compression refrigeration systems with the best absorption chillers generating just over 1 kW of refrigeration for 1 kW of energy. The higher the temperature of the waste heat, therefore, the more effective the refrigeration will be. The advantages of absorption chillers are that they can utilise a waste heat source with lower greenhouse gas emissions compared to conventional vapour compression refrigeration systems.

Use of absorption refrigeration: milk processing plant, USA1
Honeywell Farms used a lithium bromide absorption chiller to cool liquid refrigerant of the main refrigeration system below its saturation temperature. The absorption chiller operated using waste heat from a compressor driven by a natural gas engine and increased the capacity of the existing refrigeration system by 8–10% by reducing the load on the compressor. Energy savings were calculated at US$90 400/yr, for an extra capital cost of US$339 549 compared with that of a standard plant and a payback period of 3.8 years.

[1] CADDET 1996a

4.4.2 Compressed air systems

Compressed air is used extensively in dairy processing plants, mainly for the operation of valves, filling and packing machines, and for cleaning spray dryer bag filters. The cost of operating a compressed air system in a dairy processing plant can approach 10% of total electricity costs (Figure 4.1). Compressed air systems are very energy-inefficient, with around 80% of electricity input lost as waste heat. A compressor will usually consume its purchase price in electricity every year (US DOE 2004b) and therefore selecting and efficiently operating the correct type of compressor for the application can substantially reduce operating costs, as discussed in the sections that follow.

Installing a control sequencing system on multiple compressors will help the system to respond more efficiently to varying loads. Variable-speed compressors can reduce power with reduced demand. If compressors operate at variable rates or are oversized to cater for higher than usual loads, consider installing a variable speed drive (see section 4.4.4).

Lead-lag system for compressors: Murray Goulburn Cooperative, Koroit
The air compressors at Murray Goulburn's Koroit plant were changed to a lead-lag system which reduced energy consumption by approximately 10%. One compressor is set as the lead compressor, which operates until it can no longer meet demand. The second or lag compressor is then automatically switched on. A lead-lag system prevents both compressors operating at once when not actually required. The cost of implementation was $5000, with annual savings of approximately $3000.

Compressed air leaks

Leaks in a compressed air system can contribute 20–50% of total air compression output (SEAV 2002b). Table 4.10 indicates the cost of compressed air leaks. Ultrasonic detectors can be used to check for leaks; the traditional method of using soapy water on pipework is also effective. It is best to check for air leaks when the plant is shut down and background noise is minimal. It is also a good housekeeping measure to isolate compressed air on items of equipment that are shut down for extended periods (e.g. overnight or on weekends).

Table 4.10 **Cost of compressed-air leaks**

Equivalent hole diameter (sum of all leaks)	Quantity of air lost per single leak (m^3/year)	Cost of single leak ($/year)
Less than 1 mm	12 724	$153
From 1 to 3 mm	64 415	$773
From 3 to 5 mm	235 267	$2823
Greater than 5 mm	623 476	$7482

Source: SEDA 2003
Assumptions: 700 kPa system operating for 4000 h/yr; electricity cost of 8 cents/kW h

Optimising air pressure

Air pressure should be kept to the minimum required for the end use application. Sometimes operating pressures are set high to meet the demand of just one or two items of equipment. It may be possible to redesign individual items of equipment to enable pressure reduction across the plant. Alternatively, determine whether it is cost-effective to use a second compressor to service these equipment items. Table 4.11 illustrates the cost and energy savings that can be made by reducing air pressure. Compressed air is an expensive medium and its use should be avoided for activities such as cleaning or drying, where other methods such as fans or blowers could be used. It is estimated that every 50 kPa increase in pressure increases energy use by 4% (SEDA 2003).

Table 4.11 **Cost and energy savings that can be made by reducing air pressure**

	Air pressure reduction							
	50 kPa		100 kPa		150 kPa		200 kPa	
Average load (kW)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)
4	320	26	640	52	960	78	1280	104
7.5	600	48	1200	96	1800	144	2400	192
11	875	70	1750	140	2625	210	3500	280
15	1195	96	2390	191	3583	287	4780	382
30	2390	191	4780	382	7170	574	9560	764
55	4380	350	8760	701	13 104	1048	17 520	1402
110	8760	701	17 520	1402	26 280	2102	35 040	2803

Source: SEAV 2002b

Assumptions: 700 kPa system operating for 2000 h each year; electricity tariff 8 cents/kW h

Reducing inlet air temperature

Up to 6% of a compressor's power can be saved by using cooler air (SEAV 2002). When the inlet air entering a compressor is cold, less energy is required to compress it. The air should also be clean, as clogged filters at the inlet will cause a drop in pressure, reducing compressor efficiency. It is estimated that every 3°C drop in inlet air temperature decreases electricity consumption by 1% (SEDA 2003). Compressed air systems should be well ventilated and any hot compressor room air ducted away, perhaps to a heat recovery system for space heating. Table 4.12 shows energy and cost savings that can be made by reducing the temperature of compressor intake air.

It is estimated that every 3°C drop in inlet air temperature decreases electricity consumption by 1%.

SEDA 2003

Table 4.12 Energy and cost savings from reducing the temperature of compressor inlet air

Reduction to intake air temperature								
	3°C		6°C		10°C		20°C	
Average load (kW)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)
4	80	6	160	13	264	21	528	42
7.5	150	12	300	24	495	40	990	79
15	300	24	600	48	990	79	1 980	158
30	600	48	1200	96	1 980	158	3 960	317
55	1100	88	2200	176	3 625	290	7 251	580
110	2200	176	4400	352	7 260	581	14 520	1162
160	3200	256	6400	512	10 550	844	21 100	1688

Source: SEAV 2002b

Assumptions: 700 kPa system operating for 2000 hours each year; electricity tariff 8 cents/kW h

Heat recovery from air compressors

As previously mentioned, as much as 80% of the energy used to operate an air compressor is lost as heat. There are heat recovery units available that will recover heat from both water- and air-cooled compressors. However, heat recovery units for water-cooled compressors are more efficient and can provide a more significant payback on capital outlay. The energy recovery system consists of a plate heat exchanger, which transfers heat from the compressor's lubricating oil to the water. This can heat water to up to 90°C and recover up to 70% of the compression heat without any adverse influence on the compressor performance. For example, a heat recovery unit for a 37 kW single-stage, oil-injected rotary screw compressor unit has the capacity to produce 36 L/min of 73°C hot water (Atlas Copco 2003).

4.4.3 Homogenisers

The control of homogeniser pressures, in particular pressure drop, will affect the efficiency of the homogeniser and the quality of the product. Confusion in terminology for measuring pressure (e.g. gauge, absolute and differential pressure) can lead to homogeniser pressure settings that are less than optimum. Once an optimal pressure control strategy is established and understood, the energy consumption of the homogeniser can also be calculated and incorporated into plant energy-management programs. These aspects are explained further in the DPEC publication *Homogeniser performance evaluation guide manual 1996/97* (DPEC 1996/97).

4.4.4 Motors

Selecting a motor

An electric motor uses 4–10 times its purchase price in electricity annually (AGO 2003b). When choosing a motor, it is therefore wise to consider the operating costs as well as the initial purchase price. High-efficiency motors cost up to 40% more than standard motors; however, energy savings quickly recover the extra cost, usually within two years. Table 4.13 illustrates the payback periods for motors with different ratings.

Table 4.13 Payback periods for purchasing high-efficiency motors

Motor rating	High efficiency 11 kW	Standard 11 kW	High efficiency 45 kW	Standard 45 kW
Efficiency (%)	92	88.5	94.6	93.1
Hours of operation per year	6000	6000	6000	6000
Average energy cost (cents/kW h)	10	10	10	10
Purchase price ($)	922	877	2390	1680
Annual operating cost ($)	7170	7450	28 541	29 032
Payback on premium	2 months		17 months	

Source: Teco Australia 2003

Sizing a motor

It is best to avoid purchasing oversized motors to cater for future production increases, either as insurance against motor failure or simply to override load fluctuations in the production processes. Motors that are oversized run with lower efficiency and power factor. If the load is constant, size the motor as closely as possible to the load, with a small safety margin. Table 4.14 illustrates savings to be made by replacing oversized motors with motors of the correct size to meet the load — for example in Case 1 the installation of a 3.7 kW motor which is 80% loaded, compared to 7.5 kW which is 40% loaded, saves $722/yr.

Table 4.14 Cost comparison for oversized motors

	Case 1: Motor size[a]		Case 2: Motor size[b]	
	7.5 kW (40% loaded)	3.7 kW (80% loaded)	110 kW (68% loaded)	75 kW (sized to match need)
Annual energy use (kW h)	17 813	8788	627 000	427 500
Annual energy cost (A$)	$1425	$703	$51 160	$34 200
Annual energy saving (A$)		**$722**		**$16 960**

Source: Adapted from US DOE 2004c

[a] Operating 2500 h/yr

[b] Operating 6000 h/yr

Assumption: electricity cost $0.08/kW h

Information on best practice in motor management can be found on the Australian Greenhouse Office 'Motor solutions online' website, <www.greenhouse.gov.au/motors/case-studies/index.html>. The site includes a checklist, self-assessment tool, case studies and technical guides.

Information on selecting the most suitable motor for different applications can be found on the US Office of Industrial Technologies Energy Efficiency and Renewable Energy website: *Motor selector software*, <www.oit.doe.gov/bestpractices/software_tools.shtml> and the US Department of Energy website: *Buying an energy efficient motor*, <www.oit.doe.gov/bestpractices/motors/factsheets/mc-0382.pd>.

Rewinding motors

Although failed motors can be rewound, it is often better to take the opportunity to replace the motor with an energy-efficient model. It is suggested that an energy-efficient model should be purchased in preference to rewinding when the motor is less than 30 kW and the cost of rewinding exceeds 65% of the cost of a new motor (US DOE 2004a).

Variable speed drives

Variable speed drives (VSDs) reduce energy consumption by adjusting the motor speed to continually match the load of equipment such as pumps, fans and compressors. VSDs are ideal for equipment that has to operate at variable loads or be oversized to cater for occasional high loads.

The energy consumed by fans and pumps is proportional to the cube of the motor speed. For example, if a VSD on a refrigeration compressor reduced its speed by 20% the power consumed would drop by 49%. The installation of VSDs can be financially viable, but depends on the motor application and operating hours. VSDs are most economically viable for large motors. Table 4.15 shows the potential savings through the installation of a VSD for a 5.5 kW and a 18.5 kW motor operating for 8000 h/yr. In these cases, the payback can be from 18 months to 2 years.

Table 4.15 Savings due to installation of variable speed drives

	Energy consumption 5.5 kW motor with no VSD	Energy consumption 5.5 kW motor with VSD	Energy consumption 18.5 kW motor with no VSD	Energy consumption 18.5 kW motor with VSD
Annual energy use (kW h)	44 000	35 200	148 000	118 400
Annual energy cost	$3520	$2816	$11 840	$9472
Annual energy saving	$704	$2368		
Cost of VSD		$1295		$3460
Payback		1.8 years		1.5 years

Source: Teco Australia 2003

Assumptions: 8000 operating hours per year; 20% reduction in energy consumption due to VSD; electricity cost $0.08/kW h

Variable speed drive on cooling tower fans: National Foods Ltd, Murray Bridge
National Foods in Murray Bridge installed variable speed (frequency) drives on the fan motors of the refrigeration system water cooling towers. The fan motors were not required to be run at all times. Savings in energy consumption resulted (but were not quantified). The modification needed to be performed during low demand for refrigeration so that production requirements were not disrupted.

4.4.5 Lighting

Around 4–6% of total electricity consumption is used for lighting in dairy processing plants (Kjaergaard-Jensen 1999). Different styles of lighting are available for different purposes, and they have varying efficiencies. Some types of lighting and their uses are listed below, from most to least energy-efficient (DSIR 2001b).

Low-pressure sodium: This is the most efficient type of lamp at present. It is most suited to exterior lighting and emits yellow light.

High-pressure sodium: These are not as energy-efficient as low-pressure sodium lights. They are suitable for internal and external use where colour rendition is not important.

Metal halide and mercury vapour: These are commonly used for high-bay factory lighting, and emit a bluish-white light. Metal halide is 25% more efficient than mercury vapour lighting. Two types of metal halide lighting are available — standard and pulse start. Pulse start lights are more efficient and start more quickly.

Fluorescent: These are the most efficient type for lighting small areas with low ceilings, or for task-level lighting. Fluorescent lights are available as a standard long lamp or in a compact style, which can be used as a direct replacement for incandescent lamps. The initial cost is higher, but the lamps use one-fifth the electricity and last up to 10 times as long.

Standard 40 W fluorescent tubes can be replaced with 36 W high-density tri-phosphor tubes, which are 20% more efficient and produce 15% more light.

Tungsten halogen lamps: These lamps are cheap to purchase but have high operating costs. They are useful for floodlighting.

Miniature dichroic down lights: These are often used in reception areas and restaurants. Their energy efficiency is inferior to that of fluorescent lights and they should be avoided if energy consumption is a priority.

Incandescent lamps: These are the least efficient, and although they have a low purchase cost they will end up costing more in the long run because of higher operating costs and lower product life.

Table 4.16 **Comparison of different types of lighting**

	Incandescent	Tungsten 240 V	Halogen 6–12 V	Fluorescent	Metal halide	Sodium colour-improved
Capital cost	Cheap	Low	Low/ medium	Low/ medium	High	High
Relative operating costs	High	High	Medium	Low	Very low	Medium
Luminous efficacy	10–20	22	30–50	Up to 70	60–115	40–44
Wattage (lm/W)	15–1500	50–2000	10–75	8–36	35–3500	35–3500
Average life (h)	1000	2000	2000–45 000	8000–10 000	6000-8000	12 000–15 000
Depreciation	Light output falls 15% throughout life	Very little	Very little	<15–20%	45%	<15%

Source: Adapted from SEAV 2003c

Lighting use, design and maintenance

While lighting may only be a small component of a dairy plant's total energy costs, savings can often be made at little or no cost. For example, significant savings can often be made by simply turning off lights in areas that are not in use and making better use of daylight. Opportunities for reducing lighting costs include:

- locating lights at task level so they direct light where it is required instead of lighting up a large area
- segregating light switches so banks of lights can be turned off when not in use without affecting other areas
- using natural lighting such as skylights instead of electric lighting
- installing occupancy sensors to automatically turn off lighting in inactive areas
- regularly cleaning light fittings, reflectors and diffusers
- installing photoelectric sensors — to measure natural light so that lights can be adjusted accordingly, and to control security lighting
- installing auto or step dimmers that can effectively reduce the total energy consumed by the lighting system by 20–30%
- painting walls and floors in light colours.

Queensland Environmental Protection Agency

Fluorescent lamps are the most efficient type for lighting small areas with low ceilings, or for task-level lighting. The initial cost is higher, but the lamps use one-fifth the electricity and last up to 10 times as long.

Warehouse lighting rationalisation: Bonlac Foods, Spreyton
Bonlac's warehouse and cool-store complex in Spreyton was built in 1997 with most external lighting on a single switch circuit. The complex was lit continuously, wasting energy. The switching was rearranged to allow minimal lighting to be used for security at night. The cost of implementation was $7200 and savings are estimated at $11 900/yr.

4.4.6 Air-conditioning and air-handling systems

Air-conditioning and cooling systems are important in dairy processing plants for generating a cool or chilled processing environment that contributes to the quality of the final product. The two main types of cooling methods for air conditioners are direct expansion and chilled water.

Direct expansion

A direct expansion air conditioner operates on the same principles as a vapour compression refrigerator and has the same basic components. The air conditioner cools with an evaporator coil, while the condenser releases collected heat outside. The refrigerant evaporates in the evaporator coil and draws heat out of the air, causing the inside temperature to drop. The refrigerant then liquefies in the condenser coil and releases this heat. The refrigerant is pumped between the two coils by a compressor. Air or water from a cooling tower, for example, may be used as the heat sink.

Chilled water

The second type of air-conditioning system cools with water chilled to around 5–7°C. The chiller is usually located separately and the water piped throughout the plant to individual units.

Systems also have humidifiers or dehumidifiers to add or remove moisture to or from the air, and filters to clean the air. All air conditioners also have control systems with varying levels of sophistication to maintain temperature and humidity.

Choosing energy-efficient systems

Selection of an air-conditioning system should not be based on price alone. While energy-efficient models may have higher initial costs, such a system will usually pay for itself several times over in saved operating costs during its lifetime. Energy efficiency will depend not only on choosing a system that produces as much cooling per hour as possible for every watt of power it draws, but also on correctly sizing the system. An undersized system will be overworked and will not meet the plant's needs. An oversized system, on the other hand, as well as being more expensive initially, will cycle on and off more frequently and make the system less efficient.

Economy air cycles are a good way of reducing energy use in air-conditioning systems, particularly in cooler regions. Economy air cycles take advantage of outside air temperatures, reducing the use of energy for cooling.

Other opportunities for reducing the operating cost of an air-conditioning system include:

- selecting a system based on the accurate sizing of your plant's cooling requirements (Some contractors use specifically designed software to determine the best size, the number and size of ducts, and the dehumidification capacity of the system.)
- ensuring the system is accessible for cleaning and maintenance so that components such as filters, coils, ducts, fins, refrigerant, compressor and thermostats can be easily maintained and leaks repaired
- investigating cooling using off-peak tariffs
- ensuring thermostats are set to the optimum setting and installed away from heat sources
- operating the system only when necessary — use an energy monitoring and control system to control temperatures in different areas of the factory
- investigating the benefits of floor, wall and roof insulation — look at possibilities for using blinds, reflective film, eaves and vegetation
- insulating ducting and pipes, and if possible keeping ducts within the air-conditioned space
- investigating the use of evaporative coolers if climatic conditions are suitable.

4.5 Heat recovery

There are many opportunities for recovering heat in dairy processing plants; however, the feasibility of implementing such systems depends on the location of the heat source in relation to the potential area of use, the capital cost of heat recovery equipment, and the potential energy savings. In addition to the commonly used regenerative pasteurisers and sterilisers, examples of heat recovery opportunities in dairy processing plants include from heated whey during cheese processing to preheat incoming milk, from boiler flue gases, boiler blowdown and condensate recovery systems and from the heated air from spray dryers. The potential for heat recovery from evaporator condensate varies with the type and efficiency of the evaporator. For example, evaporators using mechanical vapour recompression are more energy-efficient than those with thermal vapour compression (see section 4.3.1), recovering excess heat and producing a cooler condensate (around 15°C, compared to around 60°C) (Peter Gross 2004, pers. comm.).

4.5.1 Pinch technology

A strategic method for looking at the opportunities for heat recovery is through a procedure known as 'pinch technology'. This involves analysing the heating or cooling requirements of various process streams and matching these requirements to determine the minimum amount of heat energy input into a system. The document *Introduction to pinch technology* by Linhoff March has further information and can be downloaded at <http://www.linnhoffmarch.com/pdfs/PinchIntro.pdf> (Linhoff March 1998).

4.5.2 Stratified storage tanks

A number of cheese-manufacturing plants have installed stratified storage tanks to recover heat from whey produced during cheese-making to pre-heat raw milk. Heat recovered from whey produces heated water (via heat exchange), which is then stored in a purpose-built storage tank. When required for pre-heating of raw milk, the heated water is drawn out of the storage tank, used to pre-heat the milk and returned to the same tank as cooled water. The cooled water is then stored for several hours until required for cooling the whey. The stratified tank has no physical barrier between the cool and heated layers of water and is designed to prevent excessive mixing during removal and filling of water. Further information can be found in the January 1997 issue of the *DPEC Newsletter* (DPEC 1997).

4.5.3 Improving the efficiency of pasteurisers and sterilisers

Pasteurisers and sterilisers use a regenerative heat exchange process, which recovers heat from hot pasteurised milk to pre-heat incoming chilled milk. Regeneration ratios can be calculated to determine the efficiency of the pasteuriser; this is shown in the UK publication *Reducing energy costs in dairies* (ETSU 1998).

Heat recovery from flared biogas: Murray Goulburn Cooperative, Leitchville
Murray Goulburn in Leitchville anaerobically digests wastewater, producing biogas which is flared to atmosphere. A suggested project is to recover heat from the flare to warm wastewater to an optimum temperature for digestion. Digestion currently occurs at 26–33.5°C, depending on the time of year and source of effluent. The optimum temperature, however, is 35–36°C because a temperature above 32°C is necessary to help emulsify long-chain fatty acids.

Stratified storage tank and heat recovery from wastewater: Murray Goulburn Cooperative, Leitchville
Murray Goulburn in Leitchville reclaims heat from its warm whey through a water medium. The water is then pumped into the bottom of a 200 000 L hot water bank. The hot water in the tank is transferred from the top of the tank for the pre-heat of the pasteuriser. The cost of implementation consisted of labour costs for programming and optimising several cascade loops. The system maintains cold whey temperatures for the whole day and has improved the performance of the membrane plant. The processing plant also recovers heat from its cleaning wastewater that cannot otherwise be recycled or reused. The heat reclaimed from the wastewater is used to heat incoming mains water, which will then be used in processing.

Heat recovery from cheese whey: Bonlac Foods, Wynyard
Bonlac Foods in Wynyard comprises a large cheese factory integrated with membrane filtration plants producing whey protein concentrate (for drying) and permeate concentrates. A recirculating water system was installed to use waste heat from cheese whey at 38°C to preheat incoming raw milk before it is pasteurised. The system includes a stratified storage tank to handle the time lapse between energy demand and supply. The system design was combined with plant upgrades to install a cold ultrafiltration (UF) system and increased refrigeration capacity. Overall heat savings were sufficient to shut down the second of two boilers previously used to supply steam. (Note: these savings included those derived from the change from hot to cold UF and must be offset against increased refrigeration loads.)

Heat recovery and reduction in steam usage: Dairy Farmers, Mount Gambier
Dairy Farmers in Mount Gambier reduced steam usage by removing the steam barrier on the homogeniser. The steam barrier was not required because the equipment was operated in non-aseptic mode. Some thermal energy was also saved by returning hot condensate to the feedwater tank for reuse. The project reduced energy costs by $4500 per year and made further savings of $12 500/yr by extending the life of the seals on the homogeniser.

Heat recovery from refrigeration compressors: National Foods Ltd, Penrith
National Foods in Penrith recover heat from the refrigeration compressors to pre-heat site process water. The system allows water used for cleaning to be heated to 50°C. Heated water for hosing was previously provided by a boiler.

Heat recovery from ammonia refrigeration system: Peters and Brownes Foods, Roxburgh
Peter and Brownes Foods in Roxburgh is investigating heat recovery from its ammonia refrigeration system to supply the ice-cream hot water boilers. The system will recover heat from superheated ammonia vapour (ammonia that is heated above its evaporating temperature). It is expected to save $20 000/yr in gas usage for hot water. The capital cost for the system is expected to be $50 000.

4.6 Alternative sources of energy

4.6.1 Biofuels

Biofuels are organic waste streams that have a useful energy and/or nutrient content and can be used as fuel sources to produce energy. Potential biofuels produced by dairy processing plants are methane gas from anaerobic digesters and sludge from wastewater treatment processes or separators. Sludge produced from dairy processing plants, however, is more commonly used as compost or fertiliser or as stockfeed.

Anaerobic digestion and the utilisation of methane as a biofuel is an opportunity that could be explored further by the Australian dairy processing industry, but to date there are few examples of its successful implementation. Table 4.17 gives an example of methane and energy yields from anaerobic digestion at an ice-cream plant in Minto, New South Wales. Prerequisites for the successful use of biogas include ensuring:

- all moisture is removed from the biogas
- the biogas is compatible with the boiler components to avoid corrosion
- the gas is always available at the correct pressure
- there is adequate buffering
- there are no potential toxins discharging into the wastewater system that will affect anaerobic digestion and biogas production.

Table 4.17 Sample methane and energy yields from biogas digestion for an ice-cream factory in New South Wales

	Low-rate digestion of effluent (lagoon digester)
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	$324/day @ $12/GJ

Source: UNEP Working Group for Cleaner Production 1999

Anaerobic digestion of food-processing wastewater produces biogas that may be able to supplement your plant's thermal energy requirements.

Utilisation of biogas: Warrnambool Cheese and Butter, Allansford

Warrnambool Cheese and Butter in Allansford installed an anaerobic digester in 1993 to recover biogas for use as a fuel source in their boilers. The project was only moderately successful, due to problems encountered with maintaining a constant gas supply pressure to the boilers and the presence of moisture in the gas. The biogas was not refined in any way, and it caused excessive corrosion in the boiler combustion chamber. The use of the biogas was suspended in July 2003 pending further investigation and improvements to the operation. But it has the potential to provide 80–100% of the energy requirements for the production of hot water at the site and save $290 000/yr.

Anaerobic wastewater treatment in a whey processing company: Borculo Whey Products, The Netherlands[1]

Borculo Whey Products previously had an aerobic wastewater treatment plant that used substantial amounts of electricity and produced large amounts of sludge. The system required upgrading and was replaced with a more energy-efficient anaerobic treatment system — an upflow anaerobic sludge blanket (UASB). The new system reduced energy demand for aeration by 930 750 kW h/yr and reduced energy demand for treatment and transport of sludge by 25 000 MW h/yr. Methane was also used in the manufacturing process, which reduced natural gas consumption by 700 000 m^3/yr. The total cost of the anaerobic treatment plant was US$1.8 million, with total savings in electricity, sludge handling and chemical treatment costs of US$508 000/yr. The payback period for the total investment was 3.5 years.

Gas fuel for boilers from anaerobic digestion of food waste: fruit and vegetable processor, Australia[2]

The up-flow anaerobic sludge-bed (UASB) effluent treatment system at Golden Circle produces usable biogas as one of its by-products. The effluent system treats wastewater from fruit and vegetable processing. The biogas is collected in the UASB reactors and compressed, and pumped to a gas-fired boiler to supplement the existing coal-fired boilers. Golden Circle collects and burns approximately 2.5 million m^3 of biogas per year, saving $100 000/yr in coal costs. This will improve further when the company's gas storage capacity is increased.

[1] CADDET 1996b

[2] UNEP Working Group for Cleaner Production 2004

4.6.2 Solar energy

Solar energy can be used to produce power (via photovoltaic cells) or as a source of thermal energy. There is virtually no use of solar technology in dairy processing plants to date. This is partly due to the relatively high capital cost of installation, but also because some processing plants, particularly those that produce powdered products, already have an adequate supply of thermal energy in the form of condensate water.

An advantage of solar heating systems is that, although they can have high initial costs, operating costs are low if they are well designed and properly installed and maintained. Dairy processing plants have large amounts of roof space that could be utilised for solar collectors. Possible uses of solar heat energy are to pre-heat boiler feedwater or hot water for cleaning.

Savings from pre-heating water using solar power: Zane Australia
Zane Australia uses around 100 kL of 80°C hot water daily for general cleaning and processing. The cost of heating 100 kL of water from ambient temperature to 80°C using steam is around \$80 000/yr. If a solar heating system were used to preheat the water from ambient temperature to 50–60°C, the cost of steam heating would be reduced by \$44 600. A suitable solar heating system similar to those used to heat swimming pools would cost \$120 000 to install. The solar absorber uses a low-pressure (50 kPa) unglazed solar absorber collection system to supply heating to a water reservoir stored in an insulated tank. Such a system would require a roof area of 1000 m^2. The payback period would be 2.7 years.[1]

[1] Ross Hamilton 2003, pers. comm.

4.6.3 Wind energy

Wind generators are a possible future source of alternative energy for those companies that have a constant source of 'clean wind' (i.e. wind coming from a constant direction and not made turbulent by nearby obstacles). In Australia the industry is growing, with current generating capacity enough to provide power requirements for 83 000 homes. Currently there are more than 2800 MW of wind generators in planning, enough for over half a million households, and worth \$5 billion in investment. Wind energy costs about 7.5 cents/kW h to generate, and costs continue to fall at around 4%/yr (AusWEA 2004). For Australian dairy processors, as for most large manufacturers, wind power is cost-prohibitive compared to traditional sources of power (i.e. coal-fired power generation), and to date wind generators have not been used. Possible environmental constraints to using wind power include noise and effect on visual amenity. Further information can be found at the Australian Wind Energy Association website, <www.auswea.com.au>.

Wind generator: dairy processor, UK[1]
Longley Dairy in West Yorkshire, UK installed a wind generator in 1986 which generated approximately 9% of the dairy's electricity demand. Base load demand for electricity at the dairy is 230 kW and peak demand is 1420 kW, rising to 1500 kW in hot weather. The system consists of a 23 m tower with a three-blade rotor of 17 m diameter with two 18 kW and 90 kW generators. The small generator begins to produce electricity at wind speeds of 3 m/s and the large one at 5 m/s. Rated output is at 12 m/s and the average wind speed at the site is 8 m/s. Electricity is generated at 415 V, eliminating the need for a transformer. The capital cost of the system was UK£50 000 (1986 prices) including construction and installation, and the payback period for the project was 6 years. Annual operating costs are minimal and routine maintenance is carried out every 3 months for about 2 hours.

[1] CADDET 1997

4.7 Cogeneration

Cogeneration or combined heat and power (CHP) systems use a single source of fuel to produce both electrical and thermal energy. The main advantage of a cogeneration system is the overall system efficiency, which can be as high as 80%. In contrast, the conversion efficiency of a conventional power station producing only power is only about 36%, with the remainder lost as unrecovered heat. It has been demonstrated that cogeneration results in a 20–30% reduction in energy costs with payback period of 2–4 years and reductions in CO_2 emissions of 50% (Kjaergaard-Jensen 1999). Upfront capital cost, labour and operational costs are recovered by savings on energy prices. Cogeneration plants that produce power in excess of factory requirements can export the power to the grid.

4.7.1 Types of cogeneration

There are three main application opportunities for cogeneration:

Steam turbines require a source of high-pressure steam to produce electricity and are mostly used when electricity demand is greater than 1 MW.

Gas turbines produce electricity while also providing a heat source suitable for applications requiring high-pressure steam. They can be used for smaller-capacity systems (from a fraction of a megawatt) and provide the flexibility of intermittent operation.

Reciprocating engines can be operated as cogeneration systems by recovering the heat from the engine exhaust and jacket coolant. Approximately 70–80% of fuel energy input is converted to heat that can be recovered to produce hot water up to around 100°C, or low-pressure stream.

Gas turbines have been used in New Zealand dairy processing plants such as those at Te Rapa, Te Awamutu and Hawera, which are owned by Fonterra.

4.7.2 Applicability of cogeneration to the dairy processing industry

The purpose of cogeneration is to produce electricity and heat together at a specific site more cheaply than they can be produced separately. Small-scale cogeneration plants, which could be used by dairy processors, compete with retail electricity prices; however, electricity and gas prices greatly affect the economic viability of a cogeneration plant. For a typical multi-product dairy manufacturing plant in Australia, greenhouse gas emissions could be reduced by 30–40% by adopting cogeneration technology (Lunde et al. 2003).

The Business Council for Sustainable Energy's *Cogeneration ready reckoner* is available on the BCSE website (BCSE 2003a), and provides a straightforward way of calculating a potential plant's economic viability.

Both third-party ownership and sophisticated financing are available in an 'energy performance contract', whereby a third party takes the risk of the project and is refinanced through the energy savings; this may make certain projects more economic or operationally attractive. Capital funding for non-renewable projects is also available through the Greenhouse Gas Abatement Program, offered by the Australian Greenhouse Office for larger projects and administered through the BCSE for smaller projects. The Mandated Renewable Energy Project provides financial incentives for renewable cogeneration. The BCSE *Guide for connection of embedded generation in the national electricity market*, available on the BCSE website, gives an overview of the connection process (BCSE 2003b).

5 Yield optimisation and product recovery

5.1 Overview

Efficiency in the utilisation of raw materials to optimise product yield is an important aspect of eco-efficiency and has the greatest scope for financial and environmental savings. Materials such as raw or pasteurised milk, cheese or whey, and components of milk such as fat, lactose and protein can be lost from the process and end up in the wastewater or solid waste stream. These losses are a waste of resources that could otherwise be recovered as products or co-products. They also contribute to the pollutant load of the wastewater stream, resulting in increased treatment and disposal costs.

This section discusses opportunities to reduce waste in dairy manufacturing processes, hence helping to optimise yield and efficiently utilise raw materials. These initiatives can lead to the multiple benefits of reduced volumes of solid waste, reduced pollutant loads in wastewater and increased yields of saleable products.

5.1.1 Sources of product loss

Sources of product loss in dairy processing plants are summarised in Table 5.1. Some sources of loss are unavoidable or inherent due to equipment design (e.g. separator de-sludge), while others may be due to poor operating procedures or process control. Opportunities to minimise loss are discussed throughout the chapter.

Table 5.1 Sources of product loss in dairy processing plants

Dairy product	Area of potential product loss	Waste stream
Common to all	Tankers, tanks and pipelines not sufficiently drained before cleaning	Wastewater
	Loss during cleaning, product changeovers, start-up and shutdown	Wastewater
	Spills due to frothing or poor process control	Wastewater
	Production capacity problems or production stoppages causing operating equipment to be drained of product	Wastewater/ solid waste
	Leaks (e.g. filling machine heads)	Wastewater
	Reject product including in process and returned final product	Wastewater/ solid waste
	Variations in raw materials or packaging	Wastewater/ solid waste
	Separator de-sludge	Solid waste
	Filling or packing machine inefficiencies (e.g. overfills, underfills)	Wastewater/ solid waste
Market milk	As above	
Cheese and whey	Curd adhering to processing equipment (e.g. cheddaring machines, knives)	Solid waste
	Cheese fines and milk fat loss to whey	Loss to whey stream
Powdered products	Entrainment of liquid feed in evaporators to condensate	Wastewater
	Entrainment of powder fines in spray dryer exhaust	Solid waste
	Product deposition on heated surfaces	Wastewater
Yoghurts and dairy desserts	Residue on processing equipment due to high viscosity	Wastewater

5.1.2 The cost of lost product

The true cost of waste product consists not only of raw material costs but also the cost of processing (heating, pasteurising, cooling, pumping); labour costs involved with re-testing, storage and handling; the cost of wasted packaging, and of wastewater treatment; and discharge or solid waste disposal costs. However, there are opportunities for substantial savings on the cost of raw ingredients alone, as explained below.

Table 5.2 shows typical wastewater characteristics from a number of recent reports, as well as survey data collected by the UNEP Working Group for Cleaner Production for this project. Project data for BOD_5, COD and SS are comparable to, if not lower than, those quoted in recent literature. For example, BOD_5 from Plant B ranges from 2400 mg/L to 9600 mg/L, compared with a range of 1200–2678 mg/L from survey data.

Table 5.2 **Indicative wastewater characteristics from dairy processing plants**

Wastewater characteristics pre-treatment	Plant A[a] Powder/ butter	Plant B[b] Powder/ butter	Plant C[c] Cheese/ casein	Project survey data range	Project survey average
Volume (ML/yr)	–	–	–	87–1206	500
BOD_5 (mg/L)	1300	2400–9600	8000	1200–2678	2036
COD (mg/L)	–	4200–9100	–	600–5718	3812
SS (mg/L)	490	720–5300	–	55–1377	730
TKN mg/L	93	77–280	200	–	–
pH	> 11	8.0–11	4.5–6	–	–
Total P (mg/L)	25	20–110	100	–	–

Sources: [a] Mosse & Rawlinson 1998
[b] Morgan 1999
[c] Barnett (1994) cited by Jones et al. 2002

From Morgan (1999), a mass balance calculation on milk solids loss to wastewater is defined as:

$$Q\ \text{milk} = \frac{Q \times B}{B_{milk}}$$

Where: Q_{milk} = milk lost per year (ML/yr)

Q = total flow to treatment (ML/yr)

B = milk attributed BOD load to treatment (mg/L BOD_5)

B_{milk} = BOD strength of milk (mg/L BOD_5)

Assuming a BOD_5 strength for undiluted milk of 100 000 mg/L, a wastewater flow of 500 ML/yr and a typical BOD_5 of untreated waste of 2000 mg/L (Table 5.1), the volume of lost milk to the waste stream is 10 ML/yr. For an indicative cost of \$0.25–0.50/L per litre of milk, this equates to milk losses of \$2.5–5 million per year. Even a 5–10% improvement in yields can therefore lead to substantial savings of hundreds of thousands of dollars.

A UK publication (Envirowise 1999b) suggests that the flow of wastewater from a dairy processing plant, where milk is the main product, should be less than 1 m^3/t of milk processed or 1 L/L (assuming milk density of 1 kg/L). Table 5.3 shows the wastewater to raw milk intake ratio from survey data for this project. The data indicates that wastewater flow per tonne of milk for a market milk processor ranges from 0.96 to 2.43 L/L milk processed, with an average of 1.60 L/L processed, suggesting there is opportunity for improvement in reducing wastewater volumes in Australia plants that produce mainly market milk.[1]

[1] Ratio converts to kL/t, assuming milk density of 1000 g/L

The same UK publication suggests that COD levels in market milk plants should be less than 3.8 kg/t milk processed with 1.5 kg COD/t of milk achievable, while for cheese and butter production COD should be less than 3 kg/t of product. Insufficient data was available to compare the Australian COD load with the UK benchmark.

Table 5.3 **Wastewater to milk ratio (L/L)**

Wastewater to milk ratio	Min.	Max.	Average	No. of plants providing data
Milk only	0.96	2.43	1.60	6
Cheese and whey products	1.22	2.35	1.78	3
Powders	0.66	2.47	1.62	9

Trade waste discharge costs

Trade waste (wastewater) discharge costs vary significantly according to the region and charging structure of the receiving authority. Most local councils or water authorities have adopted a 'user pays' charging structure where customers must pay for the volume and quality of the wastewater discharged, thereby contributing to the operating (and sometimes capital) costs of the waste treatment facilities. As previously mentioned, a high wastewater load represents a loss of valuable product, which is also paid for in discharge fees. Table 5.4 shows the trade waste discharge costs for a number of local councils that host dairy processing plants. The charges are for the highest category of trade waste (i.e. relatively high-strength and high-volume waste that is typically produced by dairy processors). Table 5.5 compares the cost of discharge in the different regions, based on an assumed wastewater volume and quality. The BOD and SS charge typically make up the highest proportion of the total charge. Total effluent charges can vary by as much as 300%, depending on the overall discharge costs for each region.

Table 5.4 **Trade waste charges in various regions[a]**

Wastewater load	Brisbane Water	Ipswich Water	Sydney Water	Gippsland Water	Goulburn Valley Water	Devonport City Council
Volume	$0.43/kL	$0.93/kL	$1.12/kL	Average $1.10/kL[b]	$0.34/kL	$0.237/kL
BOD_5	$1.14/kg	$1.15/kg	$0.099 + ($0.0166 × BOD/600)/kg	–	$0.075/kg	$0.531/kg
SS	$0.48/kg	$0.76/kg	$0.71/kg	–	–	$0.132/kg
Nitrogen	$0.43/kg	$0.80/kg	$0.14/kg	–	$0.37/kg	–
Phosphorus	$0.71/kg	$3.00/kg	$1.11/kg	–	$0.84/kg	–
Grease	–	–	$1.00/kg	–	–	$3.07/kg
Sodium	–	–	–	–	$0.47/kg	–

[a] As at July 2004

[b] Incorporates quality charges

Table 5.5 **Comparison of trade waste charges for Plant A[a]**

Wastewater characteristic	Assumed load	Brisbane Water ($/day)	Ipswich Water ($/day)[b]	Sydney Water ($/day)[b]	Gippsland Water ($/day)	Goulburn Valley Water ($/day)	Devonport City Council
Volume	1 ML/day	430	930	1120	1100	340	237
BOD_5	2000 mg/L	2280	1955	262	–	150	1062
SS	500 mg/L	240	152	213	–	–	66
Nitrogen	100 mg/L	43	32	7	–	37	–
Phosphorus	100 mg/L	71	255	100	–	84	–
Grease	500 mg/L	–	–	450	–	–	1535
Sodium	500 mg/L	–	–	–	–	235	
Total charge for Plant A		**$3064**	**$3294**	**$2152**	**$1100**	**$846**	**$2900**

[a] Based on council charge, June 2004

[b] Costs take into account domestic allowances limits

5.1.3 Further reading

Publications with comprehensive information on wastewater management, waste minimisation and product recovery include:

- *Milk processing effluent stream characterisation and utilisation* (Morgan 1999)
- *Sources of wastage in the dairy industry* (Hale et al. 2003)
- *Recovery of milk constituents from cleaning solutions used in the dairy industry* (Houlihan et al. 1999)
- *Environmental management tools for the dairy processing industry* (Jones et al. 2002).

These reports discuss product loss prevention for various dairy processing operations. Opportunities discussed in the reports include:

- design of processing plant
- waste characterisation
- optimisation of cleaning systems
- recovery of fat from cream, butter streams and buttermilk
- optimisation of product yield in milk, butter, cheese, powder and whey processing
- waste minimisation in evaporation and spray drying.

This chapter does not attempt to 'reinvent the wheel', and therefore does not provide detailed discussion of aspects that have been covered in past publications. Instead, it gives examples of waste minimisation and yield optimisation carried out by Australian dairy processors, and refers to past publications where appropriate.

5.2 Waste minimisation

An effective waste minimisation program will decrease the load on a wastewater treatment plant, reduce solid organic waste and lead to increased product yield and savings in energy, chemicals, water and possibly labour. In the case of wastewater, it has been found that losses indicated by product mass balances are much less than those determined from wastewater analysis. For example, tests by Harper and co-workers gave an average loss of 5.4% (from analysis of wastewater streams), whereas plant records showed losses of 1.4% (Harper et al. 1971, as cited in Houlihan et al. 1999). The accurate measurement of wastewater volumes and loads will therefore provide a more comprehensive picture of where losses are occurring, and this is one of the first steps in a waste minimisation program. Important steps in waste minimisation are to:

- determine the sources of wastewater
- locate or install effluent meters and sampling points to determine the volume and pollutant load of the plant's wastewater

- regularly monitor the volume and load of wastewater and set up a system for data processing and reporting
- identify opportunities for improvement
- implement the opportunities
- monitor performance.

A comprehensive approach to waste minimisation is covered in the publication *Environmental management tools for the dairy processing industry* (Jones et al. 2002).

Separating wastewater streams on the basis of quality can also reduce the load on wastewater treatment systems, and give opportunities for reuse that would not arise if the streams were combined (e.g. separating whey streams for further treatment).

Daily monitoring of loss: Murray Goulburn, Maffra
Murray Goulburn in Maffra uses the daily production meeting to discuss product loss/yield results. For significant incidents a loss declaration form is completed and followed up. This has raised awareness of product yield, and product losses have decreased over the past few years.

Reducing effluent during cheese-making: Bonlac Foods, Cororooke
An alternative to wet pre-stretcher salting of mozzarella cheese was investigated at Bonlac in Cororooke. A commercial dry salt application system for mozzarella post-stretching was purchased and trialled, with the aim of eliminating or at least reducing the effluent stream from pre-salting. It was found that the product made by the dry salt method did not have the required body characteristics and often contained pockets of undissolved salt. Trials on the new system were therefore abandoned.

5.3 Improving plant layout and design

Waste can be generated as a result of poorly designed processes or processing equipment. Plants should be designed to have a direct and logical flow of materials and processes. Waste should not be accepted as normal practice, and each process step should be designed to keep waste at an absolute minimum. The relocation or modification of existing factories provides a good opportunity to consider possible sources of waste and how they can be eliminated or reduced. Areas of waste in dairy processing plants identified by Houlihan and co-workers (1999) include insufficient sloping of pipes, installation of pumps in a configuration that does not facilitate complete drainage, and failure to allow adequate drainage time for equipment.

It is also good practice to consider the potential for generating waste when selecting new equipment (e.g. ease of cleaning), and this can be included in plant selection or modification criteria.

Environmental criteria for new installations: Murray Goulburn, Maffra
Murray Goulburn in Maffra, in conjunction with its formal economic and technical evaluations of new plants, also considers environmental issues for all new installations — for example, expected water consumption and how it can be minimised.

5.4 Efficient processing and process control

Waste can occur through poor process control, such as overfilling of tanks during processing or inadequate detection of product interfaces. The use of improved and more reliable instrumentation to detect product interfaces, such as conductivity or turbidity meters, is helping the dairy industry to reduce product waste and increase yields.

The reports *Milk processing effluent stream characterisation and utilisation* (Morgan 1999) and *Sources of wastage in the dairy industry* (Hale et al. 2003) review the types of instrumentation that are currently available for measuring and characterising waste. Also discussed is the importance of calibration. The Morgan report suggests that the most appropriate instrumentation for waste characterisation for a dairy processing plant (Bonlac Foods, Cobden) consists of (a) a self-cleaning light absorption turbidity meter for quick responses to changes in milk solids concentration, and (b) a combination of temperature, pH and conductivity meters to monitor CIP frequency and effectiveness, and chemical loss. The report also suggests the use of closed-circuit television on main effluent streams; this has been adopted by many Australian dairy processors, along with audible factory alarms to notify operators of abnormal waste flows.

The use of online instrumentation for measuring components such as phosphorus, nitrogen, fat, protein, BOD and COD has great potential for improving product yields. Instrumentation that is being developed includes near-infrared spectrophotometry and UV extinction, also known as nephelometry or turbidimetry (Hannemann 2003; Morgan 1999). Inline fat and protein monitoring systems that can monitor and control the composition of powders by measuring the viscosity of concentrated feed milk are being developed. The monitors allow for improved quality control, reduced product loss and better energy utilisation (Callaghan 1998).

A challenge that comes with reliance on process control systems — particularly operator interface units — is that operators can be unfamiliar with the practical operation of the plant to the extent that pumps, pipelines or valves cannot be physically identified or located. This should be taken into consideration when operators are trained, to increase their skills in troubleshooting operational problems.

Advanced process control

Advanced process control systems use sophisticated software to fine-tune operating processes, using such elements as feed-forward or cascade control schemes; time-delay compensators; self-tuning or adaptive algorithms; or optimisation strategies (Willis and Tham 2004). The end result is to increase product yield by increasing process stability and reducing product variability, with the additional benefits of reducing energy consumption and process wastes. Dairy processors have used advanced process control systems to fine-tune the operation of equipment including pasteurisers, dryers and evaporators.

Silo emptying matrix: Bonlac Foods, Cobden
Bonlac in Cobden is developing a silo emptying matrix that allows some silos and pipelines to be emptied completely. The use of the matrix is expected to improve product yields by reducing loss to wastewater during cleaning.

Effluent stream alarm: Murray Goulburn, Maffra
Murray Goulburn uses a probe to measure the turbidity of the effluent stream, which sets off an alarm on a pager carried by production supervisors when set points are exceeded, alerting them to potential product losses to drain.

Advanced process control: Murray Goulburn, Koroit[1]
Murray Goulburn in Koroit and Predictive Control Pty Ltd undertook a project in 2000 to examine the potential for advanced process control (APC) technology to enhance the operation of evaporators and spray dryers. The technology involved using model predictive controllers for integrative control to keep the process achieving its maximum potential. The system consisted of an evaporative controller, a dryer outlet temperature controller, a dryer moisture controller and an optimiser to coordinate the evaporator and dryer. Constant maximum evaporation was achieved by manipulating the evaporator feed rate, taking into consideration the concentrate tank level and dryer feed rate. The results of the project indicated that, for a 70 000 L/h evaporator, there was potential to increase powder production capacity by 3%, equating to savings of $491 000/yr for a project cost of $192 000 and a yearly support contract of $20 000. Additional savings in energy costs were not quantified.

[1] Mackay 2002

5.5 Milk receival, initial processing and storage

Waste can occur during the receival and initial processing stages if tankers and pipelines are not properly drained, due to poor equipment design or simply to insufficient time. To minimise the chance of spillage or leakage, tankers should be completely drained before the product hose is disconnected. Hoses should also be completely drained so that spills do not occur, and facilities should be installed to collect spillages (Hale et al. 2003). Loss of raw milk can accidentally occur during tank filling and storage due to overfilling of tanks, foaming, or inadequate drainage of tanks and lines before they are cleaned. A suitable monitoring and control system can overcome this and help prevent product loss from tank overfilling (high level) or foam formation (agitation during low tank levels).

Tankers should not stand for more than an hour before being unloaded; otherwise creaming occurs, which leads to losses of product during rinsing and cleaning. Once creaming occurs it is very difficult to stop the milk fat adhering to the side of the tank, even with extensive agitation (Hale et al. 2003).

Use of isolating valves: National Foods, Salisbury
National Foods in Salisbury installed extra valves to isolate the lines between each of its three silos, to stop the lines filling when milk was being unloaded into individual silos. Without the isolation valves the milk in these lines was being lost to drain when water purging took place. The cost of implementation was $15 000, with a payback period of only 3 months.

5.6 Minimising product waste during processing

5.6.1 Optimising start-up and shutdown procedures and changeovers

There are waste-reduction opportunities in improving start-up and shutdown procedures, by fine-tuning timers and accurately detecting product interfaces (as discussed in section 5.4). Start-up times, in particular, have the most potential for loss because operating processes have not reached a stable mode. Procedures to accommodate unexpected shutdowns (e.g. due to loss of power or steam) will also minimise the potential for loss.

Reclaim system for power loss: Murray Goulburn, Koroit
Murray Goulburn in Koroit installed a product reclaim system for site evaporators that reduces losses during major power flicks and boiler failures. Additional storage was provided, so that product that does not meet specification can be stored and fed back into the system once it is back online. The initiative saves $50 000/yr, with a payback period of 2 years.

Fine-tuning start-up and shutdown: National Foods, Crestmead
National Foods in Crestmead fine-tuned its product start-up and shutdown operation by reviewing product interfaces and reducing timers to maximise product recovery. The review led to annual savings of $40 000 or around 60 000 L of milk.

5.6.2 Optimising product formulation

Accurate formulation of dairy products presents opportunities for the most substantial savings in dairy processing plants. The use of computer programs is common, providing accurate figures for the blending of ingredients. Many dairy processing plants also standardise milk and milk powders with retentates and permeates, to adjust the fat and protein content and produce a more consistent product while also reducing potential waste streams.

Optimising product formulation: Dairy Farmers, Mount Gambier
Dairy Farmers in Mount Gambier introduced a more accurate method of calculating the required amount of skim milk powder for making modified milks. Rather than relying on a set ratio of skim milk powder to milk, they developed an Excel spreadsheet, based on Pearson's Square, which enabled operators to calculate the ratio required for each batch to meet product specifications. The initiative reduced the plant's use of skimmed milk power by approximately 100 kg per 100 kL, resulting in a saving of $65 000/yr.

Use of milk permeate for standardisation of powders: Warrnambool Cheese and Butter, Allansford
Warrnambool Cheese and Butter in Allansford recovers milk permeate from an ultrafiltration plant to standardise milk powder. Almost 100% of the milk permeate is utilised for standardising, and any excess permeate is sold off to other dairy companies. A major challenge was setting up the standardising equation in the logic control system to ensure that the quantity of permeate used did not reduce the protein levels below specification. The payback period for the project was 8 months.

Computer-generated product formulation: Dairy Farmers, Shepparton
Dairy Farmers in Shepparton uses formulation computer charts to impose tighter control on product mixes and to reduce the likelihood of manufacturing products outside specifications. Savings are generated by reducing the reworking of product and wastage of packaging materials and labour.

Optimising batch make-up: National Foods, Salisbury
National Foods in Salisbury improved the running efficiency of its flavoured milk pasteuriser and reduced waste by running a specific volume of white milk either side of flavour mixes (slurries) based on batch size. This improved the batch preparation process by removing the need to flush the pipelines with water between batches.

5.6.3 Production scheduling

An effective way of minimising waste in product, time, labour and inventory is by optimising production schedules to minimise stoppages and the number of changeovers. Processing capacity should be matched to filling capacity, with adequate-sized intermediate storage tanks to buffer short breaks in filling. Efficient scheduling is more challenging for those processing plants that have a large variety of products, and there is dedicated software available that accounts for factors such as changeover times, cleaning times and production capacities. Modifications to processing equipment, pipelines and control systems may be required to increase processing flexibility and reduce bottlenecks.

Improving process control and product scheduling: National Foods, Morwell
National Foods in Morwell originally set up its dairy dessert and yoghurt cooking processes so that only one batch could be processed at a time; the system was then flushed, resulting in loss of product through a water–product interface. The processes were modified so that batches could follow one after the other, effectively eliminating two water–product interfaces. The modifications saved between $40 000 and $70 000 per year for the dairy dessert product (savings for the yoghurt were not analysed), with a payback period of 1–2 years. The system could only be used for similar batches, such as white yoghurt. The yoghurt pasteuriser modification was only partially successful, due to other capacity issues such as long mixing times for different yoghurt bases and the lack of maturation storage tanks. Challenges included changing operators' behaviour and modifying the logic control system's mode.

Improving process control: National Foods, Salisbury
National Foods in Salisbury programmed changes so that the packing line fillers did not have to be flushed with water when the next product was similar in formulation; this reduced waste by eliminating water–product interface losses. A second, stronger air purge was also installed to remove residual water from packaging filling lines and reduce the product interface.

5.6.4 Separator de-sludge optimisation

Optimising de-sludge frequency for all processes that utilise centrifugal separation of liquid milk streams (e.g. cream separation, clarification) will ensure that losses of milk components are minimised during automatic de-sludging. De-sludge frequencies should be set so that sediment only just fills the sediment space in the separator bowl and blockages do not occur (Hale et al. 2003). It may be necessary to adjust the de-sludge frequency if the sediment load of the incoming milk, or the flow rate through the separator, changes. Service companies or suppliers can provide useful advice on optimising bowl opening frequency. Another initiative used by some processing plants is to install filters prior to separators to reduce discharge frequency, and thus product loss.

Optimising de-sludge frequency for all processes that utilise centrifugal separation of liquid milk streams will ensure that losses of milk components are minimised.

In certain circumstances, separator de-sludges are recycled into the process to recover useful components. For example, in anhydrous milk fat processing, milk fat has been recovered by recycling separator sludge to the process. The sludge and effluent is collected, filtered and run through a separator to recover the fat. In these cases it is important to ensure that the sediment levels do not become excessive. If separator sludge cannot be recycled in the process it can be recovered and sold as stock feed, as discussed in the next chapter.

Optimising separator de-sludge times: Dairy Farmers, Mount Gambier
Dairy farmers in Mount Gambier extended the separator de-sludge times to prevent usable milk going down the drain. As a result the plant now saves $3900/yr in reduced milk loss.

Milk filters reduce product loss: Murray Goulburn Cooperative, Koroit
Murray Goulburn in Koroit installed milk filters prior to separators to reduce discharge frequency. The initiative increased the length of time between discharges from 20 minutes to 50 minutes, saving $40 000/yr with a payback period of 1 year.

5.6.5 Minimising loss of cheese fines

Whey is a by-product of the cheese-making process, and valuable product in the form of cheese fines and milk fat can be lost to the whey stream during processing. Recent work has been carried out to reduce the loss of cheese fines by optimising knife cutting design and speed in cheese vats (Hale et al. 2003). Cheese fines can also be prevented from entering effluent streams through the use of screens or settling tanks, and cyclones have been used to recover cheese fines and whey from separator de-sludge.

An effective method of increasing cheese yield and reducing the volume of whey produced is to increase the moisture content of the cheese; however, there is a limit to this as the cheese product can become too soft and be more susceptible to bacterial spoilage.

Useful and comprehensive information on some of the more technical aspects of maximising cheese yield can be found in the paper 'Cheese yield' (Lucey and Kelly 1994).

Increasing cheese moisture: Dairy Farmers, Jervois
Dairy farmers in Jervois increased its yield by standardising the moisture level in cheese. The initiative saves around $600 000/yr.

Recovery of cheese fines and whey from separator de-sludge: Bonlac Foods, Stanhope
Bonlac in Stanhope use cyclones to recover cheese fines and liquid whey from whey room separator de-sludge. It is estimated that the initiative will save the plant $170 000/yr, with a payback period of 3 months. Challenges include keeping the product and separator cyclones clean.

Recovery of cheese fines: Bonlac Foods, Stanhope[1]
Bonlac in Stanhope used two initiatives to prevent cheese fines from entering cheese room wastewater. The first was to install screens at the points where the large losses occur. The second was to install two large settling tanks in the whey room to capture cheese fines in the process rinse water. The impact of the project was assessed by monitoring the total suspended solids levels in the cheese room wastewater. The initiative aimed to decrease the amount of solids being sent to the wastewater treatment plant and increase cheese production by over 17 700 kg/yr, or approximately 1% of production, worth approximately $100 000. The payback period was expected to be less than 4 months.

Recovery of cheese product from Cheddar Masters: National Foods, Murray Bridge
National Foods in Murray Bridge fitted knockers to the draining conveyors of two Cheddar Masters. It has been estimated that the initiative achieved a 75% reduction in waste for cheeses with a high moisture content that required washing and a 95% in waste for Cheddar.

Recovery of cheese fines: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville installed a vacuum bag sealer and implemented procedures to hand-salt waste cheese fines for preservation. The initiative reduced solid waste from the plant by 120 t and captured around $250 000 worth of product.

[1] Environment Australia 1996

5.6.6 Spray dryers and evaporation

There is potential for significant loss in the production of condensed milk and milk powders — mainly during start-up and shutdown, when operation has not stabilised, and when process equipment is being cleaned. Some loss is common in evaporators due to deposition of product onto heating surfaces, and entrainment of product in the vapour phase of multi-effect systems, leading to contaminated condensate. For dryers, product entrained in the air stream is usually removed using cyclones and bag filters or scrubbers. Online monitoring of evaporator condensate flows using turbidity or conductivity are also often used to monitor for product loss due to entrainment. When excessive entrainment is detected, flow can be automatically diverted to another use.

It is good practice to recover product during cleaning of evaporators or dryers by collecting the initial rinse water for blending back into the process or, if the quality is unsuitable, disposal as animal feed. Residual powders should also be recovered from baghouses and, where possible, blended back into the product stream or disposed as animal feed. The quality of recovered product can be an issue, due to the potential for high bacterial counts. For example, dilute product streams recovered from evaporator start-ups or shutdowns must be kept chilled to prevent them from contaminating the final product when they are blended back into the process.

Significant savings can also be achieved by generally reviewing operating practices during start-up and shutdown of evaporators, and ensuring that a maximum quantity of concentrated product is reclaimed rather than being sent to waste. This may be simply by fine-tuning practices and giving feedback to operators. Processing plants with multiple evaporators and feed lines to dryers can reduce product feed and energy losses, as the dryers can continue to operate while evaporators are being cleaned.

It is good practice to recover product during the cleaning of evaporators or dryers by collecting the initial rinse water. This can be blended back into the process or, if the quality is unsuitable, used for animal feed.

Filtering of spray dryer exhaust: Tatura Milk, Tatura[1]
A new milk powder plant recently installed by Niro at Tatura Milk has the facility to filter the exhaust air using a CIP-able bag filter. The fines product fraction is returned to the process, thus recovering the valuable powder and discharging clean air to the atmosphere.

[1] Niro 2003

5.6.7 Product recovery during filling

Filling machines can be a source of significant loss, particularly when there are operating problems and filling efficiencies are poor. Waste can also result from the production of half-filled bottles produced during start-up and shutdown, or from draining pipelines and filling machines. Milk can be collected for reprocessing, but strict hygiene procedures must be adhered to, in order to prevent the risk of contamination from spoilt product.

Milk recovery during filling: Dairy Farmers, Shepparton
Dairy Farmers in Shepparton collects milk bottles that are improperly capped during packaging and empties the milk into a vessel to be put back through the pasteuriser. This cost around $400 to implement and saves around 1000 L of milk per day.

The company also reduced loss during filling by modifying the bottle to decrease the volume of milk lost through overfilling and reducing the fill level, tightening the margin for the minimum quantity of milk in the bottle. Different thickness spacers on the filler tubes are used to control milk levels for different product recipes. A roller device has been installed on the 3 L bottle filler exit; this helps reduce loss caused by the plastic bottles bellowing out slightly while filling and then expelling milk as they pass through the filler star wheels. The initiative cost less than $1000 to implement.

Recovery of product during changeovers: Dairy Farmers, Bomaderry
Dairy Farmers in Bomaderry installed a valve arrangement, balance tank and product pump to catch all interface product from bottling machine changeovers. Around 500 L/day is now collected, producing a saving of $160/day. This product is reformulated into products such as flavoured milks, which are then pasteurised as usual. Uncollected milk often used to spill to the floor, so wastewater treatment costs have also been reduced. The payback period was 1 month.

Recovery of milk solids, Dairy Farmers, Booval
Dairy Farmers in Booval recovers valuable milk solids from product changeovers and equipment flushing. Not only is the plant now producing a valuable product from its waste but the reduction in milk solid loss has also resulted in savings in reduced trade waste costs. The payback period was 12 months.

5.7 Maximising product recovery during cleaning

Poor or inefficient cleaning procedures can be a major source of product loss, particularly if product is not recovered towards the end of production. The publication *Performance evaluation guide manual — cleaning systems* (DPEC 1998/99) outlines a process for the performance evaluation of cleaning procedures and systems for each unit operation of a dairy processing plant. Another useful report is *Recovery of milk constituents from cleaning solutions used in the dairy industry* (Houlihan et al. 1999).

5.7.1 Clean-in-place (CIP) systems

The detection of product–water interfaces is the most important aspect of product recovery during cleaning. As discussed previously in section 5.4, they are usually detected using turbidity or conductivity meters or timers. Process equipment should be emptied as far as possible before commencing CIP; the mixing of product and cleaning solutions should be avoided, as it only prolongs cleaning time and adds to wastage of product and cleaning solution. First flush of process equipment should be collected and, where possible, blended back into the process or treated and disposed of as animal feed. Some CIP systems are designed so that pipes are drained of water at the end of the cleaning cycle, which eliminates a water–product interface and minimises the loss of product on start-up. Many factories also use filters to remove gross solids (e.g. fruit pieces, cheese) on supply or return CIP lines.

Product wastage can be estimated by analysing the composition of cleaning solutions during each cleaning phase of CIP. Waste streams should be segregated into high- or low-strength streams. These can be further treated to recover product, water or chemicals or otherwise disposed to the effluent stream and/or possibly used for irrigation. CIP systems are discussed in more detail in Chapter 3, 'Water'.

Flush or burst rinsing of tanks and tankers (also discussed Chapter 3) has now been adopted by Australian dairy processing companies. The procedure can save not only in recovered product but also in water usage.

Flush rinsing of tankers: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville flush-rinses cream tankers before CIP captures product in the milk silo. The project cost $1500 and saved approximately $60 worth of butterfat per tanker flush.

Recovery of cream and oil from AMF CIP: Bonlac, Stanhope
Bonlac in Stanhope, when producing ghee, recovers cream and oil from the anhydrous milk first CIP rinse for use as feed. The initiative saves $27 000/yr, with a payback period of 1 year.

Another means of reducing product loss and minimising resource use is to minimise the frequency of cleaning. In most factories that produce milk products, the production runs can take about 8 hours, after which CIP is necessary. In the newest factory of the Dutch dairy company Campina in Heilbronn, Germany, production runs of 72 hours are reported (Somsen and Capelle 2002).

5.7.2 Pigging

Pigging systems utilise an inert, flexible plug which is propelled through a pipeline to push out remaining product in preparation for cleaning. Pigging is generally used for viscous products such as yoghurts, dairy desserts or cream. The advantage is that minimal water is used during cleaning, so that maximum product recovery can be achieved. The design of pigging systems is extremely important, to prevent the pig from being lodged mid-pipe, delaying production and causing hygiene problems. An alternative to pigging is to use sterilised air to push product through pipelines.

Replacement of pigging system: National Foods, Morwell
National Foods in Morwell installed a pigging system to recover yoghurt from various product transfer pipelines. Design problems with the system caused the pig to be lodged at one end of the pipe run, and there were problems with the line becoming contaminated with unsterilised air. The decision was made to remove the system and install a series of valves to allow product to be flushed out of the lines. The installation cost around $10 000 per line, resulting in savings of up to $50 000/yr depending on the product line. The payback was between 1 and 2 years.

5.8 Use of membranes for recovery of resources

Membranes are commonly used within the dairy industry to produce value-added products and to recover product, chemicals or water. A major advantage of membrane separation technology is that the separated substances can be recovered in a chemically unchanged form. Types of membrane separation technology commonly used in the dairy industry are microfiltration, ultrafiltration, nanofiltration and reverse osmosis. They are used in the following ways (Daufin et al. 2001; Koch 2004):

- pre-concentration of milk and whey proteins
- improved cheese yields and product consistency
- production of whey protein concentrate and valuable by-products
- fractionation of whey and lactose intermediates
- recovery and reuse of permeate waste and brine
- recycling of spent caustic and acid solutions
- control of microbial growth, and to extend the shelf life of dairy products.

Membranes are typically 'cross-flow' where two streams are produced — a 'permeate' and concentrated 'retentate'. Table 5.6 shows the relative sizes of membranes and their typical application in dairy processing. In reality, the boundaries between the four types of membrane are not uniform, as performance specifications vary from supplier to supplier. For example, one supplier's 'loose' nanofiltration membrane may be equivalent to another's 'tight' ultrafiltration membrane (Envirowise 1997).

Table 5.6 Membranes used in the dairy industry

Membrane type	Molecular weight	Approximate pore size (mm)	Application in dairy industry
Microfiltration	>100 000–3 000 000	0.01–4.0	Solution clarification; removal of bacteria
Ultrafiltration	10 000–150 000	0.005–0.1	Protein, whey, milk concentration; clarification
Nanofiltration	150–20 000	0.0008–0.009	Lactose rejection,
			Protein, whey, milk concentration; recovery of caustic from CIP; standardisation of protein; desalinisation of salty whey
Reverse osmosis	<300	0.0001–0.002	Whey, milk, lactose concentration; polishing RO permeate; de-ashing whey, lactose; clarification

Source: Adapted from Envirowise 1997 and Koch 2004

The choice of membrane depends on what is to be extracted from the feed stream, and what the resulting permeate and retentate streams are to be used for. Some dairy processing plants use reverse osmosis to polish evaporator condensate; this is discussed further in Chapter 3, 'Water'.

Another use for membrane technology is for the concentration of products such as whey or cheese milk. In the case of cheese milk, the production of a concentrated product by means of membrane filtration effectively increases the capacity of the plant; a higher concentration of casein and butterfat can be processed, providing a greater mass of curd from the same vat. This can eliminate the need to purchase larger vats (PCI-memtech 2000).

Spent CIP solutions can also be regenerated using microfiltration, ultrafiltration or nanofiltration, as discussed in Chapter 7, 'Chemical use'.

A major advantage of membrane separation technology is that the separated substances can be recovered in a chemically unchanged form.

Product recovery using membranes: Murray Goulburn, Koroit
Murray Goulburn, Koroit are trialling a microfiltration plant to recover milk powder fines from the dryer wet scrubber. There are potential savings of $100 000/yr for an outlay of $25 000. Challenges include the filtering itself, maintaining appropriate solids, CIP of scrubbers, and generally achieving suitable-quality results.

6 Solid waste reduction and value adding

6.1 Overview

Dairy processors produce significant quantities of solid waste that must be managed and disposed of responsibly to eliminate environmental risks and reduce environmental impacts and costs. The following chapter looks at sources of solid waste in dairy processing plants and the opportunities for reducing such waste. The chapter also includes value-adding to whey products that in the past were considered to be waste.

6.1.1 Sources of solid waste

The types of solid waste typically produced by dairy processors include packaging waste such as cardboard, paper, cartons and plastic; organic wastes such as sludge and reject product; and office waste. Sources of solid waste from dairy processing plants are shown in Table 6.1. They can be generated during processing, or when raw materials and products are being transported, stored and handled.

Table 6.1 Sources of solid waste in dairy processing plants

Category	Type of waste	Disposal stream
Non-organic	Cardboard boxes, paper, slip sheets	Recyclable
	Plastic wrap	Recyclable, depending on cleanliness and plastic type
	HDPE bottles and caps	Recyclable
	Foil seals	Non-recyclable
	Liquid paperboard	Recyclable
	Labels	Generally non-recyclable
	Plastic and metal drums and containers	Returned to supplier, reused or recycled
	Polystyrene	Recyclable in some areas
	Office waste (e.g. toner cartridges, paper)	Recyclable
	Canteen waste (e.g. aluminum cans, polystyrene cups)	Recyclable in some areas
	Miscellaneous (e.g. waste oil, oily rags, damaged pallets)	Recycled or landfill

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Table 6.1 **Sources of solid waste in dairy processing plants** (*continued*)

Category	Type of waste	Disposal stream
Organic	Reject product including in-process	Animal feed
	Returned final product	Animal feed
	Raw material (e.g. liquid flavours)	Rework
	Obsolete or out-of-date raw materials	Animal feed
	Lab samples and samples for online testing	Animal feed
	Separator de-sludge	Animal feed
	Baghouse fines, dryer sweepings	Animal feed
	Effluent sludge	Animal feed or compost
	Membrane retentate sludge	Animal feed or compost
	Cheese fines	Animal feed
	Fat recovered from effluent	Animal feed

6.1.2 The true cost of solid waste

The disposal of large amounts of solid waste to landfill is expensive, and is generally an inefficient use of resources. According to the Australian Food and Grocery Council, the Australian dairy sector on average generates 168 kg of waste for every tonne of product. Of this, 46 kg of waste is sent to landfill, 91 kg of non-organic waste is recycled and 31 kg of organic waste is recycled as compost, fertiliser or stockfeed. The total recycling and reuse rate is 73%. The mass of waste sent to landfill is more than the average figure of 17 kg per tonne of product for food and grocery plants generally (AFGC 2001).

The cost of generating and disposing of solid waste can include:

- treatment costs
- collection and transport costs
- disposal costs
- loss of product, including processing and raw material costs.

Waste collection and disposal in Australia is highly subsidised through a range of mechanisms; thus the true cost of these services to society is actually greater than is currently charged to industry.

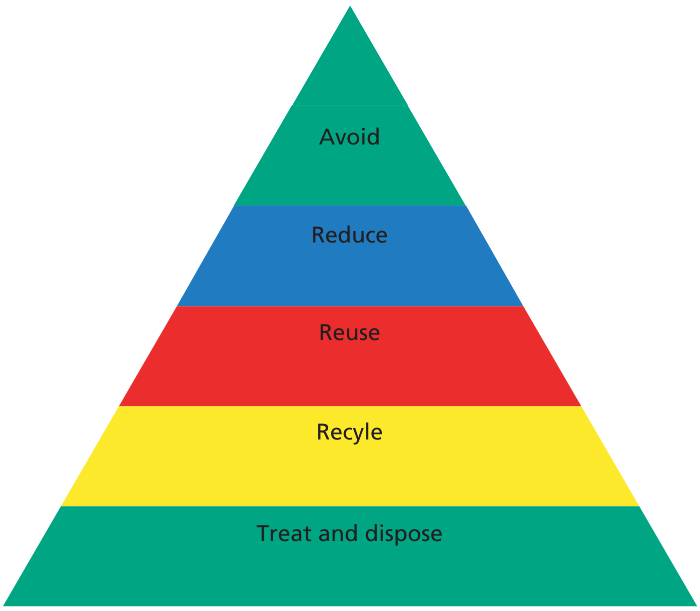
6.1.3 Solid waste management

Reducing the loss of materials and improving the rate of reuse, recovery and recycling of valuable resources is a very important aspect of eco-efficiency. The many economic, environmental and social incentives for reducing and utilising solid waste more efficiently include:

- reduced treatment, collection and disposal costs
- reduced production costs as a result of recovering and reusing product
- increased revenue from recovering product
- increased revenue from new co-products
- improved risk management
- improved environmental responsibility
- improved resource utilisation.

The waste minimisation hierarchy below in Figure 6.1 represents a sequential approach to reducing solid waste.

Figure 6.1 The waste minimisation hierarchy



- The first step in the waste minimisation hierarchy is eliminating all unnecessary solid waste.
- Next, consider how remaining solid waste can be further reduced by reusing product. Opportunities may also exist for recovering by-products that can be either reused onsite or sold.

- Finally, investigate options for using recycled materials or ways the plant can render its solid waste recyclable after use.
- The disposal of solid waste should only be a last resort after all avenues in the waste hierarchy have been explored.

An effective solid waste management program requires the input and involvement of all staff to identify opportunities for minimising the generation and cost of waste. All successes in reducing solid waste should be promoted among staff to help increase awareness of the plant's commitment to waste reduction.

6.1.4 Supply chain management

Efficient supply chain management can reduce unnecessary waste in dairy processing plants by ensuring that raw material and final product is:

- delivered at the correct time
- delivered in the correct quantity
- not spoilt in transit
- delivered in appropriate packaging
- of the correct quality or specifications
- recorded on arrival in an efficient inventory system
- stored and handled to prevent spoilage (e.g. strict temperature control of chilled products).

Computerised materials management systems are used throughout dairy processing factories to improve the efficiency of product movements and scheduling, and to reduce inventory of materials such as packaging.

Improved inventory management: Dairy Farmers
Dairy Farmers in Shepparton have reduced inventory holding levels using Advanced Planning Operations (APO) with 'just in time' planning activities. This is part of a Dairy Farmers corporate initiative to have the APO program implemented over all sites, which could save the entire company $12 million annually. Some problems with the system can occur when additional production occurs at short notice.

Reduced storage requirements: Dairy Farmers, Jervois
Dairy Farmers in Jervois have set up ongoing reviews of safety stock to try and eliminate requirements for extra coolrooms and storage. The improved accuracy of vendor delivery time has meant that the plant is unlikely to require further storage construction. Additional production needs could be a problem, however, as only small amounts of stock are kept onsite.

6.2 Value adding

In dairy processing, opportunities exist for recovering valuable by-products. These by-products may be reused in onsite processes, or perhaps sold. Thus any waste streams should be critically analysed for their potential to add value by being utilised in some other way. An added benefit of reuse or sale of by-products is that disposal costs may also be eliminated or reduced.

Whey, a by-product of cheese manufacture, has in past years been considered a waste stream. There are generally three classes of whey:

- sweet whey (pH 5.8–6.6)
- medium acid whey (5.0–5.8)
- acid whey (<5.0).

Sweet whey is produced from cheese that is coagulated with rennet, while acid whey is produced from cheese coagulated with acid (e.g. cottage cheese) or from casein manufacture. Salt whey, which is part of the sweet whey category, is produced during the pressing of salted cheese curd, such as in the manufacture of cheddar cheese (Envirowise 1999b; COWI 2000).

Membrane processes have provided the dairy processing industry with the means to produce value-added by-products that were previously sent to waste or used as stockfeed.

Membrane processes have provided the dairy processing industry with the means to produce value-added by-products that were previously sent to waste or used as stockfeed. Membrane processes are used to separate whey into permeate (lactose-rich) and retentate (protein-rich) streams. Permeate can be used to produce crystalline lactose — a valuable ingredient with uses in milk powder standardisation, baking, infant formula and pharmaceuticals. The retentate may be processed to form such products as whey protein concentrate (WPC) or demineralised whey powder. WPC is used as a food ingredient, particularly in baking and meat products where its gelatinous properties are utilised (Daufin et al. 2001; Hale et al. 2003).

Some dairy processors generate a salty effluent stream (cheese brine) from cheese production which cannot be reused without further treatment such as microfiltration. The high salt content in cheese brine makes it unsuitable for disposal onto land or as animal feed. The salt can be recovered as a saleable product through evaporation processes, as described in the third example below.

Recovery of products from whey: Dairy Farmers, Malanda
Dairy Farmers in Malanda installed a plant developed in-house to recover high-value/low-volume proteins, lactoperoxidase and lactoferrin from whey, which previously went to waste. For further information contact the Malanda plant.

Whey drying plant: Dairy Farmers, Jervois
Dairy Farmers in Jervois constructed a whey drying plant to convert a waste product into a marketable product. The plant processes 90% of the whey previously used by pig farmers or spread onto land at a cost of up to $30 000 a month.

Recovery of salt from cheese brine: Murray Goulburn, Rochester
Murray Goulburn in Rochester recovers salt from brine solution through a commercial salt farmer. Around 22 000 L/day of saline solution (6 days/week) is transported to the salt farmer to be processed through existing evaporation ponds. The major benefit to the plant is the cost recovery in repurchasing the salt for cheese manufacturing (up to 900 t/yr). The salt farmer receives a clean, concentrated and consistent source of brine — a win–win situation for both parties and the environment.

6.3 Recycling and reuse

Recycling is the reprocessing of a waste to produce another product. Of the total solid waste that is produced by dairy processing plants, 73% is recycled or reused. The types of waste produced by dairy processors that can be recycled are summarised in Table 6.1.

6.3.1 Onsite reuse of waste

There may be opportunities to reuse waste within the plant, depending on its type and quality. Successful reuse relies on avoiding cross-contamination between spoilt and acceptable-quality product. This is particularly so for foodstuffs, where the rigorous application of HACCP is necessary. For example, waste or reject milk product generated during filling can be reprocessed, as mentioned in Chapter 5; or plastic bags used for packaging bottles can be reused for waste collection during processing.

6.3.2 Establishing a solid waste recycling system

There are opportunities for dairy processing companies to increase recycling rates; but this can depend on the quantity of recyclable waste produced, the financial viability, the availability of disposal services, the cleanliness of the waste, and whether a workable recycling system has been established at the factory. For example, waste packaging that is heavily contaminated with milk or milk powder may not be suitable for recycling. Product packaging should be designed in the first place with end-of-life disposal in mind.

An effective recycling system requires good planning and monitoring. The following steps will help establish a successful solid waste recycling system:

1. Clearly label general waste and recycling bins. Pictures or colour-coding may be useful.
2. Try to locate recycling bins near to the site where the waste is being generated. If general waste is finding its way into recycling bins, consider putting a general waste bin beside the recycling bin to discourage this behaviour.
3. Design your waste recycling system carefully. Involve staff and ensure that both existing and new staff are adequately trained on how to implement the system.
4. Monitor how well the system is working. Keep records of the quantities of recyclables and general waste collected. Successful recycling relies on the careful separation of waste to avoid cross-contamination.
5. Keep staff motivated and informed on their recycling efforts, and on the economic and environmental benefits.

Clearly label general waste and recycling bins.

'Operators need to be well informed of segregation of recycling material. Close access to recycling cages or bins is important to encourage recycling. It is good to start with a few additional bins around the site to allow for any teething problems and review requirements after a couple of months.'
— Neville Fiegert, Dairy Farmers, Shepparton

' It is important to ensure that the message to all staff is clear on what is to be recycled; and set up appropriate areas without impacting on operator duties.' *— Peter McDonald, Murray Goulburn, Koroit*

Compacting solid waste can help reduce transport costs and save on storage space.

Recycling program: Dairy Farmers, Lidcombe
Dairy Farmers in Lidcombe partnered with Resource NSW to identify ways of reducing waste, and waste disposal costs, across the site. A waste assessment was conducted, and it found that 58% of the waste that was sent to landfill could be diverted through a reuse and recycling system. A recycling system was established, which halved the quantity of waste sent to landfill and reduced transportation and landfill fees by $40 000 per year.

Recycling program: Dairy Farmers, Shepparton
Dairy Farmers in Shepparton previously recycled its PET bottles by placing them in a cage for collection by a recycling company, and reduced the amount of waste going to landfill by 60 m^3 per month. The recent introduction of smaller bins that allow greater accessibility now enables the plant to also recycle more cardboard and LDPE plastic. This initiative is forecast to reduce the amount of waste going to landfill by an additional 24 m^3 per month.

Recycling program: Dairy Farmers, Malanda
Dairy Farmers in Malanda recycles 99.9% of its packaging plastic waste. Milk is washed out of the HDPE bottles, which are sent to the blow mould area for regrinding. The plant also recycles 80% of cardboard, despite having difficulties finding businesses willing to take recyclable waste in Far North Queensland.

Working with waste collectors and industry to improve recycling: Murray Goulburn, Kiewa
Murray Goulburn in Kiewa worked with waste collectors and other industries in their area to establish a 'pick-up run' for recyclables. The collection of recyclables saves the plant around $1000/yr in avoided landfill costs.

Recycling and waste reduction initiatives: Murray Goulburn, Leitchville
Murray Gouldburn in Leitchville was able to increase the proportion of recycled waste by 25%, by recycling plastic containers, plastic wrap, wooden pallets and salt dust in addition to its already established cardboard recycling program. The plant is also working in partnership with Eco-recycle Victoria to investigate the possibility of using wood chip boiler fly ash as an additive in cement and road surfacing materials, rather than sending it to landfill. Roger Knight of Murray Goulburn Leitchville says, 'The biggest issue with the initiative was getting materials picked up for recycling in a timely manner and having a suitable storage area outside for recycling zones. The key to its success is involving operators in the process so they take ownership and give feedback on the process. Continued reinforcement is also important.'

Sale of cardboard cartons: National Foods, Crestmead
National Foods in Crestmead sells its cap cartons to another company for reuse without any further cleaning or processing. This contributes approximately $1500 per year.

6.4 Reducing the impacts of packaging

Many Australian dairy processing companies are members of the National Packaging Covenant. This is a voluntary joint government and industry initiative, launched in 1999, which is aimed at encouraging industry to think about the effect of packaging along the supply chain. It is based on the principles of shared responsibility and product stewardship. Initiatives for optimising packaging use, which also reduce solid waste, include:

- lightweighting
- optimising packaging design to reduce material use
- removing unnecessary packaging
- selecting bulk delivery of products to avoid waste packaging
- ensuring efficient handling and storage to prevent damage
- improving the efficiency of packing lines.

Some dairy processors use polystyrene packaging (e.g. yoghurt containers). Although this can be

recycled, the infrastructure for broad-scale recycling in Australia has not been developed. However, the industry is investigating issues surrounding the viability of recycling polystyrene packaging through the recently formed Dairy Tub Environmental Group.

Further information on packaging can be found in the *Eco-efficiency toolkit for Queensland food processors* (UNEP Working Group for Cleaner Production 2004). The following case studies are examples of how Australian dairy processors have reduced packaging use.

'Extensive plant trials should be carried out before introducing changes to packaging.' *— Bevin Prenzler, Dairy Farmers Booval, commenting on trials with lightweighting of plastic bottles.*

Lightweighting: Dairy Farmers, Booval
Dairy Farmers in Booval, reduced its HDPE and PET packaging weight. However, the initiative was only moderately successful due to the poor performance of the lightweight packaging and problems in packing line efficiency.

Crimper to replace sticky tape: Dairy Farmers, Bomaderry
Dairy Farmers in Bomaderry, New South Wales constructed a hand-held crimper to replace the adhesive tape used to hold lids on drums in the filling process. The initiative speeded up production and removed the need for the use of over $7000 of sticky tape annually. The payback period was less than 3 months.

Reduction in cardboard content of cartons: Dairy Farmers, Jervois
Dairy farmers in Jervois have successfully reduced the butter carton cardboard content by 15%. The plant is also currently sending cheese in bulk 1-tonne boxes, instead of boxing each cheese block with cardboard.

Cartonless cheese blocks: Murray Goulburn Leitchville
Murray Goulburn in Leitchville is conducting trials to manufacture cartonless cheese blocks on request from customers. The initiative will reduce not only landfill but also the plant's packaging costs.

Thinner cardboard shippers: Dairy Farmers, Mount Gambier
Dairy Farmers in Mount Gambier has successfully trialled using thinner cardboard shippers to save on cost and impact of packaging on the environment. The thinner shippers are expected to save the plant $25 000–$30 000/yr.

Plastic lids in place of foil lids: National Foods, Murray Bridge
National Foods in Murray Bridge changed from foil lids to plastic lids on a dairy dessert product. The heat produced by the product caused the plastic lids to warp and displace. The site has since changed back to using foil lids, reducing filling waste by 70%.

Use of recycled cardboard: National Foods, Murray Bridge
National Foods in Murray Bridge changed to recycled cardboard for boxing 20 kg blocks of cheese. The initiative has been very successful, drastically reducing the cost per unit and the quantities of virgin cardboard used.

Downsizing cheese carton cardboard and reduced gauge of laminates: Bonlac, Cororooke
Bonlac in Cororooke downsized cardboard for its cheese cartons and reduced the gauge of its cheese pack laminates. The plant also reuses its cardboard cartons for cheese stock and then returns the used cartons to the manufacturer. Modifying the laminate required lengthy packing trials to determine the optimum gauge. Savings in cost and material and trade waste disposal benefits must be balanced against potential increase in packing-machine operational problems, pack integrity and customer perceptions about pack feel and appearance.

Crates produced from recycled milk bottles: Dairy Farmers, Lidcombe
Dairy Farmers in Lidcombe trialled the use of crates made from recycled milk bottles. However, the manufacturers found difficulty in sourcing recycled plastic of consistent quality from the recyclers, causing the crates to vary in performance and break easily. Their use was discontinued.

Bulk supply of packaged goods: Murray Goulburn, Maffra
Murray Goulburn in Maffra has undertaken a range of measures that has resulted in reduced solid waste. This includes the use of more stretchable material for pallet wrapping, requiring less material per pallet. Lower-ply powder bags are used for powder packaging; and, after discussions with suppliers, many chemicals are now supplied in bulk containers instead of the 25 L containers previously supplied. All remaining 25 L containers are washed out, relabelled and taken by the contractor for recycling. Trials of supplying particular products in bulk bins, as opposed to individual cartons, have also been conducted; this has been successful in reducing packaging waste.

6.5 Disposal of solid organic waste

Solid organic waste produced by dairy processing plants includes biosolids, separator de-sludges and some retentate streams from membrane processing. Biosolids are the part of the waste stream containing solids after wastewater treatment (i.e. sludge). They can be rich in nitrogen, phosphorus, potassium and other nutrients and can be useful as a soil additive. In addition, the high organic matter content of biosolids can make them useful for soil stabilisation. Depending on the method of use, dewatered solids have a water content ranging between 10% and 80%. Options for the disposal of organic dairy processing waste include:

- animal feed
- composting
- soil injection or direct landspreading.

Plants also need to consider whether waste will be classified as industrial waste and meet relevant regulatory requirements.

6.5.1 Animal feed

Dairy processing wastes such as separator de-sludge, whey and product returns provide a good source of protein and fat, and are often used as animal feed. Waste milk powder, such as that collected from the dry cleaning of a spray dryer, can be collected in bags and sold to farmers as calf food. Transport costs are possibly the biggest expense associated with this means of disposal. Compactors are also used to separate out liquid product from packaging before sending it for stock food. Compactors not only reduce transport costs but also lower landfill costs, with only a small amount of solid waste remaining after compaction.

Biosolids have been used as stockfeed, but it is important to consider their content and the possible risks to animal health. For example, some chemicals and polymers used in wastewater treatment may affect the suitability of biosolids for stockfeed. Sludges from dissolved air flotation treatment and fat from hydroclones can often be used as animal feed, whereas sludge produced from anaerobic digestion would not be suitable.

Biosolids used as stockfeed can include sludges from dissolved air flotation units.

The Australian Pests and Veterinary Medicines Authority (APVMA) has guidelines for the type and quality of animal stockfeed, including exposure levels for various chemicals potentially found in feed — visit <http://www.apvma.gov.au/residues/stockfeed.shtml>. Information can also be obtained from the Stock Feed Manufacturers Association of Australia.

A dedicated storage tank for stockfeed. Dairy processing wastes such as separator de-sludge, whey and product returns are a good source of protein and fat and are often used as animal feed.

Recovery of separator de-sludge and dryer wet scrubber solids: Murray Goulburn, Maffra
Murray Goulburn in Maffra recovers separator de-sludge and milk solids retained in dryer wet scrubbing systems for recycling as pig food. The dryer chamber washes begin with a water rinse of the chamber to recover residual powder for recycling, which is used as pig food also.

Short shelf-life milk to pig farmer: Dairy Farmers, Shepparton
Dairy Farmers in Shepparton provides product that is short on shelf life to a pig farmer. The farmer takes the milk in its finished packaging, which he then returns to the site for disposal through the plant's recycling system.

6.5.2 Composting

Effluent treatment plants in dairy factories can generate a large amount of sludge. Due the high nutrient value of sludge it is often used as a fertiliser, compost or soil conditioner. Composting is usually only viable for dairy processing plants in regional areas that have sufficient space, and where the potential odour will not upset neighbouring businesses or communities. Transporting organic waste to offsite large-scale facilities for composting may be a good alternative to landfill if transport costs are not too high. Sludge thickening is used to increase the sludge concentration and reduce transport costs. The cost of drying sludge with hot air is often prohibitive, but new drying technologies using superheated steam are more efficient (ETBPP 1999).

Disposal of sludge as compost: Murray Goulburn, Koroit
Murray Goulburn in Koroit established a composting facility on its treatment farm for sludge from the site treatment plant, saving the plant $72 000/yr in disposal costs. The payback period was 6 months. There are some issues with odour generation at certain times of the year, but this is managed by having a significant area of land buffer between the compost site and the nearest neighbour.

6.5.3 Soil injection and direct landspreading

Organic waste from dairy processing plants, including biosolids, can be soil injected or spread directly onto land. The main nutrient value of organic dairy waste is the nitrogen and phosphorus content; however, it does not always provide a balanced additive, and additional materials may need to be added. Application rates are limited by the nutrient requirements of the land, so the components of the organic waste must be known and regularly monitored to ensure appropriate levels and locations.

The obvious advantages of direct landspreading are that there is no need for further processing and the product does not need to be stored for any great length of time. Organic wastes that have been dewatered or dried can be used directly for landspreading, using a conventional manure spreader. Organic wastes can also be processed into a granulated product that can be applied as a fertiliser. Liquid biosolids can be transported by tanker to an application site and then injected 10–12 cm into the soil (Mosse and Rawlinson 1998).

There are different requirements in each state for the utilisation of sludge as a fertiliser or compost additive, so it is best to contact your local regulatory authority for more information. For example, processors applying organic waste to land in Queensland and New South Wales are required to follow the *Environmental guidelines — use and disposal of biosolids products* (EPA, NSW 1997).

Soil injection of DAF plant sludge: Dairy Farmers, Lidcombe
DAF (Dissolved Air Flotation) sludge from the Dairy Farmers plant in Lidcombe is dried and collected for direct soil injection on farms west of Sydney by the company Applied Soil Technology. The sludge must be checked for heavy metal content every 6–12 months and Dairy Farmers must sign a declaration that the significant changes to the sludge content are made known before it is collected.

Use of liquid NPN as fertiliser and stockfeed: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville is currently investigating using concentrated milk minerals (liquid non-protein nitrogen or NPN), produced as a by-product of whey membrane processing, as a stockfeed supplement or for use in fertilisers. The project coincides with other initiatives to remove the salt component by segregating the salt whey stream, which will improve the quality of the NPN.

Use of sludge as fertiliser: Warrnambool Cheese and Butter, Allansford
Warrnambool Cheese and Butter in Allansford uses sludge from its waste treatment plant as an approved organic fertiliser on its supplier farms. The plant is also carrying out trials using ultrasonic technology to break down the size of solid particles in the sludge, which would increase the level of solids and reduce transport costs.

7 Chemical use

7.1 Overview of chemical use

The cost of chemicals for dairy processing plants can be several hundred thousand dollars per year and a significant proportion of total operating costs. The dairy processing industry uses a wide variety of chemicals for cleaning, pH control of process and waste streams, and treating water for process and auxiliary uses such as boiler and cooling tower feed. This chapter discusses the use of chemicals in dairy processing plants, in particular for cleaning, and looks at opportunities to reduce or optimise chemical use with the aim of lowering operating costs and minimising environmental impacts.

7.1.1 Cleaning

Most chemicals used in dairy factories are for cleaning. Cleaning of plant and equipment is essential to maintain strict hygiene standards and eliminate or control the risk of product contamination and spoilage. Dairy processing plants typically use a combination of automated clean-in-place (CIP) systems and manual cleaning systems such as foaming and sanitising of external equipment surfaces and floors.

A CIP system is a fully enclosed automated system that delivers a number of wash and rinse cycles to the internal surfaces of processing equipment. CIP systems largely remove human contact with cleaning agents, thus reducing the risk of harmful exposure. They also reduce labour costs, as well as the wear involved in dismantling equipment. One of the main advantages of CIP systems is that they can recirculate chemicals and rinse water, thereby substantially reducing the consumption of water and chemicals. Typical CIP cycles consist of a water rinse followed by a caustic wash, a second water rinse, an acid wash, a third water rinse, and often a final sanitiser rinse. Caustic washes are usually carried out at least once a day; acid washes are less frequent, and may be carried out once or twice per week. CIP systems may be classified as single-use, multi-use or full recovery. Single-use (SU) systems dispose of rinse waters and spent solution to drain after one use, while multi-use (MU) systems recover final rinse waters and appropriate-quality spent solution for reuse. Full recovery systems typically use membrane technology to recover chemicals, water and, potentially, product.

What standard of cleaning is required?

As explained in *CIP: cleaning-in-place*, edited by AJ Romney (1990), three levels of cleaning can be identified:

- **Physically clean.** The surface appears clean but chemical residues may have been allowed to remain
- **Chemically clean.** The surface is rendered totally free from any trace of chemical residue.

- **Microbiologically clean.** This refers to the degree of microbiological contamination remaining on the surface. A surface may be 'disinfected', in which case the number of bacteria has been reduced to an acceptable level, or 'sterile', where bacteria have been completely removed (e.g. in ultra-high-temperature [UHT] processes). Thus a surface can be microbiologically clean but still have traces of chemicals.

Types of fouling

Efficient cleaning requires a good understanding of the types of fouling and the chemicals (detergents and sanitisers) used in their removal. Fouling can be divided under two general headings:

- **Organic deposits.** These are generally animal- or plant-based deposits that are composed of sugars, proteins or fats.
- **Inorganic deposits.** These are usually mineral components, such as magnesium and calcium from hard water.

Most soils are a combination of organic and inorganic deposits; for example 'milkstone' is a combination of calcium caseinate and calcium phosphate (Romney 1990). A comparison of the solubility and ease of cleaning of various surface deposits found in the dairy industry is shown in Table 7.1.

Table 7.1 **Characteristics of typical soiling found in the dairy industry**

Surface deposit	Solubility	Relative ease of removal
Sugar	Water-soluble	Easy
Fat	Alkali-soluble	Difficult
Protein	Alkali-soluble	Very difficult
Monovalent salts (e.g. $NaCl$)	Water- and acid-soluble	Easy to difficult
Polyvalent salts (e.g. $CaPO_4$)	Acid-soluble	Difficult

Source: Schmidt 2003

Milk proteins can range from those that are relatively easy to remove, to casein, which is particularly difficult. Casein has good adhesive properties and in fact is used in many glues and paints (Schmidt 2003). The nature of milk protein residue can vary greatly according to the temperature at which it is deposited; thus different equipment will require different cleaning regimes. For example, the heated surface of a pasteuriser will require a more rigorous cleaning regime than will a cold raw milk line or tank. Proteins broken down by heat can be particularly difficult to remove and require the use of highly alkaline detergents with peptising and wetting ingredients that disperse and increase the suspendability of the proteins. The attributes of detergents are explained further in the next section.

7.1.2 Detergents, acids and sanitisers

Detergents

Detergents used for cleaning are commonly composed of a mixture of ingredients to interact both chemically and physically with the fouling. A dairy detergent will have the following attributes (Romney 1990):

- organic dissolving power, to solubilise proteins, fats and sugars
- dispersing and suspending power, to bring insoluble soils into suspension and prevent their redeposition on cleaned surfaces
- emulsifying power, to hold oils and fats dispersed within the cleaning solution
- sequestering power — the ability to combine with calcium and magnesium salts and form water-soluble compounds
- wetting power, to reduce surface tension and aid penetration of the soil
- rinsing power — the ability to rinse away clearly without leaving a trace of soil or chemical on the surface.

Detergents are formulated from a wide range of materials, which usually fall within the groups of inorganic alkalis, acids and sequestering agents (Wright 1990). Examples of inorganic alkalis include sodium hydroxide (caustic soda), potassium hydroxide, sodium carbonate and sodium bicarbonate. They are commonly used in CIP systems or bottle wash applications and are effective in removing fats. Detergents can also contain peptising agents, which have the ability to disperse protein. The use of enzyme-based detergents by Australian dairy processors is becoming more common. This is discussed further in section 7.3.

Acids

Acid ingredients can be inorganic (e.g. phosphoric, nitric and hydrochloric acid) or organic (e.g. hydroxyacetic and citric acid). They are designed to remove tenacious soil, such as mineral deposits, that cannot be removed using alkali detergents.

Sequestering agents are used to prevent scale from developing and include sodium polyphosphates, gluconic acid and ethylenediaminetetraacetic acid (EDTA) (Wright 1990).

Sanitisers

Sanitisers are used by the dairy processing industry to reduce micro-organisms to a level that is safe for public health and enhances product quality. Sanitisation can be achieved using thermal methods such as hot water and steam, or chemicals such as chlorine-based compounds (e.g. chlorine dioxide) and peroxides(e.g peroxyacetic acid). Many sanitisers are significantly affected by pH and water quality. Chlorine compounds are broad-spectrum germicides which are relatively cheap and less affected by water hardness than many other sanitisers. They are, however, corrosive to many metal surfaces and are the subject of some health and safety concerns.

Table 7.2 shows the types of cleaning chemicals typically used in dairy processing.

Table 7.2 **Types of chemicals used in the dairy industry**

Type of chemical	Purpose	Comments	Examples
Alkalis	Soil displacement by emulsifying, saponifying and peptising Application: sugar, fats, protein organic soils	Generally sodium-based Do not remove mineral deposits Hazardous to handle Corrosive Increase wastewater pH	sodium hydroxide potassium hydroxide
Acids	Mineral deposit control and water softening Application: protein, sugar, mineral deposits, metal corrosion, milkstone	Both inorganic and organic, including nitric and phosphoric Hazardous to handle Corrosive Lower wastewater pH	phosphoric acid nitric acid
Surfactants	Wetting and penetration of soils; dispersion of soils and prevention of soil re-deposition.	Classified as anionic, non-ionic, cationic or amphoteric Soluble in cold water and in usual concentrations Not affected by hard water	carboxylates, sulfates, sulfonates
Sequestrants	Ability to prevent deposition of undesirable mineral salts on surfaces being cleaned	Used for water treatment	sodium polyphosphates, gluconic acid, ethylenediaminetetraacetic acid (EDTA)
Enzymes	Used in conjunction with mild detergents to break down and solubilise difficult-to-remove soils	Limited to unheated surfaces Especially useful in the cleaning of membrane processing plants	protease, lipase, amylase
Oxidisers/sanitisers	Reducing bacterial counts Utilisation of 50–200/mL chlorine increases the peptising efficiency of alkaline detergents.	Relatively inexpensive Not affected by water hardness Potential for tri-halomethane formation; minimises the development of milkstone deposits	chlorine peracetic acid quaternary ammonium chlorides

Sources: AS 4709:2001; Melrose Chemicals 2003; Parker & Longmuir 1999; Romney 1990; Schmidt 2003

7.1.3 Water quality

As mentioned in Chapter 3, water supply for dairy processors can include town, river, irrigation channel and bore water, as well as reclaimed condensate, and can vary markedly in quality. The quality of water required will also be determined by its end use. For example, water that will be in contact with product must be of drinking water quality and meet the Australian Drinking Water Guidelines (NHMRC & ARMCANZ 1996).

Water is the primary constituent of all dairy processing cleaners and thus all cleaning chemicals should be tailored to the plant's water supply. Hard water containing substantial amounts of calcium, magnesium and iron can result in scale build-up; this affects the ability of detergents and sanitisers to contact the surface, requiring cleaning, and can lead to excessive scaling in boilers and cooling towers. Hard water may require treatment such as ion exchange, or alternatively the use of detergents and sanitisers that are specially formulated for hard water. Sequestering and chelating agents can be added to form soluble complexes with calcium and magnesium to prevent such mineral build-up.

Water conditioning saves chemicals: dairy processor, UK[1]
Tims Dairy produces cultured milk products such as yoghurt. The company overcame problems with the build-up of limescale (service side) and milkscale (product side) on heat exchangers by installing three 'Hydroflow' physical water conditioning units which prevent build-up of limescale deposits by electroprecipitation. The heat exchanger is now cleaned weekly with half the amount of acid.

[1] Manufacturingtalk 2003

7.1.4 True cost of chemicals

When calculating possible savings from reduced chemical use, it is important to take a holistic approach that considers not only the initial purchasing costs but also some of the more hidden costs such as:

- managing health and safety risks including operator training
- procurement costs to obtain and deliver the chemical to the site
- inventory maintenance
- effect on wastewater treatment and disposal costs
- cost of recycling or disposing of empty chemical containers
- equipment operation and maintenance costs
- heating costs.

For example, a non-toxic and biodegradable chemical such as citric acid (used by some dairy processors) may cost more to purchase, but the overall cost to the plant may be considerably less when maintenance, operator health and safety, and wastewater discharge costs are also taken into account.

7.1.5 Environmental impact of chemicals

The main environmental impacts of chemicals used in dairy processing plants are:

- the high level of salts in dairy effluent from sodium (caustic) based chemicals and their impact on land and groundwater
- the impact of nitric and phosphoric acids on nutrient levels in discharges to waterways.

Depending on the region, high salt levels in dairy effluent can exacerbate soil salinity problems in areas where dairy effluent is used for irrigation, while excessive nutrients in the form of nitrates and phosphates can cause eutrophication (algal blooms) from land run-off and where treatment plants discharge to waterways.

7.2 Optimising chemical use

The residue of milk and milk-based products left on plant and equipment provides an ideal growth medium for biological material that can be detrimental to human health and the product's shelf life and taste (DPEC 1998/99). The degree of chemical use, therefore, is largely determined by food safety requirements and quality specifications.

Reducing chemical use by careful selection, and optimal utilisation and recovery, *without* compromising processing or food safety standards, can result in substantial savings while also improving the plant's environmental performance. There are numerous factors that influence the cleaning process, and many of these are interlinked. Changes should not be made without considering the overall impact on cleaning effectiveness and product quality.

There may be opportunities to improve the efficiency of the cleaning process and chemical use by reviewing:

- chemical types and blends
- chemical concentrations and order of use
- contact or cleaning cycle times
- process control and instrumentation
- correct temperature
- chemical recovery (for CIP systems)
- effective water treatment
- fluid velocity or mechanical action
- operator health and safety
- equipment maintenance and operation.

These opportunities for improvement are applicable to manual equipment cleaning and plant washdowns as well as CIP systems.

Validation or review of cleaning systems is necessary to prove the cleaning effectiveness of a system, and can be done as part of the contract obligation of the plant's chemical supplier. Improvements are usually achieved by extensive trials to ensure sufficient cleaning without compromising product quality.

Installation of CIP system: Pauls, Northern Territory[1]
Pauls Limited installed a fully automated CIP system for its pasteurised milk vats and associated lines. The initiative has saved the plant $40 000/yr in reduced water usage and improved cleaning effectiveness, as well as reduced chemical use. Health and safety conditions for the plant's workers have also been improved by the reduction in direct handling of chemicals.

[1] Environment Australia 2001

The Dairy Processing Engineering Centre (DPEC) *Performance evaluation guide manual — cleaning systems* provides information on evaluating cleaning effectiveness by carrying out mass and energy balances around individual unit operations (DPEC 1998/99). The manual also shows how to formulate key performance indicators against which the performance of the CIP system can be assessed.

Review of CIP cycle frequency and chemical recovery: National Foods, Salisbury
National Foods in South Salisbury reduced chemical use by 11% by auditing its CIP flip cycle (valve operation), recovering chemicals from its pasteuriser wash and decreasing the frequency of acid washes.

Annual CIP audit: National Foods, Penrith
National Foods in Penrith carries out a full CIP audit each year to review cleaning effectiveness. These audits review chemical concentration and cycle times. The plant's most recent audit saved $10 000 in detergents and 15 ML of water.

7.2.1 Chemical types and blends

Ideally a cleaning chemical will meet all cleaning requirements as well as being economical, non-corrosive, non-toxic, stable, non-dusting, effective in softening water, highly soluble and able to withstand a broad range of environmental conditions. Your chemical supplier will provide advice on the most appropriate chemicals for each cleaning task, which clean effectively while also minimising environmental impacts and ensuring operator safety.

For detergents to be effective, they require sufficient contact time. Some types of cleaning agents help to increase the ability of chemicals to bond with soiled materials, to form a thin film or foam on the surfaces which is then removed with pressure and/or water. The case study below is a good example of the advantages of blending chemicals to best suit the application. Combined detergents and sanitisers may also provide an opportunity to clean and sanitise simultaneously, thereby reducing cleaning time, chemical use and the need for multiple rinses.

Chemicals must always be selected to suit the application. For example, experiments indicate that concentrations of hydrogen peroxide as low as 50 mg/L can have a negative effect on the taste of cheese. And water treated with hydrogen peroxide and used for dissolving milk powder in the making of culture for cheese manufacture can cause difficulties due to its effects on acidic-activated cultures (IDF 1988). Care must be taken, therefore, to ensure thorough drainage of chemicals.

'Before changing to a new chemical supplier, be sure they have the range and capability to make special blends to cover all the chemicals you require.'

— Phill Lumsden, Dairy Farmers, Bomaderry, New South Wales

Alternative detergent use increased productivity: Bonlac, Stanhope[1]

Bonlac Foods in Stanhope was using a CIP process with alkaline solution, an acid detergent (nitric and phosphoric acids) and hot water to clean equipment as part of the cheese-making process. The waste cleaning solution was treated in onsite wastewater treatment ponds and then discharged to surface drains. The acid detergent was replaced by Stabilon® detergent, which is a combination of complex agents, wetting agents, anti-foam agents, cleaning activators and emulsifiers. The change resulted in a reduction in the cycle time for the CIP process from 6 h to 4.5 h, allowing more time to produce cheese, and eliminating the acid detergent in the CIP process. The net benefit was an extra $310/day through reduced chemical usage and increased cheese production.

[1] Environment Australia 1999

7.2.2 Chemical concentrations

Automated chemical dosing systems minimise the need for operator intervention, and they are a practical and precise way of avoiding incorrect dosing. Such systems are not infallible, however, and dairy processing plants should implement work procedures for the regular testing and monitoring of chemical concentrations. Over-dosing can result in increased wastewater charges and wasted chemicals, while under-dosing can lead to contamination and an ineffective cleaning operation. Automatic dosing also reduces the labour time typically associated with the manual addition of chemicals and can circumvent the associated occupational health and safety issues.

Different cleaning tasks require different chemical concentrations and there may be opportunities to reduce chemical use by optimising the concentration. For example, the cleaning of heated surfaces such as those of pasteurisers will require a higher strength than storage tanks holding raw milk. Dairy processing plants usually have separate CIP systems for pre-pasteurising, post-pasteurising, and storage and filling. This presents an opportunity to optimise the CIP cycles and the concentration of chemicals to suit the requirements of the equipment being cleaned. Ranges of alkali concentrations between 0.7% and 1.5% have been reported in the dairy processing industry, while acid concentrations range from around 0.1 % to 1.2%. Substantial savings can be achieved if chemical concentrations can be reduced.

Review of CIP chemical concentrations: National Foods, Morwell

National Foods in Morwell reduced its caustic concentrations on its dessert cooker and set specific acid concentrations on all individual CIP sets. Caustic concentration on the dessert cooker was reduced to 1.5%. Changes to both acid and caustic concentrations led to total savings of $100 000/yr. The only real costs for implementing the change were the time taken to validate the system and costs of checking product quality.

7.2.3 Cleaning cycle times

It is not uncommon for dairy processing plants, over time, to introduce inefficient or excessive cleaning cycles to compensate for product quality problems or modifications to processing equipment. Some processors have introduced regular audits of CIP systems to ensure that the efficiency and effectiveness of their cleaning systems is maintained. Such audits are carried out by internal staff or on a contract basis by chemical suppliers.

Auditing of dosing equipment: National Foods, Morwell
National Foods in Morwell reduced caustic and acid cycle times on its CIP system. During the early stages of commissioning the plant significant issues were experienced and cleaning times were increased. As the many design issues were resolved it was found that the times were longer than recommended and could be reduced without comprising product quality.

Reduced cleaning by combining acid and sanitiser step: Dairy Farmers, Malanda
Dairy Farmers in Malanda have been working in partnership with Campbell Cleantec, and have removed a rinse cycle and a sanitation step from all its cleaning circuits by changing from a caustic/acid/sanitation cycle to a caustic/acid-sanitiser one shot cycle. The initiative has saved the factory 15 000 kL/yr in rinse water with additional savings in chemical costs.

7.2.4 Control instrumentation

CIP systems are typically equipped with inline monitoring instrumentation such as conductivity and turbidity meters and timers that should be well maintained and regularly calibrated. Programming the CIP system so that it will not commence washing unless quality parameters such as temperature and concentration are met reduces the need for rewashes.

For more information on selecting and installing instruments relevant to performance evaluation of a cleaning process, see *Performance evaluation guide manual — cleaning systems* (DPEC 1989/99).

Instrumentation for cleaning improvements: Dairy Farmers, Malanda
Dairy Farmers in Malanda audited all its CIP processes. Optic sensors were used to fine-tune water and milk interfaces and conductivity and turbidity meters for cleaning improvements. Estimated savings for the improvements were $211 500/yr.

7.2.5 Effect of temperature

Maintaining the correct temperature is essential for chemical effectiveness. It can also be an opportunity to reduce energy consumption. Excessively high temperatures may increase the corrosive nature of many chemicals, while low temperatures may reduce the chemical's ability to remove soiling or kill pathogens. Check with your supplier for the minimum temperature requirements that can be used without compromising cleaning effectiveness and product quality.

7.2.6 Chemical recovery

CIP systems used in dairy processing plants may be classified as single-use, multi-use or full recovery. Single-use systems dispose of rinse waters and spent solution to drain after one use, while multi-use systems recover final rinse waters and appropriate-quality spent solution for reuse. Multi-use systems are particularly efficient when the soiling is only light and the spent chemical still retains most of its active agent (DPEC 1998/99). Rinsing and recovering product before CIP will minimise contamination and enable the chemical solution to retain its quality characteristics for a longer period of time. Full recovery systems typically use membrane systems to recover product, chemicals and water.

The use of full recovery membrane filtration systems is becoming more financially viable, allowing even greater recovery of resources. Up until quite recently attempts to recover spent CIP solution were limited because only ceramic membranes (which were available only in the ultrafiltration and microfiltration range) could withstand the extreme pH of a caustic or acid CIP solution (NEM Business Solutions 2002). Spent CIP solutions can now be regenerated using microfiltration, ultrafiltration and nanofiltration, with the potential to recover as much as 99% of cleaning solution, most often caustic (Daufin et al. 2001). The retentate from chemical recovery systems is usually disposed of to the wastewater treatment plant or sewer.

Some dairy processing plants have installed hydro-cyclones, separators and clarifiers to remove fat from soiled chemical streams to help improve the quality of recovered chemicals.

The main advantage of multi-use CIP systems is that they can recirculate and allow the reuse of chemicals and rinse water, thereby substantially reducing water and chemical consumption.

Optimising chemical recovery and reuse in CIP systems: Bonlac Foods, Cororooke
Bonlac in Cororooke assessed 15 separate CIP wash cycles. Each cycle was then improved by modifications to logic control programs, pipework/valving and return pumps to maximise recovery and reuse of caustic soda. Estimated caustic usage was reduced by 50%.

Recovery of CIP solution from milk pasteuriser: Murray Goulburn, Leitchville
Murray Goulburn in Leitchville incorporated its milk pasteuriser CIP system with the cheese CIP reuse system to prevent solution from the milk pasteuriser CIP going to drain. The initiative saves the plant around $73 000 in chemical costs and 16 000 L of hot water per day, in addition to improving the quality of its wastewater.

Upgrade of CIP system to include recovery tanks: Murray Goulburn, Koroit
Murray Goulburn in Koroit upgraded its major CIP set for evaporators to include separate dirty and clean caustic tanks, in order to increase recovery, improve the quality of the chemical supply, reduce effluent volume and reduce plant downtime. The initiative saves the plant $80 000 annually. The payback period was 13 months.

Automation and upgrade of detergent recovery system: Bonlac, Cobden
Bonlac in Cobden automated and upgraded the detergent recovery of its CIP system to reduce caustic use. The new CITECT system is now saving the plant more than $83 000/yr, including $25 000 in reduced chemical costs. Caustic concentration was reduced from 1.3% to 1.0%. The project cost was $170 000, with a payback period of 2.3 years.

Review of CIP cycle times: Murray Goulburn Cooperative, Koroit
Murray Goulburn in Koroit reduced evaporator CIP times and improved effectiveness by installing a hydro-cyclone at the distributor plates, which prevents soil from entering the evaporator. The initiative has resulted in a more effective clean and a 20% reduction in the cleaning time.

7.2.7 Operator competency and safety

Operator training and careful supervision and monitoring of processes play an important role in ensuring that chemicals are used safely and efficiently. Operator training should include how to correctly handle and apply chemicals and understand the economic, environmental and health impacts of incorrect and inefficient use.

7.2.8 Equipment operation and maintenance

Equipment such as dosing pumps, spray balls, nozzles and hose connections should be regularly monitored and maintained to ensure that excessive amounts of chemicals are not being used to compensate for poor mechanical operation or leaks. The supply pressure of chemicals and cleaning solutions should also be regularly checked, along with nozzle types, alignment, spray pattern and durability. Chemical suppliers can provide advice on the wide variety of nozzles and spray ball types suitable for individual cleaning applications.

It is also important to regularly check and calibrate instrumentation (e.g. for measurement of temperature, conductivity or flow).

7.3 Chemical alternatives

Many dairy processors are now taking a more holistic approach to chemical alternatives, in partnership with suppliers, with a view to improving cleaning efficiencies while also reducing chemical consumption and wastewater treatment costs.

7.3.1 Biodegradable chemicals

Non-toxic, organic chemicals, such as plant-based cleaning agents, may provide an opportunity to reduce maintenance and wastewater discharge costs. Some biodegradable cleaning products can be more expensive than traditional products; it is therefore important to take a holistic approach and consider some of the operational and downstream savings, and not just the initial purchase cost. Biodegradable (environmentally friendly) chemicals can be perceived as not being as effective as conventional chemicals. However, recent technological advances have meant that plant-based ingredients can now be combined to create more powerful cleaning agents and natural disinfectants. Table 7.3 shows a comparison between inorganic and organic acids used for cleaning. Biodegradable chemicals used in the dairy processing industry include acetic acid, citric acid and hydroxyacetic acid.

Peroxyacetic acid is used in the dairy industry as a biodegradable and non-toxic sanitising agent that is as effective as chlorine and can be used at low concentrations. The main advantage of peroxyacetic acid over chlorine-based compounds is that, after dosing into water, there are no problems with corrosive vapours (Chester Kidd 2003, pers. comm.). Other advantages of peroxyacetic acid include the absence of phosphates, and its biodegradability.

A number of factors do need to be considered, however, when using peroxyacetic acid. When peroxyacetic acid is added to water it creates a solution of peroxyacetic acid, acetic acid and hydrogen peroxide. The breakdown into acetic acid can increase the BOD loading of wastewater, potentially increasing wastewater disposal costs. The acetic acid can also lower the pH of the wastewater (to pH 4–5), depending on the initial concentration of the acetic acid in the peroxyacetic acid product and the dosage of peroxyacetic acid added to the water. In dairy processing, the pH of the wastewater is not significant because the volume of water containing acetic acid is mixed with much larger volumes of wastewater.

Table 7.3 **Comparison of inorganic and organic acids**

Inorganic (mineral)	Organic
High strength	Mild, stable, less corrosive
Corrosive	Safe, gentle, harmless to skin in use-concentrations
Low pH due to high degree of ionisation	Can be combined with wetting agents for penetration of soils
Under certain conditions some inorganic acids will precipitate insoluble salts Irritating to skin High concentrations dangerous to handle Damages clothing	Acid reaction tends to prevent and remove deposits of calcium and magnesium salts derived from either milk or water
Examples: hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid.	Examples: acetic acid, lactic acid, hydroxyacetic acid, citric acid, peroxyacetic acid

Source: Harper & Spillan 2004

7.3.2 Enzyme-based detergents

Enzyme-based detergents are finding acceptance in dairy processing industry for both foam cleaning and CIP applications. Enzymes speed up specific chemical reactions in mild conditions of temperature and pH. The primary advantages of enzyme detergents are that they are environmentally friendly and non-corrosive, they require less energy input in the form of heat, they can reduce wastewater costs, and they can reduce the salt levels of effluent through the reduced use of caustic-based cleaners.

Most enzyme cleaners are limited to unheated surfaces and are used on raw milk areas (unpasteurised milk lines), but some processors are now considering trialling their use on pasteurised milk lines. Recent laboratory trials show that an acid treatment followed by a short rinse with fresh water and then enzymatic treatment can clean effectively. However, some difficulties remain concerning enzyme dosing, process control and economics (Grabhoff 2002).

Use of enzyme cleaner: National Foods, Penrith
National Foods in Penrith trialled an enzyme-based detergent. However, they have experienced problems with cleaning effectiveness, so have reverted to standard cleaning chemicals.

Single phase cleaning and enzyme technology: ice-cream processor, Asia[1]
Enzymes have been used to remove milk protein from cold milk surfaces in an ice-cream manufacturing plant. A secondary component of the cleaning product removes fats and minerals, resulting in a single-phase clean, and allows the acid phase of the cleaning to be eliminated. The enzymatic clean is followed by the use of an acidic sanitiser.

[1] Chester Kidd [Market Development Manager] and Michael Stiff [Marketing Manager] 2003, pers. comm., <www.ecolab.com>

7.3.3 Reduced phosphate, nitric and sodium blends

Many conventional cleaning chemicals contain phosphates in the form of phosphoric acid and tri-sodium phosphate, and nitrogen in the form of nitric acid. Many dairy effluents also contain high levels of phosphates from product residues. Phosphates and nitrates need to be removed from wastewater streams, as they can contribute to algal blooms and oxygen starvation in waterways. As a result, some local councils include a levy on the concentration of phosphates and nitrogen in wastewater. For example, Ipswich Water in Queensland will be increasing its charges for nitrogen and phosphorus in wastewater from $0.80/kg and $3.00/kg to $2.00/kg and $9.00/kg respectively over the next few year (Mark Sherson 2004, pers. comm.). Products with less than 0.5% by weight of phosphorus are available to replace conventional cleaning chemicals for most duties (MnTAP 2003).

Many cleaning chemicals also contain sodium in the form of sodium hydroxide (NaOH), which contributes to the salt load of wastewater and exacerbates salinity levels in soil if the water is irrigated. Some dairy processors are using blends of sodium hydroxide and potassium hydroxide to reduce the sodium levels in wastewater. Water authorities are therefore introducing sodium-based charges (like phosphorus and nitrogen charges) on wastewater disposal.

Change to nitric acid blend: Dairy Farmers, Jervois
Dairy Farmers in Jervois changed from a phosphoric acid-based cleaner and sanitiser to a nitric acid-based one. This initiative resulted in a superior clean and reduced the phosphate load in the wastewater used for irrigation. This assisted with a phosphate reduction 'pollution reduction program' (PRP) in the site's EPA licence.

Replacement of phosphoric acid with citric acid: Murray Goulburn, Rochester
Murray Goulburn in Rochester is attempting to move away from using phosphoric acid, due to the resultant high level of nutrients (phosphates) in the effluent which is used for irrigation.

The company is using neutral cleaners and organic sanitisers such as citric acid, and this has reduced caustic and acid consumption by 500 L daily, as well as reducing phosphorus levels in wastewater.

A major plant recovery system for reclaiming cleaning chemicals has reduced the total dissolved salts in the plant effluent. The EPA is expecting progressive reduction in salt in irrigation water. The new recovery system has produced a 15% reduction in plant effluent conductivity.

Neutral cleaners for cold surfaces: Murray Goulburn, Maffra
Murray Goulburn in Maffra has replaced caustic-based cleaners with neutral cold surface cleaners for cleaning cold milk surfaces such as tankers. While the cold surface cleaners need to be rinsed more frequently with an acid wash, the reduced use of caustics by the plant has benefited both the environment and operators' health and safety. The use of the cleaners has reduced the salt content of the wastewater.

7.4 Chemical treatment of boilers, cooling water and condensate water

Different water use applications require different water quality, so it is wise to treat it only to the required quality for each application.

7.4.1 Boiler water treatment

Boiler feedwater may require pre-treatment to remove dissolved oxygen, hardness, silica and other minerals. Methods used to treat the water include chemical dosing and filtration, softening, demineralisation, ion exchange and de-aeration. As boiler feedwater is usually recirculated, blowdown is required to prevent concentration of impurities that can cause scale on the surfaces of the boiler tubes and reduce effective heat exchange. Blowdown should be controlled on the basis of concentration of impurities in the boiler. The installation of conductivity probes that initiate blowdown only when the water exceeds a set value prevents the unnecessary waste of water, chemicals and energy due to excessive blowdown.

7.4.2 Cooling water treatment

Cooling tower water requires treatment to control microbial activity (such as *Legionella*) to safe levels, while minimising scaling and corrosion of pipework, heat exchange equipment and the cooling tower. As with boiler feedwater, cooling water operates as a recirculating flow and therefore requires blowdown to remove solids. Various chemicals are added to cooling water, including pH adjusters, corrosion inhibitors, dispersants to keep solids in suspension, and microbiocides (similar to sanitisers). The installation of a filtration system to remove suspended materials can help to reduce chemical use while also reducing the need for blowdown and the loss of heat transfer efficiency.

7.4.3 Condensate water treatment

Information on condensate reuse and condensate water treatment can be found in Chapter 3.

7.5 Alternatives to chemical use

7.5.1 Ozone

Ozone is a powerful oxidising agent that destroys micro-organisms by oxidising their cell membrane. Ozone is usually generated onsite by creating an electrical discharge across an oxygen or air stream. The bonds that hold the O_2 together are broken and three O_2 molecules are combined to form two O_3 molecules (ozone). The ozone quickly breaks down and reverts to O_2. The O_3 molecules destroy micro-organisms by oxidising their cell membranes. Ozone is currently being promoted as an alternative to chlorine as it reacts 3000 times faster with organic materials, leaves no residue and is less dependent on pH and temperature (WaterTech Online 2003). Ozone has been used in other industries in a gaseous form to fumigate, and in an aqueous form (i.e. dissolved in water) for washing, cleaning and sanitising. It can be difficult to maintain consistent dosage rates, because the breakdown of ozone back into oxygen occurs rapidly. Examples of ozone use in the Australian dairy processing industry are so far limited to trials on cooling tower water treatment.

Ozone to treat cooling towers: Bonlac, Stanhope
Bonlac Foods in Stanhope is currently trialling the use of ozone in its cooling towers. The ozone is proving to be very cost-effective and is predicted to save the plant around \$120 000/yr in reduced chemicals. Each ozone unit costs around \$5500 and is economical to operate, using a 0.5 kW generator.

7.5.2 Ultraviolet light

Ultraviolet (UV) disinfection systems destroy micro-organisms through interaction with microbe DNA. The degree of inactivation of microbes is related to the UV dose, which is linked to UV light intensity and contact time. Factors that can affect dosage include turbidity and organic load. Some micro-organisms, such as *Giardia* or *Cryptosporidium*, may not be affected at average doses. UV light has the advantage of leaving no residue and it is not affected by water chemistry. UV light has been used by some Australian dairy processors to disinfect water used for cleaning, and for treating condensate. For example, Murray Goulburn Leitchville used UV light to disinfect water used for burst rinsing of cheese vats.

Ultraviolet disinfection of feta cheese brine: cheese processor, South Africa[1]
Clover South Africa required a non-chemical brine disinfection system that would not alter the quality of the cheese, and that was also simple and easy to maintain. The company has now installed and is successfully operating an ultraviolet disinfection system. 'We considered using conventional heat treatment of pasteurisation but the operating costs of UV are far lower than those of pasteurisation.' — Production Manager, Clover South Africa

[1] Manufacturingtalk 2003

7.6 Supply and handling of chemicals

7.6.1 Supply agreements and performance-based contracts

Seeking the advice and involvement of chemical suppliers and water treatment experts is essential. Some chemical suppliers will enter into service agreements with their customers, where they provide an advisory service that is built into the cost of the chemicals they sell. Depending on customer size and the complexity of chemical use on the site, they will conduct monthly or quarterly reviews and make recommendations on how to utilise their products to best effect. Some suppliers often supply dosing equipment at no cost, or under a lease arrangement, to ensure the correct usage of their product and its continued use with the customer.

Performance-based contracting is another way in which two companies can collaborate to improve performance. Typically used in the energy industry, performance-based contracting means that a third party takes responsibility for the management of a specific part of a business. In this case it could be a chemical supplier taking charge of water treatment. The contractor is responsible for treating all water used on the site, and has the opportunity to make changes to improve efficiency, thus sharing the benefit with the contracting company.

7.6.2 Bulk supply of chemicals

Purchasing chemicals in bulk or at higher concentration may be more economical and can save on packaging. If chemicals are purchased in more concentrated form, appropriate training should be provided to ensure safety of operators and to avoid wastage. All chemicals should be properly labelled and stored in a dry, well-ventilated and appropriately designed area. Preventive measures and clean-up procedures should be in place in case of spillage.

Consolidation of suppliers and bulk purchasing: Dairy Farmers, Bomaderry
Dairy Farmers in Bomaderry previously used nine different chemical suppliers to meet its chemical needs. The plant has since changed to just one supplier. It took a few months for the plant and the supplier to come up with a range of chemicals equivalent to those they were previously using, but they are now purchasing them at a reduced price. The plant also receives a 'group discount' as Dairy Farmers buy in bulk for several processing plants.

7.7 Further reading

There are several Australian standards with information on chemical use in dairy factories. These include:

AS 1398:1998, Iodophors for Use in the Dairying Industry

AS 1162:2000, Cleaning and Sanitising Dairy Factory Equipment

AS 1536:2000, General Purpose Detergents for Use in the Dairying Industry

AS 1087:2003, Sodium Hypochlorite Solutions for Use in the Dairying Industry

AS/NZS 1389:1997, Acidic Detergents for Use in the Dairying Industry

AS/NZS 1400:1997, Heavy-Duty Alkaline Detergents for 'In-Place' Cleaning in Dairy Factories

AS/NZS 2541:1998, Guide to the Cleaning-in-Place of Dairy Factory Equipment.

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Units, prefixes and conversions

SI prefixes

PREFIX	FACTOR
peta- (e.g. petajoule, PJ)	10^{15} (1×10^{15} J)
tera- (e.g. terajoule, TJ)	10^{12}
giga- (e.g. gigajoules, GJ)	10^{9}
mega- (e.g. megajoule, MJ)	10^{6}
kilo- (e.g. kilojoule, kJ)	10^{3}
milli- (e.g. millimetre, mm)	10^{-3} (1×10^{-3} m)
micro- (e.g. micrometre, μm)	10^{-6}
nano- (e.g. nanometre, nm)	10^{-9}
pico- (e.g. picometre, pm)	1^{-12}

Conversion factors

UNIT	CONVERSION
Length	
1 km	1000 m
1 m	100 cm
1 cm	10 mm
1 in	2.54 cm
1 ft	30.48 cm
1 yd	0.91 m
1 mile	1609 m
1 μm	1×10^{-6} m
Mass	
1 kg	1000 g
1 mg	0.001 g
1 lb	0.454 kg
1 t	1000 kg
1 long tonne	1016.1 kg
1 short tonne	907.2 kg

Volume

1 L	1000 mL
1 m^3	1000 L
1 gallon (British)	4.546 L
1 gallon (US)	3.785 L
1 cm^3	1×10^{-6} m^3
1 in^3	1.64×10^{-5} m^3

Area

1 cm^2	1×10^{-4} m^2
1 in^2	6.45×10^{-4} m^2
1 ft^2	9.29×10^{-2} m^2
1 acre	4.05×10^{3} m^2
1 $mile^2$	2.59 km^2

Density

1 g/cm^3	1×10^{3} kg/m^3
1 lb/ft^3	16.02 kg/m^3

Velocity

1 ft/s	0.305 m/s
1 mile/h	1.6 km/h
1 knot	1.85 km/h

Volumetric flow rate

1 ft^3/s	2.83×10^{-2} m^3/s
1 L/min	0.06 m^3/h

Temperature

°F	$°C \times \frac{9}{5} + 32$
°C	$(°F - 32) \times \frac{5}{9}$

Pressure

1 atm	1.013×10^{5} Pa
1 bar	1×10^{5} Pa
1 inch water	249 Pa
1 inch Hg	339 Pa
1 mm Hg	133.3 Pa

Energy

1 kW h	3.6 MJ
1 cal	4.184 J
1 BTU	1055.06 J
1 therm	100 000 BTU
1 therm	105.506 MJ

Specific heat

1 cal/g °C	4186 J/kg °C
1 BTU/lb °F	4186 J/kg °C

Thermal conductivity

1 cal/s cm °C	418.6 W/m °C
1 BTU/h ft °F	1.73 W/m °C

Calorific value

Energy source	*Energy content*
Electricity	3.6 MJ/kW h
Black coal (default washed)	27.0 GJ/t
Wood	16.2 GJ/t
Natural gas	39.5 MJ/m^3
Diesel (automotive)	38.6 GJ/kL
Diesel (industrial)	39.6 GJ/kL
Petrol (transport)	34.2 GJ/kL
LPG (non-transport)	49.6 GJ/t
Fuel oil	40.8 GJ/kL
Kerosene	36.6 GJ/kL

Glossary

Aerobic digestion	The decomposition of organic matter in the presence of free oxygen to produce carbon dioxide and water.
Anaerobic digestion	The decomposition of organic matter in the absence of free oxygen. In this process, different species of micro-organisms degrade organic matter to produce various compounds, such as methane.
Benchmark	A standard against which something can be compared.
Blowdown	Water discharged into a system such as a boiler or cooling tower to control concentrations of salts or other impurities.
Biodegradable	Capable of being decomposed (e.g. by bacteria).
Biofuel	Gas or liquid fuel made from organic matter.
Biogas	Gas produced from the digestion of organic matter under anaerobic conditions. Biogas consists mainly of methane and carbon dioxide but also contains other gases.
Biosolids	The accumulated solids separated from wastewater, which have been stabilised by treatment and can be beneficially used.
BOD	Biochemical oxygen demand — a measure of the quantity of dissolved oxygen consumed by micro-organisms as a result of the breakdown of biodegradable constituents in wastewater.
Caustic	A hydroxide of a light metal (e.g. caustic soda or sodium hydroxide) that is commonly used in the dairy industry for cleaning.
COD	Chemical oxygen demand — a measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater.
Condensate	Refers to either vapour condensate, which is condensed vapour produced from evaporation and drying processes, or steam condensate, which is produced when steam is condensed back to a liquid.
Cogeneration	The simultaneous production of heat energy and electrical or mechanical power from the same fuel in the same facility. Cogeneration is achieved through recovery of rejected heat that escapes from an existing electricity generation process.

Cow water	Condensate produced from the evaporation of milk.
DAF	Dissolved air flotation — a type of wastewater treatment technology to remove fat and suspended solids.
De-sludge	The removal of precipitate from a waste treatment system.
IAF	Induced air flotation — a type of wastewater treatment technology to remove fat and suspended solids.
EC	Electrical conductivity — a measure of how well a material accommodates the transport of an electrical current. Conductivity of water depends on the number of ions or charged particles it contains. EC is an important indicator of salt levels in dairy wastewater that is to be used for irrigation purposes.
Eco-efficiency	Defined by the World Business Council for Sustainable Development as 'the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity'.
EMS	Environmental management system — a system instituted by a company to manage its environmental impacts.
Greenhouses gases	Gases that contribute to the 'greenhouse effect' in the earth's atmosphere. The major greenhouse gases are carbon dioxide, methane and nitrous oxide.
HACCP	'Hazard analysis and critical control point' — a food safety system designed to prevent the occurrence of problems that threaten food safety. As a preventive approach it relies on identifying potential hazards and the measures needed for their control.
Hydrocyclone	A vessel that uses gravity, centrifugal force and differences in material density to separate solid particles contained in a liquid stream.
Interface	A surface forming the boundary between adjacent substances (e.g. product and rinse water).
KPI	Key performance indicator. KPIs of eco-efficiency performance are the quantities of resources consumed and quantities of waste generated per unit of production.
MF	Microfiltration — a type of membrane technology, using a pore size of approximately 0.01–4.0 μm.
TN	Total nitrogen

Na	Sodium
NF	Nanofiltration — a type of membrane technology, using a pore size of approximately 0.8–9.0 nm. Used in the dairy processing industry for purposes such as lactose rejection, protein, whey and milk concentration, caustic recovery and standardisation of protein.
Non-renewable resource	A resource that is consumed more rapidly than it can be replenished in the foreseeable future.
LPG	Liquefied petroleum gas
P	Phosphorus
RO	Reverse osmosis — a type of membrane technology, using a pore size of approximately 0.1–2.0 nm.
Sewage	Domestic waste matter carried away in sewers or drains.
Sewer	A waste pipe that carries away sewage or surface water.
Sewerage	A system of sewers carrying away sewage or surface water.
Specific heat of water	The amount of energy required to raise the temperature of one kilogram of water by one degree Celsius = 4.18 kJ/kg/°C.
SS	Suspended solids — insoluble solid particles that either float on the surface of, or are in suspension in, water.
Trade waste	Any liquid that is, or may be, discharged from trade premises.
UF	Ultrafiltration — a type of membrane technology, using a pore size of approximately 0.005–0.1 µm.