Eco-efficiency Toolkit

for the Queensland Food Processing Industry

Queensland Government
State Development and Innovation
Environmental Protection Agency

AUSTRALIAN INDUSTRY GROUP

Australian Government
Department of Agriculture, Fisheries and Forestry

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Queensland Government
State Development and Innovation
Environmental Protection Agency

FOREWORD

The food and beverage industry is one of Queensland's largest manufacturing sectors. After mining, it is our greatest goods export earner, contributing $5.3 billion (23%) to the economy and employing over 33,000 people.

World demand for safe, healthy food products grows each year and Queensland is highly regarded for the quality and consistent supply of its goods.

A key element of the Government's Smart State strategy is to give Queensland a competitive edge by enhancing our industries with 21st century technology. The achievements of Queensland's food processing industry are testament to the success of this strategy.

Queensland's food processing industry faces many challenges in the global marketplace, especially when it comes to profitability and environmental sustainability. The Queensland Government, in partnership with industry, is helping businesses improve their financial returns and their environmental bottom line.

The Environmental Protection Agency is the lead agency for promoting sustainability in industry. Its Eco-Efficiency program offers manufacturers advice on effective and efficient management of energy, water, raw materials and waste. It not only saves businesses money but provides the Smart State with another opportunity to become world leaders.

This manual pulls together a wide range of ideas, information and resources on eco-efficiency and provides business with an up-to-date and comprehensive self-assessment tool.

The Queensland Government is committed to working with the food processing industry to ensure its continuing profitability and good environmental performance for the benefit of all Queenslanders.

Hon Tony McGrady MP
Minister for State Development and Innovation

Hon John Mickel MP
Minister for Environment

Eco-efficiency for the Queensland Food Processing Industry

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Published by:
Australian Industry Group 2004

ISBN: 0 9752100 0 9 (manual)
0 9752100 1 7 (CD)
0 9752100 2 5 (Internet version of manual)

Illustrations: Paul Lennon

Acknowledgments

The Australian Industry Group and UNEP Working Group for Cleaner Production are grateful to the following individuals for their participation in this project and in the development of the toolkit.

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About the project

The Eco-efficiency for the Queensland Food Processing Industry project was undertaken with the aim of increasing the competitiveness of the Queensland food processing sector and reducing its environmental impact, through the uptake of eco-efficiency.

The project was managed by the Australian Industry Group and funded by the following bodies: the Queensland Department of State Development; the Queensland Environmental Protection Agency — Sustainable Industries Division; the Australian Department of Agriculture, Fisheries and Forestry; Brisbane City Council; and the Australian Water Association.

A steering committee was formed to guide the project. This included representatives of the funding bodies, industry associations, eco-efficiency consultants and industry.

The UNEP Working Group for Cleaner Production was commissioned to develop and produce the 'toolkit'. This involved conducting eco-efficiency assessments of Bundaberg Brewed Drinks, Buderim Ginger, Golden Circle, Stahmann Farms, Goodman Fielder (Carina) and Mrs Crocket's Kitchen, as well as visiting and making other contacts with numerous other food processing companies in Queensland.

Further information can be found at the project website:
www.geosp.uq.edu.au/emc/cp/Food_Project/default.htm

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1 Introduction

1.1 The toolkit

This eco-efficiency toolkit has been developed for food processing companies in Queensland, to increase their awareness and uptake of eco-efficiency. This chapter outlines the environmental challenges and issues faced by food processors. Although the information is specific to Queensland, much of it is also applicable to food companies Australia-wide.

Eco-efficiency is all about improving environmental performance to become more efficient and profitable. It is about producing more with less. It involves the application of strategies that will not only ensure efficient use of resources and reduction in waste, but will also reduce costs. The concept of eco-efficiency has been adopted by many industries throughout Australia and the world, and is promoted by the World Business Council for Sustainable Development (WBCSD 2000).

How to use this toolkit

The *Eco-efficiency toolkit for Queensland food processors* consists of:

1. this eco-efficiency manual
2. an accompanying CD-ROM which includes:
   a. a generic training presentation
   b. a series of Excel-based calculators
   c. a table summarising the many opportunities mentioned in the manual.

The manual lists potential opportunities for food processing companies to reduce the consumption of resources and to minimise the production of solid and liquid wastes. It includes chapters on water and wastewater, energy, chemicals, packaging, and solid wastes, and identifies the major eco-efficiency opportunities within a food processing plant.

It features a self-assessment guide, which introduces the fictional 'Sunny Fruit Juice' company and its experiences in pursuing eco-efficiency. The guide outlines the steps in undertaking an assessment, and includes pro-forma sheets designed to be copied and used. The training presentation provides a generic presentation on eco-efficiency and its application to the food industry. It is designed to be used at an introductory workshop before the commencement of an eco-efficiency project or assessment.

The calculators are designed to help managers identify the true cost of water for their plant, the amount of greenhouse gas emissions they are generating, the make-up of trade waste costs, and savings from improving the efficiency of a compressed air system.

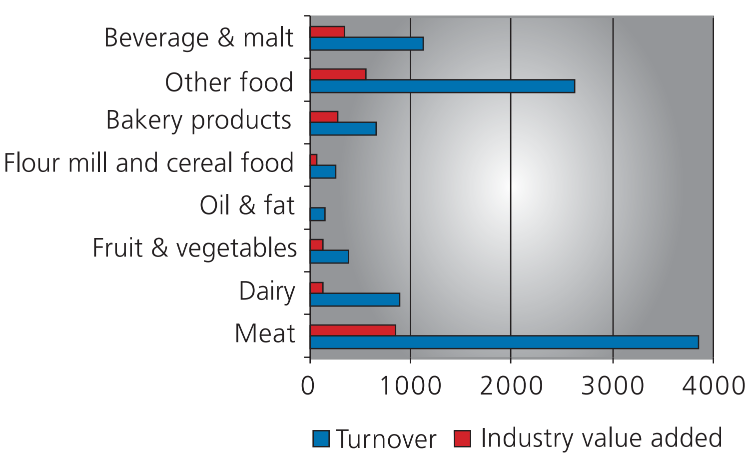
Altogether, the toolkit forms the basis of a comprehensive resource to help in adopting eco-efficiency. We suggest that you form an onsite eco-efficiency team, and use the toolkit as a guide for identifying opportunities to promote eco-efficiency within your company.

1.2 Profile of the Queensland food processing industry

The Australian food processing industry makes a significant contribution to our economy, with total sales estimated at $75 billion in the year 2001–02 (accounting for 45% of domestic spending), and exports of $26.6 billion. It is the largest Australian manufacturing industry sector and employs over 187 000 people (DAFF 2003), with around half of the firms in rural/regional areas.

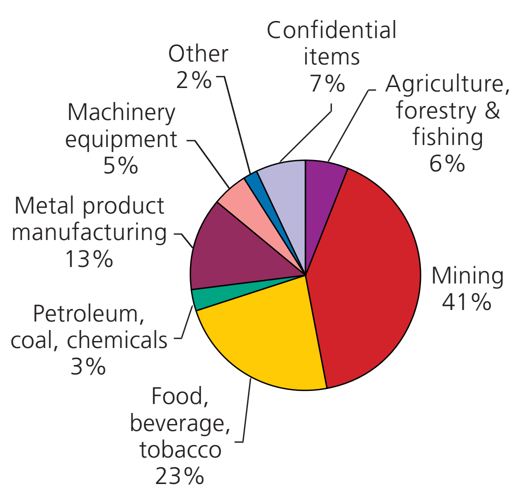
Queensland has the third-largest proportion of the food processing industry, in terms both of turnover and of employment generated. During 1999–2000, the Queensland food processing industry turned over $9.93 billion, with a value-added component of $2.34 billion; and the industry employed 35 100 people. The make-up of the Queensland food processing industry is illustrated in Figure 1.1. In 2001–02, the food processing industry (food, beverage and tobacco) contributed approximately 23% or $5.3 billion to Queensland's exports (Figure 1.2).

Figure 1.1: Turnover and IVA ($m) — Queensland food industry 1999–2000



Source: DAFF, 2003

Figure 1.2: Queensland exports 2001–2002



Source: Qld Department of State Development, 2004

The food processing industry spends more money than any other manufacturing sector on waste management and environmental protection measures. During 2000–01, the food, beverage and tobacco sector (ANZIC Code 21) spent $164 million on environment protection measures such as licences and disposal and treatment services. Of this, $68 million was spent on solid waste management and $57 million on liquid waste management. A further $100 million of capital expenditure was made for purchases to enhance environmental protection (ABS 2002).

Food processing facilities can be large producers of wastes and large consumers of resources. Our challenge is to minimise waste expenditure and resource costs to make the sector more sustainable and competitive.

1.3 Environmental challenges

1.3.1 Compliance and legislation

Environmental legislation that regulates Queensland food processing plants is administrated by authorities such as the state's Environmental Protection Agency (EPA) and local councils. Those companies that operate an 'environmentally relevant activity' (ERA) as defined in the *Environmental Protection Act 1994* (Qld) must meet licence requirements issued by the EPA. These licences generally include emissions to air and surface waters and disposal of solid and liquid wastes. Disposal of wastewater to the sewerage system is regulated by local councils.

Regulatory authorities are encouraging industries to play a more proactive role in improving their environmental performance through the use of tools such as industry codes of practice, environmental management systems (EMS) and waste minimisation plans. To encourage business to achieve more than basic compliance, government authorities such as the EPA's Sustainable Industries Division and, at national level, the Department of Environment and Heritage, are now more focused on building partnerships with business and industry groups to encourage the uptake of eco-efficiency.

1.3.2 Water supply and pricing

Of all the manufacturing industries, food processing has the highest level of water use in Australia, accounting for just over 30% or 241 706 ML per year (ABS 2002). Within the food processing industry there is great variation in water use, due to the diversity of operations taking place.

Water supply to food processing plants is generally from treated town water supplies. Some plants, however, have access to bore, river or dam waters which may be treated or used for non-food applications. As increasing pressure is placed on limited water reserves, government bodies and water authorities are actively seeking to promote greater water efficiency and encouraging water conservation strategies and incentives. The Brisbane City Council, for example, recently introduced a scheme for providing water rebates to large users of water that have developed and implemented water management plans.

Food processors are also becoming aware of the escalating cost of water. For example, since 1997 water supply costs in the Brisbane City Council region have risen from $0.60/kL to $1.13/kL (Jackson Pers. Comm. 2002). Table 1.1 shows current water supply costs for a number of Queensland councils.

Table 1.1: Queensland water supply costs

Region	Supply cost ($/kL)*
Brisbane	$1.13
Gold Coast	$0.95
Ipswich	$1.28
Townsville	$1.99
Toowoomba	$1.00
Maroochy	$0.87

*Some prices have additional base charges.

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.

1.3.3 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 currently charge on the basis of the organic loads (BOD/COD) and volumes. However, some councils have introduced additional charges for nutrient loads (nitrogen and phosphorus). Full cost recovery charging has not been applied to sewer discharges to date; but this situation is changing, and 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-pay basis until something approaching full cost recovery is achieved. For example, the Gold Coast City Council is more than doubling its volumetric discharge fee, from $1/kL to $2.18/kL, with additional incremental rises in mass load charges. Other Queensland councils, such as Maroochy Shire and Toowoomba City, are currently reviewing their cost structures with a view to recovering a greater proportion of the costs of wastewater treatment.

1.3.4 Energy and energy supply costs

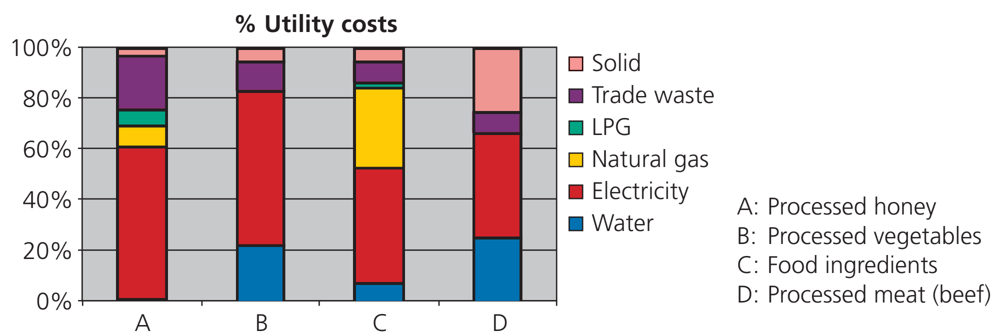
Australia has extensive reserves of fossil fuels, so its energy requirements are based almost entirely on the non-renewable resources of coal, oil and natural gas. Australia's, and in turn Queensland's, per capita demand for energy is high by world standards. Because much of the energy used depends on largely non-renewable fossil fuels, the current rate is believed to be unsustainable in the long term. Australia's overall energy consumption per unit of gross domestic product (GDP) has improved only slightly since 1970, whereas some other OECD countries have achieved improvements of more than 30% (DEH 1996).

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 Australian businesses a choice of retail companies for their supply of electricity. For some Queensland companies, this resulted in initial savings of around 10–20%. Costs have since increased with the consumer price index (McNair Pers. Comm. 2004).

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. Nevertheless, a growing awareness of the environmental impact of combusting fossil fuels (in particular increasing greenhouse gas emissions), has driven the development of alternative 'cleaner' energy sources. Sources of 'green' energy in Queensland include solar, wind, biomass and biogas. Greenhouse abatement initiatives such as the Greenhouse Challenge and the Australian Renewable Energy Certificate scheme have gone some way to increase awareness of environmental issues and encourage the more efficient and sustainable use of energy.

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 food processors to minimise energy consumption. Figure 1.3 shows a breakdown of utility costs for four food operations. A medium to large food processing company could typically spend between $100 000 and $500 000 on energy costs per year. A possible 10% reduction in energy costs can be a significant incentive.

Figure 1.3: Percentage utility costs for four food processors



1.3.5 Packaging

Food manufacturers face increasing pressure to develop and use packaging that reduces resource use, enables reuse or recycling and minimises landfill disposal. A 2001 survey by the Australian Food and Grocery Council identified packaging as the most significant environmental issue for their members during the preceding five years; 80% felt it would remain the most significant issue for the next five years, and this has been confirmed in the

2003 survey (AFGC 2003). The importance placed on packaging may have resulted from the strong increase in awareness as a result of the National Packaging Covenant (NPC), which was launched in 1999. The NPC encourages voluntary actions by signatory companies to reduce packaging waste, and is underpinned by regulation in all states to capture non-signatories. By 2004, 637 organisations had signed on to the NPC, with a significant percentage of these being from the food processing sector. This approach differs from other regulatory approaches, such as in Europe and Japan where efforts to reduce packaging waste are through increasingly stringent regulations and through making manufacturers responsible for packaging from the 'cradle to grave' — that is, from production through to responsible disposal by the consumer. In some cases packaging initiatives are driven by the legislative requirements of export customers.

1.3.6 Solid waste management

In the current climate, food processing companies are generally well aware of the waste management hierarchy to eliminate, reduce, reuse or recycle wastes. Solid waste recycling or reuse rates for most food and grocery sectors are about 80%, with an average of 4% sent to landfill (AFGC 2003). The remainder is organic waste, which may be used as animal feed, or composted or digested to produce biogas. Food 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. A recent development in some city areas is the collection of organic food waste for composting, and even for power generation (biogas).

From a manufacturer's perspective, challenges include storage of organic waste, frequency of recycling services, and management of odour. Contamination of solid wastes (particularly plastic packaging) by food and food ingredients can be a barrier to recycling, so companies may need to identify ways to remove or minimise the source of contamination. For a food processing company, solid waste disposal costs can be a relatively small or minor component of total operating costs. However, it is an area where employees at all levels can contribute and immediately see results, and which can be a good start in encouraging employees to be more environmentally aware and participate in company-wide initiatives.

An old adage is that one company's waste can be another's resource, and it can be worth the effort to regularly review waste streams and management options and spend some time looking for alternatives. This can both reduce the amount of waste sent to landfill and generate an additional source of revenue.

1.4 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 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 (WBCSD 2000) has identified a range of ways companies can improve their eco-efficiency. They can:

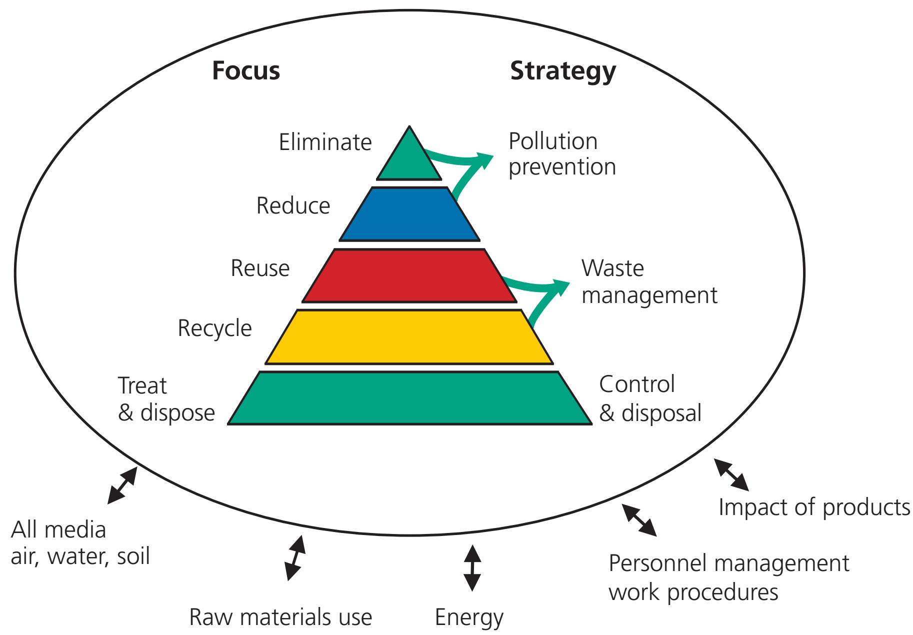
- reduce material intensity of goods and services
- reduce energy intensity of goods and services
- reduce toxic emissions
- enhance material recyclability
- maximise use of renewable resources
- extend product durability
- increase the service intensity of goods and services.

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.

1.4.1 Basic principles of eco-efficiency

Eco-efficiency involves systematically evaluating existing practices to identify opportunities for improvement. One key approach to improving eco-efficiency is through the waste minimisation hierarchy (illustrated by the waste minimisation triangle in Figure 1.4). This provides a structured way to identify opportunities, with the ultimate goal being 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. The concept of eco-efficiency is applicable to operations of any size or type. Both large and small businesses will be able to identify opportunities to operate more efficiently and make savings.

Figure 1.4: The waste minimisation triangle



1.4.2 Reasons for adopting eco-efficiency

There are many reasons for adopting eco-efficiency. Consider whether any of the following statements apply to your company. If any do apply, there may be eco-efficiency opportunities waiting to be taken:

- Your company has an interest in reducing operating costs and improving profitability.
- Your company is incurring high energy costs.
- Your company is incurring high solid waste costs.
- Your company has high water supply costs or is facing water allocation restrictions.
- Your company is incurring high wastewater treatment and/or disposal costs.
- Wastewater discharge limits for your company are becoming increasingly tight.
- Air emission standards for your operation are tightening.
- Your company is developing waste minimisation plans (e.g. water and waste management plans or signing up for the National Packaging Covenant or Greenhouse Challenge).
- Your company is trying to create an 'environmentally friendly' image and gain competitive edge or would like to improve its relations with environmental regulators.
- Your company would like to diversify into other products.
- You are adopting an environmental management system.

1.4.3 How to carry out eco-efficiency

There are a number of basic steps in carrying out an eco-efficiency assessment:

PLAN to put a program together.

MEASURE to find out how much you use and how much you lose.

ASSESS to work out what you can do to minimise losses and maximise gains.

IMPLEMENT — starting with low-cost solutions to motivate everybody.

IMPROVE by building continuous improvement and review into the program.

REPORT to communicate progress against goals.

Details on undertaking an assessment are explained further in the toolkit's self-assessment guide.

1.5 Benefits of eco-efficiency

The financial saving to be made from improving environmental performance is probably the greatest appeal of eco-efficiency.

Direct financial savings

Financial savings can usually be made in three key areas:

- **Direct savings from reduced raw material, water, energy and other resource costs**
- **Savings from reduced waste generation**
  Waste is not only a loss of valuable material but may also be costly to treat, transport and dispose. There are also often hidden costs, including pumping, handling and storage.
- **Reduced operational and maintenance costs**

Indirect benefits and financial savings

Effective eco-efficiency programs can also result in many additional indirect benefits and financial savings:

- **Reduced exposure to risk and liability**
  Environmental management plans developed as part of an eco-efficiency assessment can help to reduce risk of spills or environmental incidents.
- **Improved relations with regulators**
  The proactive approach of eco-efficiency towards environmental management is strongly supported by regulators.

- **Motivation for self-regulation**
  Eco-efficiency is voluntary and encourages the current trend towards self-regulation. Eco-efficiency is based on financial savings, so the concept has tended to sell itself.

- **Improved workplace health and safety**
  Stringent workplace health and safety legislation and the risk of company liability have meant many food processors are now seeking to find safer and more environmentally friendly alternatives — for example, eliminating the use of hazardous chemicals for cleaning or processing.

- **Enhanced public image for the company**
  Encouraging an environmentally friendly or 'green' image for your company is seen as a marketing opportunity as consumers become increasingly aware of environmental concerns related to food processing. Internationally Australia has created a green image by consistently maintaining high environmental standards.

- **Greater product diversification**
  The identification of alternative uses for wastes not only reduces the amount of waste going to landfill but also increases the efficiency of resource use, and enables the company to further diversify product range for increased profitability.

- **Competitive advantage**
  A competitive advantage can be gained through reducing operating costs and keeping ahead of the game as environment protection regulations get more stringent. This will improve the attractiveness of the company to financiers and insurers through better risk management and reduced exposure to liability.

1.6 Eco-efficiency and sustainability

Sustainable development is about recognising that the community's resources are not unlimited, and that such resources need to be used as efficiently as possible to ensure they are available for future generations. The key to achieving sustainable food processing is not only to consider financial aspects, but also to incorporate social and environmental issues into decision-making processes. In Queensland, there are various factors that make it necessary for companies to manage and minimise their environmental impacts and be more accountable for their actions. These include urban encroachment, water scarcity, pressure on infrastructure such as water treatment plants, air quality, soil salinity (for regional factories), greenhouse emissions, and increased public awareness of environmental issues.

Achieving sustainability will require continuous improvement, which means not just meeting regulatory requirements but exceeding them. Food processing companies are faced with a number of environmental challenges in the day-to-day operation of their factories. These are explored in greater detail in the following chapters of this manual, and include:

- the adoption of efficient water and energy management practices
- the efficient treatment, reuse and disposal of wastewater
- the minimisation of packaging and packaging waste
- the efficient use of chemicals
- the minimisation and management of solid wastes.

Eco-efficiency and cleaner production can help businesses meet the sustainability challenge, by demonstrating the financial benefits of reducing the environmental impacts of production activity and service provision, while aiming to maintain or improve the quality of life for future generations.

1.7 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. It requires that all relevant personnel, at all levels in the company, are informed and updated on their environmental management responsibilities. A well-structured EMS will regularly monitor how effectively the company is controlling its impacts on the environment; it will identify any deficiency that needs to be addressed and the corrective measures that need to be implemented.

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.

A company may choose to obtain third-party certification of its EMS to the ISO14000 standard. However, it can be just as effective to develop a fully functional EMS without certification.

1.8 Food safety and HACCP

'Hazard analysis critical control point' (HACCP) is commonly used throughout the food 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. Many markets for food products, particularly retail supermarket chains, insist that processing companies implement rigorous HACCP systems.

It is essential that eco-efficiency opportunities that are identified for a food company do not adversely affect food safety and quality. Increased risk (or perceived risk) can be a barrier to adopting eco-efficiency opportunities in some areas, such as water or solid waste reuse or recycling. 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.

1.9 Environmental reporting

Environmental reporting by food processing companies has increased over recent years as the public, finance sector and regulatory authorities demand greater transparency in business operations. A public environmental report can be included as a subsection of a company's annual report or may be a stand-alone document. In addition, some industry groups such as the Australian Food and Grocery Council produce sectoral reports that summarise the environmental performance of their members. Heightened public scrutiny of environmental performance has meant that many businesses are now improving their environmental performance, not only to meet regulatory requirements but also because they recognise that they are part of a community that increasingly acknowledges responsible environmental management.

Traditionally, environmental reporting has been a voluntary method of communicating environmental performance to stakeholders and the public. Pressure for public disclosure of environmental performance has increased to such an extent, however, that there is now some debate over whether environmental reporting should be made mandatory. Countries such as Denmark, New Zealand and the Netherlands have already started introducing legislation on environmental reporting.

1.10 Key performance indicators

Typical key performance indicators (KPIs) for the food industry represent the resources consumed per unit of production. Key performance indicators for a beverage plant, for example, are shown in Table 1.2. The development of benchmarks is an effective way to encourage continuous improvement within a company or industry. By comparing your plant's KPIs with those of similar processing plants, it may be possible to identify areas where there is scope for improvement.

Table 1.2: Typical key performance indicators for a beverage processor

	KPI
Product yield	kL product per kL raw material consumed
Water	kL consumed per kL product
Energy	kW h consumed per kL product, or MJ consumed per kL product
Wastewater	kL generated per kL product
Solid waste	kg generated per kL product

Many food processing plants, however, do not have comprehensive benchmark data. Comparisons between plants can also be difficult because of variations in figures as a result of differing factors such as the age of the factory, product mix, or type of technology in use. To obtain such information, the industry and individual plants need to set their own internal operation performance targets. Setting targets for individual departments within the plant is a great way to track performance, encourage competition and promote improvement.

KPIs can be linked to staff incentive schemes and to other management programs. They are an important part of an eco-efficiency program that can help in prioritising overall efficiency, and should be meaningful and easily understood.

1.11 Summary

Eco-efficiency is a powerful management strategy to reduce waste, improve efficiency, increase competitiveness and produce a more dynamic company. The focus on using resources more efficiently, and on measuring and controlling, means that everyone can understand the goals and everyone can participate. Eco-efficiency fits in with and can be part of other environmental tools such as an EMS, and can add value to company activities such as environmental reporting.

Eco-efficiency is the starting point for applying the principles of sustainable development, with the wider aim of producing a more sustainable society.

This toolkit includes a detailed self-assessment guide and information on many aspects of implementing eco-efficiency. It builds on the experiences of other companies that are on the same journey — a journey towards a more efficient and sustainable future.

2 Eco-efficiency self-assessment guide

This is a step-by-step guide to implementing eco-efficiency at a food processing plant. It is a tool to help managers and staff think about eco-efficiency in a strategic way — by assessing the plant's current resource use and waste generation, determining whether there is room for improvement, identifying ways to make the improvements, and then progressively implementing the changes.

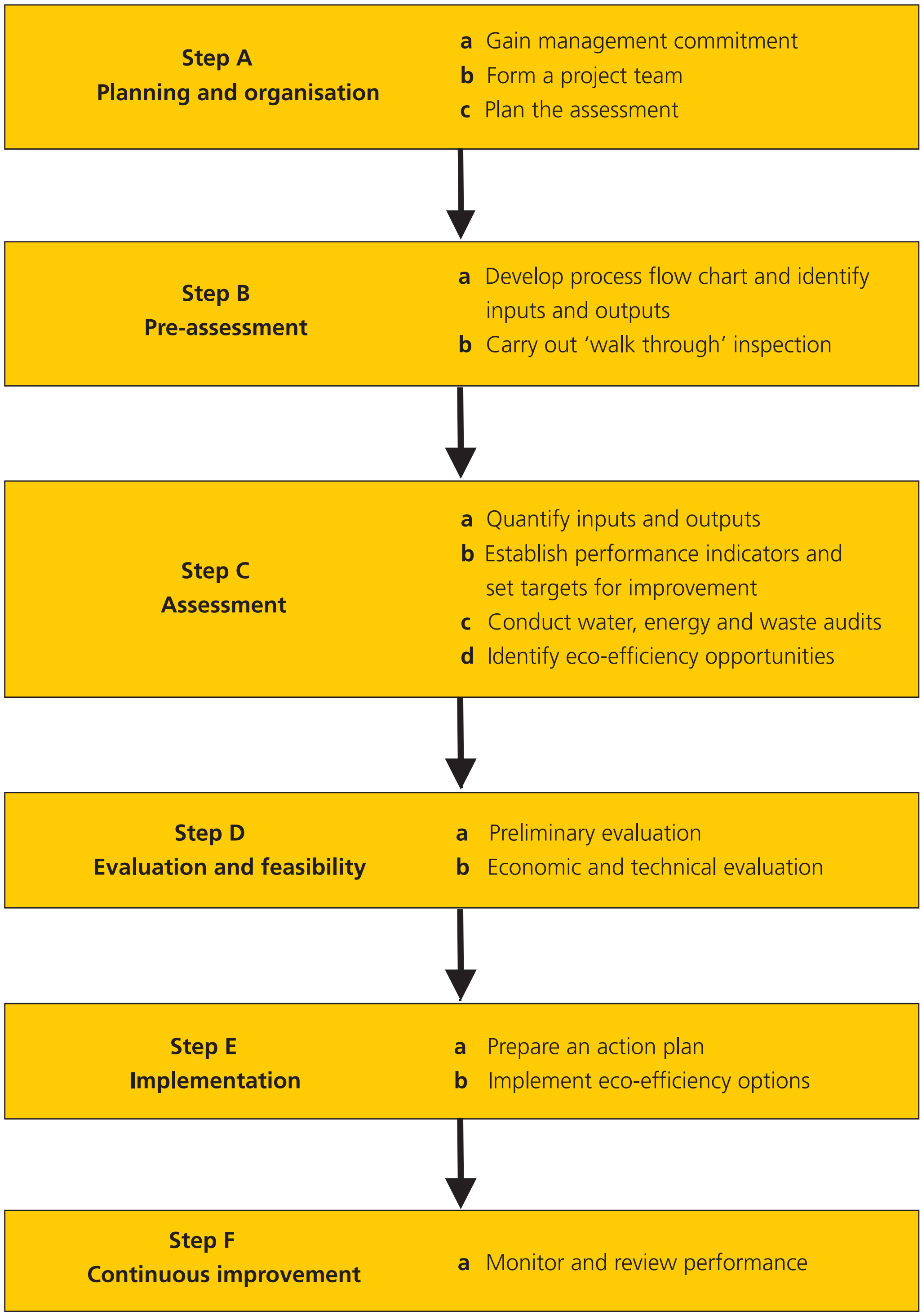
The method described in this guide is a team-based assessment that involves participation by several staff members in a company. It requires a significant amount of time, resources and commitment from management. Alternatively, the assessment can be undertaken by one or two individuals within an organisation, or perhaps by an external consultant. It is a complete assessment, which includes raw material, water and energy consumption, and waste generation. However, the company has the option of simply focusing on one aspect of eco-efficiency such as water or energy use.

Figure 2.1 shows a method for undertaking a team-based eco-efficiency assessment.

At the end of the guide are worksheets that can be used for recording information, and checklists for assessing eco-efficiency opportunities in your plant.

The steps in undertaking an assessment are illustrated by the experiences of the 'Sunny Fruit Juice Company', which are highlighted in boxes throughout this guide.

Figure 2.1: Method for undertaking an eco-efficiency assessment



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

Step A: Planning and organisation

a Gain management commitment

For a project to be successful it is essential to have total management commitment. It may first be necessary to collect some initial information on what the company is currently spending on water, energy and waste. Case studies of similar food processing companies that have saved money by becoming more eco-efficient may also help to convince your managers of the benefits of conducting an assessment.

A senior-level manager should be found who will 'champion' the project and promote the activity at a high level, and who preferably is able to provide commitment and sufficient resources to carry out the project. This person should work with the teams, regularly check on the project's progress, recognise areas of success and report back to other managers.

b Form a project team

Although an assessment can be carried out by one or two individuals, better results will be achieved by forming an eco-efficiency team. Select a team with as much expertise and experience as possible. Encourage involvement from all areas of the company, including production, maintenance, cleaning, purchasing, sales, and research and development. Expert consultants could also be included on the team to help facilitate the process.

Once a team is organised the members should nominate a project leader whose role is to organise the team and keep activities on track. The leader must have a strong commitment to the project, and ideally some skills in collecting, analysing and presenting data. The leader may also need to consult and regularly report on progress with other staff and senior management, so good communication and motivational skills are essential.

c Plan the assessment

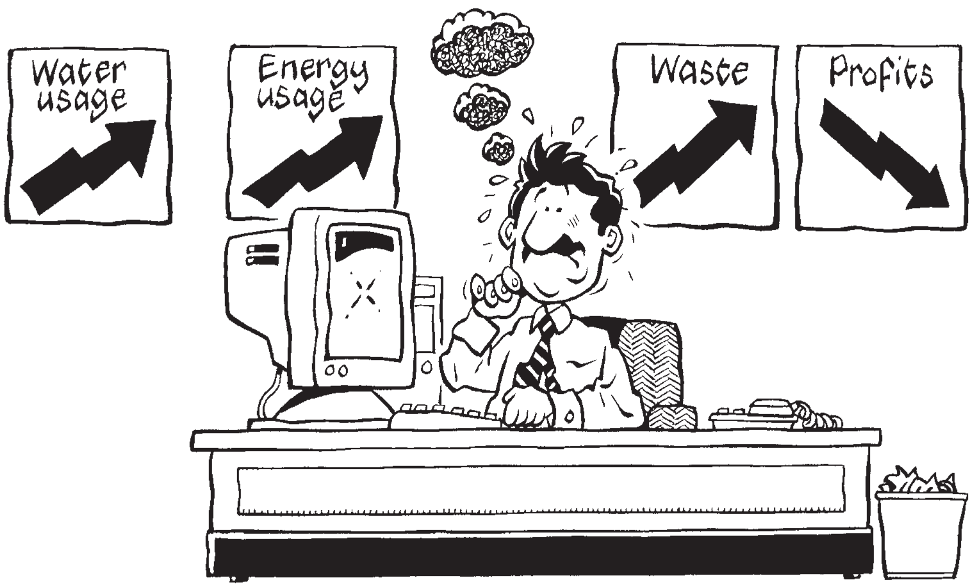
Your team may need some initial training so that they understand what is involved in an assessment. If eco-efficiency is a relatively new concept consider giving a short presentation about the potential benefits for the company. A sample PowerPoint presentation is included on the CD that accompanies this manual. The Environmental Protection Agency or Department of State Development can possibly arrange for an external person to talk about this, if requested; or contact the project team at The University of Queensland.

Set some preliminary goals for your team. For example, your team may choose to meet weekly for one or two hours, and you may aim to complete the first four steps of the project in three or four months. Assign tasks to individual team members and encourage input from everyone. There is often a large amount of information to be gathered to begin the assessment.

Worksheet 1 shows the typical information you will need to collect. But first let's meet the Waste Busters team at the Sunny Fruit Juice Company.

The Sunny Fruit Juice Co. experience

The Sunny Fruit Juice Company produces bottled fruit juices and cordials at their plant in Happy Hill, Australia. Established in 1980, the company produces 20 000 kL of fruit juice product per year. It still uses some of the original processing equipment. Sunny Fruit Juice Co. received ISO9000 accreditation in 1990 and so far has been relatively successful, with growing market sales. But the Production Manager, Bob Ballimore, can see 'troubled waters' ahead. Happy Hill City Council are restructuring their water and trade waste charges and the company will soon have to renegotiate their energy supply contract, probably at a higher rate. Sugar and fruit pulp costs are also on the rise due to the recent drought. As a result, operating costs are set to increase by 10%; and on top of that staff morale is low because some long-term employees have recently been made redundant. Bob thinks that getting his staff involved in an eco-efficiency project might improve the situation. Bob's management team are not totally convinced it will work, but have agreed to give their support.



Bob goes ahead and carefully selects his team — the 'Waste Busters'. He makes sure he gets good representation from across the whole of the Sunny Fruit Juice Co. He knows that some of the employees have some interesting ideas and he is keen to get them involved.

Waste Busters team members

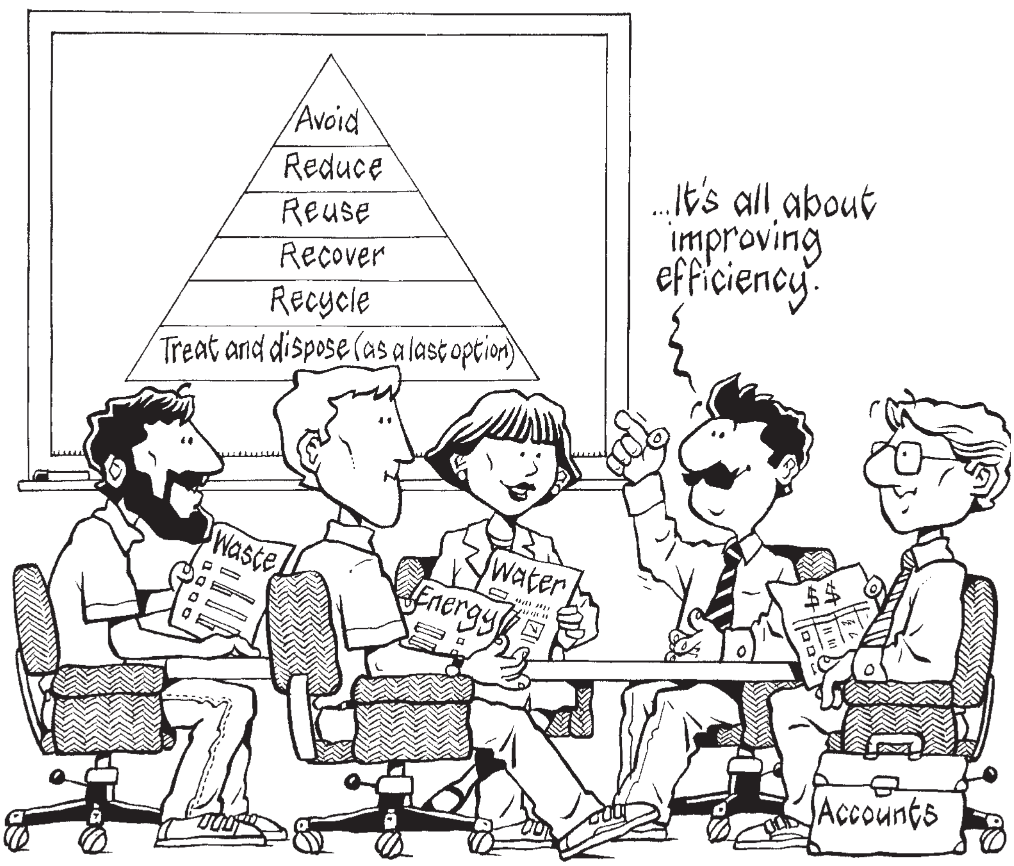
Champion: Bob Ballimore — Production Manager

Derek Dynamo — Batch Preparation
Fiona Fogg — Filling Machine Operator
Larry Lightning — Electrician
Andy Bacus — Accounts
Petria Dish — Laboratory
Pete Jones — Storeman

At their first meeting Bob explains all about eco-efficiency, using the presentation material supplied in this manual. Then, using Worksheet 1, he works with the team to assign tasks for collecting the preliminary information.

Worksheet 1: Data collection — Sunny Fruit Juice Co.

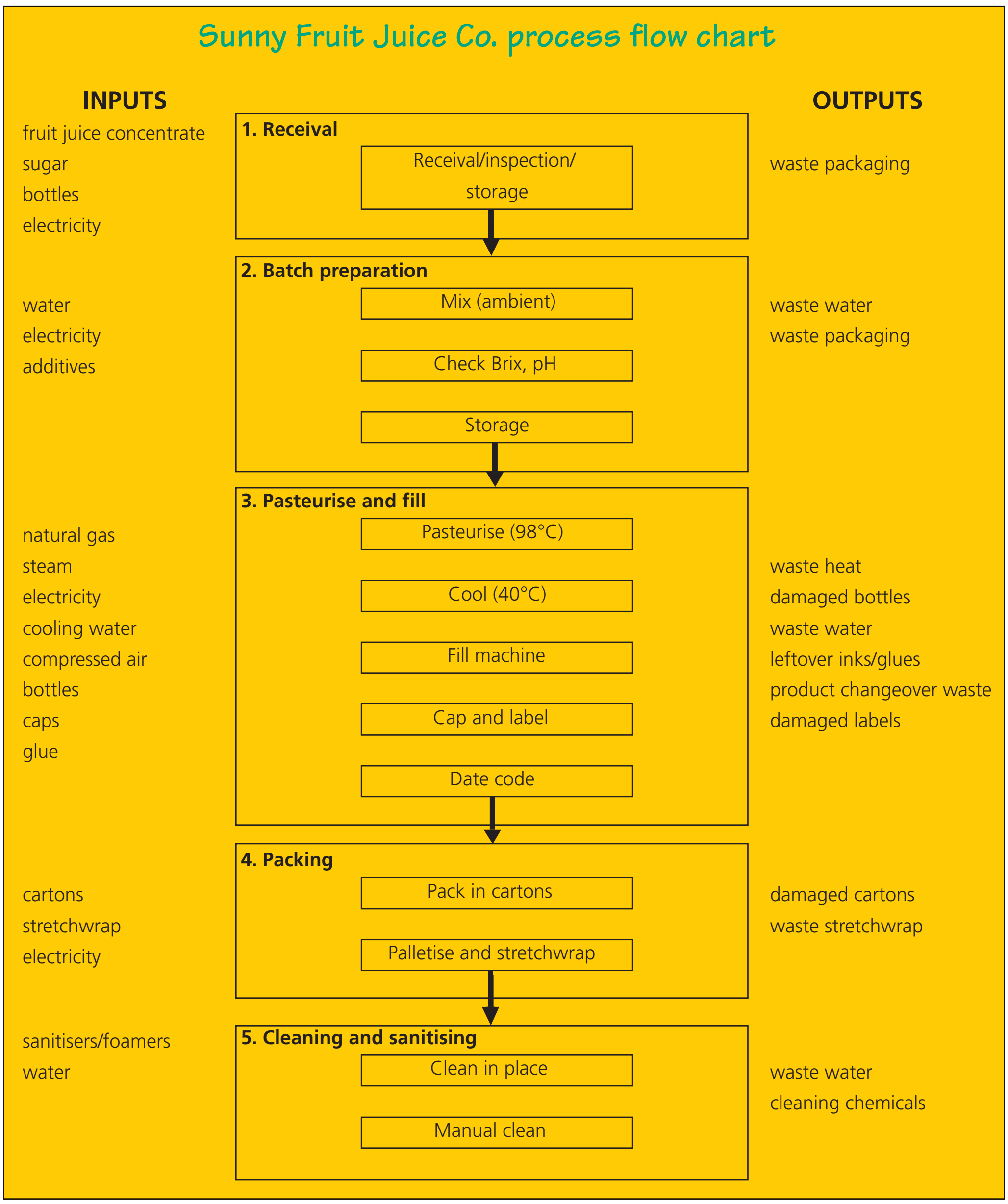
Essential information	Available	Not available	Team member nominated to collect information
Process flow diagrams		✓	Bob
Production schedule	✓		Bob
Operating hours	✓		Bob
Raw material inventories		✓	Pete
Product inventories	✓		Pete
Water invoices	✓		Andy
Energy invoices	✓		Andy
Chemical costs	✓		Derek
Trade waste invoices	✓		Derek
Solid waste invoices	✓		Fiona
Site plan	✓		Bob
Environmental audit reports		✓	–



Step B: Pre-assessment

a Develop process flow chart and identify inputs and outputs

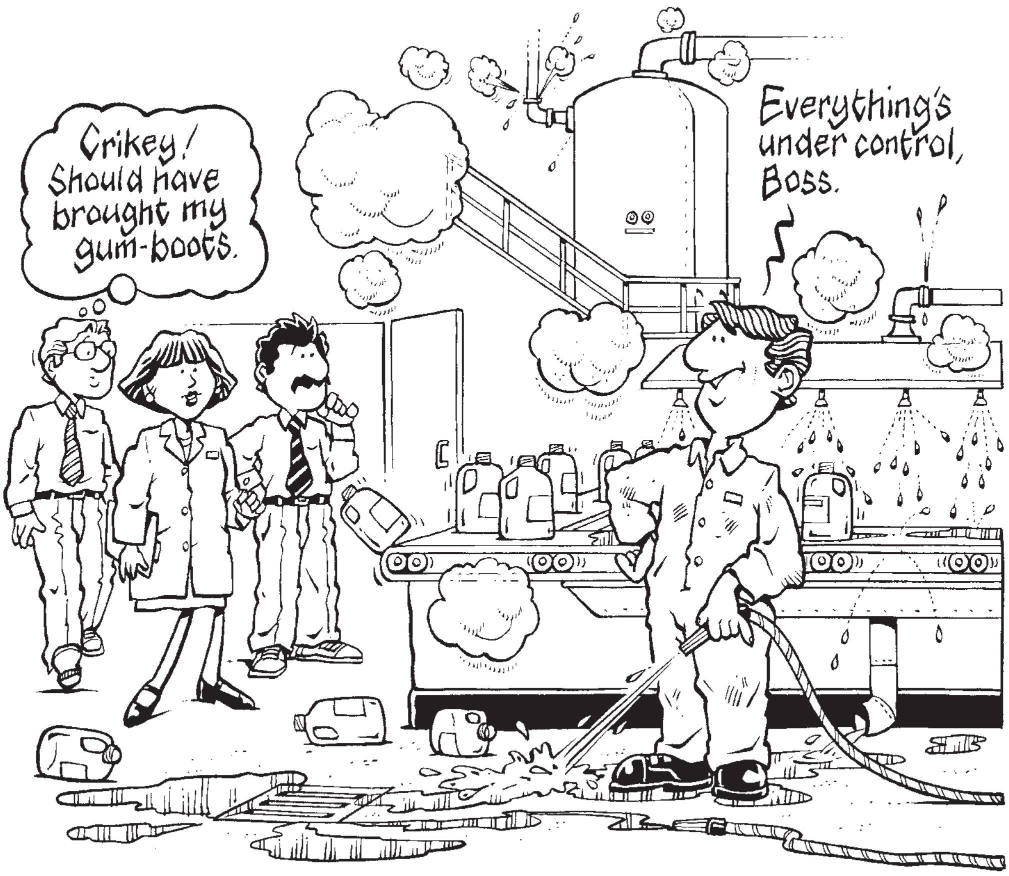
A clear understanding of how the plant operates is essential. The team must be very clear on the main processes performed by the plant, and all the inputs and outputs of these processes. One of the most important steps is to construct a flow chart identifying each of the process steps. For each step, identify all of the inputs such as raw materials, water, energy, packaging, chemicals and labour, and write them on the left side of the flow chart. Next identify all of the outputs for each step of the process and write them on the right side of the flow chart. Outputs can include product and by-product, solid waste, wastewater and air emissions. A by-product is a secondary product with some value, whereas waste has no value and may be a cost to the business. Any plant services should also be included on the chart. Check that all inputs have related outputs.



b Carry out walk-through inspection of the plant

A walk-through inspection can help to identify areas for improvement, particularly in housekeeping. Include a person who does not normally work in the particular process area. An objective team member looking at the plant with fresh eyes can often see opportunities that others may overlook. The walk-through should first cover the entire plant, and the focus can shift to specific problem areas later.

It is important to keep an open mind. Look out for obvious signs of waste, such as product that may have fallen from conveyor lines, leaking pipes and valves, accumulation of defective product and rework, steam leaks, excessively wet processing areas, spills etc. Take the opportunity to talk to operators and other staff to get a picture of what is happening in the work area and what some of the problems may be.



Step C: Assessment

a Quantify inputs and outputs

Quantitative data on all inputs and outputs should now be collected. Collect data for at least one full year of operation, to get a good representation of resource use and waste generation. It is usually best to obtain copies of original invoices so that you can examine exactly what you are paying for. Line graphs showing monthly consumption are also a great way of showing period trends and tracking progress.

Use Worksheet 2 to record data for annual resource use and waste generation.

Worksheet 2: Annual resource and waste data — Sunny Fruit Juice Co.

Inputs	Annual quantity	Unit charge	Annual cost ($)
Raw material 1: Fruit concentrate	4000 tonnes	$1500/tonne	5 040 000
Raw material 2: Sugar	800 tonnes	$535/tonne	428 000
Water	50 000 kL	$1.13/kL	56 500
Packaging	–	–	–
Cleaning chemicals	5000 L	$1.20/L	6 000
Electricity	1 100 000 kW h	10 cents/kW h	110 000
Natural gas	400 000 L	38.0 cents/L	152 000
Trade waste	20 000 kL (Av. 1000 mg/L COD)	48 cents/kL (45 cents/kg COD)	99 600
Solid waste	1500 m^3	$15/$m^3$	22 500

b Establish performance indicators and set targets for improvement

The team should now have an accurate measure of the plant's resource use and waste generation. This information can be used to develop performance indicators that will enable you to identify inefficiencies, set goals for future work and evaluate improvements.

Such performance indicators commonly represent resource use and waste generation per unit of production (per tonne or per kL of product).

Use Worksheet 3 to record your current plant performance indicators.

After gathering data on resource use for the previous year, the Waste Busters team worked out their current usage per kL of juice produced. They set some target performance indicators for water, energy and waste. Bob thought they should try to aim for a target of 4.5 kL of water per kL of juice and the team also agreed that they should aim for a 10% improvement in energy consumption. They knew it would not be easy to reduce their resource consumption and it would not happen overnight. Bob encouraged his team to go for small improvements and gradually they would see the benefits.

Worksheet 3: Current and target performance indicators — Sunny Fruit Juice Co.

	Current performance (per kL of juice)	Target performance (per kL of juice)
Inputs		
Water	5.5 kL/kL	4.5 kL/kL
Electricity	250 kW h/kL	225 kW h/kL
Gas	40 MJ/kL	30 MJ/kL
Outputs		
Solid waste (landfill)	0.3 m^3/kL	0.25 m^3/kL
Wastewater volume	3.5 kL/kL	2.5 kL/kL
Wastewater quality (COD)	1000 mg/L waste	500 mg/L waste

c Conduct water, energy and waste audits

By conducting more detailed water, waste and energy audits the team will be able to identify areas of unexplained losses; and highlight those operations or activities consuming a lot of resources or generating excessive amounts of waste.

Measuring water and energy use and the generation of waste is an ongoing process, and a regular monitoring and reporting system should be established. Reviewing water, waste and energy will also allow the team to demonstrate savings made by any eco-efficiency opportunities implemented.

The likelihood of identifying cost-effective opportunities should determine the level of detail sought in the audits. Note that it is more worthwhile to identify the largest users of resources and focus on these areas, rather than spend a large amount of time and effort looking at low-cost areas. However, if simple improvements can be made, these should always be done.

i Water audit

A simple water audit can be prepared by the team to determine the breakdown of water use. If the business uses a lot of water a 'water balance' can be undertaken, where the flow of water entering the plant is carefully measured throughout the entire process and balanced with the flow leaving the plant.

Annual usage and cost of water

Determine the plant's sources of incoming water and the annual usage of each water-using unit. Water readings should be taken from the supplier's meter readings/invoices and the business's own meter readings. A simple calculator can be found on the CD that accompanies this manual, to help you determine the true cost of water for your plant. This takes into account the total cost of supply, heating, cooling and discharge. See Chapter 3 for further information.

Record the information in Worksheet 4.

Worksheet 4: True cost of water — Sunny Fruit Juice Co.

	Heated water ($/kL)	Chilled water ($/kL)
Supply cost	$1.13	$1.13
Heating/chilling cost	$2.80	$3.00
Pumping cost	unknown	unknown
Discharge cost		
Volumetric	$0.48	$0.48
BOD (1000 mg/L, 45c/kg)	$0.45	$0.45
Treatment cost	nil	nil
True cost of water	**$4.86**	**$5.06**

Water consumption for individual unit operations

Calculate or estimate the water consumption for each individual unit operation — for example the filling machine. This should include the volume of water that is added to the product, the volume that is used for process operations and services, and the volume that is used for cleaning. The overall flow and the sum of the component flows should agree, at around 10–15%.

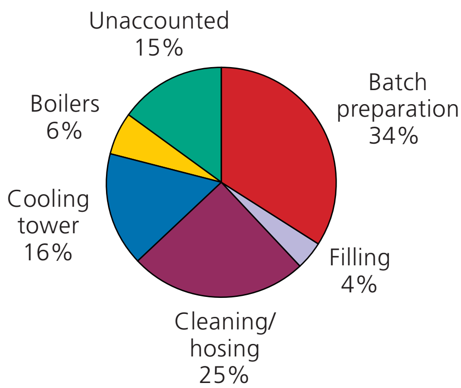
There are various measuring devices and methods that can be used to fill in information gaps. Portable flow meters, which can be hired, are useful for measuring flows around the plant. Flows from hoses or other items of equipment can sometimes be measured simply by using a bucket of known volume and a stopwatch.

Record the information in Worksheet 5.

Worksheet 5: Water consumption for individual units of operation — Sunny Fruit Juice Co.

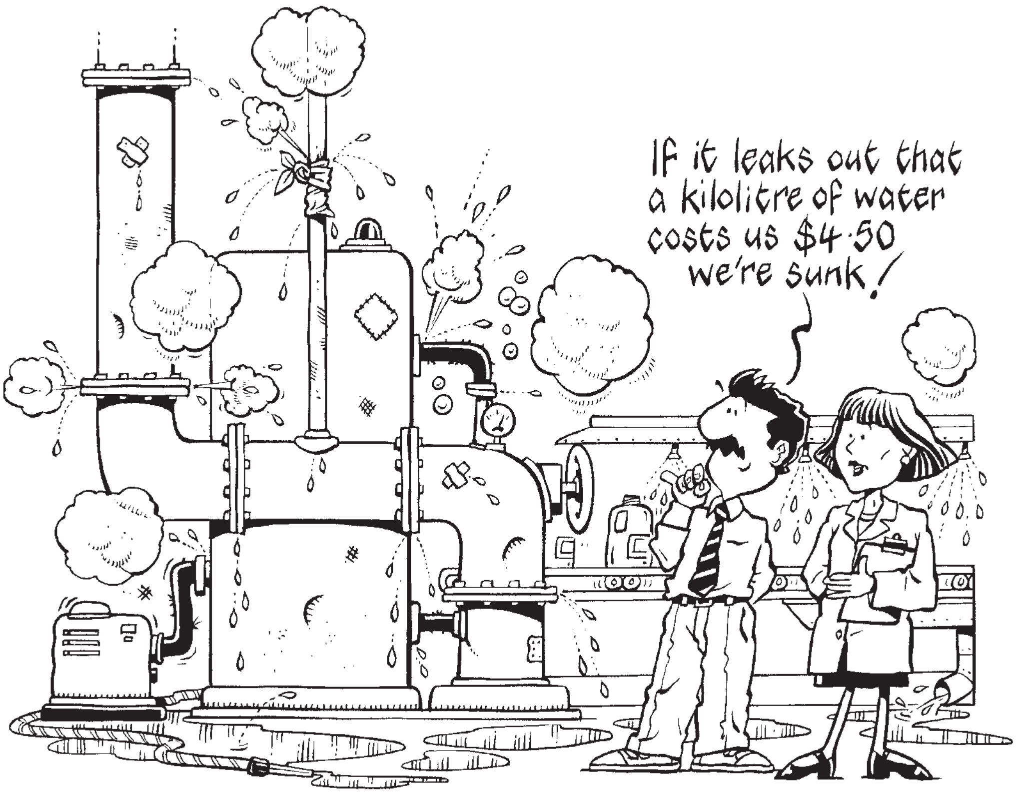
Process area/unit of operation	Volume of water used weekly (kL)	Volume of water used yearly (kL)	% of total consumed
Batch preparation	354	17 000	34
Filling	42	2 000	4
Boilers	62	3 000	6
Cooling tower	167	8 000	16
Cleaning/hosing	260	12 500	25
Total	**885**	**42 500 kL**	**85**
Actual volume purchased	**–**	**50 000 kL**	**100**
Variance/unaccounted	**–**	**7 500**	**15**

Water use — Sunny Fruit Juice Co.



Bob and his team collected as much data as they could to work out what water was being used in the factory, and in which areas. They calculated how much water was going into their juice product, and the flow meter on their boiler told them how much was being used to make steam. Derek and Fiona picked up a 20-litre bucket and a stopwatch from the store and measured the flow rate from each hose in their area. They knew the cleaning gang hosed the processing area for about two hours at the end of each shift, so they roughly calculated how much water was being used for cleaning. They also worked out how much water was being used to clean the Fogg Filler, and they were surprised to find that it was using twice the amount of water than it needed each day. 'Think how much water that will save in a year,' said Derek. 'Probably about $1500 in water supply costs.' 'Yeah, but remember it's hot water that is being wasted, so the real cost is actually about $4500 per year!' exclaimed Fiona.

After they had measured and estimated everything they could and added up all the flows, they realised there was about 15% of water being used each year that they could not account for. They spoke about this at the next team meeting, and Derek suggested to Bob that they install more flow meters around the factory to get more accurate measurements. 'You're right,' said Bob, 'how can we reduce the amount of water we're using if we don't even know where it's all being used? I'll put in an order for the flow meters now!'



ii Energy audit

Conducting an energy audit will help the team identify major energy-consuming equipment or processes. An energy audit will also highlight gaps in the reporting or metering of energy use, and pinpoint those areas where energy is being wasted.

Identify the major forms of energy used by the processing plant

Use Worksheet 6 to record the annual cost and usage rate for each form of energy (e.g. electricity, LPG, natural gas, fuel oil and/or coal).

When comparing different types of energy with different measurement units it may be convenient to convert then to a common unit such as megajoules or gigajoules. Use the following energy conversion factors to do this:

electricity	= 3.6 MJ/kW h
natural gas	= 39.5 MJ/m^3
fuel oil	= 43.1 MJ/kg
coal	= 30.7 MJ/kg
steam	= 2.8 MJ/kg (@ approx. 180°C, 900 kPa)

Plot annual and seasonal consumption patterns on a chart

By plotting consumption patterns on a chart, the team can start to identify trends or patterns in their energy use. Understanding seasonal and annual consumption will assist in a preliminary analysis of alternative tariffs, contracts or purchasing agreements. Investigate some of the supply alternatives on the Electricity Supply Association of Australia website: www.esaa.com.au .

Break down energy consumption by equipment

Breaking down the consumption of energy by the processing plant's equipment will identify areas of greatest use and opportunities for savings. Generally, heating and cooling consume the largest amounts of energy. To break down energy consumption the team will need a list of equipment, power ratings for the equipment, and details of the time it is in use.

Use Worksheet 7 to record the list of equipment items and work out the annual energy consumption for each item.

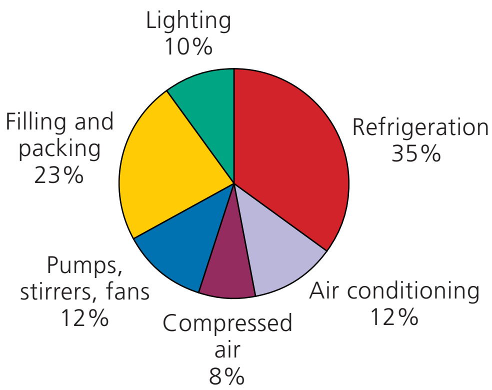
Worksheet 6: Sources of energy — Sunny Fruit Juice Co.

Form of energy	Annual usage	Annual usage GJ	Annual cost $	% of total energy cost
Electricity	1 100 MW h	3 960 GJ	$93 500	66
Natural gas	100 000 m^3	3 950 GJ	$47 400	34

Worksheet 7: Electricity Consumption — Sunny Fruit Juice Co.

Equipment	No. of items	Rating (kW)	Capacity/ load	Hours of use (h/day)	Estimated Consumption (kW h/year)	% of total
Refrigeration unit	2	44	50%	24	385 000	35%
Air conditioners	10	2.5	90%	16	132 000	12%
Compressed air	1	22	90%	12	88 000	8%
Pumps, motors	15	2	100%	12	132 000	12%
Filling & packing machines	3	23	100%	10	253 000	23%
Lighting	47	0.4	100%	16	110 000	10%
Total					1 100 000	
Actual electricity consumed					1 100 000	100%

Electricity use — Sunny Fruit Juice Co.



Larry and Pete put together a list of the major equipment items for the plant, along with their power ratings and estimated load. They calculated how long each piece of equipment operated over a full year and tried to match it to their annual electricity consumption. It took quite a bit of time and effort to get all of the information together and they were surprised with some of the results. They found the air compressor was operating about 20 hours per day, compared with only 14 hours when it was first installed. This was because of a couple of compressed air leaks that they found on the filling machine. There were also some areas in the warehouse where the lights were left on 24 hours a day when they really didn't need to be. They thought this was really a waste of energy and might not take much to fix, but sometimes it is hard to change people's habits. 'We should discuss this at the next project meeting,' Pete said.

Larry also produced some graphs showing weekly, monthly and yearly electricity usage. He noticed that every Monday morning, right at 6 am, there was a large demand for power as the first crew started work and all the equipment was turned on at once. When he compared it to the monthly invoice from Electrica Power Company, he realised that this was increasing the demand charge for electricity out of sight. 'Well, I know one thing,' Larry thought, 'not all of those air compressors need to be turned on at once. I'm sure we can reduce our demand charge if we reschedule some of those equipment start times.'

iii Waste audit

A waste audit will help the team to identify where waste is being generated and what it is costing the business to treat, store and remove offsite. The level of detail for a waste audit is often determined by the complexity of the process.

Solid waste

Use Worksheet 8 to help work out the source and costs of disposal of your solid waste.

a. List each solid waste stream that is produced by your company and identify the source and cause of the waste (e.g. waste packaging from receivals/store, used oil from No. 1 compressor).

b. Record the rate at which the waste is produced and the pattern in which it is generated (e.g. 2 m^3 of cardboard waste produced each week or one 44-gallon drum of waste oil produced each 6 months).

c. Detail whether the waste requires treatment and, if so, the cost of treating the waste.

d. Record how the waste is stored before disposal (e.g. 15 m^3 bin or 24 m^3 compactor).

e. Check your monthly waste invoices and record the waste service contractor and disposal method (i.e. landfill, recycled or other) and disposal costs. Closely check the charges and service fees on your waste invoice. Is your bin completely full each time it is serviced? Could a compactor or a smaller bin save some costs? Could the service frequency be reduced?

Wastewater or trade waste

Use Worksheet 9 to help work out the cost of discharging your trade waste.

a. Get a copy of your monthly trade waste invoice and discharge licence, and determine what you are being charged for your trade waste.

b. Determine what volume of trade waste is being discharged each week or month. You may already have a flow meter on your trade waste outlet. If not, consider whether it might be worthwhile to install a permanent flow meter or hire a temporary one to get some readings.

c. Determine what the mass load of your wastewater actually is. The mass load is a measure of the COD, BOD, suspended solids and other water quality information that you will see on your discharge licence. You may already have this information if you are regularly taking samples.

d. Work out the breakdown of your trade waste costs. For example, 40% of the costs may be due to the volume of wastewater that is produced, while 60% may be due to the mass load.

If you are unsure where your wastewater is being generated, you may want to carry out a more detailed audit of your wastewater. The information you have collected during your water audit will help you with this. Determine which areas of the plant are producing the waste, and try to determine the volume and mass load of the waste that is coming from these areas.

Use Worksheet 10 to record the details. This will help you to identify where there are opportunities for reducing your trade waste.

Worksheet 8: Solid waste audit — Sunny Fruit Juice Co.

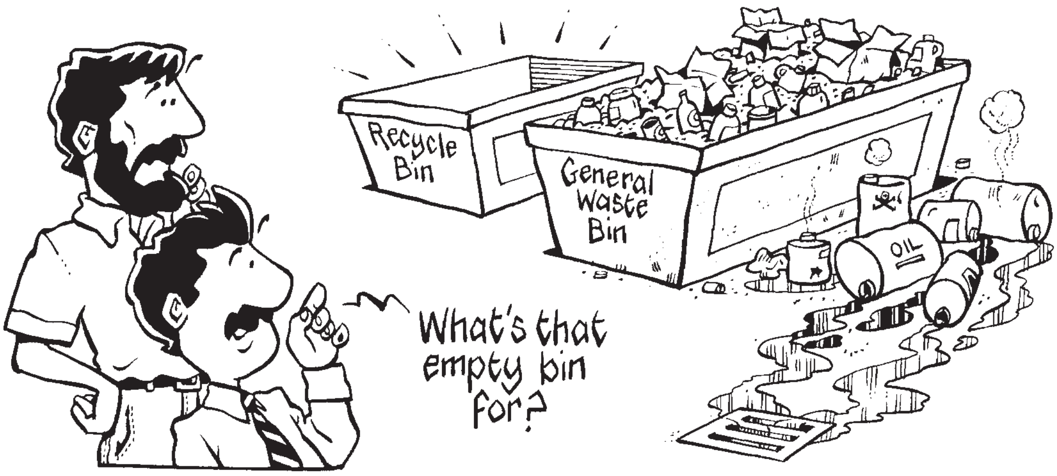
Waste stream	Source and cause of waste	Generation rate and pattern	Storage before disposal	Service contractor and disposal location	Cost of disposal ($)	Comments
Plastic packaging	Store room	10 m^3/day	15 m^3 bin	Action Waste — landfill	$15/$m^3$	Investigate recycling
Orange/ lemon peel	Batch preparation	2 m^3/day	15 m^3 bin	Action Waste — landfill	$15/$m^3$	Investigate composting

Worksheet 9: Trade waste charges — Sunny Fruit Juice Co.

Component	Licence limit	Average load (mg/L)	Average daily load (kg)	Council charge	Actual cost of discharge ($)
BOD	1000 mg/L	1000	77	0.45 $/kg	9 009
SS	10 mg/L	100	8	0.40 $/kg	832
Volume	500 kL/year	20 000 kL/year 77 kL/day	–	1.00 $/kL	20 000
				Total cost:	**$29 841**

Worksheet 10: Wastewater audit — Sunny Fruit Juice Co.

Waste stream	Source and cause of waste	Generation rate and pattern	Mass load	Comments
Tank wash water	Tank washing — batch area	10 kL/day	1500 mg/L COD	
Floor wash water	Floor washing — batch preparation	15 kL/day	200 mg/L COD	
Flush water	Filling machine	5 kL/day	1200 mg/L COD	
Blowdown	Cooling tower	2 kL/day	20 mg/L COD	



Andy obtained copies of the waste invoices for the last year. He discovered that they were paying the Action Waste Company for a weekly service of a 24 m^3 general waste bin and also a fortnightly service of a 10 m^3 bin which was for recyclable materials.

He arrived at work early that Thursday morning and noticed the Action Waste truck in the factory driveway just about to pick up a load of waste. He hurried over to check out what was actually in each of the bins. He was not all that surprised to discover that the larger general waste bin had a pile of cardboard boxes that should have been placed in the nearby recycling bin. He also noticed plastic bags full of orange and lemon peel from the fruit puree section of the factory. 'Hmmm,' he thought to himself, 'maybe that nursery down the road could take the waste fruit and use it to make compost … and I reckon if we can get the guys to put the cardboard boxes in the right bin we might be able to downsize the 24 m^3 bin or even go for a fortnightly service.'

Meanwhile, Petria was busily getting her weekly sample from the factory's wastewater tank. All of a sudden a torrent of bright orange wastewater began gushing into the tank from somewhere inside the factory. It was quite hot, because she noticed steam rising from the waste as it mixed with the contents of the tank. Just at that moment, Bob rushed past on his way to a meeting. She called after him and showed him what was flowing into the tank and down into the trade waste system. Together they followed the pipeline back into the factory and all the way back to the batch preparation area. Here they discovered Derek, happily hosing out the dregs of a batch tank. 'Hi boss!' he called. 'I've just finished that batch of Orange Fizz that was on the production schedule. I'm just cleaning the tank ready for the next batch of Luscious Lemon!' Bob quizzed Derek about the waste they had seen flowing into the waste tank. 'Yeah, boss, it's always been like that. We can never quite pump out the last few inches of product, so we end up hosing to the waste tank. Been like that for as long as I can remember.'

The three team members took a moment to talk about what could possibly be done to stop the valuable product from going down the drain. 'I'm sure Larry and the maintenance crew could help out with this problem,' said Derek. 'Yes, and we could save some of that final rinse water and use it for a first rinse next time we clean the tanks,' said Bob. 'We've been thinking of installing a system like that for a while, and now is just the time to investigate it further.'

d Identify eco-efficiency opportunities

Eco-efficiency opportunities can range from simple housekeeping improvements and minor process refinements through to major process changes or product redesign. The most significant eco-efficiency savings can often result from low-cost options such as improved housekeeping. Identifying opportunities involves rethinking conventional practices to come up with smarter solutions, using the 'waste minimisation hierarchy'. This process was described in Chapter 1, and the 'waste minimisation triangle' is depicted below in Figure 2.2. Keep in mind that it is better to reduce or eliminate the cause of the waste than it is to reuse or recycle.

Figure 2.2: The waste minimisation triangle

The chapters that follow — on water, energy, packaging, waste and chemicals — include a range of eco-efficiency opportunities which may be applicable to your food processing plant. These opportunities are also summarised in table form on the CD that accompanies this manual.

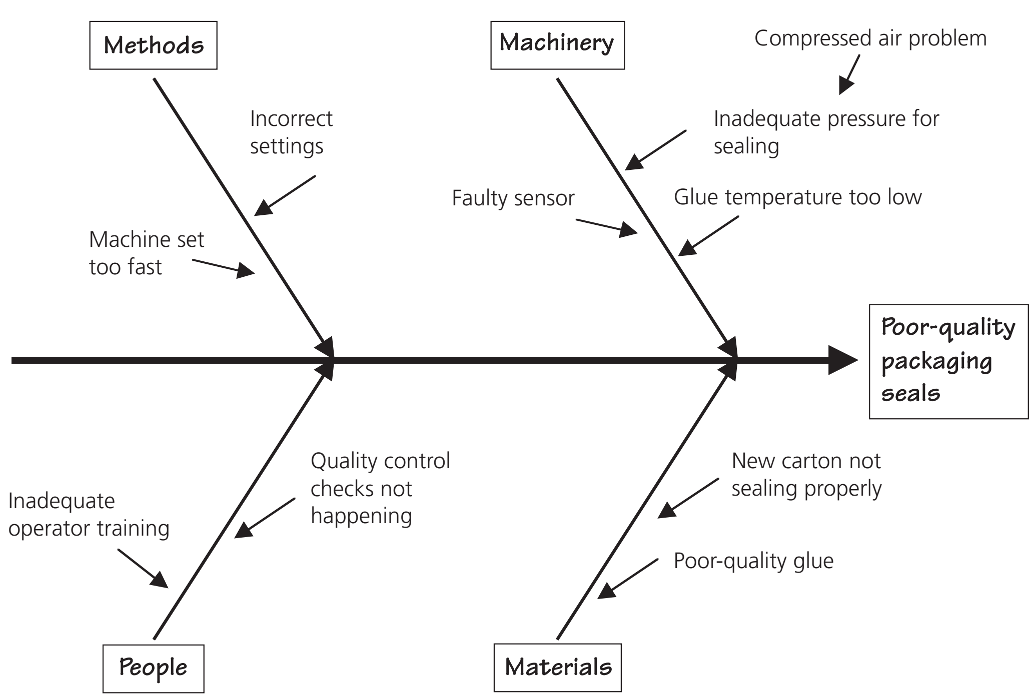
Identifying root causes of problems and generating solutions

There is often more than one contributing cause to a particular processing problem within a manufacturing plant. For example, defective product may result from a culmination of individual problems upstream of a packing line, or excessive water may be used because of a combination of plant leaks, poor process control and low staff awareness. The following section describes tools that can be used to identify the root causes of a problem and to help focus efforts for addressing them. When problem-solving, it is important to include as many knowledgeable staff members as possible, to ensure that all avenues are considered and that the potential solution does not create more problems in other areas.

Analysing root causes

The root causes can be analysed using a cause-and-effect diagram, also known as a fishbone diagram. Root cause analysis allows a team to consider all possible causes of a problem, which may be people, procedures, technology or materials. A sample cause-and-effect diagram is shown in Figure 2.3. The problem to be solved is written at the 'head' of the diagram, on the right. Members of the group suggest potential causes, which are written under the appropriate heading and make up the 'frame' of the diagram.

Figure 2.3: Cause-and-effect diagram



Why 5 times

Another method for analysing problems is to use the 'Why 5 times' tool. This method involves asking 'Why?' repeatedly, to drill down to the root of the problem. It is rarely necessary to ask 'why' more than five times. It is best explained by using examples:

Problem 1: The air compressor is running longer than before and more power is being used.

Why? The pressure setting has been increased.

Why? The old packing line has been modified and requires more compressed air than it should.

Why? The diameter of the compressed air lines is too large.

Why? The incorrect lines were installed.

Solution: Install the correct sized air lines. (The solution is reached after asking four 'Why?' questions.)

Problem 2: The refrigeration system is overloaded.

Why? Forklift operators keep leaving the coldroom door open.

Why? It wastes time constantly opening and closing the door.

Why? The door is manually operated.

Solution: Replace door with heavy curtains, or install auto-operated doors.
(This time it was only necessary to ask 'Why?' three times.)

The next step after asking the questions is to identify a solution. As mentioned above, it is important to involve as many staff members as possible. It is also important to be open to new ideas. Consult with other people in the industry, such as suppliers, other processing plants, industry associations, expert consultants or the Environmental Protection Agency. The following are some methods for identifying a solution.

Brainstorming

This method involves all members of your team. The team considers the particular problem to be addressed and suggests potential solutions, regardless of how improbable or outlandish they may initially seem. Each idea should be written on an overhead transparency, sticky note or whiteboard for everyone to view, and should not be evaluated in detail until each member has ceased putting forward their solutions. The ideas can then be evaluated. This method allows members to build on the suggestions and ideas of other participants so that a better solution can be achieved. An apparently outlandish idea may lead to an actual solution that individual members would not previously have considered.

During a brainstorming session, the use of key words can be handy tool to promote lateral thinking. Key words can be from the waste reduction hierarchy, the 'why 5 times' system or elsewhere. Consider the five areas available for eco-efficiency opportunities:

1. Product — can we modify it or its attributes?
2. Inputs — can we change or modify our inputs?
3. On-site recycling — is there anything we can recycle, reuse or take back?
4. Process — what process modifications can we make to improve efficiency and avoid waste?
5. Good housekeeping — what housekeeping improvements can we make?

Brainwriting

This is a similar tool to brainstorming, but this time the problem is written on a card and placed in a central basket. One person removes the card from the basket and writes a suggestion on it, of how to solve the problem. The card is then returned to the basket for another team member to remove, read and add to if they wish. Brainwriting allows people to overcome hesitation or uncertainty. Again team members should be encouraged to consider different solutions that may at first seem unlikely.

Conduct trials

If a solution involves making a change to your process it is always a good idea to conduct some trials. Take care not to change too many parameters at once, so you rule out the charges that don't have any effect or simply don't work.

After identifying your potential solutions, record them in Worksheet 11. After that, the next step is to carry out a more rigorous evaluation and feasibility check.

By now, the Waste Busters team had collected all their information on water, energy and waste. By simply asking questions and investigating what resources were being used in each area, they had already come up with some opportunities for improvement. They listed all the ideas on a whiteboard and discussed the potential savings. Larry and Pete were a bit dubious about some of the savings, especially the one about the solar hot water heating. Derek wasn't sure about collecting the final rinse water and reusing it as cleaning water. 'OK, OK,' Bob said, 'don't write it off before we've even checked it out. Let's go to the next step and do an evaluation and see how it all turns out.'

Worksheet 11: Potential *eco-efficiency opportunities* — Sunny Fruit Juice Co.

Opportunity	Potential resource saving							Passed preliminary evaluation Yes/No
	Water	Energy	Packaging	Chemical	Solid waste	Waste water	Other (e.g. labour, maintenance)	
Install water meters	✓	✓						Yes
Recover final rinse from tank cleans	✓			✓		✓	✓	Yes
Redesign tank piping to recover product	✓	✓		✓		✓	✓	Yes
Install more efficient refrigeration compressor	✓	✓		✓		✓		No — capital not available at this stage
Send organic waste to composter					✓			Yes
Ensure separation of recyclable waste					✓			Yes
Install solar hot water heating system		✓						Yes
Turn off unnecessary lights		✓						Yes
Eco-efficiency staff training	✓	✓	✓	✓	✓	✓	✓	Yes
Membrane filtration	✓			✓		✓		Yes

Step D: Evaluation and feasibility

a Preliminary evaluation

The eco-efficiency opportunities identified will need to undergo an evaluation process to determine their feasibility and practicality. Worksheet 12 can be used as a guide for considering the impact of the change on product quality, safety, customer expectations and environmental performance.

Record the outcome of the preliminary evaluation in Worksheet 12.

Worksheet 12: Preliminary evaluation of eco-efficiency opportunities — Sunny Fruit Juice Co.

Opportunity: Recover final rinse water from tank cleans.

Considerations	Yes	No	Comments/action
Will the change affect product quality? Are any trade-offs acceptable?		✓	
Will it affect health and safety?		✓	
Will it effectively address the issue? Will it work?	✓		
Will it affect customers' expectations?		✓	
What impact will it have on environmental performance?			Will use less water
What are the requirements on different departments (i.e. production, maintenance, purchasing)?			None after it is commissioned
Will it be easy to implement the change? Are resources available?	✓		Include in next financial year's budget
How much time and expertise is needed?			Can be done in-house

b Economic and technical evaluation

Use Worksheet 13 to evaluate the economic and technical advantages of the eco-efficiency opportunity.

Worksheet 13: Economic evaluation of eco-efficiency opportunities — Sunny Fruit Juice Co.

Opportunity: Recover final rinse water from tank cleans.

Costs of implementing the opportunity	
a Estimate the likely cost of equipment and installation and any other up-front costs associated with the change?	$5000 for pump, piping and use of existing tank
b Estimate any ongoing costs such as running costs, maintenance, materials, labour etc. for a 12-month period.	$200 (pumping costs)
Total costs (a + b)	$5200
Savings from implementing the opportunity	
c Determine the possible savings in terms of materials, water, energy, treatment, disposal etc (for 12-month period)?	$1500 in water savings
d Is the change likely to lead to an increase in production? What would be the likely range for a 12-month period?	n/a
e Quantify any other associated costs or benefits.	$500 (labour)
Total savings (c + d + e)	$2000
Payback period Payback period in months = $\frac{\$5200}{\$2000} \times 12$ months	31 months or 2.6 years

Step E: Implementation

a Prepare an action plan

Now that a list of eco-efficiency opportunities has been identified, an action plan can be prepared. Discuss each of the opportunities and agree on a course of action, dividing responsibilities among your team. Where the change will affect other departments or staff members, ensure that they are included in discussions before changes are made. If the implementation stage involves a change of work procedure, involve all stakeholders in determining why and how the change should be made. Include actions to assign resources or conduct feasibility studies for those opportunities that require further information. Divide the opportunities into short-, medium- and long-term actions.

Worksheet 14: Summary of Eco-efficiency opportunities — Sunny Fruit Juice Co.

Eco-efficiency opportunity	Capital cost	Annual saving (resources)	Annual saving ($)	Payback	Implement (date)	Person responsible
Water						
Install water meters	$2 000	–	–	–	Jul 05	Engineering Manager
Recover final rinse water from tanks	$5 000	520 kL hot water	$2 000	2.6 years	Aug 05	Engineering Manager
Redesign piping from tanks to recover more product	$5 000	20 tonnes product	$30 000	2 months	Jun 05	Workshop
Energy						
Heat recovery from air compressors	$6 000	125 000 MJ	$1 500	4 years	Dec 05	Engineering Manager
Solar heating	$15 000	–	$3 000	5 years	April 06	Engineering Manager
Turn off unnecessary lights	nil	6000 kW h	$510	immediate	Jun 05	All
Packaging						
Lightweighting cartons	$50 000	600 m^3	$15 000	3.3 years	April 06	Purchasing
Chemicals		litres				
Automatic chemical dosing	$8 000	500 litres	$2 500	3.2 years	Sep 05	Production Manager
Solid waste						
Send organic waste to compost company	nil	104 m^3	$1 560	Immediate	Jul 05	Production Manager
Ensure separation of recyclable waste	nil	50 m^3	$400	Immediate	Jul 05	All
Wastewater						
Recovery of solids using membrane filtration	$50 000	20 tonnes	$30 000	1.6 years	April 06	Engineering Manager

b Implement eco-efficiency options

The action plan will provide a general framework for when each eco-efficiency opportunity should be implemented and who is responsible for its implementation. Be sure to provide training and support for staff members where required. The implementation phase might, for example, include progress meetings, as well as morale-boosting activities such as giving rewards to staff to celebrate successes measured against key performance indicators.

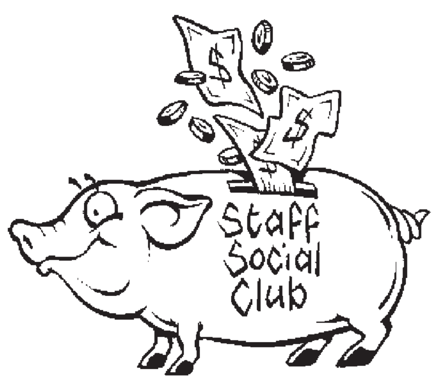
Step F: Continuous improvement

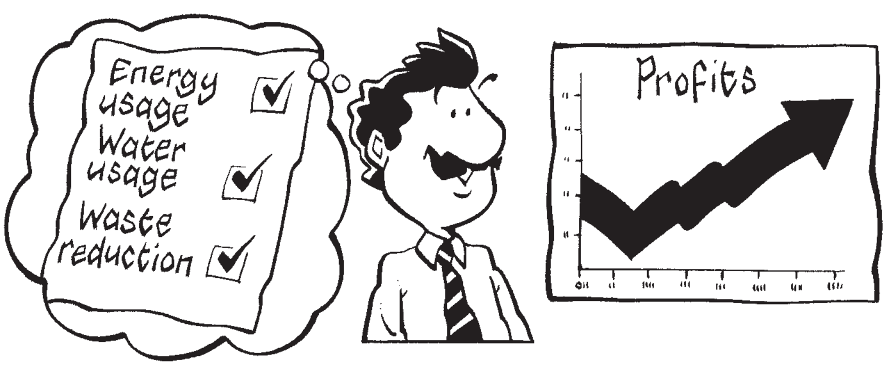
a Monitor and review performance

Once improvements have been implemented or work practices modified, it is essential that these are monitored and regularly reviewed. Report results back to relevant staff and give recognition for good performance. Use the key performance indicators to track progress over a period of time and identify trends. Results can be reviewed at regular meetings. The use of visual aids such as graphs and pie charts will keep staff informed of improvements and the effects of their actions. This is often the most overlooked stage of an eco-efficiency project. Becoming eco-efficient means continually examining progress and always trying to improve, in order to become a better-managed company overall.

The team carried out a full evaluation of each of the opportunities they had identified. Most of the ideas turned out to be quite feasible, although a couple involved quite high capital costs and so could not be done this financial year. All in all, Bob was pleased with the results of the assessment and the hard work put in by his team.

Several months went by before they had finished implementing some of the ideas identified in the assessment. They had been reviewing their performance on a weekly basis and the graphs for water, energy and waste showed a steady downward trend. They still hadn't quite reached their target performance, but they were confident that when all the ideas were fully implemented they would be close and might even improve on one or two of them. Bob congratulated the team. 'Well done, everyone! Now we only have to keep up the good work. I've got just the idea to encourage some ongoing staff involvement. What do you say if 30% of our savings for the next year are paid back as staff bonuses?' The team excitedly agreed, 'Let's do it!'





Worksheets

Worksheet 1: Data collection

Essential information	Available	Not available	Team member nominated to collect information
Process flow diagrams			
Production schedule — total tonnage or volume produced per year			
Operating hours			
Major raw material inventories			
Product inventories			
Water supply invoices for previous years. Also consider pre-treatment costs and sources (e.g. mains, surface water, groundwater)			
Energy supply invoices for previous year (e.g. electricity, LPG, natural gas, fuel oil or coal)			
Chemicals — costs and usage for previous year (e.g. detergents, sanitisers, wastewater treatment chemicals, oils and lubricants)			
Trade waste discharge invoices for previous year — volume, quality, treatment and disposal costs			
Solid waste disposal invoices for previous year — include non-recyclables and recyclables (e.g. cardboard, plastics, glass)			
Useful additional information			
Site plan			
Factory layout			
Environmental audit reports			
Trade waste and EPA licences			

Worksheet 2: Annual resource and waste data

Inputs	Annual quantity	Unit charge	Annual cost ($)
Raw material 1	tonnes or kL	$/unit	
Raw material 2	tonnes or kL	$/unit	
Water	kL	$/kL	
Packaging	units	$/unit	
Cleaning chemicals	L	$/L	
Electricity	kW h	$/kW h*	
Natural gas	MJ or litres	$/MJ	
Other			
Outputs	**Quantity generated per year**	**Unit charge**	**Annual cost of disposal**
Trade waste	kL	$/kL	
BOD	kg	$/kg BOD	
COD	kg	$/kg COD	
SS	kg	$/kg SS	
General waste	m^3	$\$/m^3$	
Recyclable waste	m^3	$\$/m^3$	

*Note: this should be an average of the demand, market and supply charges as set out on your energy bill.

Worksheet 3: Current and target performance indicators

	Current performance (per unit of product)	Target performance (per unit of product)
Inputs		
Water	kL/unit	kL/unit
Electricity	kW h/unit	kW h/unit
Gas	MJ/unit	MJ/unit
Chemicals	kg/unit	kg/unit
Packaging	cartons/unit	cartons/unit
Other		
Outputs		
Solid waste (landfill)	m^3/unit	m^3/unit
cardboard	m^3/unit	m^3/unit
plastic	m^3/unit	m^3/unit
glass	m^3/unit	m^3/unit
other	kg/unit	kg/unit
Wastewater volume	kL/unit	kL/unit
Wastewater quality		
COD	mg/L waste	mg/L waste
BOD	mg/L waste	mg/L waste
SS	mg/L waste	mg/L waste

Use the calculator on the CD that accompanies this manual to work out the actual water costs, and record the results in the following table:

Worksheet 4: True cost of water

	Heated water ($/kL)	Chilled water ($/kL)
Supply cost		
Heating/chilling cost		
Pumping cost		
Treatment cost		
Discharge cost		
True cost of water		

Worksheet 5: Water consumption for individual units of operation

Process area/unit of operation	Volume of water used weekly (kL)	Volume of water used yearly (kL)	% of total consumed
Process area			
Cleaning			
Services			
Boiler make-up			
Cooling tower make-up			
Domestic use			
Total			
Actual volume purchased			**100**
Variance/unaccounted			

Worksheet 6: Energy consumption

Form of energy	Annual usage	Annual usage (common unit)	Annual cost $	% of total energy cost
Electricity	kW h	MJ		
Natural gas	m^3	MJ		
LPG	MJ	MJ		
Fuel oil	kg	MJ		
Coal				
Other				

	Conversion Factor
Electricity	3.6 MJ/kWh
Natural gas	39.5 MJ/m^3
Fuel oil	43.1 MJ/kg
Coal	30.7 MJ/kg
Steam	2.8 MJ/kg

Worksheet 7: Electricity consumption

Process area	Equipment	No. of items	Rating (kW)	Capacity/ load	Hours of use (h/day)	Estimated Consumption (kW h/year)	Subtotal (kW h/year)	% of total
e.g. Coldroom 1	*Atlas Copco compressor*	*1*	*30*	*90%*	*24*			
Total								
Actual electricity consumed								

Worksheet 8: Solid waste audit

Waste steam	Source and cause of waste	Generation rate and pattern	Storage pre disposal	Service contractor and disposal location	Cost of Disposal ($)	Comments
e.g. plastic packaging	*batch preparation*	*1.0 m^3 per day*	*15 m^3 skip*	*JJ Richards*	*15/m^3*	*Investigate plastic recycling company*

Worksheet 9: Trade waste charges

Component	Licence limit	Average load (mg/L)	Average daily load (kg)	Council charge	Actual cost of discharge ($)
BOD	mg/L			$/kg	
COD	mg/L			$/kg	
SS	mg/L			$/kg	
Other	mg/L			$/kg	
Volume	kL			$/kL	
				Total cost	

Worksheet 10: Wastewater audit

Waste stream	Source and cause of waste	Generation rate and pattern	Mass load	Comments
e.g. product tank wastewater	*cleaning of product tanks*	*daily*	*500 mg/L BOD*	*Consider clean-in-place system*

Worksheet 11: Potential eco-efficiency opportunities

Opportunity	Potential resource saving							Passed preliminary evaluation Yes/No
	Water	Energy	Packaging	Chemical	Solid waste	Waste water	Other (e.g. labour, maintenance)	
e.g. Reduce timers on filling machine cleaning cycle	✓	✓		✓		✓		

Worksheet 12: Preliminary evaluation of eco-efficiency opportunities

Considerations **Opportunity:**	**Yes**	**No**	**Comments/action**
Will the change affect product quality? Are any trade-offs acceptable?			
Will it affect health and safety?			
Will it effectively address the issue? Will it work?			
Will it affect customer' expectations? Would your customers accept the change?			
What impact will it have on environmental performance?			
What are the requirements on different departments (i.e. production, maintenance, purchasing)?			
Will it be easy to implement the change? Are resources available?			
How much time and expertise is needed?			

Worksheet 13: Economic evaluation of eco-efficiency opportunities

Costs of implementing the opportunity
a Estimate the likely cost of equipment and installation and any other up-front costs associated with the change?
b Estimate any on-going costs such as running costs, maintenance, materials, labour etc. (for a 12-month period).
Total costs (a + b)
Savings from implementing the opportunity
c Determine the possible savings in terms of materials, water, energy, treatment, disposal etc. (for a 12-month period)?
d Is the change likely to lead to increased sales of current or new products? What would be the likely range (for a 12-month period)?
e Quantify any other associated costs or benefits.
Total savings (c + d + e)
Payback period Payback period in months = $\frac{\text{Total cost}}{\text{Total savings}} \times 12$ months

Worksheet 14: Summary of eco-efficiency opportunities

Eco-efficiency opportunity	Capital cost	Annual saving (resources)	Annual saving ($)	Payback (months)	Implement (date)	Responsible person(s)
Water		kL				
Energy		kW h/MJ				
Packaging		m^3				
Chemicals		L				
Solid waste		m^3				
Wastewater		kL				
	Total costs		Total savings			

3 Water and wastewater

3.1 Overview of water use

Australia is one of the driest countries in the world. Nevertheless, water is often taken for granted and seen as a renewable resource. The reality is, however, that fresh water is a precious and finite resource. Global access to it is becoming increasing difficult, with only 0.08% of the total water on the planet being accessible for human consumption. Currently 2.3 billion people live in water stressed areas and if current trends continue this figure will rise to 3.5 billion by 2025. That is a staggering 48% of the world's projected population (UNESCO 2001).

In Australia food processors consume more water than any other manufacturing group: they account for 34% of the total water consumption of the manufacturing sector. This equates to 180 GL of water every year (AATSE 1999). Reducing water use without compromising processing or strict food safety standards will not only result in considerable savings but will also help minimise the pressures on this valuable resource. A recent survey by the Australian Food and Grocery Council found that around 48% of companies reported reductions in water consumption over the past five years, more than half of which were by more than 10% (AFGC 2001). The survey also showed that 67% of companies expected further reductions in the next five years, suggesting a high level of awareness of water consumption issues.

This chapter discusses ways in which food processors can reduce the amount of water consumed in plant processing and cleaning, as well as any auxiliaries such as washrooms, cafeterias and gardens. The final section discusses the future trends in water reuse and recycling in Queensland and possible opportunities for food processors.

3.1.1 Typical water use by food processors

Water is used by food manufacturers for general processing; for cleaning of equipment; for the operation of utilities such as boilers, cooling towers and pumps; and for ancillary uses such as toilets and washing facilities. Processing applications include washing raw ingredients, rinsing, blanching, cooling, cooking, conveying, and use as an ingredient in food products. Table 3.1 shows the typical breakdown of water use for some food processors.

Table 3.1: Example of water use for four food processors

Water-consuming activities	Beverage (%)	Meat processor (%)	Vegetable (%)	Dairy (%)
Water in product	60	0	0	0
Plant cleaning	25	48	15	49
Cooling towers	2	2	5	6
Process operations	8	47	78	42
Auxiliary use	5	3	2	3

Source: UNEP Working Group for Cleaner Production 2002a, 2003l

3.1.2 The true cost of water

Australian manufacturers often view water as a cheap resource. This is not surprising, considering that Australians pay more for 1 L of milk than for 1000 L of water. Increasingly, however, we are seeing a shift away from this attitude, with an increased community awareness of the value of water and a trend by local councils towards full cost recovery for the supply of fresh water and treatment of wastewater.

The true value of water is often underestimated. Some of the components making up the true cost of water for food processors are:

- purchase price
- treatment of incoming water
- heating or cooling
- treatment of wastewater
- disposal of wastewater
- pumping
- maintenance (e.g. pumps and corrosion of pipework and equipment)
- capital depreciation.

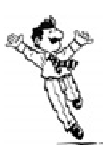
You pay for water many times — to buy it, treat it, heat or chill it, and dispose of it!

Table 3.2 provides an example of the full costs of water at ambient temperature and of hot water. It indicates that, while the purchase cost of the water is $1.13, the true cost is actually $2.33 for water at ambient temperature and $5.13 for water heated to 80°C.

Table 3.2: Example of the true cost of ambient and of hot water ($/kL)

Purchase	$1.13[3]
Wastewater treatment[1]	$0.75
Wastewater pumping	$0.05
Wastewater discharge (volume charge)	$0.40
TRUE COST FOR AMBIENT WATER	**$2.33**
Heating to 80°C[2]	$2.80
TRUE COST FOR HOT WATER	**$5.13**

1 Based on assumption of typical treatment costs for an anaerobic digester
2 Cost for heating to 80°C using steam produced by a gas boiler
3 Based on Brisbane Water supply costs



Eco-efficiency action

Determine the true cost of the water used by processes in your plant, using the calculator that can be found in the CD accompanying this manual.

3.1.3 Measuring water consumption

To understand how to manage water effectively, it is essential to understand how much water enters and leaves your plant and where it is being used. Understanding water flows will help to highlight the areas with the greatest opportunities for cost savings. There are various methods that can help you to quantify water use:

- Install flow meters to measure water use directly.
- 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 L water tank fills once every wash cycle).

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

> **You can't improve what you don't measure!**
>
> ***Edward Deming***

Flow meters

Flow meters on incoming water inlets and wastewater discharge outlets, and on equipment that uses a lot of water, 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, in order to detect possible leaks.

The cost of installing or hiring flow meters will vary according to 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) and installation costs. It is also important to consider ongoing maintenance and recalibration costs. Often a higher capital cost with lower maintenance costs will result in a reduction in overall costs over the lifetime of the meter. Table 3.3 shows the three main types of water meters for installation on or into pipework, and their distinguishing features. When selecting a meter ensure that it is designed to meet your plant's particular needs. All flow meters should be calibrated for accuracy on a regular basis or according to the manufacturer's recommendations. Remember that any informed decision-making must be based on accurate data.

Table 3.3: Types of water meter suitable for installation on or into pipework and their distinguishing features

Meter	Ultrasonic	Electromagnetic	Mechanical
How it works	Transit time meter — calculates velocity from the time taken for an impulse to pass between two sensors. Doppler meter — calculates the differences in frequency of sound waves sent and reflected off particles in the liquid.	Operate by inducing an electric field across a pipe and measuring the change in voltage relative to the flowing fluid.	Usually function by a turbine that spins in the full flow of water, a propeller with its axis parallel to the water flow, or by means of a small paddle that spins perpendicular to the flow of water.
Water quality	As this meter has no moving parts it can cope with turbid water containing some solids, liquid droplets or gas bubbles. Doppler meters can cope with water containing solids, but are more accurate if the particles are of uniform size.	As this meter has no moving parts it can cope with water containing solids.	The moving mechanical parts in the pipe may become blocked; this type of meter is therefore best suited to relatively clean water.
Accuracy	Good accuracy — around 1%.	High accuracy — around 0.2%.	Accuracy around 2%.
Pressure loss in pipe	Negligible as no moving parts in pipe.	Negligible as no moving parts in pipe.	Some pressure loss due to moving parts in the pipe.
Life span and durability	Long life span. Little maintenance — skilled repairs required. Robust	Long life span. Little maintenance — skilled repairs required. Robust.	Short life span. Low maintenance — skilled repairs required. Reasonably robust but moving parts susceptible to damage and will wear.
Reading	Digital display units; information can be downloaded to a computer; can be fitted with telemetry equipment	Digital display units; information can be downloaded to a computer; can be fitted with telemetry equipment.	Numerical gauge; most can be fitted with electronic output device.
Installation and power requirements	Simple clamp on mounting with only probes coming in contact with the fluid. Requires mains, solar or battery power.	Requires mains, solar or battery power.	Meter fitted directly in flow of water. Can work without power.
Cost	High cost — can be adjusted to fit a range of pipe sizes.	High cost; unlike ultrasonic meters, they cannot be adjusted to fit a range of pipe sizes so the cost depends on pipe size.	Low cost; mechanical meters can be cost-effective, especially for low flow rate.

Example: Pacific Data Systems[1]

Model	Pipe size (mm)	Cost
Portable AT 500	30–1000	$7600
Fixed AT 300	50–990	$5000

Example: Panametrics[2]

Model	Pipe size (mm)	Cost
Fixed AT 868	13–5000	$ 6000
Portable PT 868*	150–2000	$15 000

*Alternatively it can be hired for around $205 a day[3]

Example: ABB Instrumentation[4]

Model	Pipe size (mm)	Cost
317–050–FTR	50	$2200
317–100–FTR	100	$2500

Example: UUC Australia[5]

Model (brass)	Pipe size (L/min)	Size (BSP)	Cost (+GST)
FM.26 122–122	0.2–2	–	$613
122–322	1–9	–	$613
FM.26 222–122	2–20	–	$626
222–222	5–46	–	$626
FM.26 322–122	5–55	–	$901
322–222	10–110	–	$901
FM.26 422–122	20–180	1–	$2730
422–222	30–270	1–	$2730

1 Pacific Data Systems, 250 Orange Grove Rd, Salisbury, Qld
2 Graham Maxwell, GE Panametrics, PO Box 234, Gymea, NSW
3 Tech Rental, 125 Evans Rd, Salisbury, Qld, 4107
4 ABB Instrumentation, Unit 8, 28 Tennyson Memorial Avenue, Yeerongpilly, Qld
5 UUC Australia Pty Ltd, 9 Carrington Rd, Castle Hill NSW

Case study

Installation of water meters: Brewery, Australia
Castlemaine Brewery in Queensland installed a total of 17 water meters within the brewery to measure water usage in each functional area. The meters were connected to the utilities information system to provide managers and team leaders with real time information on water usage in their area of operation as well as statistical information and trending data. The visibility of usage as a result of installing these meters has led to significant water savings.[1]

[1] Castlemaine Perkins 2003

Eco-efficiency action

- Identify your key areas of water use.
- Install water meters in these key areas to measure and monitor water consumption.
- Compare your water use estimates with the actual flows.

3.1.4 Increasing staff awareness and involvement

The involvement and support of staff is essential, as is the total support of senior management in providing leadership and resources for reducing site water usage. Assign actions and responsibility to site champions and set targets and goals that are realistic. Display progress in reducing water use on graphs or charts to show trends, and consider linking results to incentive schemes. Celebrate successes. Encourage suggestions, and use group meetings to promote the efficient use of water. Display reminder materials, such as posters and stickers, in relevant parts of the plant. Provide training and encourage awareness where necessary.

Eco-efficiency action

- Form a water management team (which should include a representative from senior management) and assign a site champion.
- Demonstrate the support of senior management in providing direction and resources.
- Set realistic water usage targets and goals.
- Use posters and stickers to promote awareness of water efficiency.
- Implement staff suggestion schemes to encourage ideas for reducing water use.
- Promote progress on graphs, and consider linking successes to an incentive scheme.

- Regularly discuss water efficiency at staff meetings.
- Provide training where necessary.
- Publicise your business's commitment to water conservation.

'Employee involvement in environmental programs is essential for success. At Darling Downs Foods we believe that for waste management initiatives to be successful cooperation must be derived from the grassroots level upwards. The Darling Downs Foods Environmental Committee communicates intentions throughout the organisation via notice boards, an in-house newsletter "Pig Tales", appropriate signage and the circulation of Environmental Meeting minutes.'

Ross Bossian (Environmental Manager)
and Louis Gordon (Environmental Officer)
Darling Downs Foods, Toowoomba

3.2 Reducing demand for water: processing

3.2.1 Efficient spray nozzles

Water spray nozzles can be used in food processing for cleaning, conveyor lubrication or cooling heated product. Savings in water consumption can be achieved by reviewing spray and jet technology.

Spray nozzles come in hundreds of different models that are designed to suit particular needs. In recent years new technology has produced designs that allow for reduced water use without compromising spray effectiveness. Selection factors include type of spray pattern, water flow rate, spray pressure, drop size and alignment. Improved nozzles are also better equipped to tolerate reuse of dirtier water without becoming blocked. Considering the low cost, it makes sense to take advantage of the water-saving opportunities that the correct selection provides. Other factors affecting efficiency include the condition of the spray nozzles (worn or heavily scaled nozzles are inefficient) and correct placement to ensure the most effective spray pattern. The durability of nozzles is also important, as water consumption increases with nozzle wear. Table 3.4 shows how flow rate increases with wear for nozzles made of different materials. Stainless steel and nylon are the most durable.

Table 3.4: Comparison of different nozzle materials

Material	Abrasion resistance ratio	Flow increase from wear after 25 h of use (%)	Flow increase from wear after 50 h of use (%)
Aluminium	1	21	26
Brass	1	15	17
Stainless steel	4–6	4	4
Nylon	6–8	3	3
Hardened stainless steel	10–15	1	1

Source: Spray Systems Co. 2003

Case studies

Water-efficient spray nozzles: Cordial, jams and toppings processor, Australia
Schweppes Cottee's in New South Wales replaced the existing shower-style nozzles on their cordial container wash systems with water-saving nozzles and now save 7950 kL of water annually. The payback period was 10 weeks.[1]

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 their 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.[2]

Redesign of spray nozzles to better focus spray: brewery, UK
Carlsberg-Tetley Burton Brewery replaced the existing rotating head spray nozzle with a fine non-rotating slit spray nozzle that forced water through at high pressure. The new nozzle has better water contact with the cask to ensure a more thorough wash. The nozzle is also more water efficient and reliable, and requires less maintenance.[3]

[1] Environment Australia 2003a
[2] University of Minnesota 2003
[3] Envirowise 1996b

Eco-efficiency action

Review the effectiveness and efficiency of spray nozzles by:

- monitoring and conducting regular maintenance to ensure nozzles are kept in good condition
- conducting trials to determine the optimum settings (e.g. the minimum flow rate required for the spray to effectively clean equipment); the correct selection and maintenance of nozzles will have a bearing on the flow rate
- checking placement and alignment (e.g. a nozzle placed too high above the product will dissipate and be less effective); sprays should also be carefully spaced to avoid overlap.

3.2.2 Optimum rate of water flow

Sometimes equipment operates at water pressures or flow rates that are variable or set higher than is necessary. Conduct trials to determine the optimum flow for the equipment, or compare the flow rate with manufacturers' specifications to see if the flow can be reduced. To maintain a constant and optimum flow rate consider installing flow regulators.

Case study

Flow regulators on filleting benches: fish processor, UK
GW Latus installed flow regulators on the water pipes supplying its filleting benches. The flow rate was reduced from a variable 13 L/min to a consistent 8 L/min. An annual saving of A$7950 was achieved.[1]

[1] Envirowise 1999c

Eco-efficiency action

- Check the manufacturers' specifications for all water-using equipment and investigate whether the flow rate is higher than specified.
- For variable flow rates consider whether it is better to use a manual flow control valve set to the optimum rate.
- Consider installing a block valve where control valves are used to isolate a water supply and are then not being reset to the optimum rate. It may be necessary to lock the valve so that it is accessible to designated personnel only.

3.2.3 Monitoring and process control devices

Installing automatic monitoring and control devices in key sites can lower production costs.

Many devices are available to measure level, flow, temperature, pH, conductivity and turbidity. It is essential that process controls are correctly calibrated.

Water flow control

Water sprays are often used in food processing for washing, or to lubricate equipment. Avoid the use of continuous water sprays that can be left running unnecessarily during breaks in production. Linking sprays to conveyor or equipment motors using automatic cut-off switches can help eliminate water wastage.

Case studies

Control of water flow to a conveyor belt using solenoid valve: fish processor, UK
After installing meters on their equipment, F Smales and Sons found that the pre-wash stage in their filleting process was using excessive amounts of water. By fitting a solenoid value to switch off the water supply to the conveyor belt when it was not in use they were able to reduce pre-washing water use by 40%.[1]

Control of water flow to chilling and washing system using thermocouple: meat processor, United Kingdom
Thermocouples were installed on the water inlet and outlet to a chilling and washing system to feed into a control valve which optimised the flow rate of water. Supply water to the chilling and washer system was reduced by 10%.[2]

[1] Envirowise 1999c
[2] Envirowise 1999b

Level control

Inadequate level control cause product or water to overflow into the drain, generating unnecessary wastewater. The installation of simple process control instrumentation, as well as good design of processing equipment, can help reduce waste by preventing spills.

Case studies

Overflow control system: brewery, Australia
Castlemaine Perkins in Queensland installed an overflow control system on the hot water tanks of a keg line to prevent the loss of hot water to drain during filling. The initiative saves the company 30 000 kL annually.[1]

Redesign of outlet weir: poultry processor, Australia
Joe's Poultry Processors in South Australia produces smoked and ready-to-eat poultry. By redesigning the outlet weir on a scalder that was wasting 35 L of water per minute in overflow, the company was able to reduce water wastage by 55%. The payback period was 3.5 months.[2]

Modification of cooler: fruit and vegetable processor, Australia
Hot-filled bottled fruit juice is cooled before being labelled and packed. The cooler has three stages, separated by baffles or weirs. Water entering the third stage of the cooler was not equalising quickly enough, and consequently a significant volume of water overflowed to the floor and to wastewater. By installing a pipe to allow the water to equalise more quickly and preventing the overflow, the company will now save around 6660 kL of water — an annual saving of $34 000 including supply, treatment and discharge costs. The installation cost was only $400.[3]

Detection and repair of faulty valves on bottle washer: brewery, UK
Three faulty valves were causing the water tanks in a bottle washer to continuously overflow. By replacing the valves, JW Lees and Co. were able to save approximately A$32 500 in water and wastewater charges annually. The payback period was two months.[4]

[1] Castlemaine Perkins 2003
[2] Environment Australia 1997b
[3] UNEP Working Group for Cleaner Production 2003f
[4] Envirowise 1996a

Other process instrumentation

There is a wide variety of process instrumentation available to help food processors optimise product yield and minimise waste. For example pH, conductivity and turbidity sensors are widely used to detect product, chemical and water interfaces, particularly in clean-in-place systems. Such sensors can prevent product, chemicals and water from being prematurely diverted to drain and can allow for recovery of valuable resources. Differential pressure sensors can be used instead of timers or manual operators to detect pressure drops. For example, a pressure sensor across a filter cleaning system can be used to initiate cleaning only when needed, thus optimising the use of water and chemicals.

Case study

Pressure sensors replace timer: fruit processor, UK
A fruit processor used filters to remove pulp before bottling. The filters were cleaned at regular intervals determined by a timer. The timer was replaced with differential pressure sensors, and filter cleaning was initiated only when necessary. This reduced water consumption by 30%.[1]

Interface detection reduces beer loss and wastewater charges: brewery, UK
A UK brewery was losing beer worth more than A$2 300 000 annually in its wastewater. A waste audit revealed that 80% of all beer losses were from a vessel that separated the beer from the dead yeast cells. The process was modified with a capacitance level switch to enable better detection between the two phases. The company now saves around $1 800 000 annually in recovered beer and reduced wastewater charges. The payback period was only five days.[2]

[1] Envirowise 1999a
[2] ibid.

Eco-efficiency action

- Investigate at what stages in processing water is being used, and how this can be minimised to reduce the volume of wastewater generated. Consider whether better process control could be used to reduce losses, and investigate options.
- Ensure that continuous cleaning sprays are not left running unnecessarily by installing sensors to switch off the water supply.
- Install controls on water flows to process equipment, to optimise water use.
- Install timers on hoses and taps that may be left on unnecessarily.
- Investigate whether level controls will help prevent spills.
- Install controls that automatically close valves to drain when a phase interface is detected, to reduce loss of water, product or chemical.
- Regularly check that all process controls are functioning properly and are correctly calibrated.

3.2.4 Leaks

It is important that leaking equipment such as pumps, valves and hoses are promptly repaired. Equipment that is left leaking over lengthy periods can waste significant amounts of water or product. Table 3.5 gives some examples of the cost of water losses. For large equipment items that use large quantities of water, the cost of installing and regularly monitoring meters to detect leaks can be well justified.

Table 3.5: Examples of water loss from leaking equipment

Equipment	Hourly loss (L)	Annual loss (kL)	Supply water cost ($/year)	True water cost ($/year)
Union/flange (1 drop per second)	0.5	5	6	12
Valve (0.1 L/min)	6	53	60	123
Pump shaft seal (0–4 L/min)	0–240	0–2 100	0–2 373	0–4 893
Ball valve (7–14 L/min)	420–840	3 680–7 360	4 158–8 317	8 574–17 149
1 inch hose (30–66 L/min)	1 800–4 000	15 770–34 690	17 741–39 200	36 744–91 336

Assumption: Purchase cost of water: $1.13/kL; true cost of water: $2.33/kL (refer to Section 3.1.2). Hourly and annual water loss figures from Envirowise: www.envirowise.gov.uk/envirowisev3.nsf/key/d0e2836?open&login

Eco-efficiency action

- Establish a system to report, record and fix leaks promptly.
- Install meters on equipment that use large quantities of water to help monitor water consumption and detect leaks promptly.
- Compare water use with the equipment design specifications.
- Ensure that the flow meters are calibrated appropriately.
- Review trends in consumption of water use and during periods of non-use.

3.2.5 Water-efficient processing operations

By modifying existing processing operations or investigating more water-efficient alternatives, it may be possible to reduce water use in the plant. For example, some vegetable processors use water to transport vegetable product that could possibly be conveyed mechanically or pneumatically. In other cases it may be possible to use steam instead of water for blanching.

Sometimes water use can be totally eliminated, using ‘dry systems’. For example, peeling processors sometimes use a caustic bath to peel vegetables and fruits, briefly immersing them in the solution and then passing them under a heater. The peel, with residual caustic, is removed by a rubber disc peeler and pumped to a solid waste hopper, thereby preventing it from becoming part of the wastewater stream.

Counter-current rinsing is another means of reducing water in process operations. Clean water is introduced, flowing counter to the flow of food product, at the final rinse stage of a water bath. The used water is then reused as a first rinse for the incoming food.

Products are sometimes thawed or tempered (partially thawed) in open tubs of water; this consumes large quantities of water and produces high-strength effluent. Such products could possibly be thawed more efficiently using sprays, vacuum thawing, air blasting or still air. New developments in tempering using radio-frequency waves, for example, could lead to savings not only in water but also in space, energy and reduced drip loss. The product can often be tempered inside its packaging, as temperature distribution throughout the frozen mass is highly uniform. Radio-frequency tempering with its long wavelength is best suited for heating frozen blocks of seafood, fruit and vegetables from –20°C to around 0°C (Sairem 2003).

Case studies

Dry peeling versus wet peeling: vegetable processor, UK
A beetroot processor peels approximately 72 tonnes of beetroot per day. When wet and dry caustic peeling processes were compared, it was found that dry peeling reduced water use by 75%.[1]

Water reuse for boiler feed and counter-current: citrus processor, Australia
Irymple Citrus Products in Victoria reduced its water consumption by 30% by recycling condensate water for boiler feed, counter-current rinsing and, where possible, recycling water from water sprays.[2]

Modification of thawing tubs to reduce water consumption: fish processor, Australia
Tony's Tuna International in South Australia had previously thawed its pilchards using cold-water open tanks with water running continuously. By moving the water inlet to the base of the thaw-out bins, and by pulsing water exchange via solenoid valves, water consumption was reduced from over 12 L per tonne to 3.4–5.6 L per tonne. The payback period for the new piping, solenoid valves and bin adaptations was less than 1 month.[3]

Replacement of defrosting tubs with water spray system: fish processor, UK
Richard Coulbeck Ltd previously ran water continuously through defrosting tubs. After introducing a new sprinkler system, water supply costs were reduced from A$248 per day to A$50 per day.[4]

New technology for tempering: confectionery processor, New Zealand
A recent trial conducted by Keam Holdem Associates and Food Process Engineering Pty Ltd showed that radio-frequency tempering could uniformly melt cocoa blocks inside a plastic liner and cardboard carton. A 60 kW generator used with a two-zone tunnel was able to achieve a throughput of 1500 kg/hour. This type of heating overcame the problems of conventional heating methods (long lead times) and microwave heating (only able to penetrate the cocoa blocks to a depth of a few millimetres).[5]

1 Envirowise 2001
2 Environment Australia 2002c
3 Environment Australia 2003d
4 Envirowise1999c
5 Keam Holdem Associates Ltd and Food Process Engineering Pty Ltd 2003

Eco-efficiency action

- Investigate the feasibility of replacing equipment with more water-efficient systems, or 'dry' systems that are also energy-efficient.
- Consider dry mechanical transport systems where possible instead of transport by water.
- Counter-current rinse wherever possible or store final rinse water in a holding tank for subsequent pre-rinsing.
- Consider changing to a thawing system that uses little or no water, such as sprays instead of baths, use of ambient air, air blasting, radio-frequency or microwave thawing.

3.3 Reducing demand for water: cleaning

A large proportion of many food processors' water use is for cleaning equipment and surrounding areas of the plant. This can range from less than 10% of total water use for a 'dry' process such as nut processing, up to well over 40% for a meat processor or a dairy. There are numerous opportunities for reducing water use in cleaning, as this section outlines.

'One of the surprising findings of the eco-efficiency assessment was the amount of water consumed for cleaning, around 51%, in addition to a further 19% on the flume line. The installation of a second fume washer to enable the reuse of sanitiser water, the attachment of auto shut-off valves on hoses, and a very successful staff awareness program linked to an incentive scheme has seen water consumption on the site reduced by 15.7%.'

David May (Chief Operations Officer) Harvest FreshCuts 2003

3.3.1 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 using dry cleaning techniques before washdown. Wet and dry industrial vacuums can be used in most factories for easy collection and transfer of solids. In some cases usable product can also be recovered.

Although dry cleaning is practised widely in many businesses, there may still be room for improvement. Operator training and commitment are key factors in achieving good dry cleaning. Behavioural changes for manual cleaning can be achieved by raising awareness of water conservation issues, and perhaps also by incentive schemes.

Scrubber 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. These cleaners are fast and efficient, and reduce chemical use; but they may be unsuitable for small areas, or areas with restricted access.

Case studies

Dry cleaning: poultry processor, Australia
Bartter Enterprises in New South Wales reduced its water consumption by 10 000 L a day by mopping and sweeping where possible instead of hosing. Minimising the need to flush out drains by preventing build-up saved a further 3000 L per day.[1]

Dry cleaning of floors and equipment: chicken nugget processor, USA
The Equity Group in North Carolina produces chicken nuggets for McDonald's restaurants. By using dry cleaning methods to remove all dry waste from the floor and equipment, the Equity group was able to reduce BOD levels in the wastewater by 50%.[2]

1 NSW Department of State and Regional Development
2 Carawan 1996

Eco-efficiency action

- Sweep, squeegee or vacuum-clean floors and equipment to remove solids before washing down.
- Design or install drip trays or lips onto equipment and benches to help reduce the amount of material finding its way onto the floor and down drains. Trays and tubs should be easy to empty, and emptied regularly.
- Use scrapers, brushes and vacuum devices to pre-clean containers, equipment and conveyors before washing.
- Consider the use of scrubber dryers or vacuum cleaners to clean large areas of floor space.

3.3.2 Pipe cleaning

Pipes are usually cleaned manually or with a 'clean-in-place' system. Before any wet cleaning commences as much product should be removed as possible, to avoid increasing wastewater loads and wasting product. 'Pigging' systems or low-pressure blowers that propel a 'pig' (usually a solid material plug) to push out product can often be used to clear pipes. Pigs are particularly useful for the removal of viscous liquids, but usually need specifically designed or modified pipework because the pig cannot get through pumps or valve clusters.

The design of pipes and pipe run also affects cleaning efficiency. Pipes should not be oversized for the job and should be installed with a 'fall' leading to a drain point. They should be designed with minimal bends and dead legs where contamination can occur. Smaller pipework can be more easily vacuumed or air-purged of product.

Case studies

Line pigging and vacuuming of sumps: jam processor, UK
Nelsons of Aintree vacuum-cleans its sumps, gulleys and food traps and has installed a new pigging system. The amount of water used to flush the pipeline has now fallen from 2020 kL/year to 310 kL/year. In addition, 173 tonnes of saleable product is recovered annually. The COD level of the site's effluent has fallen by 76%. The payback period was only 4.2 weeks.[1]

Line pigging: toppings, syrups and blends processor, Australia
Food Spectrum in Queensland produces stabilised fruit product which is used as an ingredient in syrups and other food products. The stabilised fruit is pasteurised in a heat exchanger before being packed. Formerly, the lines were flushed with water at the end of each product run, producing a water product interface that was packed off and blended with other product batches. After this the pasteuriser underwent a 10 minute water rinse which was sent to drain. Food Spectrum has previously used starch plugs and pigs to reduce this interface, with varying degrees of success. A change to the pasteuriser allowed the company to introduce a new silicon rubber pig that better adheres to the pipework, thereby eliminating the need for flushing between product batches. This has avoided the use of about 10 minutes of water rinsing per batch and saved around $700 per year in water supply and discharge costs. The new system enabled about 7300 kg of product, worth $14 600, to be recovered.[2]

1 Envirowise 2000d
2 UNEP Working Group for Cleaner Production 2003d

Eco-efficiency action

- Investigate the use of 'pigging' systems or low-pressure blowers in pipelines to push out product.
- Optimise the time spent flushing pipes for cleaning and rinsing.
- Consider pipe design and layout for new installations to optimise cleaning needs.

3.3.3 High-pressure cleaning systems

High-pressure water cleaners are often used to clean floors and equipment. Cleaning with high-pressure water can use up to 60% less water, compared with using hoses attached to the water main (Envirowise 1998b). Mobile high-pressure cleaners can have flow rates ranging from 4 L/min to 20 L/min and pressures of up to 500 kPa.

It is important, however, that high-pressure cleaners complement cleaning procedures, and they should not be used in place of dry cleaning. In some 'high-risk' factories high-pressure cleaners can create aerosols, possibly causing the deposition of micro-organisms from the floor and drains back onto equipment and product. The use of high-pressure cleaning systems may therefore not be suitable in some instances and, if they are used, should be used carefully.

Case study

High-pressure cleaning systems: Mexican processor, USA
Sparta Foods in North Carolina replaced its water main pressure hoses with high-pressure cleaners to clean the equipment used to process flour products. The equipment can now be cleaned using half the quantity of water. The payback period was less than three months.[1]

[1] Carawan 1996

Eco-efficiency action

- Replace mains-pressure hoses used for cleaning floors and open equipment with high-pressure washers.
- Reduce the time to set up mobile pressure washers by fixing them to a ring main.

3.3.4 Trigger-operated controls for hoses

A hose left on unnecessarily for a total of one hour a day can waste between 470 kL and 940 kL of water in a year. That represents $1090–2180 a year per hose. The cost of a trigger gun can range from $20 to $100 for a heavy-duty item. Staff may need to be encouraged to use trigger guns, as they may consider them cumbersome, and possibly more susceptible to damage than open-ended hoses.*

Case studies

Trigger-operated controls on hoses: syrup, toppings and blends processor, Australia
Food Spectrum in Queensland fitted trigger-operated controls on all hoses used for cleaning, reducing water consumption for cleaning by 10%.[1]

Trigger-operated controls on hoses: poultry processor, Australia
Bartter Enterprises in New South Wales reduced its water consumption by 30 000 L per day by investing $1000 in efficient hose nozzles. This resulted in a saving of $19 000 annually.[2]

[1] UNEP Working Group for Cleaner Production 2003d
[2] NSW Department of State and Regional Development 2003

Eco-efficiency action

- Fit trigger-operated controls or water guns on hoses so that, wherever practicable, they are turned off immediately after use or when unattended.
- Install automatic reel-up hoses to help protect the hose and its trigger gun.

'To leave a 3/4 inch hose running on the floor can cost more each hour than paying the person that left it there.'

Marcus Cordingley, Environmental Systems Coordinator, Golden Circle

*Assumptions: $2.33 kL for true water cost; 260 days each year; hose flow rate of 0.5–1.0 L/s

3.3.5 Design and selection of processing equipment

Processing equipment should be designed to promote easy cleaning. This will reduce consumption of water and chemicals, as well as reducing the time taken to clean equipment. When selecting processing equipment give preference to those items that have fewer moving parts and are easier to clean. Keep in mind what difficulties operators may have in using and cleaning the equipment.

Case study

Redesigning pipework to reduce cleaning requirements: brewery, Australia
The South Australian Brewing Company's old cellar area had a long pipe run and complicated manifold system, which meant that extensive cleaning was required between batches. A new pipe layout was designed with waste reduction in mind. The new design saved $55 000 in water, beer, energy and cleaning, plus a further $10 000 in wastewater savings. The payback period was less than one year.[1]

[1] South Australian Environmental Protection Agency 1999

Eco-efficiency action

Ensure equipment allows easy access for cleaning, to avoid excessive use of chemicals and water. Ensure that all internal angles and corners are smooth and curved, and there are no exposed fasteners or rough welding at joins. All equipment should be self-draining and contain no dead legs.

3.3.6 'Clean-in-place' systems

A 'clean-in-place' (CIP) system is an automatically operated cleaning system that is designed to clean tanks, piping or other items of equipment. A CIP system usually consists of several chemical and rinse water-holding tanks, and associated pumps and piping to allow the recirculation of rinse waters and cleaning chemicals. A well-designed system minimises the use of water and chemicals, and saves labour required for manual cleaning. CIP systems are usually custom designed for specific applications.

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

- fluid-driven tank wash nozzles that 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 spray pattern and the temperature and corrosive nature of the cleaning fluids. More information on efficient spray nozzles can be found in Section 3.2.1.

Case studies

Reuse of water by CIP system: milk processor, Australia
Pauls Ltd 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 annually, with a payback period of only one year.[1]

Reuse of water by CIP system: fruit and vegetable processor, Australia
Golden Circle in Queensland conducted trials on its hot fill/cordial line designated CIP unit and found that the second-step rinse could be eliminated by extending the time for the first rinse. Eliminating the second rinse could save around 1700 kL or $4000 a year. The installation of an additional CIP tank would allow final rinses to be collected and used as a first rinse on the next wash. This would save 4350 kL per year and an additional $10 300.[2]

1 Environment Australia 2003b
2 UNEP Working Group for Cleaner Production 2003f

Eco-efficiency action

- Use sensors to shut off rinse water as soon as the solids (waste or product) have been washed out, and to avoid detergent wash cycle water from being diverted prematurely to the drain.
- Design CIP systems to allow for storage of rinse water and recovery of chemicals for reuse.
- Use membrane filtration to recover recirculated solution, thereby reducing the need to drain and refill storage tanks regularly.
- Review the operation of existing CIP systems to determine whether the settings are optimum.
- Consider ‘pulsed’ rinses which can reduce water usage.
- Investigate automatic ‘proof of clean’ checks for your system.
- Review cleaning needs (e.g. a full clean versus a simple rinse).
- Contact your supplier to determine the most suitable spray nozzle for your cleaning needs.
- Ensure the spray ball or nozzle fits the application, especially with regard to spray pattern and temperature, and chemical corrosion of materials

3.3.7 Scheduling product changeovers

If equipment needs to be cleaned after each product changeover, modify or schedule production so that the number of product changes is kept to a minimum. It may be possible to reduce or eliminate the amount of cleaning required between changeovers by processing similar products sequentially. For example, schedule more highly flavoured or dark products last.

Eco-efficiency action

- Schedule product changeovers to reduce or eliminate cleaning requirements.
- Improve production scheduling to ensure that washers are used only when fully loaded.

3.3.8 Automatic container washers

Automatic container washers can vary from front-loading automatic washers for small quantities to large conveyor washer systems. Washers are designed to carry out various duties including soaking, pre-washing, washing, rinsing, disinfecting and sometimes drying. Automatic container washers can achieve water savings of up to 95% when compared with pressure cleaning, as shown in Table 3.6.

Table 3.6: Comparison between using an automatic tray washer and using a high-pressure hose and gun to clean 2500 dirty trays each day

	Tray washer	Pressure washing
Water used (kL/day)	1	27.5
Time required (h)	6	21.0

Envirowise 1998b

Case study

Recycling wash water and system control on container washer: cordial, jams and toppings processor, Australia

Schweppes Cottee's in New South Wales has installed a collection tank, piping and pump on a cordial line container washer to enable the reuse of final rinse water for 'first wash' water. It has been estimated that the system has halved the washer's consumption of mains water.[1]

[1] Environment Australia 2003a

Eco-efficiency action

- Investigate using purpose-built automatic washers to clean containers, rather than using hoses or high-pressure cleaning methods.
- Reuse final rinse water for pre-rinse cycles in washers. If the washer already reuses water, ensure that fresh water is kept mostly for the final rinse, rather than for other sections of the process.
- Investigate adjusting the washer speed and length of cleaning cycles, to achieve the most efficient clean while still meeting hygiene standards.

3.4 Reducing demand for water: utilities

3.4.1 Blowdown in cooling towers and boilers

A build-up of dissolved solid deposits in cooling towers and boilers can reduce efficiency and cause mechanical damage. Blowdown can be used to prevent this. In order to minimise the quantity of water needed for blowdown, a conductivity probe can be installed. This will initiate blowdown only when the conductivity of the water exceeds a set value.

Water used for other equipment may be able to be recycled and reused for cooling tower make-up water, provided it is of good quality and any chemicals used are compatible with those used in the cooling circuit.

Case study

Water reuse for evaporative condenser and cooling tower make-up water: brewery, Australia
Swan Brewery in Western Australia recycles carbon dioxide purifier cooling water, can rinsing water and refrigeration cooler defrost water. The water is reused in the evaporative condensers and for cooling tower make-up water. The company saves 60 000 kL annually and 10% in wastewater treatment costs.[1]

[1] Centre of Excellence in Cleaner Production 2003a

Eco-efficiency action

- Install conductivity sensors to reduce blowdown.
- Add an automatic chemical feed system controlled by make-up water flow.
- Consider alternative sources for blowdown make-up water.
- Reuse blowdown water (particularly from boilers) for other uses such as cleaning.
- Maintain boiler systems regularly to reduce blowdown and maintain boiler efficiency.

3.4.2 Cooling tower operation

To reduce the risk of contaminants collecting in cooling towers and associated piping, the equipment must be cleaned and maintained regularly. Maintenance enhances the tower's efficiency and helps to maximise the equipment's life span.

The installation of a filtration system such as a rapid sand filter or high-efficiency cartridge filter may help to remove suspended materials that degrade the quality of cooling tower water. The reduction of fouling will help to reduce maintenance, the necessity for blowdown, and the loss of heat transfer efficiency. For cooling towers with low flow rates it may be possible to install a filter directly onto the tower outlet. For larger systems with higher flow rates this is not practical, and a side-stream filter is the most economical option.

A valve which is mechanically actuated by a float is utilised on many cooling towers to control make-up water supply. If this is the case, ensure the float is 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.

Eco-efficiency action

- Regularly maintain cooling towers to improve efficiency.
- Operate cooling towers at design specifications (i.e. temperature and flow rate).
- Check for leaks by comparing the ratio of blowdown flow to make-up flow.
- Reduce the cooling load of towers by first recovering heat from the stream to be cooled.
- Use a filtration system to remove from the cooling tower water suspended materials that cause fouling and reduce heat transfer.
- Minimise dust around cooling towers and keep heat exchange areas clean, to maximise heat exchange to cooling water.

3.4.3 Alternative cooling processes

Water can be saved if an alternative cooling medium other than cooling tower water can be found. Check whether direct or indirect contact between existing suitable hot water and cold water streams can achieve the desired cooling. In some cases, where higher water temperatures can be tolerated (up to 40°C), cooling towers can be replaced with air blast coolers; however, any water savings need to be compared with increased energy costs. Another alternative is to use the waste heat elsewhere in the processing plant by installing a heat exchanger.

Eco-efficiency action

- Investigate the feasibility of alternative cooling processes such as air blast coolers.
- Investigate whether other streams are available for cooling by direct or indirect contact.

3.4.4 Boilers and steam generators

Water lost from the boiler system in the form of steam condensate should be recovered as far as possible. Condensate recovery reduces the amount of make-up water required by the boiler to compensate for the condensate loss. Reducing condensate loss can significantly reduce water supply, chemical use and operating costs. A condensate return system also reduces energy costs, because the already hot condensate requires less energy to reheat.

Case study

Condensate recovery improvement: brewery, Australia
Castlemaine Perkins in Queensland used to send condensate at 95–98°C in the engine room to the drain. A condensate return system was installed for $15 000 to return this water to the boiler. Condensate return was increased by 5% to 70%, saving 2000 kL annually. [1]

1 Castlemaine Perkins 2003

Eco-efficiency action

- Examine the potential to install a condensate return system. Routinely inspect and maintain steam traps, condensate pumps and lines.

3.4.5 Pump seals

Pumps such as liquid ring vacuum pumps use water as a sealing and cooling medium. It may be possible to replace such pumps with dry vacuum pumps to reduce water consumption.

Sealing water on pumps can be recirculated to minimise usage. Alternatively, mechanical seals can now be installed on most pumps that require no sealing water. Such seals reduce water consumption and may reduce operating and equipment costs.

Case studies

Replacement of water vacuum pumps: brewery, Australia
Castlemaine Perkins in Brisbane replaced 14 water seal vacuum pumps with high-efficiency electrical pumps and now saves 8000 kL of water annually.[1]

Reuse of vacuum pump wastewater: fish processor, Australia
Port Lincoln Tuna Processors in South Australia produce canned tuna and sashimi. The company uses vacuum pump wastewater and reverse osmosis water permeate for cleaning. Washdown for the plant is now achieved using 85% recycled water.[2]

1 Castlemaine Perkins 2003
2 South Australian Environmental Protection Agency 2003a

Eco-efficiency action

- Recycle pump sealing water or collect for use for other purposes such as cleaning.
- Investigate installing mechanical seals that require no sealing water on pumps.
- Investigate the use of dry vacuum pumps.

3.5 Reducing demand for water: auxiliaries

Water use in amenities, kitchens/cafeterias and gardens may be a small percentage of a plant's overall water use, but there are still significant savings to be made. Practising water conservation, often by implementing simple low-cost measures, also sends a strong message to staff. Table 3.7 shows water efficiency ratings and corresponding flow rates of various appliances, while Table 3.8 shows possible savings from purchasing water-efficient products.

Table 3.7: Water appliances A to AAAAA

Rating	Level of water efficiency	Flow rates for basin taps (L/min)	Flow rates for showers (L/min)	Flow rates for dishwashers (L/place setting)	Flow rates for toilets L (average flush volume)
A	Moderate level	6.0–7.5	12.0–15.0	2.0–2.8	5.5–6.5
AA	Good level	4.5–6.0	9.0–12.0	1.5–2.0	4.0–5.5
AAA	High level	3.0–4.5	7.5–9.0	1.0–1.5	3.5–4.0
AAAA	A very high level	2.0–3.0	6.0–7.5	0.8–1.0	2.5–3.5
AAAAA	An excellent level	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 & Labelling

Table 3.8: Savings from purchasing water-efficient 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 litres 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

Sources: *Buyers Guide to Saving Water* 2003; Master Plumbers and Mechanical Services Association of Australia 2003

There are many water conservation measures that can be undertaken for auxiliary equipment. Some examples are outlined below.

Eco-efficiency action

Washrooms

Toilets

- Use sensors in washrooms to detect activity and control water, lighting and fans.
- Repair leaks and plumbing problems.
- Replace continual-flush urinals with sensor-operated urinals.
- Install dual-flush toilets or use cistern volume adjusters.

Showers

- Use water-efficient (low flow rate/high velocity) shower head (9 L/min).

Washbasins

- Use AAA-rated taps or install flow restrictors on existing taps (6 L/min). Thigh- and pedal-operated switches can be used at hand and foot wash stations.
- Install metering taps or taps with sensors.

Kitchens/cafeterias

- Use dishwashers only when fully loaded.
- Use final rinse water for pre-washes.
- Use AAA-rated taps where possible.
- Encourage good housekeeping such as rinsing fruit and vegetables in still water baths rather than under running water, thawing food in the refrigerator and not under running water, cleaning equipment before cooling, and dry cleaning cutlery and crockery before washing.

Landscaping

- Do not use water for cleaning driveways, loading docks and parking lots.
- Mulch to discourage weeds and water loss.
- Design landscapes that require less water.
- Water only when necessary and at times when evaporation is lowest (i.e. the early morning or evening).
- Install soil moisture overrides or timers on irrigation systems.
- Avoid runoff and make sure sprinklers cover the lawn or garden only.

3.6 Overview of wastewater

Industrial wastewater is any waterborne waste that is generated in industrial processes. Characteristics of wastewater that are important are the volume of wastewater generated (as this can affect treatment efficiency), the concentration of contaminants in the wastewater, and the corresponding load of contaminants in the wastewater (a function of the concentration times the volume). Depending on the loads, wastewater can have detrimental effects on the receiving environment and on public health and amenity if not properly controlled. If it is discharged to sewer, irrigated to land or discharged to surface waters it must be in accordance with any licences for such discharge. Treatment of wastewater produces two main types of material: liquid effluent and sludge. Sludge is also referred to as biosolids.

What is trade waste?

Trade waste is any water approved for disposal to sewer that is contaminated by industrial processes. Trade waste does not include domestic sewage. Charges for discharge of trade waste to sewer vary according to the location of the plant and the local authority. A trade waste cost calculator is included on the CD that accompanies this manual, to help determine the breakdown of costs and where potential savings can be made.

Sources of wastewater from typical food processing operations include:

- cleaning e.g. washdown and container washers
- washing and rinsing of food products
- heating processes (e.g. cooking, autoclaving and blanching of food products)
- cooling processes (e.g. refrigeration and air conditioning units and bottle coolers)
- blowdown from boilers and cooling systems
- leaks, spills and overflows
- pump seals.

3.6.1 Identifying sources of wastewater

It is important to identify exactly which processes in your plant are producing the various streams that make up wastewater. Quality and quantity of the various fractions making up the total wastewater should be assessed in order to identify eco-efficiency opportunities to reduce it or collect it as separate streams. This could be considered a trade waste audit.

You could take the following steps:

1. On a site plan identify each entry point feeding wastewater into the drainage system from process equipment or cleaning activities. A walk-through assessment will help identify these areas.
2. Locate any effluent meters or sampling points. The output of wastewater from a food processing plant is often sampled by local council bodies for regulatory and charging purposes. This information is essential for identifying sources of waste pollutants entering the wastewater and for monitoring the progress of efforts to reduce its quantity and improve its quality.
3. Lastly, seek information about any effluent or sludge that is removed from the site in tankers (e.g. volume, characteristics, frequency).

3.7 Reducing the volume and pollutant load of wastewater

3.7.1 Source reduction

The volume of wastewater generated by a food processing plant can be dramatically reduced by reducing water use. Naturally, using less water will probably also mean a rise in the concentration of pollutants in the smaller volume of wastewater generated.

3.7.2 Reducing pollutant load

Improving the quality of wastewater generated can be achieved by minimising the amount of product that enters a water stream. This can be through effective and well-maintained process control and initiatives such as dry cleaning, the elimination of spills and repair of leak, and the installation of drip trays, catch baskets and drainage screens.

Case study

Reducing wastewater by better process control: brewery, Australia
The South Australia Brewing Company evaluated all its packaging lines using statistical process control. The company identified that waste from the incorrect filling of cans, bottles and kegs could be reduced by correctly calibrating filling apparatus and ensuring fill detectors were working properly. Reducing filling losses has prevented 200 000 L of liquid being lost to the sewer, saving around $5000 in wastewater costs. In addition to this, $5000 has been saved in cleaning time, $80 000 in product savings and $10 000 in under-fill savings. The payback period was less than six months.[1]

[1] South Australian Environmental Protection Agency 1999

3.7.3 Segregating wastewater streams

Segregating high- and low-strength wastewater streams may help to reduce the overall pollutant load of the wastewater or allow for the treatment of different kinds of waste. As a consequence, it may be possible to reuse the water from some wastewater streams with little or no treatment. Separating wastewater streams may also help maximise the quantity of product that can be recovered. For example, the separation of hot and more heavily contaminated wastewater streams from the main stream can help improve fat recovery. Methods of product recovery are examined further in the next section.

Case study

Segregation to enable water reuse and starch recovery: snack food processor, UK
A snack food company previously treated its wastewater to remove solids and oils, which were then processed into animal feed cake. The company now segregates its wastewater into three main streams: the potato wash water that is reused after the grit has been removed; the cold starch water that is recycled after good-quality starch has been removed; and the hot starch water containing oils that is used for animal feed cake. The initiative has reduced wastewater costs and reduced water consumption by 19%.[1]

[1] CIAA 2002

Eco-efficiency action

- Minimise the amount of product entering water streams by effective and well-maintained process control, as well as dry cleaning, eliminating spills and repairing leaks, and installing drip trays, catch baskets and drain screens.
- Investigate whether segregating wastewater would help to reduce pollutant load or enable water reuse.

3.8 Recovery of products and energy from wastewater

3.8.1 Product recovery

During processing, materials lost to the wastewater stream contribute to the pollutant load. These losses can also represent a loss of valuable resources. Advances in technology now enable resources lost to wastewater streams to be extracted and recovered. For example, solubles in water removed from freeze-dried wheat are recovered from a waste stream and used to supplement egg whites (Phillips and Associates Inc. 1997).

Membrane technology is becoming increasing popular in the food processing industry. The membrane treats wastewater by physically filtering out specific substances while retaining others. One of its major advantages is that it allows substances to be recovered chemically unchanged, thus making the recovered substances more readily available for reuse. Membranes may not be suitable for use where excessive fouling is likely. The main disadvantages associated with membrane technology are the potentially high capital costs, production of a concentrated backwash with significant microbial contamination, and the handling and management of contaminated chemicals necessitated by periodic cleaning of the membranes.

Case study

Recovery of fats from effluent: dairy processor, Australia
Bonlac Foods in Victoria manufactures anhydrous milk fats (AMFs) at its Stanhope and Cobden plants. The refining of AMFs produces an effluent stream (soap stock) that has a high organic load (a COD load of 1.5–4 t/day). Because of the wastewater's high COD it often overloads the treatment system. At Stanhope a land disposal technique was developed, costing the company $160–170 000 annually. The company now recovers fats from the AFM soap stock wastewater by cracking the emulsion with nitric acid and then recovering the fat in a centrifugal separator. The recovered fat is collected by a stockfeed manufacturer. Product waste has been reduced from 6% to 1–2%. The Stanhope plant no longer needs to pay land disposal costs, which saves $170 000, and the Cobden plant has reduced effluent costs by $70 000. The sale of recovered fat brings in an additional $21 000 in annual revenue. The payback period was only six months.[1]

Membrane technology enables product recovery and water reuse: cheese processor, UK
Joseph Healer Ltd was previously losing around 90% of the milk the company used for cheese-making in its wastewater (whey), which was either disposed of or spread on farmland. The company installed a three-stage ultrafiltration, nanofiltration and reverse osmosis membrane wastewater treatment system to recover whey protein and lactose; and the water was reused for cleaning membrane units and as boiler feedwater. The new treatment system is now saving the company A$1 643 684 annually. The payback period was 1.5 years.[2]

[1] Environment Australia 1999a
[2] Envirowise 2003b

3.8.2 Energy recovery

Energy recovery from wastewater streams is discussed in Chapter 4. Options for energy recovery include anaerobic digestion and fermentation, and the subsequent use of biogas. Energy available from biogas from the digestion of food processing wastewaters can provide 10–20% of a plant's thermal energy requirements (UNEP Working Group for Cleaner Production 1999).

Case study

Savings to be made by anaerobic digestion: ice cream processor, Australia
A feasibility study was undertaken for the Streets Ice Cream factory in Minto, New South Wales to determine the potential for recovering energy from effluent and sludge streams by anaerobic digestion. The best option identified was an anaerobic lagoon digester that operated with the existing treatment plant. It could be installed for $400 000 with a payback of two years. Savings included $26 000 annually in electricity costs and $21 000 annually in recovered heat or $ 47 000 in natural gas costs. Other benefits include an annual reduction of $143 000 in sewer charges, $13 000 in electricity consumption for the aeration of the sequenced batch reactor plant, and a reduced sludge disposal requirement of $50 000.[1]

[1] UNEP Working Group for Cleaner Production 1999

Eco-efficiency action

- Investigate opportunities to recover product from your plant's wastewater streams.
- Investigate opportunities to recover energy (in the form of biogas) from your plant's wastewater stream using anaerobic digestion.

3.9 Water and wastewater recycling and reuse

Some wastewater streams are relatively clean and can often be recycled or reused onsite. If the quality of wastewater streams is not suitable, some form of treatment may be necessary to make the water suitable for reuse. In some cases it may be necessary to segregate wastewater systems to allow for reuse, as previously discussed. Food health standards will not allow the reuse of water on edible product or in a process where water may come into contact with edible product.

Some incentives that have been encouraging the food processing industry in Queensland to recycle water include:

- recognition of the true cost of water and of the fact that reducing water use will lower production costs
- new water charging arrangements by local governments to recover water costs
- higher costs associated with operating and upgrading wastewater treatment plants to meet rising standards
- tighter government controls on the quality and quantity of wastewater discharge
- increasing awareness of the detrimental effects on the environment of excessive water use
- increasing pressure on limited water supplies.

The Queensland Water Recycling Strategy (QWRS)

The QWRS is a Queensland Government initiative aimed at encouraging the adoption of water recycling that is safe, environmentally sustainable and cost-effective. The strategy's aim is to develop the best and most effective ways to manage municipal, industrial and agricultural effluents and urban stormwater as a resource rather than as a waste .

The QWRS outlines a set of action plans that help promote sustainable water recycling in Queensland. These include amending existing laws to support water recycling, and developing new legislation to deal with water recycling issues, especially approval processes.

The strategy recognises the great potential for industry to reduce water use by internal recycling. The recycling of treated municipal effluent in industry is also seen as an area of great potential; however, its applicability to the food processing industry may be limited due to strict food hygiene standards.

The Queensland Environmental Protection Agency (EPA) has prepared guidelines for the safe use of recycled water, which will be released for public comment early in 2004. Once these draft guidelines have been accepted as government policy the department hopes to develop industry-specific codes of practice for the use of recycled water. The guidelines cover laws affecting water recycling in Queensland, planning a recycled water scheme, responsibilities in water recycling, general safeguards for use of recycled water, and recycled water safety plans. For more information about the Queensland Water Recycling Strategy and Guidelines visit the Queensland Environmental Protection Agency website www.epa.qld.gov.au/environmental_management/water/water_recycling_strategy/

Some guidelines that have also been developed at a national level by the National Water Quality Management Strategy (NWQMS) including:

- Guidelines for Sewage Systems — Use of Reclaimed Water (2000)
- Australian Guidelines for Urban Stormwater Management (2000)
- Guidelines for Sewage Systems — Effluent Management (1997)
- Effluent Management Guidelines — Dairy Processing Plants (1999)
- Effluent Management Guidelines — Wineries and Distilleries (1995).

3.9.1 Onsite water recycling and reuse

Often final rinse water is relatively clean and may be suitable for recycling or reuse within the plant.

Reuse and recycling of process water

There may be opportunities for recycling relatively clean water with minimal treatment. By modifying washing equipment to include a recovery tank to store final rinse water, for example, it may be possible to recycle the water for subsequent pre-rinses. It may also be possible to reuse process water for other plant operations such as cleaning, cooling or boiler make-up water.

Case studies

Reuse of container washer rinse water for cooling: beverage processor, Australia
Cola Coca Amatil in New South Wales made pipework modifications to capture container rinse water, which is now used in the evaporative cooling towers. The new system saves the company 6 ML annually, a saving of $15 000 in wastewater charges. The payback period was less than six months.[1]

Water recycling in vegetable washer: fresh salad processor, Australia
Harvest FreshCuts in Queensland modified its vegetable washing system to enable water to be internally recycled, and now saves $22 300 in water and disposal costs annually. The payback was immediate.[2]

Counter-current washing and water reuse for cleaning: brewery, UK
Carlsberg-Tetley Burton recovers the final wash water used in cask washing for reuse up to four times in other stages of the washing process. Water is recovered after each use and is finally used to wash down the conveyor belt. The company has reduced external rinses from 16 300 kL/year to zero, pre-rinses from 7700 kL/year to zero and conveyor washing from 11 000 kL/year to zero.[3]

Water reuse in pasteuriser: brewery, Australia
The South Australian Brewing Company recycled water in its bottle and can pasteuriser and saved $60 000 in fresh water consumption annually. The payback period was 10 months.[4]

1 Environment Australia 2003c
2 UNEP Working Group for Cleaner Production 2002b
3 Environment Australia 2003c
4 Envirowise 1996b

In single-pass cooling systems water is circulated once through a piece of equipment and is then sent to drain. To remove the same heat load, single-pass systems use 40 times more water than a cooling tower operated at five cycles of concentration (Federal Energy Management Program 2003b). Typically single-pass cooling equipment includes ice machines, vacuum pumps, air compressors, air conditioners and hydraulic equipment. Single-pass cooling equipment can be modified to operate on a closed loop so that water is recirculated. Alternatively, another use may be found for discharged single-pass cooling water, such as boiler or cooling tower make-up water or irrigation.

Case studies

Closed loop circuit on compressor: fish processor, UK
Previously water from the skinning machine compressor in a fish processing plant ran to drain. By introducing a closed loop circuit with a chiller to maintain a consistent temperature, the company has been able to save $61 000 annually in reduced water and effluent charges. Payback period was three years.[1]

[1] Envirowise 1999c

Reuse of wastewater

Options to reuse wastewater will be dictated by HACCP quality controls and the need to meet food safety requirements.

Case studies

Recycled water system: brewery, Australia
Castlemaine Perkins in Queensland previously sent water used in the packaging process (package rinser, pasteuriser overflow and filler vacuum pumps) to trade waste. A recycled water system was installed to collect each grade of water and treat them separately by filtration and chemical treatment as required. The water was then used where appropriate as boiler make-up water, cooling tower water, and for irrigation and hose-down. It is estimated the system saved 30 000 kL of water and $50 000 per year. The cost of implementation was $220 000.[1]

Improvement in wastewater quality and water reuse: snack food processor, Australia
The Smith's Snackfood Company in South Australia was generating wastewater containing 10% solids. Treating the wastewater was costing the company $130 000 annually. In addition to this, the build-up of solids often caused flooding and consequently stopped production. By introducing hydrocyclones into the potato and corn lines, however, the company is now able to separate solids from the effluent using strong centrifugal forces. The cleaner water from the hydrocyclones is collected in holding tanks and recycled into the system. Waste disposal costs have fallen from $144 per tonne to $40 per tonne. The payback period was five weeks.[2]

Reuse of water from settling dam for initial washing of raw material: ginger processor, Australia
Buderim Ginger in Queensland sends its wastewater from its washing process to a settling pond. After the solids have settled, the water flows back to another dam that supplies water for the initial washing of the raw ginger. The company saves 19 ML annually — around 15% of the company's total water use. This represents a saving of $16 500.[3]

[1] Castlemaine Perkins 2003.
[2] Environment Australia 2003g
[3] UNEP Working Group for Cleaner Production 2003k

Plants that are required to use filters to treat water before processing may be able to recover some of the costs by recycling the backwash water used to clean the filters. Some backwashing processes incorporate air to further reduce the amount of water required.

Case studies

Water recovery and reuse by filtering backwash water: beverage processor, Australia
Coca Cola Amatil in New South Wales cleans 10 sand and carbon filters daily and then recycles the backwash water from the filtering process through a treatment plant for reuse in processing. The initiative has reduced trade waste discharge by 25% and saved the company a further $100 000 in water charges.[1]

Reuse of backwash water for make-up water: cordial, jams and toppings processor, Australia
Schweppes Cottee's reuses backwash water from its sand filters for cooling tower make-up water, boiler feed water and line lube water. The company saves $8280 annually. The initiative involved installing collection tanks, piping and pumps, with a payback period of five months. [2]

1 Environment Australia 2003c
2 Environment Australia 2003a

3.9.2 Offsite reuse of wastewater

The nutrients contained in some kinds of effluent may be a useful resource. Options for the beneficial utilisation of wastewater include crop production, forestry, land rehabilitation and even aquaculture.

Crop and pasture production

The use of treated wastewater on crops may be a viable option for food-processing plants located in rural and semi-rural areas. Crops being cultivated using treated wastewater include grains such as sorghum and corn, and fast-growing varieties for hay production. The use of wastewater is regulated by the Queensland Environmental Protection Agency to protect the environment and ensure public safety.

Case studies

Irrigation of pasture with wastewater: tomato paste processor, Australia
Heinz Watties in Victoria treats all its wastewater in dams and then uses the treated water to irrigate dairy pasture.[1]

Irrigation of pasture with wastewater: dairy processor, Australia
Bonlac Foods in Victoria (Darnum Plant) discharges its low-solids general factory wastewater and rinse water to a primary or secondary treatment system. For five months of the year treated water is irrigated onto pasture to optimise growth rates while maximising water utilisation and nutrient uptake.[2]

1 Environment Australia 2002d
2 Darnum Cleaner Production Initiative 2003

Forestry and land rehabilitation

The use of wastewater for forestry operations or land rehabilitation involves matching the nutrient needs of forest crops with nutrients that may be available in some kinds of food processing wastewater, such as nitrogen and phosphorus. A number of trial effluent plantations in Victoria have shown that eucalyptus and conifers can have very fast growth rates when irrigated with treated wastewater (Stackpole 2001).

Case study

Winery wastewater irrigates red gum plantation: winery, Australia
Berri Estates Winery in South Australia produces large quantities of wastewater from washing down the plant and its equipment, as well as a smaller volume of wash water from its distillation process which has a high COD level. The high COD content means that the wastewater produces an offensive odour when left to stand in evaporative lagoons. To resolve the problem, the company is now using the wastewater to grow a plantation of Murray River red gums. The establishment of the plantation is an economical and sustainable wastewater disposal alternative, which has eliminated odour problems while also producing a future timber resource for the company.[1]

[1] Environment Australia 2001c

Aquaculture

While only in its infancy in Australia, the use of treated wastewater as a nutrient food supply for algae and fast-growing species such as duckweed is common throughout Asia. Duckweed can be fed to fish, poultry and cattle (Landesman 2001).

Case study

Wastewater to grow duckweed for stockfeed: biotechnology company, Australia
Bio Tech Waste Management (BTWM) is a privately-owned company in New South Wales which is utilising duckweed to cleanse wastewater, and is researching the use of the harvested biomass as a feed supplement for livestock including fish. The company has used wastewater from municipal sewage treatment works, abattoirs and food processing plants. The company has undertaken extensive trials at a piggery and a beef cattle feedlot. Data from these sites has shown that wastewater treated by the BTWM system meets NSW EPA guidelines for continuous irrigation or discharge into river systems.[1]

[1] Bio Tech Waste Management 2003

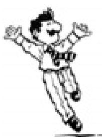
3.9.3 Stormwater collection

For food processing plants with large roof areas, collecting stormwater may be an option to supplement existing supplies. Rainwater collected from roof surfaces can be of suitable quality for non-process applications such as cooling water. It is estimated that a factory in the Brisbane region with a roof area of 6500 m^2 could potentially collect 6500 kL/year with an average rainfall of 1000 mm/year (ABM 2003) saving around $6500. For a capital outlay of $15 000, including storage tank and treatment unit, the payback period could be around two years.

Case study

Stormwater collection: ginger processor, Australia
Buderim Ginger in Queensland harvests stormwater from the ground floor of its green ginger receiving area and the roof of the ginger wash plant. A first flush system directs the initial volume of rainwater to the wastewater treatment plant and the remainder is directed to the wash collection pits. The water is used for the initial wash of fresh ginger from the farm.[1]

[1] UNEP Working Group for Cleaner Production 2003k



Eco-efficiency action

- Identify relatively clean wastewater streams and attempt to match them with your plant's water demands (e.g. recycle through process equipment or reuse for other plant operations).
- Investigated changing single-pass systems to closed-loop systems. Alternatively, find another use for discharged single-pass cooling water.
- Identify whether treated wastewater streams could help to meet the plant's water needs.
- Investigate the recovery of filter backwash water.
- Consider opportunities to use treated water in the cultivation of crops, or for forestry operations or land rehabilitation.
- Investigate the use of treated wastewater as a nutrient food supply for algae and fast-growing species of duckweed for stockfeed.
- Consider the viability of collecting stormwater to supplement water supplies.

3.10 Wastewater treatment

3.10.1 Wastewater treatment options

The degree of treatment necessary for treating wastewater will be determined by the end use — for example whether the wastewater is to be discharged to sewer, reused on or off the site, or discharged to surface water.

It is highly unlikely that one individual treatment process will be capable of effectively removing all the contaminants from the wastewater. Usually a sequence of treatment processes is required to enable separation of several of the contaminants from the wastewater and to provide a multiple protection barrier. For example, producing water of a very high quality normally requires a treatment process that combines most of the following steps:

- screening and settling to remove gross particulate material
- biochemical oxidation to convert soluble carbon to carbon dioxide, oxidise ammonia and remove nutrients
- filtration to remove any solid residue from the water
- activated carbon adsorption to separate non-biodegradable organics
- reverse osmosis to reduce the dissolved solids in the water
- disinfection to kill any residual micro-organisms and maintain quality in the distribution system.

Treatment processes used in wastewater treatment fall into three main categories: physico-chemical (primary treatment), biological (secondary treatment), and disinfection processes (part of tertiary treatment).

Physico-chemical or primary treatment

Primary treatment removes material that floats, such as oil and greases, and organic and inorganic solids that settle, such as food particles. For example, the primary treatment of potato wash removes around 90% of the solids. Table 3.9 describes some common types of primary treatments.

Table 3.9: Primary treatment of wastewater

Type	Method	Principal pollutants removed
Flotation (e.g. dissolved air flotation)	This treatment separates pollutants by removing solids that rise to the surface due to their lower density, where they can be concentrated and then skimmed off. Temperature can have a major bearing on the efficiency of this process. In most systems the wastewater is pressurised by the addition of air. The very small air bubbles attach to the solids and reduce their density so that they rise.	Suspended solids or oils and grease
Gravity separation/ sedimentation	This treatment separates pollutants with different densities. Some solids, such as oils and grease, float and can be skimmed off; other solids settle to the bottom. In some cases chemicals such as lime or polyelectrolytes are used to help coagulate and agglomerate smaller particles into larger particles, thereby increasing their density and associated settling rates.	Suspended solids or oils and grease

Biological or secondary treatment

Secondary treatment may incorporate the removal of organic matter, and in some cases nutrients such as nitrogen and phosphorus. It typically utilises 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, or into more cell matter (sludge) that can be removed and usually dewatered, stabilised and removed offsite. Table 3.10 describes some common types of secondary treatments.

Table 3.10: Secondary treatment of wastewater

Type	Method	Principal pollutants removed
Anaerobic (e.g. anaerobic ponds and digesters)	This treatment duplicates nature by allowing bacteria in the absence of oxygen to convert high-strength waste organic material into more inert biological cells, carbon dioxide, water and methane. This methane can then be used in the plant as an alternative energy source, depending on the amount that is generated.	BOD
Aerobic (e.g. aerobic ponds, activated sludge and tricking filters)	This provides an environment where bacteria in the presence of oxygen convert low-strength wastewater into more cells (as biomass), water and carbon dioxide. The micro-organisms then settle as sludge in a secondary clarifier or pond. Oxygen needed by the system is usually provided by an artificial aeration system. In the case of aerobic filter treatments the micro-organisms grow on filter media as wastewater trickles over the surface medium.	BOD

Disinfection or 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, to produce a very high-quality effluent.

The use of tertiary treatment technology by the food processing industry is steadily increasing as more businesses realise the potential for reusing water and recovering product. Innovative developments in membrane technology are lowering the costs of treatment processes and are making them affordable in many small to medium-sized water recovery and recycle applications. Table 3.11 describes some common types of tertiary treatments.

Table 3.11: Tertiary treatment of wastewater

Type	Method	Effect of treatment
Chemical precipitation/ suspended solids	The use of a chemical agent and coagulants causes dissolved and suspended substances to precipitate out of solution.	Removal of BOD, fats and solids, salts, lime, ferric chloride, sulfides.
Membrane	A membrane allows specific types of substances to pass through while retaining others. Membranes are categorised according to size:	Removal of:
	Microfiltration	solids and oils from liquids and slurries
	Ultrafiltration	solutes from solids, colloids, emulsions and macromolecules; fats and solids
	Nanofiltration	water from water solute mixture
	Reverse osmosis (smallest pore size)	water from water solute mixture.
Centrifugation	Centrifugal force causes components to flow outwards.	Separation of oil and water and large particles.
Evaporation	Uses heat, sometimes with a reduction in pressure to vaporise components from a liquid.	Removal of inorganic salts.
Distillation	Uses differences in volatility between the components of a liquid.	Separation of solvent mixtures and volatile organic compounds.
Filtration	Water moves through filter beds and screens, which remove substances.	Reduction of suspended solids or oils and grease.
Ultraviolet disinfection	UV contains energy that is absorbed in the DNA of micro-organisms, disrupting reproduction at the cellular level.	Removal of micro-organisms, such as coliform bacteria, viruses, protozoa.
Chlorination	Chlorine is used for disinfection.	Removal of pathogenic organisms such as bacteria, viruses and protozoa.
Carbon absorption	Carbon removes refractory organic compounds.	Removal of tannins, lignins and ethers.
Ion exchange	Water is demineralised.	Removal of ammonia, phosphate, nitrates, calcium.

3.10.2 Selection of a wastewater treatment system

The choice of wastewater treatment system will depend on:

- location of the plant
- budget
- available space
- characteristics of the wastewater, such as types and load of contaminants, volume of wastewater, and variations over time in the amount of wastewater generated
- 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?).

There is a large and increasing number of technology options available to food processors.

An eco-efficient approach to selecting and operating a wastewater treatment system involves considering:

- 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 system to treat wastewater to meet regulatory requirements
- the complexity of the process and risk of system failure
- the suitability and reliability of the system to meet the specific demands of the food processing type.

Case study

New wastewater treatment reduces wastewater charges and enables sludge to be recycled: bakery, Australia
Goodman Fielders in New South Wales installed a dissolved air filtration (DAF) system in 1997 to replace filtration pits used to separate solids from wastewater. This improved the quality of waste while also producing up to 10 000 tonnes of organic solids for use as a soil supplement on pastureland. The reduction in wastewater charges and redirection of waste from landfill to pastureland recovered the cost of installing and operating the new system in 18 months.[1]

[1] AFGC 2001

Eco-efficiency action

- Determine the sources of wastewater effluent.
- Locate or install effluent meters and sampling points to determine the volume and pollutant load of the plant's wastewater.
- Seek information about the quantity and quality of effluent or sludge removed offsite.
- Select wastewater treatment systems that specifically meet the demands of your plant's wastewater, and that can effectively treat wastewater to meet regulatory requirements (Seek evidence of this from similar plants before you purchase. It is also wise to have a performance guarantee from the firm to ensure that the treatment plant will meet the specifications in any licence or trade waste requirement.)
- Ensure that any wastewater treatment plant selected does not give rise to offensive and noxious odours or generate excessive noise that may impact on nearby neighbours, as this could breach EPA licence or development permit conditions.
- Select wastewater treatments that can satisfy both current and future opportunities for water reuse, product and energy recovery, and effluent or biosolid recycling.
- When selecting a wastewater system consider the resources required such as electricity, chemicals, labour and monitoring.

'The most important actions in waste treatment cost reduction strategies are those that stop producing the waste in the first place.'

Marcus Cordingly, Environmental Systems Coordinator, Golden Circle

4 Energy

4.1 Overview of energy use

Food processing plants are large users of energy for refrigeration, cooking, heating, sterilising, air conditioning and handling, and for operating processing and auxiliary equipment. Sources of energy in Australian food processing plants are commonly coal-generated electricity, natural gas and LPG, and to a lesser degree combustible fuels (coal and fuel oil).

Table 4.1 shows examples of the breakdown of energy use in three food processing plants. Energy use patterns vary considerably from one plant to the next, so this should be regarded as an example only.

Table 4.1: Examples of energy use in three food processing plants

Percentage of electricity and gas use	**Beverage plant**	**Meat processor**	**Vegetable processor**
Electricity — % total energy use	48%	33%	98%
Thermal use — % total energy use	52% (gas)	66% (coal	2% (gas)
Breakdown of electricity use			
Refrigeration & chilled water	30%	54%	61%
Compressed air	11%	7%	15%
Air conditioning	2%	–	3%
Lighting	8%	3%	3%
Process equipment	49%	36%	18%
Breakdown of gas use			
Processing	100%	17%	0%
Hot water production		13%	100%
Rendering	N/A	70%	N/A

Source: UNEP Working Group for Cleaner Production 2002a, 2003l

For food plants with products that must be kept cool, refrigeration is often the largest user of electricity and can account for up to 60% of total use. Other large electricity users are air conditioning systems and the multitude of motors that drive pumps, fans, conveyors and processing equipment. Gas consumption is most often used to produce steam or hot water for heating, sterilisation, cleaning and other processing requirements. A recent survey by the Australian Food and Grocery Council (AFGC 2001) found that 'energy consumption for some Australian food and grocery companies is higher than relative international standards', indicating that there is scope to reduce energy usage. Eco-efficiency opportunities that will reduce energy consumption include:

- optimising the operation of energy-consuming equipment
- recovering heat energy
- exploring alternative sources of energy
- cogeneration
- considering less energy-intensive products

4.1.1 The cost of energy

Table 4.2 shows typical costs for some energy sources used by food processing plants. It should be noted that there is considerable variation in the price paid for fuels and electricity within the industry, depending on the supplier and the negotiating power of the business.

Table 4.3 shows typical fuel costs for steam production in coal, natural gas and oil boilers. These costs do not include operating costs such as chemicals, labour, maintenance and ash disposal.

Table 4.4 shows typical fuel costs for water heating.

Table 4.2: Typical costs for primary energy sources

Fuel costs	Calorific value	Typical fuel cost ($/quantity of fuel)	($/GJ)
Coal	30.7 MJ/kg	$55/tonne	$1.79
Fuel oil	43.1 MJ/kg	$425/tonne	$9.86
Natural gas	39.5 MJ/m^3	$0.47/$m^3$	$12.00
Electricity	3.6 MJ/kW h	$0.08/kW h	$22.22

Table 4.3: Typical fuel costs for steam production[1]

	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	107 kg coal/t steam	74 m^3 gas/t steam	72 kg oil/t steam
Cost	**$5.87/t steam**	**$35.17/t steam**	**$30.50/t steam**

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

Table 4.4: Typical fuel costs for direct heating of water with electricity or gas to 84°C[1]

	Direct water heating	
	Electricity	Gas
Heat input required (MJ)	282 MJ/kL	282 MJ/kL
Quantity of fuel/power	78.2 kW h/kL	7.1 m^3 gas/k
Cost	**$6.26/kL**	**$3.38/kL**

[1] Assumes 95% efficiency of hot water system. Heating from 20°C

Source: Tables adapted from UNEP Working Group for Cleaner Production 2002a

'Energy usage reduction is a process of continuous improvement, and is never finished. In three years the Butter Producers reduced their annual energy and water costs by 33%. These lower costs have been maintained for the last four years, despite price increases. The challenge of improving process and reducing input costs makes my job more interesting.'

Darryl Markwell, Engineering Manager,
Butter Producers Cooperative Federation Limited

4.2 Reducing the demand for steam and hot water

Process steam installations are independent energy systems, where the steam boiler is the power source, generating steam at the required pressure. Lagged pipe circuits are used for distributing the steam and recovering the condensate. If the pressure and flow control systems are correctly sized, the system will be capable of delivering the required energy effectively on demand. The following sections look at opportunities for improving the efficiency of your steam system. Energy costs of a system increase in proportion to the steam that is wasted and significant savings can therefore be made.

4.2.1 Boiler efficiency

Steam generated by boilers is generally used for heating via heat exchangers, or is applied directly into or onto the product. Industrial process steam 'dry saturated' is generally used for heating. Its temperature/pressure relation makes it easy to control. Dry saturated steam can be further heated to increase its pressure and temperature — to become superheated steam. Superheated steam can be used to drive turbines and reciprocating engines.

Burner set-up

The amount of oxygen in the flue gas and stack temperature are two important factors that determine boiler efficiency. Unnecessary fuel will be consumed when boilers are operating with excess air; and monitoring of the stack temperatures can determine whether maximum heat transfer is occurring. Boilers operating at less than optimum conditions will burn fuels inefficiently and emit unnecessary combustion gases.

Fuel-to-air ratio

Regular flue gas analysis can help determine the operating efficiency of the boiler. The most common and least expensive gas analyser systems are the chemical absorption carbon dioxide and oxygen analysers. These can be fitted onto an existing boiler, or hand-held analysers can be purchased or hired from instrument supply companies. Such systems usually reduce energy consumption by 1.5–2%, with a typical payback period of 18 months to 3 years (SEAV 2002). The ratio of boiler air to fuel can be adjusted to obtain the optimum mix of flue gases, using oxygen trim systems. Optimum percentages of oxygen (O_2), carbon dioxide (CO_2) and excess air in exhaust gases are shown in Table 4.5. Table 4.6 shows the potential fuel savings resulting from the installation of online oxygen trim control.

Table 4.5: 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 4.6: Fuel savings from installing online oxygen trim control

Boiler capacity (MW)	Fuel savings (GJ/year)	Fuel savings ($/year)	CO_2 (tonnes/year)	Simple payback (years)
0.5	318	3 816	19	2.0
0.75	476	5 712	28	1.3
1	635	7 620	37	1.0
2	1 270	15 240	75	0.5
3	1 905	22 860	112	0.3
4	2 540	30 480	150	0.2
5	3 175	38 100	187	0.2
6	3 810	45 720	224	0.2
7	4 445	53 340	262	0.1
8	5 080	60 960	299	0.1
9	5 715	68 580	337	0.1
10	6 350	76 200	374	0.1

Source: Adapted from SEAV 2004

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

Boiler operation

There are a number of basic factors that contribute to the efficient operation of a boiler (Schneider 2004):

- The boiler should operate as close as possible to the design pressure. The pressure can be maintained by means of back-pressure valves, thereby reducing unnecessary energy supply to non-essential process areas.
- The feedwater tank temperature should be maintained at 80–90°C.
- The feedwater supply should be modulated and delivered at the rate at which steam is consumed. The system should not be ‘shocked’ by the addition of a large batch of cold water.
- A steam accumulator should be used to support expected peak demand for a short period of time.
- Good communication between the boiler operator and production operator is essential to avoid unnecessary sudden high-demand situations.

These factors are discussed further throughout the following sections.

Stack temperature and gas side fouling

The stack gas temperature should be recorded immediately after the boiler is serviced and cleaned, and this value taken as the optimum reading. The stack gas temperature should be regularly checked and compared with the optimum reading at the same firing rate.

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. Scale acts as an insulator and inhibits heat transfer; preventing the build-up of scale, even on small boilers, can therefore result in significant energy savings. Fuel waste due to boiler scale can be as much as 5% in fire-tube boilers.

Eco-efficiency action

- Investigate installing individual flue meters or purchasing/hiring a portable flue analyser, and compare readings with optimum gas percentages.
- Install a combustion management system to control air and gas flows.
- Regularly record the flue gas temperature. This should be part of a preventive maintenance program.
- Regularly clean boiler tubes to remove scaling.
- Obtain advice from boiler supplier or maintenance contractor.

4.2.2 Matching steam supply with demand

If the steam supply potential at the boiler house is too high compared to the plant's actual steam demand, boiler efficiency will reduce, resulting in unnecessary fuel wastage. Continual cycling is a good indicator of an oversized boiler (or boilers). As the plant's steam demand is often variable at different times of the year, the ideal would be to have two or more boilers sized to best meet the prevailing demand, and operate them in a flexible manner to meet the variable loads.

Variable demand during the day, especially when it peaks for short periods (for example when large capacity plant is first started), can be addressed through the use of a 'steam accumulator'. This is 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. Accumulators also consistently produce better-quality steam than do modern boilers, and they act as a 'damper' for the boiler, thus providing enhanced fuel efficiency.

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'.

Good communication between boiler operators and end users can make significant savings in boiler operating costs.

Eco-efficiency action

- Start up boilers as late as possible and shut them down as early as possible.
- To meet peak loads, investigate the use of an accumulator, rather than a large boiler or several small boilers.
- Use metering instrumentation (steam, water and fuel meters) to help match steam supply with demand. If appropriate, meter the steam flow to different sections of the plant separately.
- Ensure boilers are operating at their maximum possible design working pressures.

Case study

Matching steam supply with demand: dairy processor, Australia
Staff at the Murray Goulburn dairy in Victoria formed a cross-functional energy team which included representatives from each part of the factory, including operators, supervisors, maintenance and boiler personnel. The team achieved annual savings of $180 000 (1536 tonnes of greenhouse gas emissions) through improved coordination between the boiler house and the operations team. Boiler attendant Phill Chapman explained: 'Before, we would only be warned about the need for steam about 40% of the time. Now it is 95% of the time, and we are learning more about the factory and the processes that require steam. It means we can work the boilers more efficiently and have the confidence to take them offline without compromising production needs.' Improvements were also made to the start-up and shutdown procedures of the evaporator and dryer. Other expected savings through a range of other initiatives amounted to $223 000 (1895 tonnes greenhouse gas emissions).[1]

[1] Industry, Science and Resources 2003

4.2.3 Steam distribution

Steam distribution pipework must be sized and installed correctly. The unavoidable heat loss from pipework systems will be greater if the pipes are oversized or poorly laid out. For example, steam should feed into distribution headers with valved outlets so that unused plant can easily be turned off.

The velocity of steam in pipework should never exceed about 40 m/s, but pipes should not be sized on velocity alone. Pressure drop along the length of pipe involved must also be checked to ensure it is not excessive. In practice, this means that main distribution lines will usually have velocities of 15–25 m/s, and even less on very long runs. Properly sized control valves will usually be one or two sizes smaller than the properly sized pipe in which they are fitted.

Inevitably, steam pipework systems are always losing heat, even when insulated, resulting in condensate which must be removed. If condensate is not properly removed it could eventually fill up the steam system; at the very least wet steam would be fed into plant, with a resultant loss in efficiency, heat output and production.

On start-up the steam system will always be full of air — a gas that cannot be condensed — and this must be properly expelled. If it is not, it will pass into the plant and reduce efficiency, heat output and production; it will also aggravate corrosion.

Steam pipes must be laid sloping down in the direction of flow. To be really effective, a slope of 1:100 or greater should ideally be aimed for. When this causes the pipe to come too close to the ground or floor, a vertical 'relay point' to a higher level, which can then turn to slope down again, must be installed.

The condensate must be automatically drained out of relay points, and at any other low points where it could collect — and never at points more than 30–50 m apart. These should all be made into 'full-bore' (i.e. pipe bore) collecting pockets fitted with suitable steam traps.

Terminal ends and remote or high points in the distribution system should be fitted with automatic air vents.

Where steam quality is in doubt, or when maximum possible plant output is required with whatever steam is available, 'steam separators' should be installed (these ensure the driest possible steam at all times). The baffle-type separator has been shown to operate more consistently over a wider range of flows and pressures.

4.2.4 Rectification of steam leaks

Leaks allow live steam to be wasted, with the result that more steam production is required to meet the plant's need. In turn, this results in the consumption of more boiler feed water, fuel to run the boiler and chemicals to treat the water. For example a hole 1 mm in diameter on a steam line at 700 kPa will lead to an annual loss of 3000 L of fuel oil or 4300 m^3 of natural gas (SEAV 2002).

It is also better to use 'bellows-sealed valves' instead of conventional gland-sealed valves. The glands of these valves are sealed using a flexible metal bellows, and therefore do not leak and require no maintenance. Over time, the extra initial cost of these valves is more than offset by the maintenance savings — notably labour and time — and the elimination of steam or other fluid loss to the atmosphere.

Case study

Reducing the fuel costs of steam production: fruit processor, Australia
By improving boiler efficiency, Ardmona Foods in Victoria reduced fuel costs by 18% and increased raw product tonnage by 4%. A focus was placed on improved maintenance and water treatment, expanded insulation of factory lines, prompt repair of steam leaks, and improved operating procedures to achieve optimum efficiency, while also meeting load variations. The increase in the boiler's operational efficiency also reduced the time needed to clean the boiler by 70%.[1]

[1] Environment Australia 2003f

Eco-efficiency action

- Locate and repair leaks from steam and condensate return lines.
- Use bellows-sealed valves instead of conventional gland-sealed valves.
- Use expert advice to assess the effectiveness of the steam system.

4.2.5 Maintenance to reduce waterside fouling

Boiler feedwater must be properly treated, in order to:

- minimise scale build-up in the boiler (notably on the heating surfaces)
- help ensure good steaming conditions within the boiler (so that good-quality steam is always generated)
- minimise corrosion (and erosion) throughout the whole boiler, steam distribution, steam usage, and condensate return systems.

Scale acts as an insulator, reducing heat transfer and increasing the gas-side metal temperature. Not only does scale increase fuel consumption but, if left untreated, it also reduces the life expectancy of the boiler. A coating of scale more than 1 mm thick can easily result in a 3% increase in fuel consumption. Table 4.3 shows the loss of fuel due to scale deposits.

Boiler water treatment is not simply a matter of dosing the water with chemicals. There are various mechanical/engineering techniques that help condition the water and reduce the use or need for chemicals. The simplest of these is heating the boiler feed tank to 80–90°C. This drives off a considerable amount of oxygen, reduces the need for oxygen-scavenging chemicals, and it usually allows the chemicals that *are* used to work better.

Employ a specialist water treatment company that expresses a concern for what happens throughout the whole steam system rather than just in the boiler itself. They will regularly monitor and report on the effectiveness of the boiler water treatment regime and how it is affecting the whole steam system, and advise on chemical dosing and mechanical/engineering solutions.

Table 4.7: Energy loss due to scale deposits

Scale thickness (mm)	Fuel loss, % of total use
0.4	1
0.8	2
1.2	3
1.6	3.9

Source: US DOE 2001

Eco-efficiency action

- Employ a specialist water treatment company to give advice and help on how to provide quality steam at all times.

4.2.6 Condensate return systems

Steam condensate contains valuable heat energy and should be returned to the boiler feed tank. The condensate (and associated flash steam) contains about 26% of the fuel used to raise the steam in the boiler. Or to put it another way, a 5°C increase in the temperature of the feedwater will save around 1% of the fuel used to raise steam (SEAV 2002).

In addition, the condensate is effectively ‘distilled water’ and will require far less treatment than make-up water (e.g. from the town main). Being effectively recycled, condensate return systems also reduce wastewater charges and water supply costs.

Eco-efficiency action

- Return as much condensate as possible to the boiler feed tank, using pumps or pump-traps where necessary or where they will improve efficiency.
- Monitor the plant for flash steam loss (plumes of steam escaping from vents and other discharges from the condensate system).
- Reduce loss of condensate in the form of low-pressure steam (flashed condensate) by replacing flash tanks with a closed high-pressure condensate return system.

4.2.7 Maintenance of steam traps and condensate lines

A steam trap is an ‘automatic valve’. In the presence of steam it closes, preventing steam from passing through it and being wasted before it has given up its heat and condensed. In the presence of water it opens, to allow the discharge of condensate. Depending on its type, it may also, with greater or lesser efficiency, open to discharge non-condensable gases.

Regular testing and maintenance of steam traps and condensate lines can, and usually does, save money and time as well as improving operating efficiency. Traps can be checked by plant staff or an outside contractor.

Depending on its type and design, a stream trap can fail open or closed, or somewhere in between. If a trap fails ‘closed’, it will flood the plant with condensate, and heat output and production will cease. This will be readily apparent and will immediately be fixed. If the trap fails ‘open’, although all the condensate will be removed, uncondensed live steam will escape. This will not usually affect heat output and production. Consequently, this type of failure usually goes unnoticed, and even when it is noticed there is likely to be no urgency to get it fixed. Energy will be wasted and operating costs will go up.

Traps can also fail 'partially open'. If this tends towards waterlogging, it will affect heat output and production and should be noticed. If it tends towards live steam loss, it is unlikely to be noticed.

Traps that are losing steam can waste hundreds or thousands of dollars a year, almost always far more than the cost of their replacement or repair. Their urgent detection and rectification is essential.

Clearly, the best way to be sure that all traps are working properly is to test them regularly, and not rely on noticing any effect they may have on heat output or production.

Eco-efficiency action

- Regularly monitor the operation of all steam traps.
- Repair or replace faulty traps. Do not allow leaking traps to receive less attention than they deserve.
- Talk with your supplier or contractor about ensuring steam straps are correctly sized, are the correct type for the system, and are properly installed.
- Install the type of steam trap monitoring system that employs a 'steam leakage sensor' at each trap on all new and reworked installations. Consider its installation on existing plant.

Case study

Maintenance of steam traps: sauce and dressings processor, Australia
An audit by consultants at Cerebos Foods in Victoria revealed 9 out of 64 steam traps were leaking, and a maintenance program to monitor and repair steam traps was developed. The company now saves $10 800 on natural gas annually. The payback period was eight months.[1]

[1] SEDA 2003d

4.2.8 Rationalisation of boiler use and steam lines

At many plants the boiler operates outside production hours, possibly at reduced load, to heat water required for cleaning or the hot water supply for amenities. In such situations it may be more economical to install a smaller steam boiler for times of low load, or a dedicated hot water system to produce hot water, rather than operate a large steam boiler inefficiently at reduced load. Or it may be practical and economic to increase the hot water storage capacity so that sufficient hot water may be made in advance, perhaps 'trickle-fed' with steam during the course of the whole day. This can also be a use for flash steam recovery.

For some plants, particularly older plants 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, and there may be much unused, redundant pipework and branch lines. This results in more steam pipework than is really required, and consequently greater heat loss (and greater steam production), as well as more opportunity for leaks and other problems.

Eco-efficiency action

- Investigate whether it is more economical to install a smaller hot water system to produce hot water outside production hours, a smaller steam boiler for low loads, or increased hot water storage.
- Rationalise the length and sizing of steam pipework to reduce heat loss and leaks.

Case study

Replacement of inefficient boiler: syrups, toppings and dry mix processor, Australia
Food Spectrum in Queensland replaced an old inefficient 750 hp (about 560 kW) boiler with two 750 kW unattended water tube boilers. For the equivalent steam production the company has increased its efficiency by 5% and now saves $3500 annually.[1]

[1] UNEP Working Group for Cleaner Production 2003d

4.2.9 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 4.8. It is also important that sources of moisture are eliminated to prevent insulation from deteriorating, and that damaged insulation are promptly repaired.

For example, 1 m^2 of uninsulated surface, with steam at 700 kPa, will lose around 225 MJ in a 24 hour period. That is approximately 81 000 MJ of natural gas, or 2 tonnes of fuel oil, per year (SEAV 2002).

Prevent insulation from deteriorating by eliminating sources of moisture and ensuring that damage is repaired promptly.

Table 4.8: 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
Insulated with polystyrene	0.096	0.03	$115

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.

Eco-efficiency action

- Insulate any surface over 50°C including boiler surfaces, steam and condensate return piping and fittings.
- Regularly check for damage to insulation.

4.2.10 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 feed water. 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 can be pre-heated to as much as 540°C, with inlet flue gases entering at 1000°C and leaving at 700°C (Muller et al. 2001). Flash steam can also be used for pre-heating combustion air.

Variable speed drives can be installed on induced draft and forced draft fans.

Eco-efficiency action

- Improve boiler efficiency by installing heat recovery equipment such as economisers, recuperators or flash steam combustion air heaters.
- Install variable speed drives on boiler fans.
- When replacing boilers, investigate the option of converting to a more efficient fuel (e.g. electricity to gas).

Case study

Preheating of boiler feed air and monitoring of oxygen in the stack flue gas: coffee manufacturer, South Korea

The efficiency of an oil-fired boiler was increased by modifying the boiler so that heat was recovered from the flue gas to preheat the air, and the forced draft fan was controlled by variable speed drive using O_2 trim control. As a result of these modifications flue gas temperature dropped from 240°C to 150°C and oxygen concentration in the flue stack reduced from around 5.5% to 2.5%. Installing the variable speed drive on the fan saved the company $95 000 annually (7067 GJ/year) in fuel oil consumption and $18 500 annually (234 MW h/year) in electricity.[1]

[1] SEAV 2002

4.2.11 Reducing hot and warm water use

Hot or warm water may be used unnecessarily in a factory. For example, hot water may be used for cleaning where warm or cooler water may be sufficient. Table 4.9 shows the increase in cost by heating water from 22°C to various temperatures using steam produced by a gas-fired boiler.

Table 4.9: Cost of heating water[1]

Temperature (°C)	MJ required	Cost ($/kL)
50	139	1.67
55	162	1.95
60	185	2.22
65	208	2.50
70	232	2.78
75	255	3.06
80	278	3.33
85	301	3.61

[1] Assumptions: Gas cost of $0.012/MJ steam production (boiler); efficiency of 95% and hot water production efficiency of 95%.

Eco-efficiency action

- Consider all of your uses of hot or warm water and determine whether these can be replaced with warm or cooler water respectively.
- Set hot water temperature to minimum required while still meeting hygiene standards.

Case study

Reduction in the bottle heating water: soft drink processor, Australia

Bundaberg Brewed Drinks in Queensland is currently undertaking trials to reduce the temperature of its bottle-warming machine in accordance with daily ambient temperature conditions. By aiming to warm bottles to 5°C above dew point temperature, the company could save $1760 annually, with immediate payback.[1]

[1] UNEP Working Group for Cleaner Production 2003a

For more technical information on efficient steam utilisation, visit the Spirax Sarco website at http://www.spiraxsarco.com/learn/ or email Steam Link at steam@steamlink.com.au.

4.3 Refrigeration

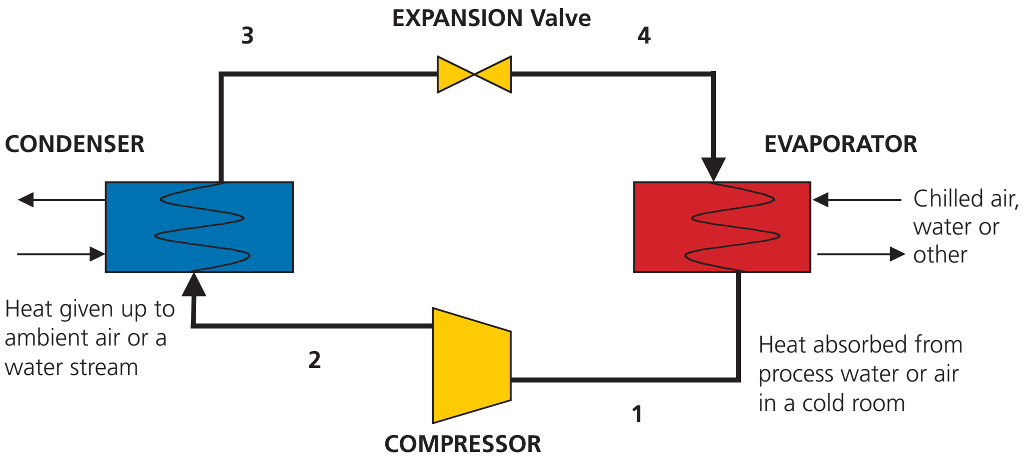
4.3.1 Refrigeration systems

Refrigeration systems are often the major consumers of energy in a food processing plant.

There are several types of refrigeration systems, but the most common is known as a 'vapour compression cycle'. Figure 4.1 shows the components of a typical refrigeration system and provides a simple explanation of how such a system works.

The system uses a fluid called the refrigerant, which changes its state from gaseous to liquid throughout the refrigeration cycle, using its latent heat of evaporation to cool the product. The refrigerant is in a cold gaseous state at the inlet (suction) (1) to the compressor, and after being compressed by the compressor, it is discharged as a hot gas (2). It is at the compression stage that the energy is consumed. The hot gas enters the condenser, where it gives up its latent heat of evaporation to a secondary medium — either water or air. The refrigerant leaves the condenser as a hot liquid (3). The hot liquid then passes through the expansion valve which, as the name suggests, expands the hot liquid to become a cold liquid. The final temperature of the refrigerant depends on the temperature requirement of the product being refrigerated. The cold liquid is injected into the evaporator where it is boiled off (evaporated) to a cold gas by the heat of the product being refrigerated. The cold gas returns to the inlet (suction) of the compressor.

Figure 4.1: A typical vapour compression refrigeration system



Indirect cooling

The cooling of a product can also be achieved indirectly using a secondary medium — air, water, brine or glycol. In this case a refrigerant is used to cool a secondary medium, which is then pumped to the point required.

Operation of refrigeration compressors

The work horse of a refrigeration system is the compressor, which usually consumes between 80% and 100% of the system's total energy use. 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 (e.g. scroll, reciprocating, screw or centrifugal)
- compressor load (e.g. reciprocating compressors are efficient at peak load, whereas screws, scrolls and centrifugals are most efficient between 80% and 90%)
- temperature difference of the system — that is, the initial temperature and the number of degrees by which the system is required to cool (e.g. a refrigeration system may need to cool a 12°C stream down to 5° (a difference of 7°C). Temperature difference is particularly important for food refrigeration as it determines room humidity. If a refrigerated room or cabinet is too dry the product will burn. High temperature differences produce low humidity. The compressor and evaporator must be sized to ensure the temperature difference is correct.

All of these factors affecting energy consumption are discussed in the following section.

4.3.2 Compressor selection

There are three main types of compressors used for refrigeration — reciprocating, rotary screw and scroll. Centrifugal compressors are generally used for air conditioning. It is important that the compressor and evaporator are suited to the refrigeration duty and that the coefficient of performance (COP) of the whole system is as high as possible. The efficiency of a refrigeration system is measured by the co-efficient of performance (COP) which is the ratio of cooling output (kilowatt) compared with energy input (kilowatt). The higher the COP, the higher the efficiency of the system. Software programs from manufacturers can help to demonstrate the efficiency of different compressors under varying conditions. Table 4.10 compares the applications of the four main types of compressors.

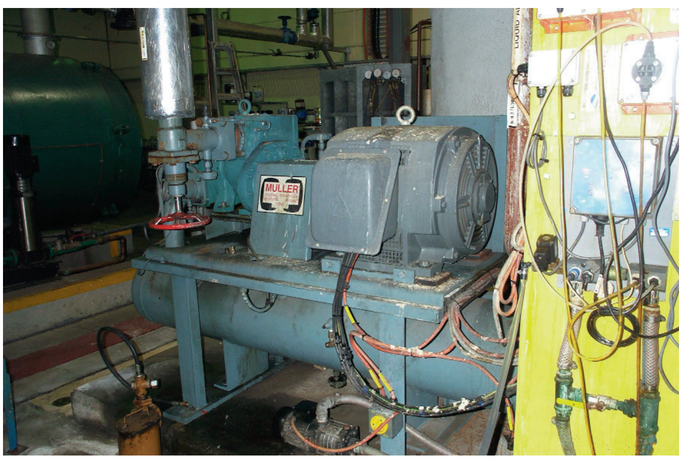
Table 4.10: Refrigeration compressor applications

Compressor type	Application	Method of operation	Method of capacity control	Efficiency at part load	Typical capacity (kW)
Scroll compressor	Small to medium commercial applications	One fixed and one orbiting scroll compresses refrigerant	Do not usually feature capacity control	N/A	Up to 50
Reciprocating compressor	Small domestic/ commercial use to large-scale industrial use	Refrigerant compressed by pistons	(a) Cylinder unloading (b) Discharge to suction	(a) Minimal loss in efficiency at part load (b) Reduced efficiency	<12–2800
Rotary screw compressor	Mostly large-scale industrial use	Refrigerant compressed by positive displacement in a fixed volume	Slide valve or lift valve	Reduced efficiency at part load	12–2800
Centrifugal compressor	Mostly large industrial scale use for high-pressure applications	Centrifugal forces compress refrigerant	Inlet valve throttling or discharge to suction	Reduced efficiency at part load	700–>2800

Sources: ETSU 2000; Muller et al. 2001

Eco-efficiency action

- Ensure that compressor and evaporator are suited to the refrigeration duty, and that the coefficient of performance (COP) of the whole system is as low as possible. Refrigeration compressors should not be oversized and operating inefficiently at low partial load.
- Talk to your refrigeration system supplier about the best systems for your needs.



Refrigeration compressors should be suited to the refrigeration duty, and the COP of the whole system should be as high as possible. Software programs from manufacturers can help to demonstrate the efficiency of different compressors under varying conditions.

4.3.3 Compressor load

Compressor selection should be based upon achieving the highest COP possible. Most manufacturers will provide a profile of efficiencies at varying load conditions so it is possible to compare all compressors and select the most efficient for the duty. If a compressor is not required or is oversized it operates at only partial load and the energy efficiency may be reduced. A sequencing or capacity control system to match the compressor with the load could help to improve efficiency, as long as the load stays above 50% (DETR 1999). The control system must be sophisticated enough to ensure the load is properly shared. 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.

If a compressor is not required, it is better to turn it off than to operate it at part load.

Eco-efficiency action

- Ensure multiple compressors are operating economically. Installing a capacity control system to match the compressor with the load will help in most cases to improve efficiency, as long as the control system is sophisticated and the load stays above 50%.

4.3.4 Minimising temperature difference

Compressors and evaporators must be properly sized to suit the load and the temperature of the product. 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. A refrigeration system with a small evaporator and condenser may mean a smaller initial capital outlay; however, running costs may be greatly increased by the need for a larger compressor.

Condensers should be sized correctly to maintain the optimum condensing temperature within the capabilities of the refrigeration system — that is, the temperature of the medium condensing the refrigerant should be as low as possible. If the condenser is too large, however, the refrigerant can actually subcool* and this will affect the function of the expansion value.

In the case of a cooling tower, water is continuously being evaporated from the cooling coil surfaces of the tower, and scale will be formed by the precipitation of salts. This can cause a higher condensing temperature, and increase the energy consumption of the system. It is important to keep evaporative condenser surfaces and spray nozzles free of

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

scale build-up by using a water treatment program. Also, take advantage of lower ambient temperatures in winter when the cooling tower or air-cooled condenser may be running at less than full capacity.

Increasing the evaporating temperature will increase the compressor efficiency, so 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; however, do not overcool more than is required. Again correct selection is imperative. Ensure the evaporator is cleaned and defrosted when necessary to prevent the evaporator temperature from dropping and to maintain good heat transfer, and examine the possibility of continuous defrosting.

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

Eco-efficiency action

- Ensure the condenser and evaporator are correctly sized to maintain the lowest condensing temperature and highest evaporating temperature within the required duties and capabilities of the refrigeration system.
- In winter, allow the condensing temperature to float down with the ambient temperature if possible.
- Clean condensers regularly to promote efficient heat transfer.
- Ensure air-cooled condensers have unrestricted air flow.
- Clean and defrost evaporators when necessary to prevent the evaporator temperature from dropping.
- Ensure suction lines are insulated. The lower the suction gas temperature, the greater is the compressor efficiency.
- Make sure the compressor is located in a cool and well-ventilated area.
- Ensure compressors are effectively lubricated and cooled to prevent bearing friction and increased temperature, which would reduce compressor efficiency and increase operating costs.

4.3.5 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 can then be used elsewhere in the plant. Once installed and optimised, a hot gas bypass defrost system can assure frost-free evaporator operation. Once the evaporator is no longer covered in ice its cooling capacity will be increased. Hot gas bypass defrosting also adds considerably less moisture into the cooling space compared to traditional defrosting practices such as hosing.

Eco-efficiency action

- Investigate using hot refrigerant vapour discharge from the compressor to defrost evaporators.

Case studies

Energy management control system: ice cream processor, Australia
The Nestlé ice cream plant in Victoria has a large refrigeration system, which uses around 13 GW h per year of electricity, costing around $960 000.

A feasibility study for the refrigeration system showed the compressors were operating under no load, there was a large number of compressor start-ups, and the suction temperature of 12°C into the compressors was far above the 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, improving valve selection so that the correct suction gas temperature (3°C) could be recovered, which would enable the compressors to operate at higher loading and minimise stopping.

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

The project cost the company $59 000 and took four months. Nestlé now saves $100 000 annually in electricity costs, and a reduction in electricity demand of 340 kV A has resulted in a further annual saving of $12 000. 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%.[1]

Energy management control system: chicken processor, Australia
Inghams Enterprises in Victoria produces frozen chickens, ducks and turkeys and oven-fresh snacks. The company installed a new energy management system to reset the condenser pressure in response to weather conditions and the suction temperature according to the time of day. Part-loading the compressor was avoided by changing the operations of the ice-making machine. (Ice is also produced at night using off-peak rates.) The improvements resulted in annual savings of $38 000 and a 1340 tonne reduction in CO_2 emissions. The project cost $61 800, with a payback period of 1.6 years.[2]

1 SEAV 2002
2 SEAV 2003a

4.3.6 Reducing load on refrigeration systems

Once the required temperature is achieved, refrigeration systems will operate at low load and consequently lower efficiency. The operation of the refrigeration system at low load over non-production periods such as weekends can be seen as an inefficient use of power. It may be possible to switch off refrigeration plants during the night on non-production days (e.g. weekends). In modern refrigeration systems, temperatures increase only slowly when refrigeration is turned off and it can often be off for up to 15 hours without compromising the temperatures allowed in food safety regulations. The down side is that the plant will have to work harder initially to draw the temperature back down after the shut-off period, and this will negate some of the savings. However, electricity consumption for refrigeration can be reduced by around 50% for the non-production periods (weekends) by turning the system off at night (Cain 1986).

If the food product requires considerable cooling once it has been placed in the refrigerated room or cabinet it may be worth considering a specifically designed 'pull down' room that operates at peak load all the time. This would enable the product to cool efficiently and then be transferred into a larger holding room at or near holding temperature.

Fan energy

Fan energy has to be paid for twice — first in fan energy itself, and then in extracting the heat energy input to the air. Variable speed drives, coupled with a programmable controller, can cycle off fans and refrigerant feed during low load times. In some freezers fan energy is of the same order as the product load and is thus a major cost. For plate freezers that have no forced air circulation and higher suction pressures, the energy savings can be around 50% despite the higher capital costs for this type of freezer (Council of Australian Food Technology Association 1994). The table below compares the costs of small plate and airblast freezers. For this example, the additional $20 000 in capital cost would be paid back in just over one year by lower electricity consumption.

Table 4.11: Costs and benefits of small capacity and air blast freezers

		Plate freezer	Air blast freezer
System power	(kW)	39.1	58.8
Hours run/week	(h)	116	152
Energy used/week	(kW h)	4 535.6	8 937.6
Weekly production	(t)	57.12	57.12
Energy used/tonne	(kW h/t)	79.4	156.5
Annual production	(t)	2 700	2 700
Annual energy use	(kW h)	214 420	422 525
Annual energy cost		**$17 154**	**$33 802**
Capital cost of freezing equipment		$145 000	$80 000
Capital cost of refrigeration system		$147 000	$195 000
Total capital cost		**$292 000**	**$275 000**

Source: Graham 1996

Eco-efficiency action

- Minimise the sections of plant that require refrigeration.
- Investigate the possibility of shutting down the refrigeration system during non-production periods such as weekends and nights.

- If the product requires considerable cooling, consider using a specially designed 'pull down' room that is at peak load all the time and then transferring the product to a holding room.
- Install a programmable controller that can cycle off fans and refrigerant feed during low load times.

Case studies

Cycling of fans: fruit cold storage, USA
The Regal Fruit Co-op in Washington was astonished that 60% of the heat in an apple storage facility came from the cooling fans themselves, which operated 24 hours a day. A monitoring system was installed to turn the fans on for only six hours a day on a repeating cycle of two hours on and six hours off. The company is now saving US$15 000 a year on electricity, with a payback period of 3–4 years. As a result of re-examining the design system, researchers also discovered that by reducing the oxygen content of the storage room they could increase the temperature a few degrees and reduce the dehydration of the fruit. Where Regal might have sold 100 partially-dehydrated bushels of apples, they can now sell 85 bushels of good-quality juicy apples. The productivity rise enabled a payback period of less than one year.[1]

Reduced load on refrigeration system: butter manufacturer, Australia
The Butter Producers' Co-operative Federation Ltd in Queensland reduced the load on their refrigeration system in various ways: by adjusting the product room temperatures to suit the usage; repairing cold room door seals; fitting sensors to cold room doors to stop refrigeration during loading periods; raising the refrigeration pressure set point; and optimising the sequencing of the condensers. The condenser fan control was also improved, so that the fans would switch on only when the cooling water temperature or condenser pressure was too high, rather than being linked with the condenser water pumps. The improvements cost $500 in thermostats and wiring; they saved $10 800 per year (9600 kL/year) in water supply costs for the evaporative condenser and an estimated $8000/year (530 000 MJ) in gas savings.[2]

1 Centre for Energy and Climate Solutions 2003
2 UNEP Working Group for Cleaner Production 2003b

4.3.7 Reducing heat ingress to refrigerated areas

Up to 10% of the power consumption in refrigeration plants can be from heat ingress through doorways and from lighting being left on. Many plants rely on good operator practice to keep doors closed. This is not always effective, and automatic door closure or alarm systems should be considered. Plastic strip curtains or swinging doors are essential at the entrances to frequently opened areas.

Lights add to the heat load. Sensors and timers can be used to ensure lights are used only when necessary.

Sanitising agents rather than hot water can be used to clean chillers. Concrete floors can absorb heat from hot water, increasing the temperature by up to 20% (Cleland 1997).

Eco-efficiency action

- Ensure insulation is optimised and well maintained.
- Install energy-efficient lighting that gives off less heat.

- Encourage good operator practice, closing doors quickly and turning off lights in unoccupied refrigerated space. If this is not effective consider automatic door closure and light switches, or alarm systems.
- Maintain door seals and insulation.
- Consider replacing sliding doors with self-closing doors.
- Utilise cold room space effectively and consider whether unused space can be closed off.
- Ensure product is cooled as much as possible before being placed in refrigerated areas.

Case studies

Refrigeration efficiency: cold storage of food products, USA
Henningsen Cold Storage stores and freezes food products but uses 58% less energy than a conventional refrigeration facility. Measures implemented to achieve this include roof and wall insulation, fast-acting doors in loading docks, and lighting that automatically dims when the room is unoccupied. The company also chose oversized evaporators and condensers with high-efficiency motors. The effect was to reduce the condensing temperature from 35°C to 29°C while the variable speed drive motors boosted efficiency by 5%. An automatic purger ensures operation at the minimum allowable condensing temperature. The system is monitored by a refrigeration control system.[1]

Door discipline: MIRINZ research, New Zealand
The Meat Industry Research Institute of New Zealand (MIRINZ) has reported an instance where improving door discipline on a 4000 tonne capacity cold store with two doors led to an annual saving in electricity of A$14 000.[2]

Air curtains: vegetable processor, New Zealand
Watties Frozen Foods in New Zealand installed air curtains in two bulk stores that hold produce at 18°C. The curtain reduced the transfer of heat and moisture when the freezer doors were left open by a factor of 60–80%.[3]

[1] City of Portland Office of Sustainable Development 2003
[2] Wee & Kemp 1992
[3] NZ CAE 1996

4.3.8 Refrigerants

Leakages

Leakages of refrigerant can reduce a system's efficiency by 40% and should be kept to less than 2% of the annual charge. It is the organisation's responsibility to ensure that all refrigerant emissions are prevented where possible; failure to do so may lead to an offence under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cwlth). Around 50% of all leaks from commercial refrigeration systems occur at flared joints. Other likely sites are flexible hoses and damaged pipes (March Consulting Group and ETSU 1997).

You can calculate your approximate leakage rate from the amount of refrigerant you use to top up the system. Table 4.12 shows some typical annual leakage rates and best-practice leakage rates.

Table 4.12: Typical refrigerant leakage rate and best-practice leakage rates

Type of refrigeration system	Average annual charge (kg)	Typical annual leakage rates (%)	Best-practice leakage rates (%)
Small direct expansion installation (e.g. cold room)	5	15	0.5
Central cooling plant (e.g. brewery cooling services)	40	4	0.5
Transport refrigeration	8	8	2

Source: March Consulting and ETS 1997

Selection and performance

The choice of refrigerants suitable for your system will largely be determined by the compressor type, the operating pressures of the refrigerant, the age of plant, the compatibility of materials such as seals and gaskets to the new refrigerant (where refrigerant conversions are carried out), and the required cooling capacity of each system (AIRAH 2003).

The most appropriate refrigeration system is one that has a high coefficient of performance (COP) — that is, it has characteristics that will result in a minimum power requirement per unit of refrigeration capacity. All refrigerants perform differently, depending on the particular system. To compare the performance of different refrigerants it is necessary to look at each refrigerant on the basis of identical operating conditions. Performance characteristics of refrigerants can be found in the *Refrigerant selection guide 2003* published by the Australian Institute of Refrigeration Air conditioning and Heating (AIRAH) and available at www.airah.org.au. The booklet discusses the environmental impacts of refrigerants and provides a selection guide to fluorinated and natural refrigerants. Only allow your system's refrigerant to be changed by an authorised contractor. Always check with the equipment and refrigerant manufacturer when considering new-generation refrigerants, to ensure total compatibility of all system components, refrigerant and refrigerant oil.

Chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) based refrigerants that contribute to the depletion of the ozone layer and global warming should now be rare, as a result of being phased out in accordance with the Montreal Protocol.

Refrigerant lubricants

Lubricants are used to minimise wear on compressors and improve their effectiveness during the compression cycle. Refrigerant oils are designed to mix with refrigerants and will circulate though a refrigeration system in varying quantities, depending on the system design. Circulating refrigerant oil coats internal surfaces of all components including piping, evaporators and condensers. Heat transfer characteristics of evaporators and condensers can be affected by the internal oil film characteristics. New-generation synthetic lubricants developed for new-generation refrigerants may not necessarily be compatible with existing refrigeration systems that use CFC or HCFC refrigerants. If you are considering retrofitting an old-style refrigeration system, check with equipment and refrigerant manufacturers to make sure that all components are compatible and the system will not be affected.

Case study

Change in freezer refrigerant leads to energy savings: ice cream supplier, Australia
Unilever owns two million ice cream freezers worldwide. The company, in cooperation with Austria Haustechnik AG and the Danish Technological Institute, tested 75 identical ice cream freezers, which differed only in the type of refrigerant they used. Of the 75 freezers, 50 used hydrocarbon (HC refrigerant R290) and 25 used standard hydrofluorocarbon (HFC refrigerant R404A). The 75 freezers were field tested during the 2000 Olympic and Paralympic Games in Sydney, and afterwards in supermarkets, service stations and shops in Sydney and Brisbane. Each cabinet was fitted with two temperature data loggers to record temperature inside and outside the cabinet, as well as a power meter to record consumption. Field tests showed that the new HC freezers operated satisfactorily and used approximately 9% less energy than the standard R404A freezers.[1]

[1] Elefsen et al. 2003

Eco-efficiency action

- Regularly detect and repair refrigerant leaks.
- Investigate converting your system, where possible, to an ‘ozone benign’ refrigerant. Consult your refrigeration contractor for further information on this.
- Investigate the use of refrigerant additives.

4.3.9 Absorption refrigeration

Absorption chillers allow cooling to be produced from heat sources such as low-grade steam or hot water rather than electricity. The COP of absorption refrigeration, however, is very low. The very best absorption chillers will generate 1 kW of refrigeration for 1 kW of energy. They are generally used where there is adequate waste heat such as condensate from a steam system or a hot water reticulation system. The higher the temperature of the waste heat, therefore, the more effective the refrigeration will be. Many units are relatively small gas-forced air conditioning units; commercial sized units are less common. Absorption chillers may be worth considering if a plant has a readily available waste heat source, or electrical load limitations. Absorption chillers can perform efficiently at very low loads; however they may be unable to respond well to load changes. Capacity can be boosted by a standby electrically driven chiller.

Case studies

Absorption chillers and cogeneration: confectionery producer, Australia
Cadbury Schweppes in Victoria uses chilled water for refrigeration and air conditioning. The chilled water is produced by three lithium bromide absorption chillers. A cogeneration system uses a steam-driven turbine to produce power. Waste heat from the turbine is used to operate the absorption chillers. The plant utilises 8.5 kg of steam to produce 1 tonne of refrigeration while also generating some electricity. The plant produces power for 5 cents/kW h while producing chilled water at no cost. The steam turbine has recently ceased operation, so the company now has to use steam heat directly from the boiler, which is not proving as efficient.[1]

Absorption refrigerator: noodle manufacturer, Japan
At a noodle-making factor in Japan an absorption refrigerator was installed in the combined heat and power system of a diesel engine unit and electric power generator. The absorption refrigerator is run from the waste heat from the engine and the waste warm water from noodle production. The absorption refrigerator cools the water from 21°C to 16°C. A conventional unit then cools the water to 5°C to cool the noodles. The addition of the absorption refrigerator means that the capacity of the conventional chiller is increased by 45%.[2]

1 Russell Hopton, Cadbury Schweppes, Ringwood, Victoria, personal communication 18/7/2003
2 Bogaert 2000

Eco-efficiency action

- Consider absorption refrigeration as a possibility for your plant if there is a waste heat source readily available or electrical load limitations.

4.4 Compressed air systems

Compressed air systems can incur significant cost in food manufacturing, accounting for up to 10% of electricity costs in a food plant (SEAV 2002). Compressed air systems are very energy-inefficient, with around 80% of electricity input lost as waste heat. It is essential that compressed air systems are properly designed, that their operation is optimised, and that they are regularly serviced and maintained.

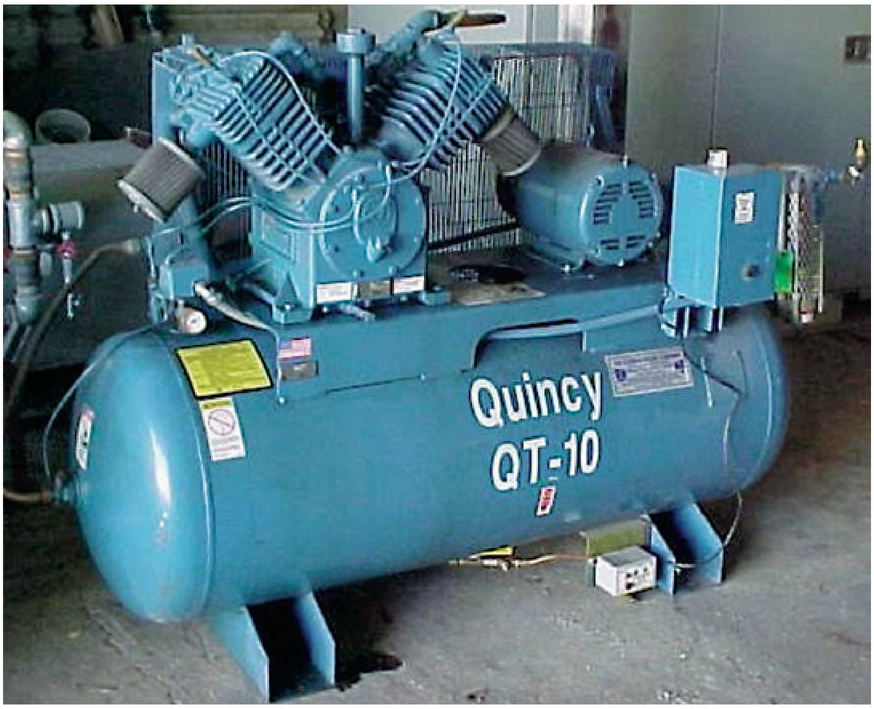
A compressed air calculator has been provided in the CD-ROM that accompanies this manual. The calculator shows potential savings from repairing compressed air leaks, reducing the operating pressure of the compressed air and reducing the temperature of the inlet air.

4.4.1 Choosing a compressor

A compressor will usually consume its purchase price in electricity every year (Department of Industry, Science and Research 2001) and therefore selecting and efficiently operating the correct type of compressor for the application is essential.

There are three types of air compressors commonly used in industry (ETSU 2000):

1. **Reciprocating compressors** are the most energy-efficient of all compressors, at both full load and part load, and are suited to high pressures. They are, however, high-maintenance, relatively expensive, noisy, and require large foundations. This type of compressor is best for short operating periods with fluctuating load.
   Mode of operation: piston in a cylinder.



A compressor will generally use its purchase price in electricity every year, so selecting and efficiently operating the correct type of compressor for the application is essential.

2. **Screw compressors** are quiet, compact, less expensive and simple to operate. They are well suited for heat recovery. They are much less efficient at part loads. This type of compressor is best for operations that require a constant air supply.
   Mode of operation: two meshing screws rotating in opposite directions.

3. **Centrifugal compressors** have a large and controllable capacity. They are quiet and efficient down to a loading of about 60%. They are, however, precision machines and therefore quite expensive.
   Mode of operation: high-speed rotating impellers.

Be sure to check that the system is easy to maintain and maintenance can be conducted by plant personnel. For example the air filter, oil filter and oil separator should be easy to reach, check and replace. Air tubing should be flexible, as rigid tubing is more likely to leak.

Case study

Improving compressor efficiency: nutritional products processor, USA
Mead-Johnson Nutritionals produces nutritional products for children and adults.

The plant's three 300 horsepower rotary screw compressors were having difficulties meeting the minimum pressure requirements, and the company was considering purchasing a new compressor.

An independent consultant observed that there was insufficient air storage, that the retort purge process caused the demand for compressed air to fluctuate, and that leaks consumed one-third of the plant's peak output.

The company decided to improve efficiency by installing a management information system to accurately monitor the system, as well as adding approximately 13 500 L more air storage. An intense leak detection and repair campaign was introduced and two small 15 horsepower compressors were installed to supply air to the volatile retort purge process. The new configuration now allows one compressor to be base loaded, and another to operate at around 60%, while the two smaller 15 horsepower compressors operate at 50%. The remaining 300 horsepower compressor was retained as a back-up. By taking a compressor offline and reducing leakage rates, the company is now saving $102 000 annually (4% of the plant's power costs) and no longer needs to purchase an additional compressor. The payback period was 2.6 years.[1]

[1] US DOE 2003

Eco-efficiency action

- When purchasing a compressor, consider the long-term operating costs as well as capital cost.
- Carry out regular and effective maintenance and leak checks.
- Turn off compressors when not in use.

4.4.2 Sizing a compressor

Select a compressor size that will suit the load demand. It is often better to add additional compressors later than to oversize initially. 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 existing compressors operate at variable rates or are oversized to cater for high contingent loads, consider installing a variable speed drive which could potentially save up to 50% on power costs (see Section 4.5).

Case study

Variable speed compressor: snack processor, Australia
Snack Brands Australia purchased a variable speed compressor to efficiently meet varying load demands. Although a standard compressor was cheaper, the high-efficiency compressor will save the company $10 000 in energy costs annually, with a payback period of just over two years.[1]

[1] SEDA 2003a

Eco-efficiency action

- Purchase a variable speed compressor or install a variable speed drive to meet varying load requirements.
- Install a sequence controller on multiple compressors to help the system respond more efficiently to varying load requirements.

4.4.3 Compressed air leaks

Leaks in a compressed air system can contribute 20–50% of total air compression output (SEAV 2002). Table 4.13 indicates the cost of compressed air leaks.

Table 4.13: Cost of compressed air leaks

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

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

Ultrasonic detectors can be used to check for leaks; soapy water on pipework is also effective. Staff should be aware of the importance of monitoring leaks and repairing or replacing parts promptly. It is best to check for air leaks when the plant is shut down and background noise is minimal.

Case study

Leak repairs and reduction in air pressure: honey processor, Australia
An eco-efficiency assessment for Capilano Honey in Queensland identified that repairing the leaks to the air compressor system would save $4000 annually.[1]

[1] UNEP Working Group for Cleaner Production 2003c

Eco-efficiency action

- Regularly check for compressed air leaks, and repair any leaks promptly.
- Remove all redundant pipework and isolate sections of the air distribution systems that are not in use, to minimise leakage.

4.4.4 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. Investigate redesigning 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 4.14 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.

Every 50 kPa increase in pressure increases energy use by 4%.

SEDA 2003b

Table 4.14: 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	875	70.0	1 750	140	2 625	210	3 500	280
7.5	1 195	96	2 390	191	3 583	287	4 780	382
11	1 755	140	3 510	281	5 265	421	7 020	561
15	2 390	191	4 780	382	7 170	574	9 560	764
22	2 945	236	5 890	471	8 835	707	11 780	942
30	4 380	350	8 760	701	13 104	1 048	17 520	1 402
37	5 975	478	11 950	956	17 930	1 434	23 900	1 912
55	8 760	701	17 520	1 402	26 280	2 102	35 040	2 803
75	12 750	1 020	25 500	2 040	38 250	3 060	51 000	4 080
110	875	70	1 750	140	2 625	210	3 500	280
160	1 195	96	2 390	191	3 583	287	4 780	382

Source: SEAV 2002

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

Case study

Air pressure reduction and leak identification program: brewery, Australia
Carlton and United Breweries in Victoria were able to reduce electricity consumption for air generation by 1% by implementing an awareness and leak detection program, and reducing the air pressure used to dry bottles before labelling. The trial involved replacing highly compressed air with air knives at reduced air pressure.[1]

[1] Environment Australia 2002b

Eco-efficiency action

- Ensure air pressure is kept to the minimum required for the end use application.
- Make sure that air is not being used inappropriately, such as for cleaning.

4.4.5 Reducing inlet air temperature

The condition and temperature of air entering the compressor is very important. When the inlet air into a compressor is cold, less energy is required to compress the air. In fact up to 6% of a compressor's power can be saved by using cooler air (SEAV 2002). The air should also be clean, as clogged filters at the inlet will cause a drop in pressure, reducing compressor efficiency.

Every 3°C drop in inlet air temperature decreases electricity consumption by 1%.

SEDA 2003b

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 4.15 shows energy and cost savings that can be made by reducing the temperature of compressor intake air.

Table 4.15: 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
11	220	18	440	35	725	58	1 450	116
15	300	24	600	48	990	79	1 980	158
22	440	35	880	70	1 450	116	2 900	232
30	600	48	1 200	96	1 980	158	3 960	317
37	740	59	1 480	118	2 440	195	4 880	390
55	1 100	88	2 200	176	3 625	290	7 251	580
75	1 500	120	3 000	240	4 950	396	9 900	792
110	2 200	176	4 400	352	7 260	581	14 520	1 162
160	3 200	256	6 400	512	10 550	844	21 100	1 688

Source: SEAV 2002

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

Eco-efficiency action

- Make sure air intakes are placed in clean, cool areas.

4.4.6 Optimise the distribution system

Installing a ring main or grid distribution system will help to improve the pressure balance of the system. Looped systems such as these allow any line losses to be balanced out in the two or more paths. As a result the pressure can often be reduced, as the end user is served from two or more different directions. Correctly sizing the distribution pipes can also help to reduce system pressure and energy consumption. Pipework should be sized to meet the air velocities required while also allowing additional surge capacity to reduce pressure fluctuations.

Eco-efficiency action

- Consider installing looped distribution pipes to improve the pressure balance of the system.
- Check distribution pipework to ensure it is suitably sized, and pressure drops and fluctuations are minimised.

4.5 Efficient motors

4.5.1 Selecting a motor

An electric motor uses 4–10 times its purchase price in electricity annually (Australian Greenhouse Office 2003). When choosing a motor, therefore, it is essential 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 4.16 illustrates the payback periods for motors with different ratings.

Table 4.16: Payback periods for purchasing high-efficiency motors

Motor rating	High efficiency 11 kW	Standard 11 kW	High efficiency 45 kW	Standard 45 kW
Pole	4	4	4	4
Efficiency (%)	92	88.5	94.6	93.1
Hours of operation per year	6 000	6 000	6 000	6 000
Average energy cost (cents/kW h)	10	10	10	10
Purchase price ($)	922	877	2 390	1 680
Annual operating cost ($)	7 170	7 450	28 541	29 032
Payback on premium	2 months		17 months	

Source: Teco Australia 2003

Eco-efficiency action

- Investigate the advantages of purchasing a high-efficiency motor compared to a standard motor.
- Investigate purchasing high-energy-efficiency motors rather than repairing (rewinding) existing motors.

4.5.2 Sizing a motor

Avoid purchasing oversized motors to cater for future production increases, or as insurance against motor failure. Also avoid an oversized motor to simply override load fluctuations in the production processes. If the load is constant, size the motor as closely as possible to the load. Table 4.17 illustrates savings to be made by replacing oversized motors with motors of the correct size.

Table 4.17: Cost comparison for oversized motors

	Motor size[1]		Motor size[2]	
	7.5 kW (40% loaded)	3.7 kW (80% loaded)	110 kW (15% oversized)	75 kW (sized to match needs)
Annual energy use (kW h)	17 813	8 788	627 000	427 500
Annual energy cost (A$)	$1 425	$703	$51 160	$34 200
Annual energy saving (A$)		**$722**		**$16 960**

Source: US DOE 2004

[1] Operating 2500 h/year

[2] Operating 6000 h/year

Assumption: Electricity cost 0.08 cents/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 US Department of Energy website: www.oit.doe.gov/bestpractices/motors/factsheets/mc-0382.pdf (Buying an energy efficient motor).

Eco-efficiency action

- Select motors that will meet load requirements as closely as possible.

4.5.3 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 or power of fans and pumps is proportional to the cube root 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 4.18 shows the potential savings through the installation of a VSD for a 5.5 kW and a 18.5 kW motor operating for 8000 hours per year. In these cases, payback can be up to three years.

Table 4.18: 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	$3 520	$2 816	$11 840	$9 472
Annual energy saving		$704		$2 368
Cost of VSD		$1 295		$3 460
Payback		1.8 years		1.5 years

Source: Teco Australia, http://www.teco.com.au

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

Eco-efficiency action

- Check suitability of variable speed drives or multi-speed drives on fixed speed motors such as compressors, pumps and fans.

Case studies

Variable speed drive: brewery, Australia
The Swan Brewery in Western Australia installed a variable speed drive on the motor at the wastewater treatment plant. The VSD is expected to reduce annual electricity consumption by 22 000 kW h or the equivalent of 230 tonnes of CO_2 annually.[1]

Variable speed drive: bakery, UK
Robertsons Bakery is a medium-sized commercial bakery with two production lines. The business installed two new VSDs to control the vacuum fans on bread de-panners. The VSDs have reduced energy consumption by 41.1% and now save the business A$13 400 annually. The payback period was 1.3 years.[2]

1 Centre of Excellence in Cleaner Production, Curtin University 2003a
2 CADDET 2003

4.6 Lighting

4.6.1 Energy-efficient lighting

Different styles of lighting are available for different purposes. They also have varying efficiencies. The following describes the different lighting types and their uses, from most to least energy-efficient (Industry, Science & Resources 2001).

Low-pressure sodium: This is the most efficient lamp type at present. It ismost suited to exterior lighting and emits yellow light. Colour is not discernible using these lights.

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 tube, which are 20% more efficient and produce 15% more light.

Tungsten halogen lamps: 240 V 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 4.19: 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)	15–1 500	50–2 000	10–75	8–36	35–3500	35–3500
Average life (h)	1 000	2 000	2 000–45 000	8 000–10 000	6 000–8 000	12 000–15 000
Depreciation	Light output falls 15% throughout life	Very little	Very little	<15–20%	45%	<15%

Source: Adapted from SEAV 2003c

Magnetic ballasts in fluorescent fixtures should be replaced with electronic ballasts. They are more expensive, but they will reduce energy use by between 4 W and 7 W per unit. They also extend the life of the tube and reduce flickering.

Eco-efficiency action

- Check where appropriate energy-efficient lighting can be used.

Although energy-saving fluorescent light bulbs have higher initial costs, they use only one-fifth the electricity and last up to ten times as long.

4.6.2 Lighting use, design and maintenance

While lighting may only be a small component of a plant's total energy costs, savings can often be made with 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.

Eco-efficiency action

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

Case studies

Lighting and air conditioning improvements: biscuit processor, Australia
Arnott's in New South Wales implemented a few simple changes to their lighting and air conditioning and now save $13 740 annually. Occupancy detectors were added to light switches, the number of office lamps was reduced by 30%, and delay push buttons were used to replace conventional switches where appropriate. In the manufacturing areas photoelectric sensors were installed. Air conditioning schedules were adjusted to fit with occupancy time, and staff were trained in energy awareness. The payback period was two years.[1]

Lighting management system: soft drink processor, Australia
Coca Cola reviewed lighting requirements across each of its bottling plants and PET bottle manufacturing plants in Australia. They investigated a range of energy-saving opportunities such as dimming systems, switching systems and installation of energy efficient lamps. A Clipsal C-Bus switching system that individually controls each lamp was installed at the WA site. As a result, lighting electricity consumption has dropped by 30–40% across all sites, saving $30 000–$5000 annually at some sites, with a payback of 2.5–4 years.[2]

[1] SEDA 2003c
[2] Australian Greenhouse Office 2002

4.6.3 Removing unnecessary lighting

Investigate removing or reducing light in over-lit areas. It may even be possible to remove one tube from double fluorescent fittings. To calculate the annual savings from 'de-lamping', the following equation can be used.

$$\$ = \frac{(N \times P \times H \times T)}{1000} + \text{cost of replacing lighting}$$

$ = annual savings
N = number of lamps removed
P = power rating of lamps (W)
H = usage per year (h/year)
T = electricity charge ($/kW h)

Eco-efficiency action

- Conduct a light audit.
- Reduce light in areas where less light is needed (e.g. corridors).

4.7 Air conditioning and air handling systems

Air conditioning systems serve to maintain humidity and temperature levels in the plant. An air conditioning system will consume as much as 50% of the energy consumption in a commercial building and, as a result, presents many opportunities for improving the energy profile. It is important to understand the components of your air conditioning system and how it operates, before you can fully appreciate the importance of correct type and size, proper installation, regular maintenance, and finally its correct and efficient use.

4.7.1 Types and components of air conditioners

There are two main types of cooling methods for air conditioners — direct expansion and chilled water.

Direct expansion

Direct expansion air conditioners operate on the same principles as a refrigerator and have 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 a control system with varying levels of sophistication to maintain temperature and humidity.

Several types of air conditioning systems are typically found on food processing sites:

Window unit air conditioners

These are installed in windows and used to cool individual offices or rooms. If these units are used only when needed they may be a less expensive alternative to larger central units, although their efficiency is generally lower. The compressor, expansion valve, hot (condenser) and cold (evaporator) coils, fans and control unit are all contained in the one unit.

Split system unit or central air conditioners

This type of air conditioning system splits the unit into two, with a hot side and a cold side. The cold side contains the expansion valve and evaporator coil. These are usually placed inside the building in a cabinet with an air handler. The air handler blows the air through the coil and then directs the air to the room or through the building, through a series of ducts. The hot side contains the condenser and compressor. A split system generates less noise inside and, because the compressor and condensing coils can be larger, it can also have a greater cooling capacity. The outside units can be placed on the roof and can be quite large. Alternatively there can be smaller modules that are linked to different air handlers to cool specific areas.

Packaged central air conditioners

This type of system has the evaporator, condenser and compressor all located in the one cabinet, which is usually located outside the building or on the roof. The cabinet is connected to the building with supply and return air ducts.

4.7.2 Choosing energy-efficient systems

Do not base your choice of a system on price alone. While energy-efficient models may have higher initial costs, keep in mind that 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 your plant's needs. An oversized system, on the other hand, apart from being more expensive initially, will cycle on and off more frequently and make the system less efficient.

Choose a contractor that can use a computer program to accurately determine the cooling load for your plant, as well as the optimum number of supply and return ducts. Consider whether the plant has different zone requirements or areas where precise temperature control is required.

Evaporative coolers

Evaporative coolers cost around half as much as central air conditioning systems and only use one-quarter of the energy (EERE 1999). Evaporative coolers operate by cooling external air by evaporation, and blowing it inside the plant. Openings are required in the plant to enable warm inside air to escape and be replaced with cooler air. Evaporative coolers can effectively cool large areas, but they are suitable only for areas with a hot dry climate, and require frequent maintenance.

4.7.3 Correct installation

The correct installation of air conditioning systems by certified contractors can improve their efficiency and reduce future maintenance requirements. Ensure that the refrigerant and airflow are those specified by the manufacturer. If possible, keep ducts within the air-conditioned space. If ducts are installed above the ceiling where temperatures will be higher, make sure they are heavily insulated. Ensure the system is accessible for cleaning and maintenance. Where possible, install condenser units in a cool location. Noise levels should also be considered, with the location of units and thermostats away from heat sources.

4.7.4 Maintenance of air conditioning systems

Failure to regularly maintain your system will reduce the system's energy efficiency and performance and reduce its life span.

Filters: Dirty filters obstruct normal air flow and reduce the system's efficiency. Clean or replace filters every month or two in the hot season. Undue pressure can be placed on the compressor if filters and coils are not maintained regularly.

Coils: Neglecting to clean filters can also result in dirt reaching the evaporator coil, reducing thermal efficiency. Condenser coils may also be exposed to the outside environment. If possible, keep the area immediately around condenser units free of debris and vegetation.

Ducts: Studies have shown that between 10% and 30% of air in the average central air conditioning system escapes from ducts (EERE 1999). A contractor can test ducts to ensure they are airtight and seal them with duct mastic.

Fins: Aluminium fins on evaporator and condenser coils can bend and obstruct airflow. Use a fin comb to correct this problem.

Refrigerant: If the level of refrigerant is low, the system either is leaking or was undercharged at installation. A contractor should first test and repair leaks, before charging the system with the correct amount of refrigerant. Make sure captured refrigerant is disposed of legally.

Compressor: Frequent cycling of oversized systems can increase the need for compressor and fan maintenance. Check motor oil and belt tightness. Electrical wiring should also be checked and cleaned, as it can be prone to corrosion.

Thermostat: Check that the thermostat is indicating the correct temperature.

4.7.5 Efficient operation

Correct sizing, installation and maintenance can help to ensure years of efficient use. System operation also needs attention.

Operate only when necessary: Often air conditioning can be turned off for more than an hour before the plant is closed. Consider installing a programmable thermostat.

Utilise off-peak tariffs: Cooling and heating during off-peak periods can substantially reduce the plant's temperature, as the thermal mass may be retained for some time and reduce the load at peak rates.

Close off unused areas.

Do not overcool or overheat: This can be prevented by allowing the temperatures to fluctuate within a dead band rather than maintaining a constant temperature. This may not always be possible, of course, due to processing requirements.

Use an economiser cycle: If an air conditioning system does not have an economiser cycle, it will fail to utilise outdoor air effectively when it is cooler than return air. This is particularly so at night. Economiser cycles can be added to systems that fail to take advantage of potential savings.

Energy monitoring and control system: Such systems can be used to schedule cooling according to the time of day. They can be used to load-shed at times of plant maximum demand.

Reduce solar gain: Investigate the benefits of floor, wall and roof insulation and reduce solar heating with blinds, reflective film, eaves and vegetation.

Eco-efficiency action

- Choose an energy-efficient system.
- Accurately size your plant's cooling requirements by choosing a contractor that can use a computer to determine the best size, the number and size of ducts, and the dehumidification capacity of the system.
- Ensure that systems are installed by a certified contractor, and use the refrigerant and air flow specified by the manufacturer.
- Systems should be accessible for cleaning and maintenance. Regularly maintain your air conditioning system (filters, coils, ducts, fins, refrigerant, compressor and thermostat) and repair leaks.
- Investigate cooling using off-peak tariffs.
- Consider whether a central system or floor plant would best meet your needs, and what would be the best kind of air distribution system.
- Whenever possible use outside air economy cycles, especially at night.
- Ensure thermostats are set to the optimum setting and install away from heat sources.
- Only operate your system when necessary. Check out an energy monitoring and control system to schedule cooling according to the time of day.
- Investigate the benefits of floor, wall and roof insulation. Look at possibilities for using blinds, reflective film, eaves and vegetation.
- Insulate ducting and pipes, and if possible keep ducts within the air conditioned space.
- Investigate the use of evaporative coolers if climatic conditions are suitable.

4.8 Heat recovery

In some circumstances rejected surplus heat can be recovered and reused. There are a number of waste heat sources from which useful heat can be recovered. Table 4.20 gives examples where sources of waste heat have been recovered and used for other applications.

Table 4.20: Examples of heat recovery in the food processing industry

Sources of waste heat	Applications for recovered heat	Industry examples
• Hot exhaust from baking ovens	• Preheat warm and humid proofing ovens	**Baker: Goodman Fielders Baking, Australia** Savings: 500 GJ for one 8-hour shift Payback: 3.5 years[1]
• Hot exhaust from fryer • Surplus heat from boiler flue gases	• Preheat air for dryers • Heat water for blanchers • Preheat boiler feedwater • Process water	**Snack food processor: McCain Foods, UK** Savings: A$443 261 Payback 3.5 years[2]
• Lubrication oil cooler from a rotary screw compressor	• Preheat boiler feedwater	**Bluebird Foods, New Zealand** Savings: A$4370 Payback period: 2 years[3]
• Heat from gas engines used to drive kiln fans	• Preheat the kiln air	**Malt processor, Australia** Savings: $70 000 Payback period: 2.5 years[4]
• Heat from the freezer condenser • Heat from the superheater on compressor	• Water at 65°C for cleaning 24 hours a day	**Chicken processor: Danpo A/S, Denmark** Savings: 2500 MW h Payback period: 3.2 years[5]
• Heat from compressor lubrication oil • Heat from boiler blowdown	• Preheat boiler feedwater	**Food processor: Jordan** Savings: 53 t/year Payback period: 0.6 year[6]
• Condensate return	• Preheat boiler feed water	**Food processor: USA** Savings: A$20 944 Payback period: 2.6 years[7]

Sources:
1 Environment Australia 1997a
2 CADDET 1995
3 Energy Efficiency and Conservation Authority 1996
4 Environment Australia 2001a
5 CADDET 2000
6 Royal Scientific Society 2003
7 Muller et al. 2001

4.8.1 Calculating potential heat recovery

The practicality of recovering heat is most commonly limited by the distance between the heat source and the potential application. It is possible to recover heat from wastewater streams. However, they tend to have a low heat density, and heat recovery can be complicated by the presence of contaminants in the wastewater, which can block heat exchangers. These aspects must be considered to determine whether heat recovery is viable. To identify any viable opportunities for heat recovery, estimate the amount of energy (MJ) available for each waste heat source (see Table 4.21) and match this up with the quantities required for each potential application. This is a very crude technique for identifying heat recovery opportunities.

Table 4.21: Sample calculation of heat recovery potential

Equipment	Energy input (MJ)	Percentage waste heat	Theoretical recoverable heat (MJ/day)	Heat recovery efficiency (MJ/day)	Actual recoverable heat	Potential saving per day[1]
Refrigerant desuperheater and condenser	80 000	20%	16 000	75%	12 000	$144
Steam boiler condensate return	335 000	20%	67 000	75%	50 250	$603
Boiler blowdown	335 000	20%	6 700	75%	5 025	$60
Oven	5 000	58%	2 900	75%	2 175	$25
Air compressor	2 250	80%	1 800	75%	1 450	$17

Source: Adapted from MLA 2002

Assumption:

[1] Potential savings per day based on 0.012 $/MJ gas

The following examples show workings for potential heat recovery from boiler blowdown and another waste heat source — in this case a refrigeration condenser.

Example 1: Calculating potential heat recoverable from boiler blowdown

Potential heat recovery = blowdown rate × heat content

Example workings

Blowdown rate (kg/h) = $(F \times S) / (B - F)$

F = boiler feedwater TDS in mg/L

S = steam generation in kg/h

B = maximum TDS in boiler in mg/L

Blowdown rate for existing fired boiler

= (300 × 1252) / (3000 – 300) = 139 kg/h

Boiler operates at a pressure of 1000 kPa and blowdown water is at 184°C.

Heat content = 782 kJ/kg

Potential heat recovery = 139 kg/h × 782 kJ/kg

= 109 MJ/h

Assuming 90% of heat could be recovered, plant operates 10 h each day, 240 days each year

Heat recoverable annually = 109 MJ/h × 0.9 × 10 h/day × 240 days/year

= 235 GJ/year

Value of recovered heat = 235 GJ/year × $11 GJ

= $2600

Source: Adapted from MLA 1997a

Example 2: Calculating the potential heat coverable from refrigeration condenser water to preheat feed water (in this case a kettle)

Potential heat recovery = flow rate × specific heat × temperature differential

Example workings

Chiller condenser water temperature	35°C
Chiller condenser water flow rate	19.6 kL/h
Kettle feedwater inlet temperature	23°C
Kettle feedwater required temperature	80°C
Kettle feedwater instant flow rate	12 000 L/h
Kettle feed total volume	4 200 L/day (6 batches × 700 L/batch)
Specific heat of water	4.18 kJ/kg/°C

Potential heat recovery	= flow rate × specific heat × temperature differential
	= 4 200 × 4.18 × (35–23)
	= 210 672 kJ/h
	= 210 MJ/h

Assumptions: Chiller condenser water stream flows only 60% of operating time; plant operates 10 hours each day, 240 days each year; 80% of heat can be recovered.

Heat recoverable annually	= 210 × 60% × 80% × 10 hours × 240 days
	= 242 GJ/ year
Value of recovered heat	= 242 × $11/GJ
	= $2 661/year

Source: UNEP Working Group for Cleaner Production 2003d

For a more detailed and accurate heat recovery assessment, a technique called ‘pinch analysis’ should be used. This analyses the heat available from various process streams and determines the minimum external heating and cooling requirements. An energy management specialist can be employed to undertake this. See Table 4.22 for some typical energy savings using pinch technology.

Table 4.22: Typical energy cost savings using pinch technology

Plant type	Energy cost savings (%)	Payback (months)
Food products and dairy	30	12
Brewery	25	24
Edible oil	70	12–18

Source: SEAV 2002

Eco-efficiency action

- Investigate the potential for heat recovery and the use of pinch analysis.

Case studies

Heat recovery from refrigeration plant: brewery, Australia

Carlton and United Breweries have reduced the use of steam by recovering heat from warm return coolant (brine) from the refrigeration system. The energy is used to vaporise and heat CO_2. The removal of heat from the brine has resulted in savings of 100 kW of electrical load on the refrigeration plant and the elimination of steam load from heating CO_2 has reduced gas consumption by 97 000 GJ annually — a double saving from using an alternative heat source.[1]

Heat recovery for pre-heating water: butter manufacturer, Australia

The Butter Producers' Co-operative Federation Ltd in Queensland designed and installed jacketed stainless piping on all of their product lines. Town water counter-flows through the jacket, recovering heat from the liquid butter. The product temperature is lowered to 60°C (from 85°C) and the water temperature is raised to 65°C. The water is stored and used for washdown. This lowers the refrigeration load for product cooling and reduces the electricity required for heating water, saving about $8400 annually.

The jacketed pipes are also used for finer temperature control of the volumetric fillers. The previous method of heating was steam tube wound around the circumference of the product tube. The temperature variations were causing fill weight variations. Now heated water (supplied from a domestic hot water system) is recirculated through the jacket by a pump and can control product temperature to within 1°C. The cost of installation was approximately $4000 in materials, and the welding was done in-house. The boiler is no longer required every day, saving $8000 annually in energy costs.[2]

1 SEAV 2003b

2 UNEP Working Group for Cleaner Production 2003b

4.9 Alternative sources of energy

4.9.1 Solar energy

Solar heating

While solar hot water heating is particularly suitable for Queensland's climate, its use in the industrial sector has been limited to date. Examples of solar heating in the food processing industry can be found for pre-heating boiler feedwater, however. Solar heating systems usually have high initial costs and low operating costs if they are well designed, and properly installed and maintained.

Commercial solar water heating systems typically consist of a collector, where the water absorbs heat from the sun, and an insulated storage tank. In some cases the fluid in the collector is a glycol mixture which is heated by solar energy and then passed through a heat exchanger to heat the water. Storage tanks can be mounted on or within the roof to take advantage of gravity or thermosiphoning to circulate the water. For storage tanks at ground level, or systems that are attached to existing hot water systems, a pump is required to circulate the water.

Flat plate collectors (solar panels)

Flat plate collectors can increase water temperatures to around 70°C. They usually consist of copper tubes placed on a dark-coloured metal absorbing plate. The tubes and absorber plate are enclosed in weathertight housing with a clear glass or plastic cover glazing which maximises heat absorption. Water or other fluid passes through the tubes and absorbs the heat energy. A standard panel is 2 m^2 in area and produces 5 kW of heating energy per day (based on yearly averages). The approximate capital cost is about $1000 per panel installed. For example 20 panels per day could provide enough energy to heat 15 kL of boiler feed water from 20°C to 80°C daily (UNEP Working for Cleaner Production 2002a).

Tube collectors

Simple solar heating systems commonly used for heating swimming pools are rows of plastic tubes (usually black to increase absorption) through which water is pumped and heated. This type of system can increase temperatures to 60–70°C. A disadvantage is that they usually require considerable roof space.

For systems where a higher temperature is required, an air-evacuated tube collector can be used. This consists of a glass outer tube and an air-evacuated inner tube or absorber. In order to reduce heat loss by convection, the air is pumped out of the collector tubes. The absorber contains a heat transfer fluid that evaporates and is then condensed, transferring solar energy to water or another medium. The tubes must be re-evacuated once every one to three years. As there is very little heat loss, evacuated tube collectors can reach temperatures of up to 120°C (Solarserver 2003).

Case studies

Example of savings from preheating water using solar power: Zane Australia
The subject of this example is a company that 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 per year. 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]

Solar heating panels to preheat water: chocolate drinks and coffee processor, Australia
A solar heating system at Novartis Consumer Health in Victoria includes 36 solar panels, nine gas burners to supplement the solar heat and one 3000 L insulated hot water holding tank. The water is used for cleaning and must be at least 75°C. The solar panels heat the water to between 50° and 60°C and a gas booster heater increases the temperature a further 20°C. Gas consumption has dropped by about 50% as a result of solar heating.[2]

1 Hamilton Pers. Comm. 2003
2 SEAV 2003d

Eco-efficiency action

- Investigate opportunities to use solar power to heat or preheat water or other process stream.

Electricity generation using photovoltaics

Photovoltaic (PV) systems are being more widely considered in both the residential and the commercial sectors as conversion to renewable energy systems becomes more important. It is envisaged that PV systems will be affordable for residential applications within 10 years, and the Australian Greenhouse Office has been providing rebates to assist with this. For commercial applications, however, PV systems are still not a financially viable option and there are currently no rebates available. Promising new technology may make it possible for the solar modules to be applied as a thin film to coat building materials; they could then be integrated with building materials such as roofing to reduce costs.

PV systems not only avoid the need to purchase electricity from the grid but they can also include the option to sell power to the grid as ‘green energy’. Under the current national scheme there is also the opportunity to purchase ‘renewable energy certificates’.

4.9.2 Biofuels

Most food waste has a useful content of energy and/or nutrients. In Australia, such organic waste is disposed of to landfill, used in horticultural and agricultural sectors as compost and liquid fertiliser, or applied in the generation of renewable energy. Sources of organic waste include the by-products of food processing, as well as by-products of agricultural crops, forestry operations, municipal sewage and solid waste, and even high-energy crops grown specifically for biofuels.

There are two main types of biofuel energy conversion processes, which are discussed here in more detail:

- **biochemical conversion**, which includes anaerobic digestion and fermentation processes
- **thermochemical conversion**, which involves direct combustion and gasification of biofuels.

Biochemical conversion

Biochemical conversion involves the breakdown of high-moisture biofuels by micro-organisms to produce gaseous or liquid fuels. The two processes commonly used are anaerobic digestion and fermentation. To date, fermentation processes for producing biofuels have not been able to compete with other technologies, such as the production of petroleum and ethanol blended fuels, without some form of assistance. Research is being undertaken on advanced fermentation systems to further develop this field.

Anaerobic digestion and biogas recovery is best suited to large food processing plants with high-strength wastewater, such as dairy processing plants or breweries.

Anaerobic digestion

Anaerobic digestion is the decay of organic material in the absence of oxygen in a controlled environment. The digestion process produces biogas, which can be used as an alternative fuel. Biogas is made up of methane, carbon dioxide and other components such as hydrogen sulfide (H_2S) and moisture. Methane concentrations in biogas can range from 52% to 95% (v/v), but 60–80% is more common (Wheatley 1990). Biogas with a typical methane content of 65% has a heating value of 22.4 MJ/m^3, compared with pure methane, which has a heating value of 39.5 MJ/m^3.

The moisture and H_2S content of biogas can lead to corrosion in boilers. However, this can be alleviated in a number of ways. Moisture can be removed using a condensate trap and H_2S can be removed by passing the biogas through a scrubber containing iron filings, or by other methods. Alternatively, by warming the boiler to operating temperature before introducing the biogas it may be possible to avoid the need to scrub the gas to remove H_2S (MLA 2002).

Energy available from biogas produced by the digestion of food-processing wastewaters can provide a substantial proportion of a plant's thermal energy requirements (UNEP Working Group for Cleaner Production 1999). Table 4.23 shows the methane and energy recoverable from biogas produced by anaerobic digestion of wastewater from an ice cream factory using an anaerobic lagoon.

Table 4.23: Sample methane and energy yields from biogas digestion for an ice cream factory, NSW

	Low-rate digestion of effluent (lagoon digester)
Material available for digestion	3 060 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 cost	$324/day @ $12/GJ

Source: UNEP Working Group for Cleaner Production 1999

The economic viability of generating and using biogas is quite site-specific. A reasonable return on investment (2–4 years) may be possible under the following situations:

- where the infrastructure for utilising the biogas already exists (i.e. an existing gas boiler, hot water system or gas generator)
- where a high cost is paid for heating fuel such as LPG
- where the company can benefit from reducing the cost of effluent disposal (e.g. sewer discharge by augmenting wastewater treatment capacity with an anaerobic digestion process).

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

Case studies

Gas fuel for boilers from anaerobic digestion of food waste: fruit and vegetable processor, Australia
The upflow 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 per year in coal costs. This will improve further when the company's gas storage capacity is increased.[1]

Green energy from broadscale anaerobic digestion of food waste: Earthpower, Australia
Earthpower has commissioned a waste-to-energy facility at Camellia, New South Wales. An anaerobic digester at the plant has the capacity to convert 210 tonnes/day of food waste from industrial, commercial and domestic sources to biogas and fertiliser. The energy in the biogas is used to produce 3.5 MW of electrical energy and about 6 MW of heat energy, which is enough energy to power 3900 homes. At full capacity, the plant can produce 8000 tonnes/year of granulated organic fertiliser.[2]

[1] UNEP Working Group for Cleaner Production 2003f
[2] Earthpower 2003

Thermochemical conversion

Thermochemical conversion uses high temperatures to break down biofuels. The process is used for organic wastes with low moisture content. Thermochemical conversion includes direct combustion and pyrolysis/gasification.

Pyrolysis involves heating biofuels in the absence of oxygen to produce crude oil liquids, gases with an energy content up to 50% of natural gas, and solid carbon and ash. Gasification involves heating with air to produce syngas, which has about 20% of the heating value of natural gas. The cost of gasification/pyrolysis facilities is relatively high and the throughput required greater than that generated from most individual food processing plants. Therefore, to be economically viable, such a facility would process organic waste from numerous food processing plants as well as additional sources.

Direct combustion is the simple process of burning organic waste to produce steam, electricity or heat. This very simple process is being used by food processing plants to dispose of their waste organic material, while also helping the plant to meet its energy needs. For example, the direct combustion of agricultural waste such as bagasse from sugar cane can meet the entire energy requirements of a sugar mill and produce excess electricity for sale to the grid.

Case study

Direct combustion of macadamia nut husks: macadamia nut processor, Australia
Suncoast Gold Macadamias of Queensland, in partnership with Ergon Energy, combust more than 5000 tonnes of macadamia shells annually in a cogeneration plant to produce steam and 'green electricity'. Macadamia shells have a high calorific value (22 MJ/kg) and are very low in ash, making them an ideal fuel source. The boiler was custom-made to burn macadamia shells and is rated at 6 MW thermal energy; it produces high-pressure steam at 350°C. The company produces 9.5 GW h of electricity per year, of which 1.4 GW h per year is used by the plant; the rest is exported and traded in the national electricity market. The facility provides an environmentally sustainable and economical disposal alternative for waste that is reducing greenhouse emissions by around 9700 tonnes annually. This is the equivalent of taking 2000 cars off the road every year.[1]

[1] Ergon Energy 2003; Suncoast Gold Macadamias Biomass Co-generation Facility 2003

Eco-efficiency action

- Investigate the viability of recovering energy from high-strength wastewater by anaerobic digestion.
- Investigate the viability of recovering energy from low-moisture organic waste by direct combustion.
- Check the potential to recover energy from the solid waste of other businesses.

4.10 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. The efficiency of a cogeneration plant can be as high as 80%, because energy is being extracted from the system in the form of both heat and power. In contrast, at a conventional power station producing only power, the conversion efficiency is only around 36%, with the remainder lost as unrecovered heat.

Cogeneration is thus seen as providing good environmental outcomes because less fossil fuel is consumed, which results in the conservation of fossil fuel resources and reduced greenhouse gas emissions.

4.10.1 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.

4.10.2 Applicability of cogeneration to the food 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 compete with retail electricity prices, while larger-scale plants compete with wholesale prices (which are currently low). Electricity prices (and gas prices, if applicable) affect the economic viability of a cogeneration plant. The payback period for a cogeneration plant is typically around 3–4 years, with the up-front capital cost, labour and operational costs being recovered by savings on energy prices. Where a waste stream (such as the macadamia shells) is used as a fuel, savings can also be made on waste disposal.

The Business Council for Sustainable Energy *Cogeneration ready reckoner* is available on the BCSE website (BCSE 2003), and gives a straightforward result as to 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 and the Queensland 13% gas target for non-renewable energy. The BCSE *Guide for connection of embedded generation in the national electricity market*, available on the BCSE website (www.bcse.org.au), gives an overview of the connection process.

Case study

Cogeneration: malt processor, Australia

Adelaide Malting in South Australia produces malted barley for the local, interstate and overseas beer-brewing industry. A study by a local gas supply company concluded that the company could improve its efficiency by replacing electricity-powered fans with fans powered by gas engines. The heat recovered from the gas engines could then be used to heat the malt drying air, thereby eliminating the need for electricity-powered malt-drying equipment. The company now saves $70 000–$75 000 annually and has boosted plant capacity by 20%. The payback period was two years.[1]

[1] Environment Australia 2001a

5 Packaging

5.1 Packaging overview

5.1.1 The role of packaging

Packaging is any material used for the containment of raw materials or processed goods. It plays an important role in protecting the product and helps to prevent spoilage. It ensures the safe handling and delivery of the product and helps to identify the product and its contents. Packaging is also a marketing tool used to brand and sell the product.

Although packaging plays an important environmental role in preventing wastage, it consumes valuable resources such as energy and water, and ultimately produces waste that has to be disposed of, reused or recycled. The public expectation for environmentally responsible packaging is growing, along with high expectations about packaging performance, convenience and presentation. Advancements in packaging design and materials over the last decade reflect the industry need to balance environmental considerations with commercial necessities. An Australian Food and Grocery Council survey showed that food and grocery manufacturers identified packaging as being the most significant environmental issue of the last five years (AFGC 2001). Over 80% of the respondents also felt it would remain the most significant issue for the next five years. The importance placed on packaging may result from increased awareness as a result of the National Packaging Covenant (see Section 5.1.4 below).

Investigate the contents of your plant's general waste bins. Do the bins contain packaging material that could be eliminated, reduced, reused or recycled?

5.1.2 Types of packaging

There are three main categories commonly used for packaging

1. Primary packaging: used around the product at the point of sale (e.g. bottles, plastic bags and containers)
2. Secondary packaging: groups a number of items together until the product is sold (e.g. boxes and strapping)
3. Tertiary packaging: enables the product to be transported and handled (e.g. pallets, padding and shrink-wrap).

Table 5.1 lists common types of packaging materials and their typical uses.

Table 5.1: Common types of packaging

Use	Type of packaging	Example	Characteristics
Bottles and jars	Glass	Jam jars	Recyclable, cheap, non-reactive
	Polyethylene terephthalate (PET)	Soft drink bottles	Recyclable, expensive, clear, tough
	Polyethylene — high density (HDPE)	Milk bottles	Recyclable, very common plastic, opaque
	Polyvinyl chloride — unplasticised (UPVC)	Cordial and juice bottles	Recyclable, hard, rigid plastic that may be clear
Cans	Aluminium	Beverage cans	Recyclable, reacts with acid unless coated
	Tin or tin coated steel	Fruit, vegetable, meat, fish and oil cans	Recyclable, cheap
	Steel	Coffee tins	Recyclable, needs lacquer to protect from contents
Boxes	Cardboard Virgin or recycled Non-coated or coated Single or corrugated Combined with plastic or foil — liquid-proof	Cereal boxes	Recyclable, relatively cheap, compostable, combustible
Containers	Polypropylene (PP)	Ice-cream container	Not easy to recycle, hard but flexible, many uses
	Polystyrene (PS)	Yoghurt containers	Not easy to recycle, rigid and brittle
	Polystyrene — expandable (EPS)	Meat trays, takeaway food containers	Foamed, cheap, lightweight, good for thermal insulation
Flexible	Cellophane (regenerated cellulose)	Clear film	Biodegradable, heat resistant, good oxygen and moisture barrier
	Polyvinyl chloride — plasticised (PPVC)	Wrap, bags and tubing	Not easy to recycle, flexible, clear, elastic
	Polypropylene (PP)	Potato crisp bags	Not easy to recycle, strong but flexible, many uses
	Polyamide	Boil-in-a-bag-pouches	Tough, high melting point

Table compiled from information in *Case studies in the food industry* 1994 and BHP Steel Australia 2003

5.1.3 The true cost of packaging

Packaging that leaves food processing plants as waste is not only costly for the business to dispose of but is also a waste of valuable raw materials and previous processing and handling costs.

It is easy to overlook the fact that the true cost of packaging also includes the costs of:

- purchasing the packaging material
- transporting the packaging materials for delivery
- transporting existing packaging with the product
- operating the packing process
- handling, rehandling and storage space
- any further processing (e.g. folding cardboard into boxes)
- disposing of waste packaging (e.g. damaged packaging materials and trimmings)
- any product loss as a result of deficient or damaged packaging

5.1.4 The National Packaging Covenant

The National Packaging Covenant was launched in 1999 and is a joint government and industry initiative. It is a voluntary scheme aimed at encouraging industry to think about the effect of their packaging along the supply chain. It is based on the principles of shared responsibility and product stewardship.

The covenant seeks signatories from all links in the packaging chain including raw material suppliers, designers, packaging manufacturers, retailers, packaging consumers, government and collection agencies. By October 2003 over 600 companies, state and local governments and relevant industry associations had become signatories, agreeing to abide by the principles set down in the covenant. The signatories to the covenant have adopted product stewardship policies and produced action plans that seek to evaluate and improve the environmental outcomes of their packaging.

The covenant has served as a catalyst for many companies wanting to implement waste reduction programs. For more information see the National Packaging Covenant website at http://ea.gov.au/industry/waste/convenant/council.html

Company contributions to the National Packaging Covenant have also helped to funded many projects such as the Best Practice Kerbside Recycling Program for local councils, public place recycling, community education trailers, and a transport logistic study for transporting the recyclables to markets.

5.1.5 The waste minimisation hierarchy

The waste minimisation triangle below represents a sequential approach to reducing packaging waste.

The waste minimisation triangle (as discussed previously in Chapter One) provides a structured order and approach that can be taken to reduce packaging waste.

- The first step in the waste minimisation hierarchy is eliminating all unnecessary packaging wastage.
- Next, consider how remaining packaging can be further reduced, utilising the best types and grades of materials and optimising design. Packaging waste can also be reduced by good handling, storage and packing practices that reduce damage.
- Once all reduction options have been exhausted, look for opportunities to reuse packaging, either around the plant or by returning it to the supplier for reuse.
- Finally, investigate options for using recycled materials in your packaging, or ways the plant can render its packaging recyclable after use.
- The disposal of packaging waste should only be a last resort after all avenues in the waste hierarchy have been explored. Successes in reducing packaging waste should be promoted among staff to help increase awareness of the plant's commitment to waste reduction.

The sections that follow describe eco-efficiency opportunities to reduce packaging waste from each level of the waste minimisation hierarchy. The opportunities are supported with case studies from Australian companies that have explored such opportunities and successfully reduced their packaging waste.

5.2 Avoiding unnecessary packaging

All unnecessary packaging that is not essential for the protection, containment, handling or identification of the product should be eliminated.

5.2.1 Packaging design

Eliminating unnecessary packaging often involves changes in design. For example, it is often possible to eliminate:

- unnecessary layers (e.g. bags within bags or boxes)
- unnecessary tertiary packaging (e.g. replacing corrugated boxes with reusable containers or with shrink-wrap that is only a fraction of the weight)
- unnecessary labelling (e.g. ink printing directly onto packaging to replace paper labels)
- adhesives.

Case studies

Chicken processor, Australia
Ingham Chicken has eliminated the use of over 3 million plastic trays by bagging whole birds in permeable shrink bags rather than on a plastic tray with a soaker pad.[1]

Sugar processor, Australia
Sugar Australia in Queensland eliminated a second layer of paper in preformed bags by using a single layer of heavier paper to achieve an overall paper reduction.[2]

Ice-cream processor, Australia
Weis in Queensland eliminated the need for an outer master carton by using the inner wrapper as the retail pack. The thickness of the product wrap was also reduced from 50 μm to 40 μm.[3]

Smallgoods processor, Australia
Hans Continental Smallgoods in Queensland have eliminated paper labelling on 15 product lines through the introduction of printed top-films.[4]

Spices and recipe mixes processor, Australia
McCormick Foods in Victoria produce over 400 products including spices, seasonings, sauces, jellies and recipe mixes. A trial of a new wrap-around cardboard case reduced the use of cardboard by 43% and eliminated the need for over 1000 km of adhesive tape per year.[5]

Fruit bar processor, Australia
Bellis Bars in South Australia eliminated the use of pallet pads by relying on the good condition of pallets to prevent damage to the product. The company avoided the unnecessary consumption of 9100 m^2 of cardboard, a yearly saving of $6955.[6]

1 Ingham Enterprises Pty Ltd 2003
2 Sugar Australia Pty Ltd 2003
3 Weis Australia Pty Ltd 2003
4 Hans Continental Smallgoods Pty Ltd 2003
5 McCormick Foods Australia Pty Ltd 2003
6 Bellis Fruit Bars Pty Ltd 2003

5.2.2 Bulk delivery

Delivering in bulk can eliminate the need for tertiary packing, and transport costs can be reduced by choosing the lightest suitable tertiary packaging possible. A comparison between Australian Food and Grocery Council surveys in 1993 and 2001 shows that the number of companies using larger trading units has increased by 22% (AFGC 2001).

Examples of bulk delivery methods include intermediate bulk containers (IBC) and tanker delivery. IBCs are typically cube-shaped containers that fit onto a standard pallet. Their shape makes them efficient to store and transport.

Case studies

Bulk delivery in pallet boxes instead of drums and bags: prepared foods, Australia
Eurest in Queensland produce soups, sauces and pre-prepared style products. The company reduced purchasing, logistic and landfill costs by working with suppliers to deliver goods in bulk. For example, the company now receives its milk and cream in 1000 L pallet boxes instead of 10 L bags, and crushed tomatoes in 1000 L aseptic pallet boxes instead of 200 kg aseptic drums.[1]

Replacement of drums with bulk tanker delivery and reusable pallecons: sugar processor, Australia
Sugar Australia in Queensland converted from delivering industrial syrup to customers in drums to using reusable pallecons or bulk tanker delivery.[2]

Bulk delivery handling system for sugar: ginger processor, Australia
Buderim Ginger in Queensland is in the process of replacing their existing manual handling sugar system with a bulk handling network. Currently 4000 tonnes of sugar is delivered in 25 kg multi-wall paper bags, totalling 60 000 units annually. A bulk dry or liquid sugar system will reduce this packaging to less than 1000 units. The company also now uses 1000 L sanitised bulk containers to deliver the product 'Ginger Refresher' to contract packers instead of 200 L polylined steel drums.[3]

1 Eurest Prepared Foods 2003
2 Sugar Australia National Packaging Pty Ltd 2003
3 Buderim Ginger Pty Ltd 2003

5.2.3 Alternative handling and distribution

It may be possible to eliminate the need for packaging by changing handling and distribution techniques — for example by using pneumatic conveyors linked to bulk silos or storage tanks to move liquids and powders, or using ring main systems for delivering chemicals around the plant.

Case studies

Bulk delivery of flour to silos attached to a pneumatic distribution conveyor: bakery, Australia
Goodman Fielder in Queensland has eliminated the need for tertiary packaging of its flour by having it delivered in bulk for storage in two large silos. The flour is then distributed around the plant via a pneumatic conveyor.[1]

Ring main system for chemicals: poultry processor, Australia
Bartter Enterprises in New South Wales installed tanks and a ring main system for the bulk delivery of chemicals, to eliminate the use of numerous polypropylene and HDPE containers. The system also reduced chemical wastage and the cost of cleaning chemicals, producing a saving of $25 000 annually. The payback period was one year.[2]

1 UNEP Working Group for Cleaner Production 2003f
2 NSW Department of State and Regional Development Small Business 2003

Eco-efficiency action

- Investigate whether unnecessary packaging can be eliminated.
- Investigate potential to deliver in bulk.
- Consider alternative ways to handle and distribute product.

5.3 Reducing packaging

Once all unnecessary packaging has been eliminated, further opportunities to reduce the remaining packaging should be considered. This can be achieved in a variety of ways, as discussed below.

5.3.1 Lightweighting

Reducing packaging often means altering the design of the product and/or the materials used in the packaging, using only the properties that are important to the packaging function. Many packaging companies now use computer programs to assess the effects of design change. For example, the bottle manufacturer Sidel can now digitally simulate the mechanical strength of specifically shaped bottles to determine the thickness required, while keeping the weight of the bottle to a minimum (Food Technology and Manufacturing, 2001).

The AFGC survey of 2001 showed that 67% of food and grocery companies have focused their packaging waste reduction efforts on lightweighting. As the case studies below illustrate, lightweighting can reduce material, storage, transport and energy costs. The survey also showed that two-thirds of food and grocery companies planned to change their packaging material in the future.

Examples of lightweighting include:

- reducing the thickness of packing materials
- using lighter materials (e.g. replacing steel drums with lightweight reusable, long-lasting and chemical-resistant plastic drums or containers)
- replacing cardboard boxes and trays with shrink-wrap
- optimising structural shape (e.g. by altering the dimensions of a box it is often possible to reduce the amount of material required without reducing its volume)
- lightweighting one-trip pallets with a high recycled material content for air freight.

Case studies

Material, freight and storage cost reductions from replacement of tubs with lightweight VPP bags: fresh salad processor, Australia
Mrs Crocket's Kitchen in New South Wales and Queensland replaced 95 g plastic tubs with lids for packing salads with 14 g cryovac VPP (vertical pouch packaging) packs. The new bags use 80% less material than the conventional tub. The bags have boosted the quality and shelf life of the salads, and are leak resistant and user friendly. The new cryovac bags have improved the company's freight and storage effectiveness by 30%. A pallet can now hold 19 200 VPP packs instead of 1200 empty tubs and lids. In other words, for every 10 pallets of VVP film delivered there are 150 fewer pallets of tubs and lids. The tubs could also utilise only 70% of the available space in a carton.[1]

Energy savings from lightweighting cardboard boxes: meat processor, Australia
Meat stored in lighter weight E-flute cardboard (1.5 mm) will freeze in around 15–20% less time than the thicker B-flute (3 mm) cardboard.[2]

Lightweighting of wrap film: tea processor, Australia
Nerada in Queensland reduced the thickness of the poly overwrap film that covers its packets from 30 μm to 25 μm and has reduced consumption by 1259 kg annually. The company also reduced the thickness of stretch wrap used on pallets and reduced consumption by 4516 kg annually.[3]

Lightweighting of cans and jars: packaged foods processor, Australia
Heinz in Victoria and New South Wales have worked with suppliers to reduce their tinplate thickness for steel cans by 20% and the glass weight for baby food jars and sauce bottles by 20% over the past 10–15 years. They have also reduced cardboard weight for corrugated outer cartons by 80%.[3]

Redesign of cardboard box: frozen food processor, Australia
McCain Foods in Victoria redesigned the cardboard box for their 'Dinner Bowl' to a wrap-around sleeve to achieve a 47% weight reduction in cardboard per product.[5]

Redesign of pail: dairy processor, Australia
Attiki Holdings in New South Wales were able to reshape a 2 kg pail used for yoghurt and cheese products and achieved a 70 g reduction in weight.[6]

1 *Food and Pack*, December 2002
2 MLA 1996, 1997
3 Nerada Tea Pty Ltd 2003
4 Heinz Wattie's Australasia 2003
5 McCains Foods (Aust) Pty Ltd 2003
6 Attiki Dairy Products 2003

5.3.2 Reducing the use of adhesives

Adhesives are used to fasten and seal packaging. Reducing the use of adhesives not only reduces packaging costs but also often makes recycling easier. The use of adhesives can be reduced by:

- optimising the width of tape
- using kraft paper tape rather than plastic tape to help the recycling process
- improving box rigidity
- spot gluing to reduce usage
- considering PET strapping, especially for boxes with detachable lids.

Case study

Spot gluing: tea processor, Australia
Nerada in Queensland changed the glue mechanism on their machines to a spot sealing system and have reduced their glue usage by 1200 kg annually.[1]

[1] Nerada Tea Pty Ltd 2003

5.3.3 Optimising packing operations

Packing lines are frequently made up of a number of different machines such as sorters and washers, fillers, cappers, labellers and packers, which are connected together by manual handling processes or more often by conveyor lines. The poor design and operation of packing lines results in the waste of product and packing materials. It also reduces production efficiency.

Packing line efficiencies can be improved by identifying bottlenecks and ensuring these operate at the highest possible efficiency. The operating speed of equipment upstream and downstream of the bottleneck should be adjusted accordingly. Packing line efficiencies

Avoid unnecessary waste of packing material and product by improving packing line operations and optimising packaging design.

can be analysed by creating a series of graphs called V-graphs, as explained in the Envirowise publication 'Packing line savings in the food and drink industry, GG157 www.envirowise.gov.uk.

Case study

Training to improve packing efficiency: confectionary processor, Australia
Bellis Fruit Bars in Western Australia reduced packaging waste by 2.6% by training leading hands to supervise the operation of a wrapping machine.[1]

[1] Bellis Fruit Bars Pty Ltd 2003

5.3.4 Efficient receiving, handling and storage

Improving the receiving, handling and storage of packaging goods is an effective and simple way to reduce waste. Examples of efficiency include:

- checking for damaged packaging materials when they are delivered to the plant and discussing any recurring problems with the supplier
- timing deliveries so that the material is stored for a minimal amount of time to avoid waste from damage and ageing
- storing material carefully to reduce damage (e.g. avoiding storing cardboard in damp areas)
- minimising orders for packaging to fit with marketing requirements.

5.3.5 Complementary packaging design

Primary packaging should be designed to maximise its fit into the secondary packaging. Secondary packaging should then be designed to maximise its fit into tertiary packing (e.g. to fit on a standard pallet).

Packaging design that achieves maximum space efficiency will reduce the costs of materials, handling and transport.

Case studies

Optimising primary and secondary packaging: honey processor, Australia
Capilano Honey in Queensland introduced square PET and pail packs in 1999 to improve carton utilisation. The company previously packed round glass jars.[1]

Maximising space efficiency reduces handling and transport costs: bakery, Australia
George Weston Foods improved their carton utilisation and pallet configuration and reduced their carton use by 20%. The improvement in space efficiency resulted in an annual reduction of 4500 pallets and 100 truck movements.[2]

[1] Capilano Honey Limited 2003
[2] George Weston Foods Limited 2003

5.3.6 Reducing waste from conversion processes

Conversion machines produce formed packaging and ready-for-product packing from unformed packaging materials. Select conversion machines with feed stocks that minimise trimmings waste.

For example, about 18–20% of the plastic bag material used in conventional vacuum packing processes is lost as offcut waste. The trimmings result from using plastic that is supplied as individual pre-cut bag, which are trimmed to size during forming. Machines are now available that use rolls of plastic tubing and produce the bag size required. This means that, instead of keeping 30–40 different bag sizes in stock, only four or five different roll widths are required. Overall cost reductions are in the order of 25–30% and the capital cost is around $50 000 per machine installed (MLA 1996).

Eco-efficiency action

- Lightweight by altering the types and grades of materials used in the packaging.
- Lightweight by optimising packaging design (e.g. shape and size).
- Reduce the use of adhesives (e.g. reduce glue consumption or tape width).
- Use recyclable and recycled adhesives (e.g. kraft paper tape, PET strapping).
- Monitor causes of damage to packaging and discuss recurring problems with supplier.
- Time deliveries so that materials are stored for a minimal amount of time to avoid waste from damage and ageing.
- Store packaging carefully to avoid damage.
- Seek commitment from suppliers to waste reduction.
- Design primary, secondary and tertiary packaging to achieve maximum space efficiency and reduce transport costs.
- Reduce waste from conversion processes.
- Check how your packing operations can be optimised. Refer to the Envirowise publication ‘Packing line savings in the food and drink industry’ GG157.

5.4 Reusing packaging

The next step, if it is not possible to further reduce or avoid some aspects of a plant's packaging, is to consider whether it can be reused. Find out how much packaging your plant reuses and how much is sent to landfill. Approximately 28% of companies use refillable or reusable packaging for their products, which is an indication that there is large scope for companies to improve in this area (AFGC 2001).

5.4.1 Reuse of packaging by suppliers

Returning packaging to suppliers reduces material, disposal and storage costs. Discuss with your suppliers the opportunities and advantages to both parties of reusing packaging. This is particularly applicable where back haulage allows packaging to be easily returned for reuse. Examples of packaging that could be returned to suppliers for reuse include:

- pallets
- drums
- IBCs (intermediate bulk containers)
- plastic containers and crates
- cardboard boxes
- wooden holding crates
- padding, such as separators and inflatable air bags
- bulka bags.

Reusing packaging can drastically reduce overall costs, as Table 5.2 below shows.

Table 5.2: Lifetime comparison of one-way and reusable 0.6 m^3 shipping containers by material

Type of container	Weight (kg)	Initial cost (A$)	Estimated life (no. of trips)	Average cost per trip (A$)
Corrugated one-way	0.7	0.80	1	0.80
Corrugated reusable	1	1.62	5	0.32
Plastic reusable	2.5	16.82	250	0.07

Source: Buckorn Inc. 1991

Case studies

Return of bins to supplier: pre-prepared foods processor, Australia
Eurest in Queensland produces soups, sauces and pre-prepared style foods. The company's fresh minced meat is now supplied in plastic bags in large returnable bins, thereby totally removing cardboard from the waste stream.[1]

Reusable crates: vegetable processor, Australia
Harvest FreshCuts in Queensland already have their fresh produce supplied in returnable crates, which are collected for reuse by the supplier. By replacing cardboard boxes for its own supply of products to retailers the company could potentially save a further $110 000 annually. Capital costs include a crate washer for $70 000. The payback period is 1–2 years.[2]

1 Eurest Australia 2003
2 UNEP Working Group for Cleaner Production 2002b

5.4.2 Reuse of packaging by the plant

The reuse of packaging such as containers, drums, boxes and pallets to store or transfer materials around the plant can be cost-efficient. Check the number of times packaging is reused around the plant before it is recycled or disposed of and look for opportunities to improve the frequency of this reuse. Consider whether the packaging from suppliers could also be used to meet the plant's own needs.

Case study

Reuse of incoming packaging for secondary packaging: bakery, Australia
George Weston Foods in Victoria uses incoming cardboard packaging to provide padding on top of the pallets used to hold or store breadcrumb products. By reusing the cardboard $9000 in waste costs is saved annually by the company.

1 George Weston Foods Limited 2003

5.4.3 Reuse of packaging by other businesses, customers or community groups

One man's waste is another man's treasure.

Other businesses, customers or community groups may have a use for your plant's packaging waste, so investigate the reuse of packaging beyond your plant and its suppliers. Advertise in the local area to determine the viability of another business removing or purchasing your businesses waste. Also consider using the packaging waste of another business in your plant.

Case study

Reuse of packaging waste by other businesses: cheese processor, Australia
Jaycroix Cheese in New South Wales provides 50% of its small clean cartons to local businesses for reuse.[1]

1 Jaycroix Cheese Pty Ltd 2003

5.4.4 Design to encourage packaging reuse

Multiple-use packaging should be designed to promote the maximum amount of reuse. For example, reusable packaging should be designed so that it is easy to clean, with no inaccessible dead spaces. Liners can also be used to encourage easier cleaning; and they are usually cheaper to dispose of than the container or drum itself. Reusable packaging should also be long-lasting, to extend its life expectancy; for example, crates could be reinforced with plastic or steel corners and edging.

5.4.5 Avoiding damage to promote reuse

The number of times packaging can be reused will be increased by careful handling and storage to avoid damage. Ways this can be achieved include following correct handling procedures, such as lifting drums by the base or centre rather than by the top rim. Equipment that is used to handle packaging, such as pallets and cardboard boxes, should be equipped to minimise damage (e.g. plates or rubber-tipped tines).

Ensure the equipment used by your plant to handle packaging is equipped to minimise damage.

Eco-efficiency action

- Return packaging to suppliers for reuse (e.g. pallets, drums, IBCs, plastic containers and crates, cardboard boxes, wooden crates and padding).
- Reuse packaging around the plant to store or transfer materials.
- Investigate options for other businesses, customers or community groups that could reuse packaging waste.
- Check the viability of advertising your plant's packaging waste or utilising another plant's packaging waste.
- Ensure reusable packaging is designed to be simple and easy to clean.
- Ensure reusable packaging is designed to be long-lasting (e.g. reinforced corners and edging).
- Follow correct handling procedures to avoid damaging packaging.
- Ensure that handling equipment is equipped to minimise damage.

5.5 Recycling packaging

Recycling enables waste products to be reprocessed for further use. Recycling conserves valuable resources and reduces landfill. In 2001, 77% of companies were using recycled and recyclable packaging compared with 17% in 1993 (AFGC 2001).

5.5.1 Separating recyclable waste

Successful recycling depends on separating recyclables from mixed waste streams to avoid contamination. A system needs to be established for segregating the plant's recyclable packaging waste. The system must be clearly signed and all staff must be trained to dispose of packaging waste correctly. For large volumes of waste it is worth considering hiring or purchasing a compactor to maximise storage space.

Packaging waste that can be recycled includes:

- **Glass containers and bottles:** Each year Australians recycle 360 000 tonnes of glass (Waste Wise WA 2000). New glass can be made with up to 100% cullet (crushed recycled glass). In Australia the average amount of cullet in glass is 45% (Waste Wise WA 2000). Each tonne of cullet saves 1.1 tonnes of raw material, so energy savings depend on the percentage of cullet. For example, 20% energy savings are possible from new glass composed of 80% recycled glass and 20% raw material, compared to new glass with no recycled glass content (Lauzon and Wood 1995).
- **Steel cans, bottle tops and jar lids:** Currently 42% of steel cans are recycled in Australia (BHP 2003). Recycling one tonne of steel saves 1.5 tonnes of iron ore and 0.5 tonnes of coke and uses only 40% of the water that would otherwise have been used to produce new steel (Lauzon and Wood 1995). Making steel from recycled steel can also saves energy, with recycled steel using only a quarter of the energy that it takes to make steel from raw materials (EcoRecycle VIC 1999).
- **Aluminium cans and foil:** In 2001, 69% of the aluminium cans produced were collected for recycling (Aluminium Can Group 2002). Making aluminium cans from recycled aluminium uses only 5% of the energy that it takes to make them from raw materials (EcoRecycle VIC 1998). Because of the recyclability and high value of aluminium, the industry has been able to introduce a very successful refund incentive scheme. In 2001, the community received $36.4 million through the collection of aluminium cans.
- **Paper and cardboard:** In 1999–2000, Australians used almost 1.5 million tonnes of packaging paper, from which over one million tonnes was recovered for recycling (EcoRecycle VIC 2003). Paper recycling uses 99% less water than producing white paper from wood chips. There are many grades of recycled paper and board. Fibres in the paper and board degrade during processing and become shorter. The shorter the fibre the less they are able to bond together, and this limits the number of times the paper can be recycled.

- **Aseptic and gable top carton:** In Australia, approximately 120 million milk and juice cartons are recycled annually into high-quality office paper (Waste Wise WA 2000). These cartons consist of paper board between layers of plastic. Aseptic cartons (e.g. long-life cartons or UHT cartons) also contain additional layers of plastic and foil. The Association of Liquidpaperboard Carton Manufacturers states that five sheets of office paper can be made from one recycled milk carton (ALCM 2003).

- **Plastics:** There is such a wide variety of plastics currently on the market that a code system has been developed to help overcome sorting difficulties. Once sorted, the plastics are shredded, chopped or ground. The material is then washed to remove contaminants, and dried. The plastic is finally made into pellets or a powder and used by reprocessors to produce a variety of innovative products. For example, it takes about 25 recycled soft drink bottles to make one fleece jacket.

  Table 5.3 below shows the seven codes for sorting plastics and some uses for recycled plastics. Currently, it is only economically viable to recycle plastics with code numbers 1, 2 and 3 for the domestic market.

Table 5.3: Plastic codes and some uses for recycled plastics

Plastic code	Name of plastic	Some uses of virgin plastic	Some uses for plastic made from recycled waste plastic
1 PETE	Polyethylene terephthalate PET (clear and tough)	soft drink and mineral water bottles	soft drink bottles (multi- and monolayer), detergent bottles, clear film for packaging, carpet fibres, fleecy jackets
2 HDPE	High density polyethylene HDPE (common, white or coloured)	freezer bags, milk and cream bottles and milk crates	compost bins, detergent bottles, crates, mobile rubbish bins, agricultural pipes, pallets
3 V	Unplasticised polyvinyl chloride UPVC (hard, rigid, may be clear)	clear cordial and juice bottles and blister packs	detergent bottles, tiles, plumbing, pipe fitting
	Plasticised polyvinyl chloride PPVC (flexible, clear and elastic)	bags and tubing	hoses inner core, industrial flooring
4 LDPE	Low density polyethylene LDPE (Soft and flexible)	Lids of ice-cream containers	film for builders, industry packaging and plant nurseries, bags
5 PP	Polypropylene PP (Hard but flexible)	potato crisp bags, ice-cream containers, drinking straws	compost bins
6 PS	Polystyrene PS (Rigid, brittle, clear (glassy)	yoghurt containers	clothes pegs, coat hangers, office accessories, spools, rulers, video/CD boxes
	Expandable polystyrene EPS (foamed, light, thermal insulation)	meat trays, takeaway containers	
7 OTHER	Others e.g. acrylic and nylon		

Source: EcoRecycle Victoria 2003

Recycling glass reduces your plant's landfill costs while also saving valuable raw material and energy.

Case studies

Colour-coded bin system: frozen food processor, Australia
McCain Foods in Victoria introduced a colour-coded bin system and diverted 65% of waste material from landfill. The system of six bins included three for recyclable packaging waste — blue for cardboard and paper, purple for plastic film and strapping, and black for steel cans.[1]

Recycling of polystyrene boxes: vegetable processor, Australia
Harvest FreshCuts in Queensland recycles polystyrene boxes, saving $1500 a year in land disposal costs.[2]

Recycling of PET bottles: soft drink processor, Australia
Coca Cola Amatil established its own PET recycling plant in Australia to recycle used clear PET bottles back into new ones. The plant can produce bottles with up to 35% recycled content. The plant has also been upgraded recently to recycle coloured PET bottles to produce an industrial fibre-grade resin for industrial textiles such as road bases.[3]

Recycling of trimmings: dairy processor, Australia
National Food's HDPE offcuts from on-site bottle manufacture are reground and returned to the site's feedstock stream.[4]

[1] McCains Foods (Aust) Pty Ltd 2003
[2] UNEP Working Group for Cleaner Production 2002b.
[3] Coca Cola Amatil Ltd 2003
[4] National Foods Ltd 2003

5.5.2 Maximising the ability to recycle packaging materials

To ensure the maximum recycling rates of your plant's packaging it is important to understand factors that have negative impacts on the recycling process. Discuss with your suppliers and recyclers how your packaging could be improved to maximise its recyclability. For example, try to avoid packaging that necessitates a number of different materials. If composite packaging is necessary, design the package so that the individual components can be separated for recycling. Also select packaging components that do not interfere with the recycling process (e.g. labels, inks and colourings, adhesives, seals, handles, inserts, liners, laminates and closures).

Case study

Improving the recyclability of packaging: honey processor, Australia

In an effort to maximise recycling rates of their packaging Capilano Honey in Queensland are working with suppliers such as Amcor, LeMac and Visy to improve on:

- suitability of metal closures for recycling
- suitability of safety seals for recycling
- effect of ink coding information on the recyclability of jars and bottles
- effects of self-adhesives and wet label types on the recyclability of jars and bottles.

The company is also investigating the effect of hot melt glue, tape and printed carton stickers on the recyclability of secondary packaging.[1]

[1] Capilano Honey Limited 2003

5.5.3 Purchasing policy

Review your packaging and raw material suppliers' willingness to align with your company's commitment to reduce packaging waste. The AFGC survey of 2001 indicated that 26% of companies stipulate minimum environmental standards from packing suppliers. Only 9% require suppliers to be signatories of the National Packaging Covenant.

Your company's purchasing policy will dictate the criteria by which materials and products are purchased. Incorporating the requirements to purchase packaging made from recyclable material or material/products that can be recycled will help conserve valuable resources and create secondary markets for recycled products. It will also encourage your customers and suppliers to use and produce more recycled goods.

The Buy Recycled Business Alliance of Australia is an organisation of more than 30 businesses with a purchasing power of $30 billion. The companies aim to increase the purchase and use of products and materials with recycled content. For more information visit the organisation website on www.brba.com.au . The site contains a toolkit for buying recycled packaging materials and useful links to product directories.

Case study

Recycled content purchasing policy: soft drink processor, Australia
Coca Cola Amatil is a key driver and founding member of the Buy Recycled Business Alliance. Coca Cola Amatil's purchasing policy gives preference to purchasing products and materials made from recycled content, such as PET soft drink bottles, glass, aluminium and cardboard.[1]

[1] Coca Cola Amatil Ltd 2003

5.5.4 Increasing community awareness

Information on packaging provides opportunities for consumers to make informed purchasing choices. Information regarding the recyclability of packaging material can be displayed on packaging. This can include the recycling logo and any classification codes as shown Table 5.3.

Case studies

Recycling information on side panels: dairy processor, Australia
Dairy Farmers conducted a biodiversity and recycling awareness program by printing information on the side panels of milk cartons.[1]

Rewards for participation in recycling programs: dairy processor, Australia
Pauls collect-a-cap programs financially reward schools for participating in a recycling program, encouraging children to collect caps from milk bottles and collect the 10c a lid.[2]

[1] Dairy Farmers 2003
[2] Pauls Ltd 2003

Eco-labelling to promote consumer choice

Eco-labelling is a voluntary method of environmental performance certification that has evolved as consumers in Australia, and around the world, have become increasingly aware of the environmental impacts of the products and packaging they are purchasing. Eco-labelling is aimed at providing accurate and credible information that can help consumers differentiate those manufacturers that have attempted to reduce the impact of their products on the environment.

Ultimately eco-labelling is aimed at rewarding companies for good environmental performance. Many food manufacturers have recognised that eco-labelling can translate into a market advantage, and are seeking a recognised label that promotes their green credentials.

To be credible, eco-labels must be verified by an independent third party that sets environmental standards and has investigated the product. The Australian Environmental Labelling Association (ALEA) has recently launched the Australian Ecolabel Program, which provides an independent environmental verification and certification program in general compliance with international standard for environmental labelling ISO 14 024. It is also the Australian member of the Global Ecolabelling Network. For more information on certified products, the Australian Ecolabel Program and voluntary environmental labelling standards, visit the ALEA website at http://www.aela.org.au/homefront.htm.

5.5.5 Using biodegradable packaging

Biodegradable plastics are currently more expensive than conventional plastics. However, it is predicted that by 2005 many biodegradable plastics will be cost-competitive with conventional plastics, in both Europe and North America (Nolan ITU Pty Ltd 2002).

An example of biodegradable packaging is starch. This is a natural polymer that can be used for applications such as bread bags and overwrap. Another example is moulded pulp packaging, which is made using newspaper, kraft paper and other waste paper, and is suitable for packaging such as fruit and vegetable trays.

Eco-efficiency action

- Separate recyclable packaging material from mixed waste streams. Ensure that the system is well signed and all staff are trained to separate the waste correctly.
- Store separated recyclable packaging waste carefully to avoid degrading its quality.
- For large volumes of recyclable waste, consider hiring or purchasing a compactor to maximise storage space.
- Maximise the recyclability of the packaging material your plant uses. For example, avoid packaging that requires a number of different materials or composite materials that cannot be easily separated in the recycling process. Make sure that any packaging components such as labels, inks, adhesives, laminates and closures do not interfere with the recycling process.
- Attempt to use packaging and raw material suppliers that share your company's commitment to reduce packaging waste.
- Provide accurate information regarding the recyclability of packaging material. This should include the recycling logo and any plastic classification codes. Information on packaging also provides opportunities for consumers to make informed purchasing choices.
- Promote recycling through education and awareness programs — for example by providing information on company websites about recycling, providing financial rewards for participation in recycling programs, or providing information on recycling on the packaging itself.
- Investigate opportunities to use biodegradable packaging.

5.6 Disposing of packaging

If all waste minimisation opportunities have been exhausted and no more packaging material can be eliminated, reduced, reused or recycled, efforts should then be concentrated on the safe and correct disposal of packaging.

5.6.1 Minimising impact of disposal on the environment

Consider the impact that packaging material will have on the environment at the end of its life cycle, and investigate ways of minimising this impact. This includes considering the material's toxicity and whether this can be reduced. Modify the design of packaging to reduce or eliminate any hazards it may present to wildlife. For example, some biodegradable bags and bottle cap rings are designed so that they cannot be removed from the bottle, to prevent wildlife consuming plastics or becoming entangled.

Eco-efficiency action

- Investigate opportunities to reduce the impact that packaging material has on the environment and its wildlife.

6 Solid waste reduction and value adding

6.1 Overview of solid waste

6.1.1 The generation of solid waste

Solid wastes are the by-products from manufacturing food products. The types of solid wastes typically produced by food processors include packaging waste, organic food waste and office waste.

At a food processing plant solid waste can be generated during the production process or when raw materials and products are being transported, stored and handled.

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. Food processing companies in Australia are starting to realise the value of managing their solid waste to identify where product and revenue are being lost. Solid waste recycling rates in the food sector are high. A recent Australian Food and Grocery Council survey indicated that the average proportion of product sent as waste to landfill by food and grocery manufacturers in Australia is 4%, and the recycling and reuse of inorganic waste is around 80% (AFGC 2003). The remaining 16% consists of organic material that is further utilised for products such as compost or stock feed.

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

- treatment costs
- collection costs
- disposal costs
- loss of product costs, 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 that what 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 to reduce costs, increase revenue and avoid disposal of waste to landfill 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 while also creating more employment and competitive manufacturing industries
- improved social responsibility through food donations to welfare agencies
- improved environmental responsibility.

However, the collection of waste contributes to noise and air pollution, and landfill sites themselves can produce leachates and gases that can have adverse effects on environmental and human health.

Food waste going to landfill can also encourage vermin and the proliferation of inappropriate wildlife. The sites have large management, rehabilitation and ongoing maintenance costs.

This chapter follows the ‘waste minimisation hierarchy’ approach to identifying opportunities for reducing solid waste (see Figure 1.4 in the introductory chapter). It addresses the efficient utilisation of resources, and concludes with eco-efficiency opportunities to explore alternative uses for waste through recycling.

6.2 Reducing solid waste

6.2.1 Improving plant layout and design

Solid waste can be generated as a result of poorly designed buildings or storage conditions. Design and storage conditions can also be a problem during transitional periods when companies are outgrowing their processing plant.

Plants should be designed to have a direct and logical flow of materials and processes. It is important to consider how waste is generated when designing new factories or when relocating to a new plant, and to investigate the feasibility of modifying existing plants to reduce waste.

Case study

Reduction in fruit waste through better storage: syrups, toppings and blends processor, Australia
Food Spectrum in Queensland previously lost around 135 tonnes of fruit each year from the defrosting process. The company relocated and now places the fruit in a temperature-controlled room in 1000 L stainless steel bins. It has cut product loss by an estimated 50%.[1]

[1] UNEP Working Group for Cleaner Production 2003d

6.2.2 Supply chain management

A very effective way to reduce unnecessary waste in food processing plants is to ensure that raw materials are:

- delivered at the correct time
- delivered in the correct quantity
- not spoiled 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.

For larger companies with many movements in materials before, during and after processing, supply chain management can be complemented with a computerised materials management system.

6.2.3 Improving process design

Poorly designed processes and equipment can generate waste. It is important that waste is not accepted as normal practice and that each step in the process is designed to keep waste at an absolute minimum. A walk through the plant with a person who does not usually work in the area can often help to identify areas of waste that others may no longer notice.

Case studies

Reduction in product waste by optimising product changeover: pet food processor, Australia
Uncle Ben's in Victoria used an air-driven 'pig' to clean the line between its mixer and the filler with each product changeover. The last 5 m of the line, however, could not be pigged because of obstruction by inline magnets and the product pump. In order to clean this section of pipe the company would flush water through the pipe and dump the waste product in the filler. Any water remaining in the pipe was then pushed through by the new product, creating even more watery waste. To prevent this additional waste, the company installed dump valves near the inline magnet to allow the flush water to be dumped as the flush occurred. The initiative saves Uncle Ben's around $100 000 annually. The process modification cost $40 000, making the payback period less than 6 months.[1]

Reduction in icing waste by changing to bulk preparation and storage: bakery, USA
Supermom's Bakery in Minnesota produces donuts. By moving to bulk preparation and storage, the company was able to eliminate the need to wash 65–100 icing mixing buckets daily. The icing is now mixed once a day instead of several times a day, and is stored in three large stainless steel mixing vats. In addition to saving $2000 annually in lost icing, which was previously washed down the drain, and $40 000 annually in cleaning costs, the temperature-controlled vats also produce higher-quality icing. The payback period was one year.[2]

[1] Environment Australia 2002e

[2] Minnesota Technical Assistance Program 2003

6.2.4 Improving process operation, control and maintenance

In all processes the final product varies in quality. Wastage or the need for rework occurs when a process or final product fails to reach the plant's set specification range. Some product variation can be the result of the process design and the inputs used For example, natural variation in the sizes of bottles may result in different headspaces when they are filled. Some causes of product variation, however, are irregular and occur outside the design of the process. For example, a jammed filler head may cause part-fills, or defective fill detectors may cause over- and under-fills. In the food processing industry it is estimated that 15% of product variation results from these kinds of problems and defects (McBride 1997). A 15% improvement in process operations can result in sizable savings as well as increased productivity. These causes in product variation are usually the easiest to identify and should be fixed immediately. Good maintenance, the use of process controls, and standard operating procedures can prevent many of these problems from arising. Quality improvements to the process operation and design should move away from ad hoc repairs and towards prevention.

Case studies

Improvement in packing operations to reduce filling waste: brewery, Australia
The South Australian Brewing Company implemented standard operating procedures and evaluated all its packaging lines using statistical process control. The company found that, by regularly calibrating the filling apparatus and ensuring that all the fill detectors were working properly and not overfilling, they could save $80 000 annually in product. A further $10 000 was saved by not under-filling, and another $5000 in effluent savings. Cleaning time was reduced by $5000 annually. The company invested $50 000 in calibration services and new devices. The payback period was less than six months, and the total beer production productivity increased by 2.5%.[1]

Increased product yield and reduced waste in beverage processing: beverage processor, Australia
The Bundaberg Brewed Drinks beverage plant produces ginger pulp as a by-product during filtration of brewed concentrate. A centrifuge was being used to separate the pulp from the brewed concentrate. A new, more efficient decanter has recently been commissioned, which has increased the yield of filtrate by 9%, delivering an extra 35 000 L of product worth $39 000 annually, and producing less waste pulp. The decanter allows for finer control and it is possible to adjust the sediment level of the filtrate by turning a dial. There is also less operator intervention required for clearing filter blockages, giving an additional labour saving of $7500. The payback period for installing the decanter was less than two years.[2]

1 South Australian Environmental Protection Agency 2003b
2 UNEP Working Group for Cleaner Production 2003a

Eco-efficiency action

- Investigate improving the plant's design so there is a direct and logical flow of materials and processes to minimise waste.
- Improve storage conditions to minimise waste.
- Ensure materials are recorded on arrival in an efficient inventory system and delivered at the correct time.
- Ensure quality and quantity of materials are correct.
- Ensure materials are not spoiled in transit or damaged due to inappropriate packaging.
- Investigate the benefits of a computerised material management system.
- Investigate where waste is being generated due to poorly designed processes and equipment.
- Investigate where waste is being generated due to inefficient operating procedures, poor process control or lack of maintenance.

6.3 Reusing solid waste

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 spoiled and acceptable quality product. This is particularly so for foodstuffs, where the rigorous application of HACCP is necessary. The reuse of packaging waste within the plant is discussed in Chapter 5.

Case studies

Reuse of dough: pizza and noodles processor, Australia
Nestlé Pakenham plant in Victoria previously sold waste dough and rejected bases and noodles to a piggery. An analysis by the company revealed that on average 380 kg of dough was dumped every day. The company decided to reduce the amount of wastage by saving some of the dough for reworking the following day. After extensive quality testing, the company discovered that in fact they could keep all the leftover dough for reworking the following day — with the exception of Friday, because the dough could not be stored successfully over the weekend. Instead of dumping 1900 kg of dough per week Nestlé now dumps only 220 kg, which represents a saving of $30 000 annually.[1]

Reuse of bread waste: bakery, Australia
Tip Top Bakeries in Western Australia has reduced the amount of solid waste going to landfill by 8%. The company uses all overruns and fresh damaged stock for making breadcrumbs. Production food waste is considered to be valuable and nutritious for composting, and is thus diverted where possible to animal feed, especially for milk cows and beef cattle.[2]

1 Centre for Excellence in Cleaner Production 2002
2 Environment Australia 2003e

Investigate whether waste product can be hygienically recovered and reworked or reused by your plant.

6.3.2 Reuse of waste by other businesses

Other businesses, customers or community groups may have uses for your plant's solid waste, so investigate the reuse of waste materials beyond your plant and its suppliers. Advertise in the local area. Consider also whether your plant could use the waste from another business.

6.3.3 Foodbank donations

Donating unsaleable food waste that is still fit for human consumption to 'foodbanks' not only helps to provide a social service to the community, but also reduces the wasteful and costly disposal of usable product.

Recognised foodbanks require welfare agencies to sign legal contracts undertaking that none of the food products they receive will be sold, exchanged or bartered. This ensures that donations in no way undermine the interests of the donating businesses.

There many factors that may make a food product unsaleable yet suitable for a food donation:

- **Incorrect labelling** (e.g. wrong labels, labels not holding, changes in labelling regulations). If the incorrect labels pose a health risk (e.g. there is an ingredient that could cause an allergic reaction), the foodbank is required by law to add its own correct labels to the product.
- **Damaged packaging.** Packaging must still prevent any possible risk of food contamination and meet all food health and safety standards.
- **Incorrect packaging** (e.g. wrong weight).
- **Over-production runs.**
- **Discontinued product and end of season excess stock.**
- **Expired promotional competition.**
- **Offcuts** (e.g. smallgoods).
- **Damaged product** (e.g. fruit).
- **Production line changeover items.**
- **Items past their 'best before' date.** In an agreement with donating companies, the foodbank stipulates how long after the 'best before' date a donated product can be kept (see below).

Foodbank Queensland

Foodbank Queensland accepts donations from over 100 manufacturers to supply more than 2000 welfare agency members; these in turn distribute cooked meals and parcels to over 15 000 Queenslanders each week (Foodbank Queensland 2003). In its first five years Foodbank Queensland has distributed more than 3 million kg of food.

The foodbank will collect both irregular and regular donations of fresh, frozen, canned and packet foods fit for human consumption. Foodbank Queensland currently collects food donations throughout South-East Queensland. A receipt for the value of the food is given to all donating businesses, as the donations are tax deductible. The donor pays a small fee for each consignment, but this is considerably less than disposal costs would be, and is also tax deductible.

Donations may be accepted if the 'best before' date is only an indication of the manufacturer's quality standards and the item is still fit for human consumption. The food must also have been stored in compliance with the relevant codes of practice. Such items are mostly dry foods such as canned items.

To make a donation, or for information, contact the Foodbank Queensland hotline on (07) 3395 8422 or visit their website on www.foodbankaustralia.org.au/queensland (Foodbank Queensland 2003; Schneider 1999).

Case study

Reduction in waste by donations to the foodbank: fruit and vegetable processor, Australia
Golden Circle in Queensland donates canned food and beverages to the foodbank and saves $4000 in waste costs annually, while also providing a valuable service to the community.[1]

[1] UNEP Working Group for Cleaner Production 2003f

6.3.4 Animal feed

Some food processing waste that is high in nutrients and roughage can be fed directly to animals without further processing. Food processing by-products can provide livestock with roughage (e.g. corn cobs and husks), energy (e.g. treated cooking oils and rendered animal fats) and protein (e.g. brewers' grain). The disposal of food waste through animal feeding is common in the vegetable, bread-making and dairy processing sectors. Transport costs are possibly the biggest expense associated with this means of disposal.

The feeding of food processing waste that contains animal matter (meat, meat products or imported dairy products), or vegetable matter that has been contaminated by animal matter, poses a serious risk of introducing serious diseases such as bovine spongiform encephalopathy (BSE). The BSE-free status of Australian meat products ensures Australia's continued access to domestic and international markets.

Case studies

Green waste for pig farm: fresh salad processor, Australia
A fresh salad processor in Queensland generates around 30 tonnes of green vegetable waste per week. The waste is transported to a storage bin, which is then collected by a dairy farmer. The company saves $52 000 annually in avoided landfill costs.[1]

Fruit and vegetable waste for cattle feed: fruit and vegetable processor, Australia
Golden Circle in Queensland generates around 4000 tonnes of fruit and vegetable waste annually. The waste is distributed to dairy farmers, saving the company $840 000 annually in composting costs.[2]

[1] UNEP Working Group for Cleaner Production 2003n
[2] UNEP Working Group for Cleaner Production 2003h

Feeding waste food product to animals reduces your plant's landfill costs while providing a nutritious food supplement for primary producers.

6.3.5 Solid waste as a potential fuel source

Solid waste from food processing plants can be used as a substitute for fossil fuels. This includes direct combustion of organic food waste such as nutshells, and the generation of biofuels. Wastes that are high in moisture content may be of limited value in energy extraction unless subjected to specialised preparatory processes such as pyrolysis, gasification or anaerobic digestion. The use of solid waste as a potential fuel source is discussed further in Chapter 4.

Eco-efficiency action

- Attempt to reuse organic and packaging waste within the plant. The rigorous application of HACCP principles can help obviate risks of cross-contaminating foodstuffs.
- Advertise in the local area for businesses that may be able to use or purchase your waste as a raw material.
- Search for waste materials that your plant may be able to utilise from other businesses in the local area.
- Investigate opportunities to donate to the foodbank, to reduce landfill costs while providing a valuable social service to the community.
- If your food waste is high in nutrients, roughage or energy consider whether it would make a viable animal feed. This opportunity is subject to national and state animal production, export and health legislation.
- Investigate the recovery of energy from solid waste by direct combustion or conversion to a biofuel.

6.4 Product recovery and value adding

6.4.1 Product recovery during processing

Recovering product by process modification can result in considerable savings in product, as well as a reduction in the volume of solid waste and associated disposal costs.

Case studies

Recovery of extract by process modification: brewery, Australia
The South Australian Brewing Company previously removed unwanted solids after the extract boiling stage. The trub (consisting of removed solid and a high percentage of valuable extract) was then sent offsite as animal feed. The company now removes the extract from the trub and returns it to an earlier production process, saving around $40 000 in raw materials. The process modification cost $43 000, making the payback period 1.1 years.[1]

Recovery of juice: fruit processor, Australia
The Banksia Food Company in Sydney previously discharged excess juice extracted in the steam blanching process to drain. The company is now concentrating the excess juice, together with peelings and cores, for use as a sugar supplement in sauces and jams. The new product is now bringing in returns of between $6000 and $10 000 annually.[2]

[1] South Australian Environmental Protection Authority 2003b
[2] Environment Australia 1988

6.4.2 Extraction of valuable products

Organic by-products can contain useful ingredients such as proteins, vitamins, carbohydrates, fats, lipids, colouring, chitin, oils, flavours and antioxidants. Valuable resources can be produced, provided their extraction is cost-effective. Manufacturing industries that utilise products extracted from food waste by-products include other food processors, livestock and fish feed processors, pet food manufacturers, renderers, and many cosmetic and biomedical manufacturers. Table 6.1 gives examples of products that can be extracted from food processing by-products and their usefulness for other manufacturing industries.

Table 6.1: Examples of products that can be extracted from food by-products

By-product	Extracted products and their application
Egg shell	Collagen — for cosmetics and biomedical products Gelatin — food and confectionery constituent, ice cream texturiser Sialic acid — precursor for many anti-inflammatory drugs
Cheese whey	Edible protein Lactose sugar — baking, infant formula and pharmaceuticals
Slaughterhouse waste (rendering)	Edible fats — baking and jellies, animal feed, pet food, pharmaceuticals, cosmetics Protein — animal feed and fertiliser Gelatin — edible food, coatings on tablets, cosmetics, glue, bone china and photographic materials
Fish and seafood processing waste	Protein — pet food, animal meal and fertilisers Chitin/chitosan — biomedical, clarifying agent for fruit juice and wine, cosmetics, water treatment and coatings for biomedical intrusive devices e.g. prawn shells Oils Lipids Antioxidants Flavours — e.g. crab and prawn waste Pigment — e.g. red colour from crab waste
Rice hulls	Silica from hulls — insulator during steel manufacturing
Fruit and vegetable waste	Oils — cosmetics, confectionery and pharmaceuticals e.g. apple and kiwi seed oil for cosmetics, grape seed oil for low cholesterol frying oil e.g. d-limonene from citrus peel can be used for cleaning action Flavours — e.g. onion, watermelon and peach waste Lycopene — cancer-inhibiting compound e.g. tomato skins Starch/glucose — e.g. potato waste Colouring — e.g. blueberry waste Pectin — e.g. mango and citrus peels

Source: UNEP Working Group for Cleaner Production 2004

Case studies

Extraction of protein, sugar and d-limonene from citrus peel: orange juice processor, Australia
The Original Juice Company in Victoria recovers several saleable products from its orange peel waste. The investment in product recovery equipment has reduced disposal costs for the company from $40 000 a month to a mere $3000 a month.

Pressed orange peel is sold for cattle feed, along with juice from the peel which is converted into molasses. A citrus oil recovery system produces d-limonene, a natural petrochemical-free agent used for household cleaning. The company is now generating over $250 000 each year from the sale of recovered products.[1]

Extraction of protein from fish waste: tuna processor, Australia
Fortuna in Queensland processes fresh broad bill and tuna fish into high-quality loin and steak pieces for the domestic and export market. The company disposes of all its fish waste at no cost or for a small profit. The fish waste is utilised by a protein extraction business to produce cattle feed and by organic farmers for use as a fertiliser. All fish waste is removed off the site nightly. Before exploring more efficient waste utilisation opportunities the business was paying a disposal company to remove a 3 m^3 bin of waste from the site daily for disposal at landfill. This practice for disposal of fish waste has now been extended to all the fish receivers/processors in the local area.[2]

Development of pharmaceutical product from ginger pulp, Beverage processor, Australia
The Bundaberg Brewed Drinks beverage processing plant produces around 1600 kg per week of waste ginger pulp, which was previously being sent to landfill. Trials are under way with a pharmaceutical company to produce a new ginger-based product. If this is successful, Bundaberg Brewed Drinks will save around $520 per year in avoided landfill costs and receive revenue of around $1600 per year for the ginger pulp.[3]

[1] Food Victoria 1996, 1998
[2] UNEP Working Group for Cleaner Production 2001b
[3] UNEP Working Group for Cleaner Production 2003a

Eco-efficiency action

- Investigate whether product can be recovered during plant processing to reduce waste and the loss of valuable product.
- Investigate opportunities to extract valuable ingredients from your plant's by-products to reduce waste and generate additional revenue.

6.5 Recycling

Recycling is the reprocessing of a waste to produce a different product. A recent survey by the AFGC indicated that 81% of food and grocery companies operate in-house segregation of products for recycling (AFGC 2001). Table 6.2 shows the types and typical percentages of plant and office waste that are recycled by food companies. The table suggests there are still opportunities in the food industry for increased recycling rates and reduced costs. The types of packaging material that can be recycled are discussed in Chapter 5.

Table 6.2: 'In-house' recycling rates for food and grocery companies in 2001

Plant waste (post industrial)	Proportion of waste recycled
Paper/board packaging	72%
Plastic packaging	49%
Metal packaging	44%
Food wastes	35%
Other	9%
Office waste (post-consumer)	**Proportion of waste recycled**
Paper	77%
Cardboard	63%
Plastic containers	37%
Metal containers	37%
Glass	23%
Organics	7%
Other	0%

Source: AFGC 2001

Clearly label recycling bins and try to locate them near to the site where the waste is being generated. Train and motivate staff to recycle, and regularly monitor how the bins are being used.

6.5.1 Establishing a solid waste recycling system

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 they, and any new staff, are adequately trained on how to implement the system. If the system is not working effectively, give staff refresher training on the coding system.
4. Monitor how well the system is working. Keep records on 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 the economic and environmental benefits.

Recyclable materials include aluminium cans, foil and trays, cardboard boxes (plain and wax-coated), cooking oils, bottle corks, plastic and metal drums, whitegoods, glass, meat offcuts (blood & bone, feathers etc.), oil and oil filters, organic food waste, refrigerants, wooden pallets, high-grade paper, steel cans, toner cartridges, computers, paper and plastics including pallet wrap, bags, strapping and bottles.

Case studies

Recycling of solid waste: confectionery processor, Australia
Cadbury Schweppes in Victoria increased their solid waste recycling from 5% to 50% and now save $80 000 annually. The company also optimised its material use, handling and process parameters to improve weight control and reduce wastage, and saved a further $185 000 annually.[1]

Recycling of solid waste: fruit processor, Australia
Banksia Food Products in Sydney processes and packs apples for baking and catering. Previously all packaging waste was removed with general waste, at an annual cost of $3000–$4000. The company now bales its cardboard and other waste packaging and has it removed free of charge for recycling.[2]

[1] Environment Australia 1999b
[2] Environment Australia 1988

6.5.2 Development of new products

Creating a market for a new product made from a by-product can change a solid waste problem into a valuable source of revenue and employment.

Case studies

Timber products from waste rice husks: RMIT, Australia
The RMIT University in Melbourne has produced a material from waste rice husks, thermoplastic polymer resins and nylon carpet offcuts that promises to replace timber in roadside posts, building panels, and spacers for shipping steel around the world. The Huski-I-Bond blocks are stronger, cheaper and more friction-resistant than wood, making them suitable for dunnage blocks. The material is also resistant to rot, fungus and termites, making it excellent for roadside posts. The panels are flexible but have a remarkable load-bearing capacity, which could make them particularly good in earthquake-prone areas. Not only could such technology help to utilise over 100 million tonnes of rice hull waste annually worldwide, but it could also reduce pressure on a depleting natural resource.[1]

PET bottles into clothing: beverage processors, Australia
In Australia around 6000 tonnes of recovered PET is exported overseas, where it is made into polyester for clothing and lingerie production. Australia also uses around 13 000 tonnes of recovered resin made from PET bottles locally recycled by Coca Cola.[2]

1 RMIT 2003
2 Planet Ark 2003

6.5.3 Composting

Composting utilises oxygen, water and bacteria to decompose organic matter into a soil additive. The final product of composting is microbiologically stable and less odorous, as the heat generated in the process kills harmful pathogens. Fruit and vegetable processing wastes are particularly suited to composting. Meat, dairy, oil, grease and fat processing waste is difficult to compost and, because of its high nutrient value, is probably more suited for use in livestock feed. For many food processing companies, the cost and space required to produce compost onsite is more than the revenue to be gained. Transporting organic waste to offsite large-scale facilities for composting may be a good alternative to landfill if transport costs are viable.

6.5.4 Vermicomposting

Vermicomposting is a sustainable method of recycling waste that produces a valuable end product. The process involves turning organic material into worm castings (vermicast). The advantage of vermicomposting over conventional composting is that it produces a product with a higher concentration of nutrients, which is thus more valuable. Vermicomposting typically supplies a variety of compost and soil blends to landscape contractors and horticultural retailers.

Waste produced by seafood processors, canning processors, biscuit processors, bread makers and vegetable and fruit processors have all been used by the vermicomposting industry (A & A Worm Farm Systems 2003). Paunch waste (the gut contents from slaughtered animals) is a particularly good feed source for earthworms, as it is often high in odour, water and coarse-quality forage. Other food processing waste may be suitable for worm farming, but it frequently needs to be mulched and mixed with other wastes to reduce its acidity and to produce a uniform feed stock (Dynes 2003).

Transporting food processing waste to nearby commercially operated vermicomposting companies may be a cost-effective alternative to landfill.

Case study

Organic waste sent to worm farm: supermarket chain, Australia
A Coles supermarket in Queensland has managed to reduce its landfill costs from \$37.50/m^3 to \$6.95/m^3 by eliminating its organic matter content. The organic waste is generated in the supermarket's fresh food section, which consists of a fruit and vegetable unit, bakery, deli and meat unit. A total of 600 tonnes of organic food waste per month, from many participating supermarkets, is separated into 240 L wheelie bins and delivered to a nearby worm farm. The organic waste is converted to fertiliser, potting mix and soil conditioner, which is then packaged at the plant and sold to customers back at the supermarket.

UNEP Working Group for Cleaner Production 2001

6.5.5 Direct landspreading

In some cases food processing waste can be applied directly to the soil. 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. Food processing wastes suitable for landspreading are usually not odorous, do not contain harmful pathogens and decompose readily. Refer to the Queensland Environmental Protection Agency, Environmental Operations Division, for landspreading guidelines.

6.5.6 Biosolids

Biosolids are the part of the waste stream containing solids after wastewater treatment. They can be rich in nitrogen, phosphorus, potassium and other macronutrients and can be useful as a soil amendment. In addition the high organic matter content of biosolids can make them useful for soil stabilisation. Biosolids contain 1–10% solids. Depending on the method of use, dewatered solids have a water content ranging between 10% and 80% (Tasmanian Department of Primary Industry, Water & Environment 2003). The biosolids can be dried using a range of artificial drying technology or in drying beds.

Biosolids are used widely in the United States and Europe; and New South Wales and Western Australia currently use around 80 000 tonnes of biosolids on cereal crops such as wheat, oats, canola and barley (Long 2001).

Land injection for crop and pasture production

Liquid biosolids can be transported by tanker to an application site and then injected 15–20 cm into the soil. Soil injection is currently not allowed in Queensland because, if misused, biosolids could pose a health risk and might leach into surface and groundwater supplies.

Case study

Soil injection of wastewater for pasture production: Australia
Bio-Recycle in New South Wales is a privately owned company that injects food processing and treated grease trap wastewater with a solid content less than 10% into the rooting subsoil for pasture and crop production.[1]

[1] Bio-Recycle Australia 2003

Landspreading and fertiliser production

Biosolids that have been dewatered or dried can be used directly for landspreading using a conventional manure spreader (Western Australia Water Corporation 2003). Biosolids can also be processed into a granulated product that can be applied as a fertiliser. The main nutritional value of biosolids is their high nitrogen and phosphorus content; however, they do not always provide a balanced additive, and additional materials may need to be added. Application rates are limited by nutrient requirements.

Case study

Biosolids for agricultural land or compost: water corporation, Australia
The Western Australia Water Corporation produced 75 000 tonnes of dried anaerobically digested biosolids cake in 2001–02. The biosolids cake can be applied directly to agricultural land. The cake has also been used on pine stands to shorten pulpwood and lumber production cycles, particularly on marginally productive soils such as sands in WA. The corporation also produced 4800 tonnes of biosolids pellets and 1500 tonnes of lime-amended biosolids that can be used as a soil additive to increase low pH in soils. Another more processed form of biosolids is produced under contract by a composting and landscaping company; this is suitable for use in domestic gardens as well as public parks and gardens.[1]

[1] Western Australia Water Corporation 2003

Eco-efficiency action

- Establish an effective recycling system. Clearly label or colour-code and locate bins near the site where waste is being generated.
- Train staff on how to implement the recycling system and monitor how the system is working.

- Keep staff motivated and informed about their recycling efforts.
- Investigate the possibility of creating a new product and market for your solid waste.
- Consider sending your organic waste to a worm farm.
- Consider landspreading as an alternative to landfill for your organic waste.
- Investigate the possibility of offsite composting as an alternative to landfill.
- Consider the viability of dewatering your biosolids for land spreading or fertiliser production.
- Investigate opportunities to recycle biosolids for use as a soil conditioner through soil injection.

7 Chemicals

7.1 Overview of chemical use

The food processing industry uses substantial quantities and varieties of chemicals to:

- clean and sanitise food products and their packaging
- clean and sanitise plant and equipment
- treat water for washing, cleaning, sanitising and processing
- treat boiler or cooling water.

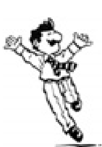
Water treatment, cleaning and sanitation in food processing plants are essential factors in ensuring that food products do not become contaminated. The degree to which a plant treats its water, cleans and sanitises is largely determined by food safety requirements, quality specifications and market expectations. Reducing chemical use *without* compromising processing or strict food safety standards can result in substantial savings, while also improving the firm's environmental performance. Some eco-efficiency initiatives that can be explored to help optimise the use of chemicals are discussed in this chapter.

7.1.1 True cost of chemicals

Like other costs of production, the true cost of chemicals has many hidden components. Not only does it include the initial purchasing cost of the chemical, but it can also include:

- procurement costs to obtain and deliver the chemical to the site
- inventory maintenance
- consequent waste treatment and disposal costs
- equipment operation and maintenance costs
- heating costs
- management of health and safety risks, including operator training.

Savings in chemical use can be made by taking a holistic approach to selecting chemicals, which considers not only the purchase cost but also many of the hidden costs. For example, a non-toxic and biodegradable chemical may cost more to purchase, but the overall cost to the plant may be considerably less when maintenance, safety and wastewater discharge costs are also taken into account.



Eco-efficiency action

- Consider the true cost of chemical usage on your site and use this information when selecting suitable chemicals for your needs.

7.2 Optimising chemical use during cleaning

There are many factors that influence the cleaning process, including chemical selection, concentration and application methods; and optimising these can help to reduce chemical use. However, all these factors may be interlinked and one should not be changed without the overall impact on the others being considered.

Cleaning and sanitising programs in modern food plants are systematic procedures that include a series of steps, usually in the following order:

1. **dry cleaning** to remove most of the solid/semi-solid components and avoid adding them to the wastewater stream
2. **first rinse** to minimise the soil load in the cleaning system
3. **detergent wash** to remove remaining soil through manual or mechanical scrubbing
4. **second rinse** to prevent redeposition of soil on the clean surface
5. **sanitising** (this step is only required if there is direct contact with the product)
6. **final rinse** to prepare equipment and surfaces for processing.

7.2.1 Clean-in-place (CIP) systems

A clean-in-place (CIP) system is a fully enclosed automated system that delivers a number of wash and rinse cycles to processing equipment. CIP systems largely remove human contact with cleaning agents, thus reducing the risk of harmful exposure. (CIP systems are also discussed in Chapter 3 of this manual.) One of the main advantages of CIP systems is that they can recirculate and allow the reuse of chemicals and rinse water, thereby reducing consumption by as much as 50%. The use of membrane filtration systems is becoming more financially viable, allowing greater recovery of water and chemicals. CIP systems are also usually equipped with inline monitoring instrumentation that measures the concentration and temperature of chemicals. Correct chemical dosing is usually controlled by conductivity sensors, which should be well maintained and recalibrated to ensure that the correct amounts of chemical are being used for dosing.

It is not uncommon for food processing plants, over time, to introduce inefficient or excessive cleaning cycles in response to product quality problems or modifications to processing equipment. There may be opportunities to improve the efficiency of CIP systems by reviewing cleaning cycle times. This can usually be achieved by extensive trials to ensure sufficient cleaning without compromising product quality. For example, improvements can be made by experimenting with the duration of each step in the cleaning cycle to ensure the most efficient use of chemicals and water. You should consider the size and shape of items to be washed, and the quantity and type of soiling, and determine whether the duration of the current cleaning cycle could be shortened or the system pressure could be reduced.

Combining detergents and sanitisers may also make it possible to clean and sanitise simultaneously to reduce cleaning time, chemical use and the need for multiple rinses.

One of the main advantages of CIP systems is that they can recover and recirculate chemicals and rinse water.

Case studies

Optimising chemical recovery and reuse in CIP systems: dairy, Australia
A Victorian dairy processor assessed 15 separate CIP wash cycles. Each cycle was then improved by modifications to Programmable Logic Controller programs, pipework/valving and return pumps to maximise recovery and reuse of caustic soda. Estimated caustic usage was reduced by 50%.[1]

Conductivity sensors on CIP systems: dairy, UK
The Taw Valley Creamery was able to reduce its cleaning times and detergent consumption by 15% after installing conductivity sensors on all its CIP systems.[2]

[1] UNEP Working Group for Cleaner Production 2003o
[2] Envirowise 1999

Eco-efficiency action

- Maximise recovery and reuse of chemicals in CIP systems.
- Optimise chemical use in CIP systems by using conductivity sensors. Ensure all dosing systems are well maintained and regularly recalibrated.
- Investigate whether cleaning cycles can be shortened while still maintaining required levels of cleaning and sanitation. Consider grouping items with different cleaning requirements.
- Combine steps, if possible, by using a combined detergent and sanitiser.

7.2.2 Chemical concentration

Routine monitoring of dosing levels is essential to ensure that the correct concentration of chemicals is being used in the cleaning process. Overdosing of chemicals is wasteful, and underdosing can lead to contamination and an ineffective cleaning operation. Be sure all chemical concentrations meet the supplier's recommendations. Automated dosing systems provide a practical and precise way of overcoming the problems of human error and labour time typically associated with the manual addition of chemicals (Australian Standards 2001: AS 4709-2001). This precision not only reduces chemical use but may also reduce staff time and wastewater charges.

Case studies

Improved dosing control reduces chemical use: fruit and vegetable processor, Australia
Golden Circle reduced the volume of lime used for effluent dosing by adding a timer to the dosing control system, which allowed for lag time in sensing effluent pH. Previously the lime was diluted to prevent excessive addition of lime and overdosing of effluent. The change resulted in water savings of 5 ML/year ($12 000/year) because the lime no longer had to be diluted. There were additional savings in reduced lime consumption. The cost of implementation was $200.[1]

Control systems reduce chemical consumption: vegetable processor, Australia
Harvest FreshCuts introduced a second flume and additional control systems on the vegetable washing line, and this has enabled sanitiser concentrations to be reduced by 30% without any loss of efficiency in microbial kill. This has resulted in a saving of $45 000 in sanitiser costs.[2]

1 UNEP Working Group for Cleaner Production 2003h
2 UNEP Working Group for Cleaner Production 2002b

Eco-efficiency action

- Check that work procedures and laboratory testing are effective enough to ensure that the concentration of the chemicals being used meets manufacturers' recommendations or documented operating targets.
- Calculate the cost benefit of automating or upgrading dosing systems.

7.2.3 Chemical selection

There is a wide variety of detergents and sanitisers now available to food processors. Talk to your supplier about the most appropriate chemical for each task — which will optimise the cleaning process while also minimising environmental impacts and ensuring operators' safety. Changing to more suitable chemicals may reduce the amount of chemical required for the cleaning task while also improving cleaning effectiveness. Also consider the nature of the soil to be removed. Soiling can vary widely in composition; it forms when food comes into contact with preparation areas, as well as from airborne dirt, water scale, and films caused by cleaning agents or by microbial activity (Schmidt 2003). Incorrect selection of chemicals can lock soils and make them more difficult to remove. Also consider the condition of the soil when it is to be removed — will it be fresh soiling or dried deposits?

Sanitisers should destroy micro-organisms rapidly, be stable, preferably be able to withstand a broad range of environmental conditions, and maintain their sanitising power when used in combination with other chemicals.

Case study

Alternative detergent use increased productivity: dairy, Australia
Bonlac Foods were 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. They treat waste cleaning solution in onsite wastewater treatment ponds and then discharge 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. As a result of the change, the cycle time for the CIP process could be reduced from 6 hours to 4.5 hours, allowing more time to produce cheese; and the acid detergent was eliminated from the CIP process. The net benefit was an extra $310 per day.[1]

[1] Environment Australia 2001b

Careful selection of chemicals for cleaning and sanitising should consider:

- effectiveness and suitability for the job
- the best application method for the chemical (i.e. foaming or non-foaming)
- exposure time, temperature and concentration specifications
- whether it is approved for surfaces coming into contact with food
- toxicity, and the operator safety requirements
- impact on the environment, and how it will affect the pollutant load of wastewater
- corrosiveness
- stability and ease of storage, and the possible impacts of any spillage.*

Table 7.1 shows detergent types commonly used in the food industry, and their main functions. Table 7.2 shows commonly used sanitising chemicals and their application.

*Further information is provided in AS 4709-2001, 'Guide to cleaning and sanitizing of plant and equipment in the food industry', on types of detergents and sanitisers and what they are used for (Australian Standards 2001).

Table 7.1: Detergent types commonly used in the food processing industry

Detergent type	Application	Major functions	Disadvantages
Multi-purpose	Easy-to-remove soil	Manual, pressure and foam cleaning all surfaces	May not be as effective for some applications
Heavy-duty alkaline	Sugar Fats Protein Organic soils	CIP and soak tank Breaking down fats to suspend in solution Breaking down fats to form soaps Forming colloidal solutions	Do not remove mineral deposits Hazardous to handle Corrosive Increase wastewater pH
Acidic	Protein Sugar Mineral deposits Metal corrosion Milkstone*	Mineral deposit control Water softening	Hazardous to handle Corrosive Lower pH of wastewater
Enzyme assisted	Proteins Fats Oils	Used in conjunction with mild detergents to break down and solubilise difficult to remove soils	Limited to unheated surfaces
Complex phosphates	Fats Proteins	Soil displacement (by emulsifying and peptising) Dispersion of soil Water softening Prevention of soil redeposition	Environmental impact of phosphates in wastewater

*milkstone = mineral deposit from milk

Sources: Schmidt 2003; Melrose Chemicals; AS 4709-2001

Table 7.2: Sanitising chemicals commonly used in the food processing industry

Sanitiser type	Application	Disadvantages	Benefits
Chlorine-releasing compounds	Wide-ranging activity	Corrosive Dissipates rapidly Odourous and irritant Activity decreases with organic matter concentration Ineffective above pH 7.5	Relatively inexpensive Not affected by water hardness Potential for tri-halomethane formation
Iodophors/ iodine complexes	Wide-ranging although less effective against bacterial spores than chlorine	Slow-acting at pH 7 or above Cannot be used above 50°C High cost High phosphate levels Requires iodophor/formulated product — otherwise poor solubility in water Staining on some surfaces	Activity better than chlorine with higher organic concentrations Less corrosive than other sanitising chemicals Non-irritant Dissipates slowly
Quaternary ammonium compounds	Not as wide-ranging as chlorine or iodine	Effective in acid pH Affected by water hardness Can cause foaming problems in CIP	Non-corrosive Medium cost Residual antimicrobial activity
Acid-anionic combinations	Not as wide-ranging as chlorine or iodine	Slightly corrosive and irritating Not effective at alkaline pH High cost	Can be used as an acid rinse and sanitiser Low odour Less corrosive than some other sanitising chemicals
Peroxyacetic acid	Wide-ranging activity	Concentrated form hazardous, irritant and corrosive Effective at pH less than 7–8	No phosphates Stable at low concentration Biodegradable

Sources: Schmidt 2003; Melrose Chemicals; AS 4709-2001

Eco-efficiency action

- Talk to your supplier about the most appropriate chemicals and applications for your needs.
- Routinely review exposure time, temperature and concentration specifications.
- Ensure that all chemicals are approved for surfaces coming into contact with food.
- Consider the toxicity of the chemical and the usage requirements for health and safety of operators.
- Consider what impact the chemical will have on the environment, and how the chemical will affect the pollutant load of wastewater and discharge costs.
- Consider the impact the chemical will have on maintenance, and in particular its corrosiveness.

7.2.4 Chemical alternatives

Biodegradable chemicals

Non-toxic, biodegradable chemicals, such as plant-based cleaning agents, may provide an opportunity to reduce maintenance and wastewater discharge costs while also contributing to a safer environment for employees. Some environmentally friendly cleaning products can be more expensive than traditional products, so it is important to take a holistic approach and consider some of the operational and downstream savings, and not just the initial purchase cost. Environmentally friendly chemicals are often perceived as not being as effective as conventional chemicals. However, recent technological advances have made it possible to combine plant-based ingredients to create more powerful cleaning agents and natural disinfectants. For example, citrus oil extracted from orange peel (d-limonene) is being used to produce a natural petrochemical-free solvent and cleaning agent suitable for removing grease and fat (Naval Facilities Engineering Service Centre 1999).

Alternatives to chlorine-based sanitisers

Chlorine compounds are broad-spectrum germicides that are relatively cheap and less affected by water hardness then many other sanitisers. They are, however, corrosive to many metal surfaces and are currently the subject of some health and safety concerns.

Peroxyacetic acid is gaining acceptance in the food industry as a biodegradable and non-toxic sanitising agent that is as effective as chlorine and can be used at low concentrations. In the fruit and vegetable industry, for example, peroxyacetic acid is being used for microbial control in flumes (conveying and washing product) and to wash product.

One of the advantages of peroxyacetic acid is that, once it is dosed into water, there are no vapour issues as with chlorine-based compounds (Kidd & Stiff Pers. Comm. 2003). Its other advantages include the absence of phosphates and foam, and its biodegradability. Peroxyacetic acid-based sanitisers are widely used in the dairy processing industry.

A number of factors do need to be considered, however, when using peroxyacetic acid. When it 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 4 or 5, depending on the initial concentration of 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 less of an issue because the water containing acetic acid is mixed with much larger volumes of wastewater than in the vegetable processing industry.

Reduced phosphate blends

Many conventional cleaning chemicals contain phosphates in the form of phosphoric acid and tri-sodium phosphate. Phosphates need to be removed from wastewater streams because they can contribute to excessive plant growth (blooms) and oxygen starvation in waterways. As a result, some local councils include a levy on the concentration of phosphates in wastewater. Products with less than 0.5% by weight phosphorus are available to replace conventional cleaning chemicals for most duties (MnTAP 2003).

Enzyme-based detergents

Enzyme-based detergents are finding acceptance in food industry applications 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 and often require less energy input in the form of heat. Most enzyme cleaners are limited to unheated surfaces.

Physical versus chemical sanitisers

Physical sanitising involves the use of either hot water or steam. Typically hot water circulation is used, because it is easier to regulate. The advantage of physical sanitising is the elimination of chemical sanitiser; however, its application is limited due to the energy required to produce steam or hot water, and its suitability and effectiveness for some applications (e.g. external surfaces). Chemical sanitation is therefore predominant in the food industry.

Case study

Single-phase cleaning and enzyme technology: ice cream processor, Asia
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 allowing the acid phase of the cleaning to be eliminated. The enzymatic clean is followed by the use of an acidic sanitiser.[1]

[1] Kidd & Stiff Pers. Comm. 2003

Eco-efficiency action

- Investigate alternative, environmentally friendly detergents and sanitisers such as chlorine alternatives, reduced phosphate blends and enzyme detergents.

7.2.5 Chemical application methods

Detergents and sanitisers can be applied by a number of methods including spraying, fogging, soaking, foaming, pipeline flow or aerosol methods. Application methods will use chemicals and mechanical force to varying degrees as necessary to achieve cleaning and sanitation outcomes. They may be manual or automated, open or closed systems and may require equipment to be disassembled. It is important to ensure that the chemicals, the equipment and the application methods are compatible and achieve the most effective clean while also minimising wastage. Factors to be considered include exposure time, temperature and pH, concentration specifications and dosing, operators' health and safety, and the requirements of effective equipment operation and maintenance. Your supplier will provide valuable advice on each of these aspects.

Exposure time

Often, the longer a chemical is in contact with the surface that requires cleaning the more effective it will be. Ensure that cleaning procedures optimise cleaning contact time and the chemical constituents of the cleaning agent effectively bond to the cleaning surface, because intimate contact is as important as prolonged contact. For example, gels form a thin film on the surface to increase exposure time, and are then usually removed with pressure. Foaming chemicals are a mix of surfactants and concentrated solutions of alkaline, acid or enzyme cleaners, which are self-foaming. Foaming can give more contact time between the detergent and soiled surface and may improve cleaning performance. Foams are also easy to rinse away, thereby reducing consumption of water and chemicals.

Correct temperature

Maintaining the correct temperature is essential for effectiveness of the chemicals. Excessively high temperatures may also increase the corrosive nature of many chemicals, while low temperatures may reduce the chemical's ability to remove soiling or kill pathogens.

Operator competence and safety

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

Equipment operation and maintenance

Optimising the operation and maintenance of cleaning and sanitising equipment will ensure that excessive amounts of chemicals are not being used to compensate for poor mechanical or thermal operation. For example, worn dosing equipment may result in excessive use of chemicals. Discuss optimising nozzle effectiveness with your supplier. This could include nozzle type and alignment, spray patterns and pressure. Nozzle selection and the importance of nozzle maintenance and durability are discussed in Chapter 3.

Case study

Foam/thin film cleaners: dairy, Asia
An Asian milk processing plant uses foam/thin film cleaners with a mobile boosted-pressure cleaning system (Ecolab's 'Scanio Topax Hygiene System') to clean infant formula roller dryers. The cleaning product is applied with a soft bristle broom to create a thin film on the surface of the roller dryers and is then washed off using high-pressure/low-volume water. Previously a powdered product was applied, which required more manual handling. The use of the foam/thin film cleaner has resulted in reduced cleaning time (replacement of powder with thin film cleaner; more automation), reduced water use (replacement of open-ended hose with pressure cleaning system) and improved working conditions (replacement of manual process with more automated cleaning equipment).[1]

[1] Kidd & Stiff Pers. Comm. 2003

Eco-efficiency action

- Check with your supplier that chemical application methods (spray balls, nozzles etc.) are compatible with the chemical used.
- Train and supervise operators to use chemicals safely and efficiently.
- Optimise the operation and maintenance of cleaning and sanitising equipment. For example, investigate nozzle effectiveness, durability and maintenance.

7.3 Chemical treatment of boiler and cooling water

Water use applications vary in the water quality they require, so it is important to use only the quality needed for each application.

7.3.1 Boiler water treatment

Boiler feed water requires pre-treatment to soften the water and to remove dissolved oxygen, silica and other minerals. Methods used to treat the water include chemical dosing and filtration, softening, demineralisation, ion exchange and de-aeration.

As boiler feed water 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. It is important to control blowdown and match it to the concentration of impurities in the boiler. Installing conductivity probes that initiate blowdown only when the water exceeds a set value prevents unnecessary waste of water, chemicals and energy due to excessive blowdown.

The method and point of addition of chemicals to boiler water is also important. For example, sodium sulfite may be used to scavenge dissolved oxygen to prevent corrosion in the boiler tubes. The point of addition is important because, if exposed to air, sodium sulfite is consumed before it is even added to the water.

7.3.2 Cooling tower treatment

Cooling water is treated to control the activity of microbes such as *Legionella* to safe levels required by standards, while at the same time minimising scaling and corrosion of pipework, heat exchange equipment and the cooling tower. As with boiler feed water, cooling water operates as a recirculating flow and therefore requires blowdown to remove solids. A range of chemicals are added to cooling water, including pH adjustors, corrosion inhibitors, dispersant 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.

Case study

Improved control of water treatment chemicals: National Research Laboratory, USA
With the assistance of its chemical supplier, the Argonne National Laboratory East (ANL-E) improved its boiler, chiller and cooling tower water treatment program. The laboratory used a statistical control program, trialling newly developed chemicals, installing timers on chemical feed pumps and implementing scale minimisation measures. The laboratory reduced water treatment costs from A$642 857 to A$390 000.[1]

[1] ANL-E 2002–03

Eco-efficiency action

- Do not over-treat water. Maintain only the quality required for the application.
- The frequency of boiler blowdown should where possible reflect the concentration of impurities in the water. The installation of conductivity probes that initiate blowdown only when the water exceeds a set value will prevent unnecessary wastage of water, chemicals and energy through excessive blowdown.
- Discuss options to minimise chemical use with your supplier.

7.4 Water quality and chemical effectiveness

Impurities in water can drastically reduce the effectiveness of the cleaning chemicals. For example, hard water containing substantial amounts of calcium, magnesium and iron hardness can result in scale, affecting the ability of detergents and sanitisers to make contact with the surface that requires cleaning. In such cases the addition of buffering agents to highly alkaline (above 8) or highly acidic (below 5) water may help to improve the effectiveness of chemicals while also reducing mineral build-up. Your chemical supplier will be able to provide you with 'built' or fully formulated products to treat hardness chemicals.

Case studies

Caustic with Stabicip Therm additive: Asia
The use of sodium hydroxide and the additive Stabicip Therm® (chelated additive for caustic cleaning solutions) was used to clean mixing and storage equipment, to remove the need for acid cleaning. (Stabicip Therm® has sequestering ability which eliminates water hardness and other mineral salts.) This allowed caustic concentration to be reduced from 2.5% to 1.0%. Stabicip Therm® also aids rinsing and eliminates the need for nitric acid cleaning.[1]

Water conditioning saves chemicals: dairy processor, UK
Tims Dairy produces cultured milk products such as yoghurt. The company overcame problems with lime scale and milk scale build-up on heat exchangers by installing three 'Hydroflow' physical water conditioning units, which prevent build-up of lime scale deposits by electroprecipitation. The heat exchanger is now cleaned only once week and only half the amount of acid is needed.[2]

[1] Kidd & Stiff Pers. Comm. 2003
[2] Manufacturingtalk 2003a

Eco-efficiency action

- Talk to your chemical supplier about conditioning water if impurities are reducing the effectiveness of cleaning chemicals.

7.5 Alternatives to chemical use

7.5.1 Ozone

Ozone can be used in gaseous form to fumigate, and in aqueous form (dissolved in water) for washing, cleaning and sanitising. Ozone is usually generated onsite by creating an electrical discharge across an oxygen or air stream. The bonds that hold the oxygen (O_2) together are broken and three O_2 molecules recombine to form two ozone molecules (O_3); they quickly break down and revert to O_2. The O_3 molecules destroy micro-organisms by oxidising their cell membranes. Some of the uses of ozone in the food processing industry include washing of fruit and vegetables, sanitation in breweries, and cleaning in meat and fish processing plants (Rice 2003).

Ozone is currently being promoted as an alternative to chorine, as it reacts 3000 times more rapidly with organic materials, leaving no residue; it is also less dependent on pH and temperature (WaterTech Online 2003). As ozone is a very powerful oxidant it is subject to stringent environmental and workplace health and safety regulations. It can be difficult to maintain consistent dosage rates because the breakdown of ozone into oxygen occurs rapidly.

Case study

Ozone in water to sanitise: vegetable processor, USA
Strickland Produce used ozonated water to wash and sanitise fresh cut salads, resulting in 50–60% less water usage, and significantly reduced chlorine treatment and effluent discharge costs.[1]

[1] Rice 2003

7.5.2 Ionisation

Ionisation is another alternative to sanitation chemicals, using an electrode cell to release silver and copper ions into a stream of water. The positively charged silver and copper ions are attracted to the negatively charged surface of the micro-organisms, distorting the cell structure and preventing the absorption of nutrients (Tripax Engineering 2003). Trials using ionisation to sanitise water by a vegetable processor in Australia showed that the system worked best when there was little organic material in the water and a relatively low product throughput and only a low ionisation strength was required (UNEP Working Group for Cleaner Production 2002b).

Case study

Tarn-pure ionisation under trial: carrot processing plant, Australia
A new ionisation system is being used to sanitise 80 000 tonnes of fresh carrots using 200 000 L of sanitised water per day. Test work results base on overseas experience are expected to show that ionisation is as effective as chlorination.[1]

[1] Tripax Engineering 2003

7.5.3 Ultraviolet light

Ultraviolet (UV) disinfection systems destroy micro-organisms through interaction with microbial DNA. The degree of inactivation of microbes is related to the UV dose, which is determined by 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. Ultraviolet light has the advantage of leaving no residue and is not affected by water chemistry.

Case studies

Ultraviolet disinfection of fetta cheese brine: cheese processor, South Africa
Cheese processor 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,' reports Clover South Africa's Production Manager.[1]

Medium-pressure UV disinfection system: food processor, UK
Heinz UK installed a medium-pressure UV disinfection system to treat water originating from a private borehole. The water passes through an iron and manganese filter, and then a membrane filter, before finally reaching the UV system. Around 95% of the UV-treated water is used for washing and rinsing equipment, with the remaining 5% used in product make-up. The clean technology has no effect on taste, colour or odour of Heinz's products.[2]

1 Manufacturingtalk 2003b
2 Manufacturingtalk 2003c

Eco-efficiency action

- Investigate whether there are alternative methods to conventional chemicals, such as ozone, ionisation and ultraviolet disinfection, that are more cost-effective and reduce environmental impacts.

7.6 Supply and handling of chemicals

7.6.1 Supply agreements and performance-based contracts

It is essential to seek the advice and involvement of chemical suppliers and water treatment experts. 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. They will conduct monthly or quarterly reviews — depending on customer size, and the complexity of chemical use on the site — and make recommendations on how to utilise their products to best effect. Some suppliers supply dosing equipment at no cost, or under a lease arrangement, to ensure the correct usage of their product and its continued use by 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 is an arrangement whereby 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, whereby it can share 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. (The benefits of reducing packaging materials are described in Chapter 5.) If chemicals are purchased in more concentrated form appropriate training should be provided to ensure operators' safety 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 established, in case of spillage. Automatic dosing systems can improve operators' safety and reduce labour requirements while also improving efficiency.

Case studies

Buying chemicals in bulk: poultry processor, Australia
Bartter Enterprises changed to buying chemicals in bulk and, in conjunction with the chemical supplier, the company will install chemical storage tanks and a ring main system for bulk delivery of cleaning chemicals. The $10 000 installation cost will be offset by savings of $10 000 per year.[1]

Solid concentrate water treatment chemicals: food processor, USA
A Midwest food plant converted to using a solid concentrate chemical dosing system for its boiler feed water treatment. A solid block of chemical is progressively dissolved in a reservoir of water, which is then emptied into the boiler feed water pipe. This resulted in savings of A$2571, as well as a reduction in the amount of heavy lifting required, and storage and disposal of drums of liquid chemicals.[2]

Chemical process control system: brewing ingredients processor, UK
Murphy and Son previously manually processed batches of chemicals ranging from 100 L to 3000 L. The company has now installed a continuous process control system designed to improve process efficiency and remove health and safety concerns by reducing the operator's exposure to chemicals. A spokesman for Murphy and Son said, 'Where previously the operator had to move between three floors and numerous operating stations to open valves manually and conduct visual checks on tank levels and volumes, he now simply presses a sequence of buttons to control and monitor the whole process from a single station.[3]

[1] NSW Department of State and Regional Development 2003
[2] APTech Group Inc. 2002
[3] Manufacturingtalk 2003d

Eco-efficiency action

- Investigate service agreements and performance-based contracting with your supplier.
- Investigate purchase of chemicals in bulk or at high concentration to reduce costs and save on packaging.
- Ensure chemicals are properly labelled and stored in dry, well-ventilated areas. Preventive measures and clean-up procedures should be in place in case of spillage.
- Investigate automatic control systems to improve operators' safety and reduce labour requirements, while also improving efficiency.
- Review your dosing systems and consider whether they could be improved through a more automated system.

Resources

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Units and conversion factors

Mass

mg	milligram (1 mg = 10^{-3} g)
g	gram
kg	kilogram (1kg = 1000 g)
t	tonne (1 t = 1000 kg)
kt	kilotonne (1 kt = 1000 t)

Volume

L	litre
kL	kilolitre (1 kL = 1000 L)
ML	mega litre (1 ML = 1000 L)
m^3	cubic metre (1 m^3 = 1 kL)

Length

mm	millimetre
cm	centimetre (1 cm = 10 mm)
m	metre (1 m = 100cm)
km	kilometer (1 km = 1000m)

Flow

L/sec	L per second
L/min	L per minute

Pressure

Pa	Pascal
kPa	kiloPascals

Energy

J	joule (1 W = 1 J/s)
kJ	kilojoule (1kJ = 1000 J)
MJ	megajoule (1 MJ = 1000 kJ)
GJ	gigajoule (1 GJ = 1000 MJ)
kVA	kilovoltampere (1 kVA = 1000 VA)

Electrical energy

kW	kilowatt (1 kW = 1000 W)
kWh	kilowatt hour (1 kW h = 3.6 MJ)
MWh	megawatt hour 1 MW h = 1000 kW h)
GWh	gigawatt hour (1 GW h = 1000 MW h)

Temperature

°C	degrees Celsius

Pollutant Load

mg/L BOD	milligrams per litre Biochemical Oxygen Demand (A measure of the quantity of dissolved oxygen consumed by micro-organisms as the result of the breakdown of biodegradable constituents in wastewater)
mg/L COD	milligrams per litre Chemical Oxygen Demand (A measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater)
mg/L TSS	milligrams per litre Total Suspended Solids

List of useful web links

Australian

Environment Australia
http://www.deh.gov.au/industry/corporate/eecp/industry.html#3

Queensland Environmental Protection Agency
http://www.epa.qld.gov.au/environmental_management/sustainability/industry/case_studies

UNEP Working Group for Cleaner Production
http://www.geosp.uq.edu.au/emc/cp

Centre of Excellence in Cleaner Production
http://cleanerproduction.curtin.edu.au

NSW Environmental Protection Agency
http://www.epa.nsw.gov.au/cleaner_production/index.htm

NSW Department of State and Regional Development
http://www.smallbiz.nsw.gov.au/textonly/issues/innovation/

Sustainable Development Energy Authority
http://www.seda.nsw.gov.au

Victorian Environmental Protection Agency
http://www.epa.vic.gov.au/business_sustainability/sme/default.asp

Sustainable Energy Authority Victoria
http://www.seav.vic.gov.au/advice/business/index.html

Eco-recycle Victoria
http://www.ecorecycle.vic.gov.au/www/default.asp?casid=2502

South Australian Environmental Protection Agency
http://www.environment.sa.gov.au/epa/ecoefficiency.html

Australian Greenhouse Office
http://www.greenhouse.gov.au/business_industry.html and
http://www.energystar.gov.au/programs/qld.html

Worldwide

Envirowise
www.envirowise.gov.UK

CADDET
http://www.caddet.org/links/index.php

US Environmental Protection Agency
http://www.epa.gov/p2/aboutp2/index.htm

International Cleaner Production Clearinghouse
http://www.emcentre.com/unepweb/tec_case/CaseStudy_main.htm

Enviro$ense
http://es.epa.gov