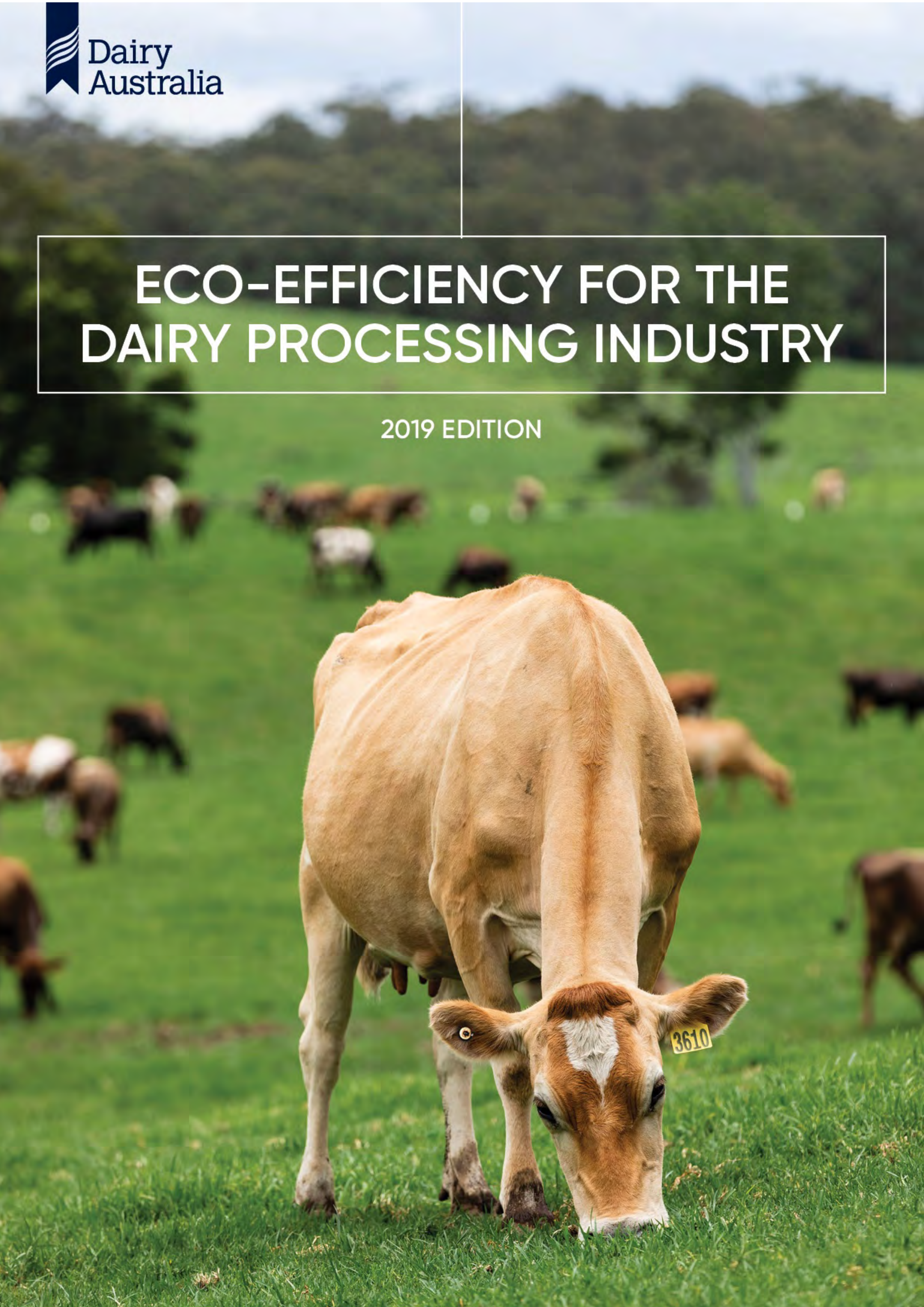


Dairy Australia

ECO-EFFICIENCY FOR THE DAIRY PROCESSING INDUSTRY

2019 EDITION

Eco-efficiency for the Dairy Processing Industry, 2019 Edition

Prepared for:
Mr Ian Olmstead
Program Manager - Manufacturing Innovation & Sustainability - Trade & Industry Strategy
Dairy Australia, Level 3, HWT Tower, 40 City Road, Southbank, Victoria, 3006

2019 Update Prepared By:
The Ecoefficiency Group Pty Ltd
Penny Prasad, Jane Gaffel, Nicole Price
www.ecoefficiencygroup.com.au

THE ECO EFFICIENCY GROUP

2004 Edition Prepared By:
The UNEP Working Group for Cleaner Production in the Food Industry
Environmental Management Centre, The University of Queensland, St Lucia
Penny Prasad, Robert Pagan, Michael Kauter and Nicole Price

Sustainable Business
Level 9, 121 Walker Street, North Sydney
Patrick Crittenden

Publication by:
Dairy Australia 2019

Disclaimer: While every attempt has been made to ensure that the information in this publication is correct at the time of printing, errors can occur. The information is provided as general information only. Specific issues relevant to your workplace should be considered in light of this and on an individual basis. You should consult with professional advisers familiar with your particular factual situation for further advice.

Contents

Table of Figures

Table of Tables

INTRODUCTION

CHAPTER 01

1.0 Introduction

Welcome to Eco-efficiency for the Dairy Processing Industry 2019, a revision of the 2004 publication of the same name. This manual has been developed to help the Australian dairy processing industry increase its competitiveness through increased awareness and uptake of eco-efficient practices. The manual seeks to consolidate and build on existing knowledge, accumulated through projects and initiatives that the industry has previously undertaken to improve its use of raw materials and resources and reduce the generation of wastes. Where there is an existing comprehensive report or publication, the manual refers to this for further information.

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

The manual explores opportunities for reducing environmental impacts in relation to water, energy, product yield, solid and liquid waste reduction and chemical use.

There are numerous new case studies in this edition as well as some originals[1] (dated as 2004 Ed.).

[1] It should be noted that a number of dairy companies that provided case studies for the 2004 edition have since changed ownership. In all cases, where we have used these previous case studies in the 2019 edition, we have referred the current owner.

INDUSTRY PROFILE

CHAPTER 02

2.0 Industry profile

The Australian dairy processing industry makes a significant contribution to the national economy. It is one of the key sectors of Australia's agricultural economy, ranking third in farmgate value behind beef and wheat at $3.7 billion for the 2016/17 financial year. The industry exports around 37% of milk production at a value of over $3 billion. The entire dairy industry employs approximately 42,000 people, with 17,600 of these employed in dairy manufacturing (Prasad, et al., 2004) (Dairy Australia, 2017).

Milk production is concentrated in the south-east corner of Australia, with New South Wales, Victoria, and Tasmania accounting for 86% of total output. In 2016-17, the industry produced approximately 9,015 million litres with product utilised as drinking milk (29%), cheese (32%), skim milk powder (26%), whole milk powder (5%) and other (8%) (Figure 2.1). Included in these figures is the production of 282,000 tonnes of milk powders, 336,700 tonnes of cheese and 99,950 tonnes of butter. With the domestic population increasing along with increased per capita consumption of dairy products, the import of dairy produce is an increasing trend, with 34% of cheese consumed in 2016-17 from international markets (mostly New Zealand) (Dairy Australia, 2018a).

The proportion of drinking milk to milk converted to other dairy products differs significantly between states (Figure 2.2) (Dairy Australia, 2017). In 2016-17, around 51% of manufactured product (in milk equivalent terms) was exported and the remaining 49% sold on the Australian market. This contrasts with drinking milk, where over 90% was consumed in the domestic market.

In Australia, milk is processed by farmer-owned cooperatives and multi-national companies, both privately owned and publicly listed.

Multinational dairy companies operating in Australia include Fonterra (New Zealand), Kirin Group of Japan (Lion Dairy and Drinks), Lactalis Group of France (Parmalat) and Saputo Inc of Canada (Saputo Dairy Australia).

As Table 2.1 shows, there are approximately 136 core dairy manufacturing sites (excluding small, artisanal producers) across Australia, many of which are in rural areas. Figure 2.2 shows utilisation of raw milk for each state and by major process lines.

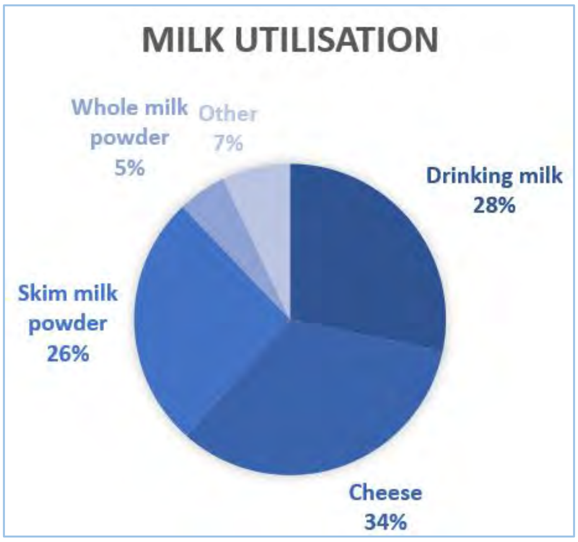


Figure 2.1: Utilisation of raw milk 2016–17 (Dairy Australia, 2017)

Table 2.1: Major Australian dairy manufacturing sites as at 2015

State	No. of sites
NSW	25
Vic.	55
Qld	13
SA	14
WA	10
Tas.	18
NT	0
Australia	136

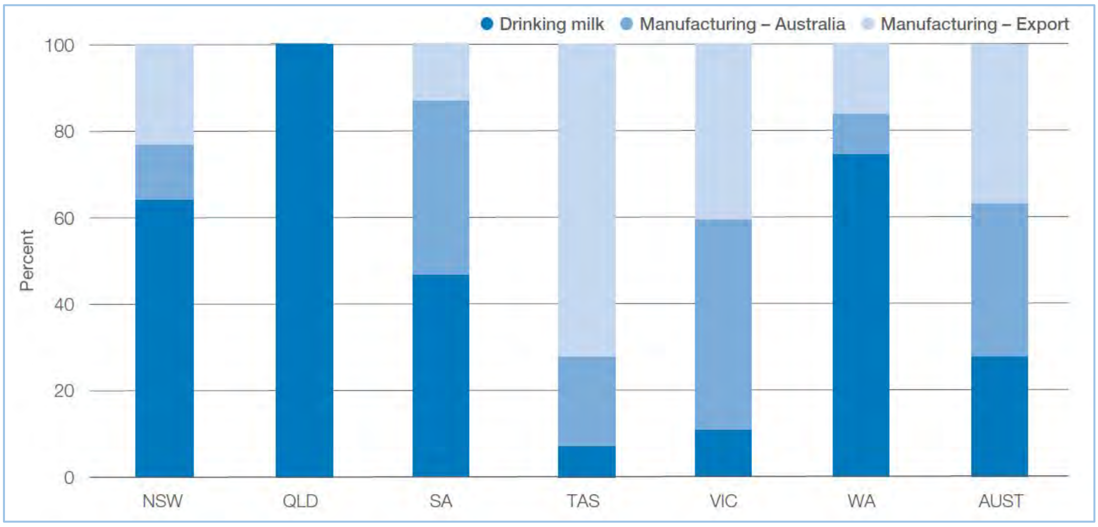
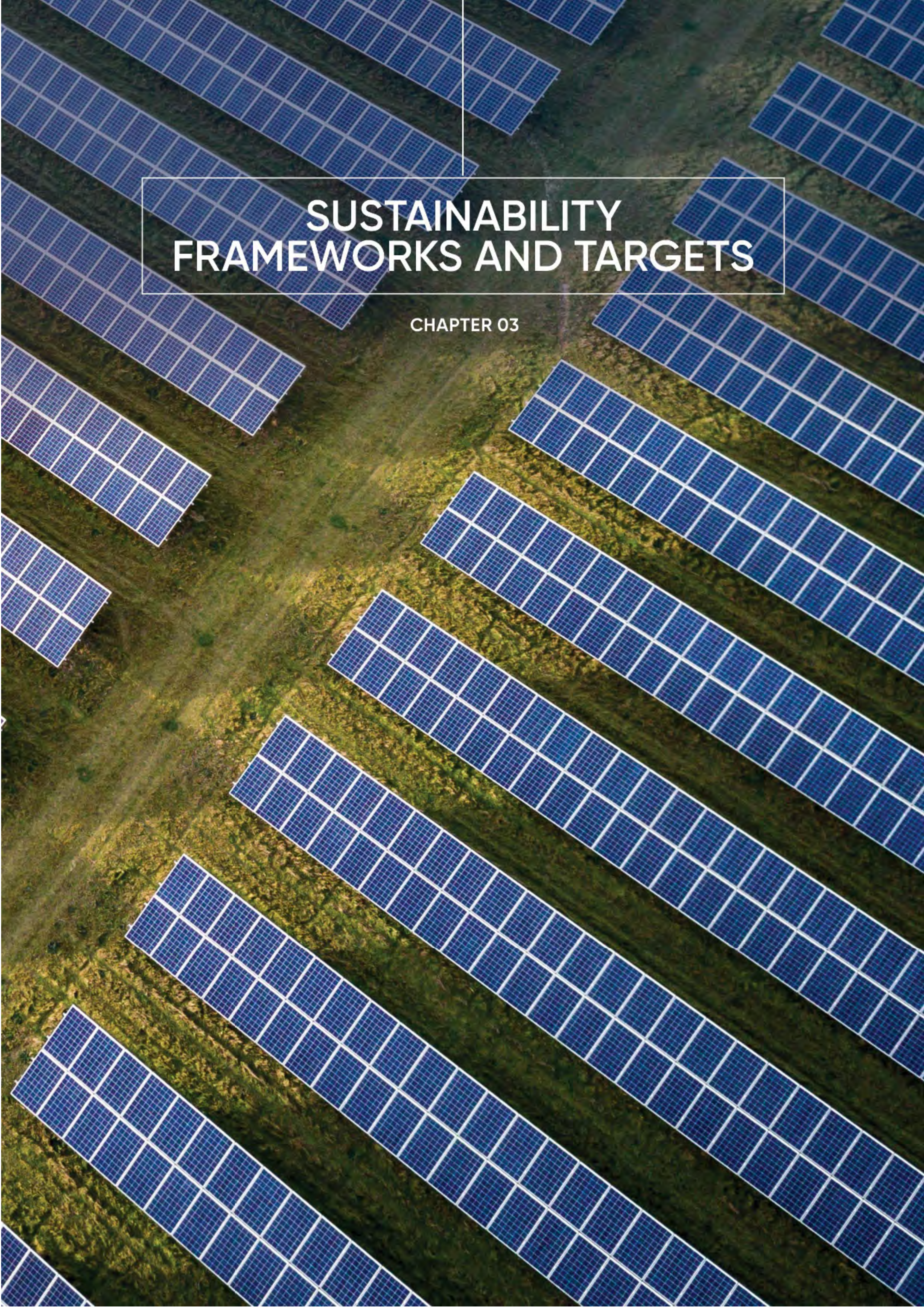


Figure 2.2: Utilisation of raw milk 2016–17 (Dairy Australia, 2017)

SUSTAINABILITY FRAMEWORKS AND TARGETS

CHAPTER 03



3.0 Sustainability Frameworks and Targets

The Global Reporting Initiative

The GRI is an international independent organization that helps businesses, governments and other organizations understand and communicate the impact of business on critical sustainability issues such as climate change, human rights, corruption and many others. It has pioneered sustainability reporting since the late 1990s. In October 2016, GRI launched the first global standards for sustainability reporting. The GRI Standards are a trusted reference for policy makers and regulators, and have a modular structure so they can be kept up-to-date and relevant. Of the world's largest 250 corporations, 92% report on their sustainability performance and 74% of these use GRI's Standards to do so. See www.globalreporting.org

An Australian Dairy Industry Sustainability Framework was launched in 2012 following extensive consultation with dairy farmers, manufacturers and other stakeholders (see www.sustainabledairyoz.com.au). In 2013, 11 goals and 41 measures were agreed to provide guidance to farmers, manufacturers and industry bodies on shared priorities and commitments to reach set goals by 2020. The goals and measures span the value chain from farm inputs such as feed, through farm production, manufacturing, retail and packaging, export and consumption. The selection of goals is informed by various international standards including the Global Reporting Initiative and the United Nations Sustainable Development Goals (GRI, 2018). There are three environmentally related goals for dairy processors to be achieved by 2020 and based on 2010/11 levels. These are:

- To reduce the consumptive water intensity of dairy processors by 20% (ML/ML raw milk processed).
- To reduce greenhouse emission intensity by 30% (tonnes CO_{2e}/ML raw milk processed).
- To reduce waste to landfill by 40% (tonnes/ML raw milk processed).

An essential step in using the GRI framework is to undertake a materiality assessment to help prioritise what is important and relevant to an organisation. Materiality is the threshold at which aspects of a company's operations become sufficiently important or "material" that they should be reported on (GRI, 2017b). Many large Australian dairy processing companies are following this framework on an individual basis and have set their own environmental targets. For example, Fonterra has identified GHG emissions associated with their business operations as a material issue and has therefore commenced reporting on this and set a target of net zero carbon emissions by 2050 and a 30% reduction in manufacturing energy use by 2030 (Fonterra, 2017).

Eco-efficiency key performance indicators (KPIs) for dairy processors are shown in Table 3.1. The development of industry benchmarks and performance targets against these KPIs is an effective way to encourage continuous improvement within or between companies. By comparing one plant's KPIs with those of similar processing plants, it is possible to get a feel for where industry best practice lies and therefore identify areas where there is scope for improvement.

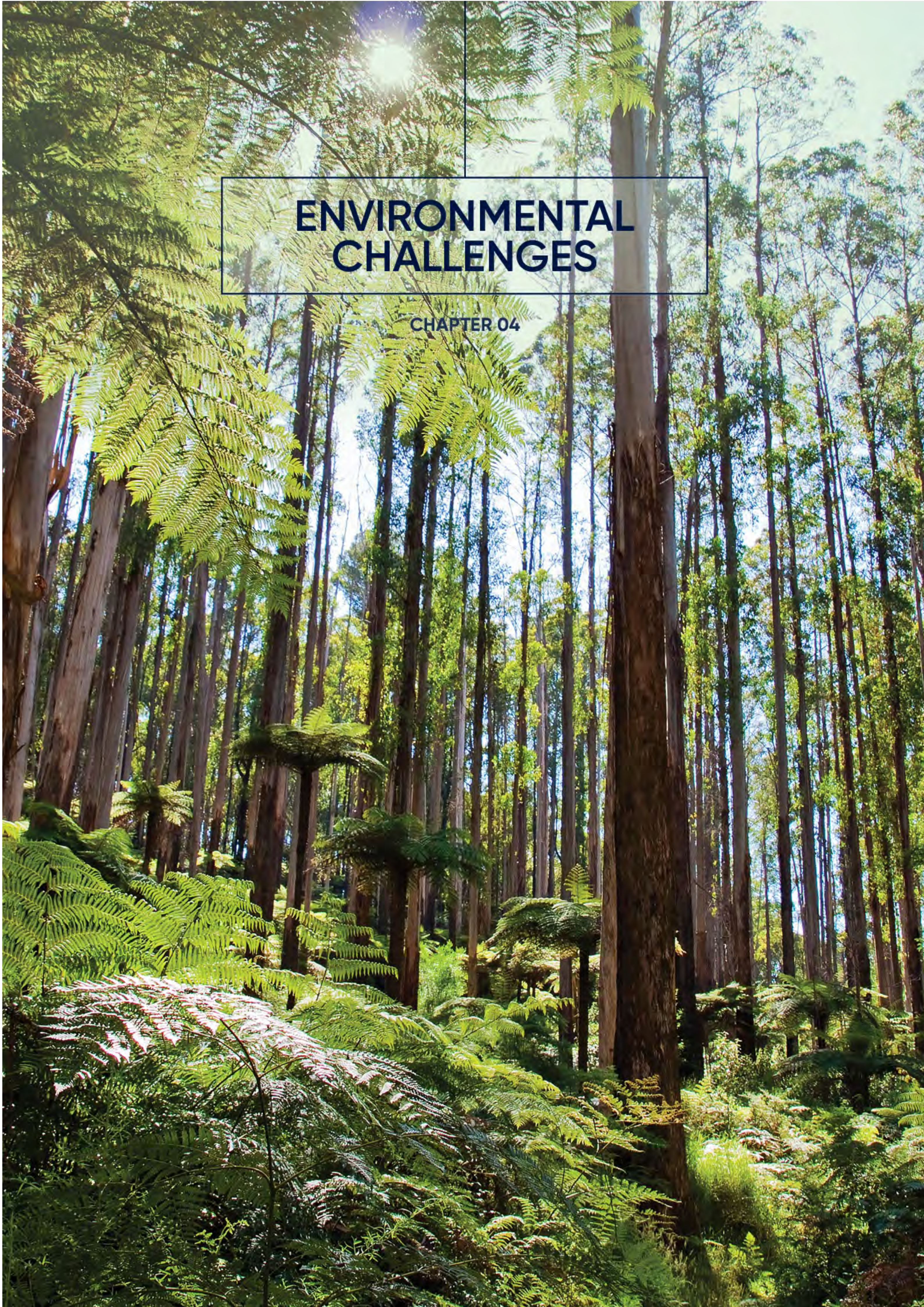
It is useful to link KPIs with staff incentive schemes and to other management programs. They are a useful tool for staff engagement and can help in prioritising overall efficiency.

Table 3.1: Key performance indicators for a dairy processor

Component	KPI
Product yield	kL or tonnes product per kL raw material consumed
Water	kL consumed per kL or tonne product
Water-to-milk ratio	kL water per kL raw milk processed
Water reuse %	kL water reused per kL total water used
Energy	MJ consumed per kL or tonne product
Energy-to-milk ratio	MJ energy per kL raw milk processed
Carbon	kg CO_{2e}/kL raw milk or tonne product
Wastewater	kL generated per kL or tonne product
Solid waste to landfill	kg generated per kL or tonne product
Solid waste recycled	% solid waste recycled

ENVIRONMENTAL CHALLENGES

CHAPTER 04



4.0 Environmental Challenges

4.1 Compliance and legislation

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

4.2 Water security and cost

Water supply to dairy processing plants varies according to location, but may be from town water, bores, rivers, dams or irrigation channels. With most areas in Australia experiencing drought periods and competing demands on available water, secure access is a consideration for some dairy processors. As an example, up until November 2018 Burra Foods had experienced water constraints at its Korumburra site, particularly during the late summer period of recent years, due to its shared water allocation with the surrounding township. Three local reservoirs fed the town and as the town and factory grew they placed increasing demand on these limited water resources. Fortunately, the Victorian government has recently supported the connection of Korumburra to the Victorian water grid, meaning that water can be sourced from further afield, improving water security and alleviating this constraint to production and growth (Burra Foods, 2019). Fonterra's Stanhope factory must store its entire winter supply to allow maintenance of water channels by the local water board. Government bodies and water authorities continue to promote greater water efficiency and encourage water conservation strategies.

Water supply costs for Australian processors vary according to the region, ranging from around $1.20/kL in Tasmania to $4.30 in South East Queensland. Water supply costs are discussed further in Section 6.0 - Water. Many water authorities are continuing to move towards full cost recovery of supplied water to the consumer, in order to encourage water conservation and to cut costs (Aither, 2017).

Over the entire life cycle of a dairy product, including milk production on farm, transportation and dairy processing, 99% of the total water consumption can be attributed to the farm (Lunde, et al., 2003). For the industry as a whole, therefore, efforts to make major gains in reducing the environmental impacts of water consumption should be focused on the farm. Nevertheless, there are gains to be made by dairy processors in minimising water consumption within factories. Depending on the product mix, dairy processing plants can use substantial volumes of water for equipment cleaning, cooling towers, boilers and other processes.

4.3 Wastewater discharge

Wastewater discharge costs vary according to the region, and according to whether the waste is being discharged to land, surface waters or the sewerage system. Plants discharging treated wastewater to municipal sewerage systems face the highest costs. Most water authorities charge on the basis of the organic loads (BOD/COD in $/kg) and include a separate volumetric charge ($/kL). Some utility operators include additional charges for nitrogen, phosphorus and sodium loads as well as oil and grease content and suspended solids. Charging structures can also be used to 'send a message' to customers and encourage measures such as waste minimisation to reduce loads. Charges can be reduced for processors by installing onsite treatment systems to reduce the organic and nutrient loads.

Factories that dispose of effluent directly to land generally do not pay disposal charges but must meet licence conditions for the quality of effluent with respect to components such as mineral content, salt level, BOD or COD, phosphorus, nitrogen, and oil and grease. The option to discharge to land can also be weather dependent as irrigation to land generally needs to be suspended when it rains. Processors taking advantage of this option therefore often require significant pond storage volumes.

4.4 Energy security and cost

As with most Australian industries, dairy companies rely heavily on fossil fuels — particularly coal-generated electricity, thermal coal and natural gas — for their energy supply. However, worldwide, the availability of renewable energy sources is growing as a result of government policies driven by climate change which have supported a transition to a permanent reduction in the supply costs of renewables which is causing disruption to energy markets that have been traditionally based on fossil fuels.

Australian manufacturers, including dairy, have seen their electricity supply cost double in the seven years from 2007-08 to 2014-15 (Figure 4.1) with expectation of continued price increases (Wood, et al., 2017). Australian dairy processors spend in the order of $170 million per year on energy supply across the sector and were anticipating a further 50-70% price rise in new energy contracts negotiated in 2017/18 (Dairy Australia, 2017). In Australia, contributing factors to the rise in electricity prices are decreasing demand in grid electricity (which increases fixed and variable supply costs for a smaller pool of customers), increase in electricity sourced from renewables and closure of a number of coal-fired power generators which has impacted on the capacity to supply power to the national energy market (Wood, et al., 2017). Wholesale gas prices have also tripled over the last 5 years (Figure 4.2) due to LNG exports impacting on domestic supply.

Energy markets are transforming around the world with three key trends in the way businesses use, produce and contract their energy (EEC, 2018). These trends include; the global transition away from fossil fuels as renewable energy sources reach cost-parity, the decentralisation of the energy grid with multiple sources of generation, and more proactive involvement by business to control their electricity demands and sources.

Australia has a national renewable energy target of 20% by 2030, and this will also help drive growth in sustainable energy supply in manufacturing (CEC, 2017).

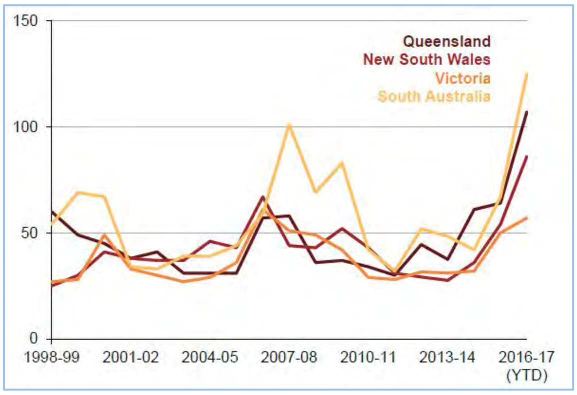


Figure 4.1: Annual volume weighted average spot electricity prices $/MWh
(Wood, et al., 2017)

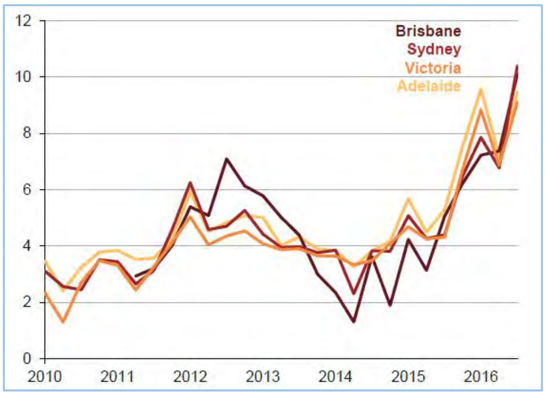


Figure 4.2: Quarterly gas prices, $/GJ

Energy is typically the greatest of all utility costs. As an example, due to rising gas and electricity prices, from 2016 to 2018 Burra Food's combined electricity and gas bill was anticipated to increase by almost $4 million per annum. (DMSC, 2017). The increased cost of energy has therefore been a major driver for Burra Foods and other dairy processors to reduce energy use, with many initiatives being undertaken in recent times. Processors must also manage the increased risk of supply interruptions and the impact that has on product quality and processing costs.

Burra Foods Energy Management (DMSC 2016/17 Scorecard)

As with all Australian dairy processors, Burra Foods is facing increasing utility costs. From 2016 to 2018, their combined electricity and gas bill increased by almost $4 million per annum. The company installed 600 m^2 of PV solar array which was expected to deliver 2.4% of electricity needs with a five-year payback. More solar, wind turbine, gas tri-generation turbines, renewable energy fed boilers and other options are being evaluated.

4.5 Carbon Emissions

The Australian dairy industry recognises it has an important role to play in saving energy and reducing greenhouse gas emissions (GHG). They acknowledge the Intergovernmental Panel on Climate Change's (IPCC) assessment of holding the increase in the global average temperature to below 2°C (UNFCC, 2015). Australian agriculture contributes approximately 15% of Australia's greenhouse gas emissions (GHGs) with the dairy industry as a whole contributing 12% of Australian agriculture's emissions. Of this, approximately 70% to 95% is from farms and 5% to 30% is from manufacturing depending on the dairy product in question (Lundie, 2013)The dairy industry's approach is to focus on target setting and reporting on emissions arising from manufacturing, while continuing to fund projects and programs which have proven to reduce emissions arising from farming (ADIC, 2016).

Voluntary Climate and Support Programs applicable to manufacturers

National Energy Productivity Plan – The NEPP commits to develop further measures to improve energy productivity in the industrial and resources sectors. Measures in early-stage development promote voluntary action and support research. For example, helping businesses self-manage energy costs through information, capacity building and improved services, recognising and promoting business leadership and best practice and voluntary commitment programs. The NEPP includes a target of a 40% improvement in energy productivity by 2030.

www.environment.gov.au/energy/national-energy-productivity-plan

Clean Energy Innovation Support - The Clean Energy Finance Corporation (CEFC) is working with the private sector to deliver capital investment solutions to reduce emissions from industrial processes. ARENA can fund research and development to assist with reducing emissions from the industrial sectors from renewable energy.

See www.cleanenergyfinancecorp.com.au/ and www.arena.gov.au/about-arena/

National Carbon Offset Standard - A National Carbon Offset Standard is available for manufactured products to demonstrate climate leadership. Carbon neutral products can create brand differentiation and gain a competitive edge, for example through carbon-smart procurement chains. www.environment.gov.au/climate-change/carbon-neutral

4.6 Solid waste management

Solid wastes generated by dairy processors include:

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

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

A major driver in reducing plastic waste is the Chinese government ban on accepting much of the world's scrap paper, cardboard and plastic. Up until early 2018, about 70% of Australia's waste was being sent to China for recycling. The ban is forcing Australian government and industry to explore initiatives and opportunities to reduce such wastes.

For dairy processors, solid waste disposal costs are still a relatively minor component of total operating costs. It is, however, an area where employees at all levels can contribute and immediately see results, and this can be a good start in encouraging employees to be more environmentally aware and participate in company-wide initiatives. The waste minimisation hierarchy in Figure 4.3 represents a sequential approach to reducing solid waste — with steps to avoid, reduce, reuse, recycle and lastly treat and dispose waste. This is discussed further in Section 9.0 Solid waste reduction.

Figure 4.3: The waste minimisation hierarchy

4.7 Packaging

There is increasing support for Australian manufacturers, including dairy, to reduce the environmental impacts of packaging. In April 2018, Australia's federal, state and territory environment ministers endorsed a target of 100 percent of Australian packaging being recyclable, compostable or reusable by 2025 or earlier. The Australian Packaging Covenant Organisation (APCO), represents over 900 leading companies, and is the leading organisation endorsed by government to help deliver this target. APCO is a co-regulatory, not-for-profit organisation that partners with government and industry to reduce the harmful impact of packaging on the environment (APCO, 2018). Most dairy processing companies are signatories to APCO.

The two main challenges for dairy processors with regards to packaging are to make the packaging easier for customers to recycle, reuse or compost and to also use recycled content in their own packaging to provide a market for recycling.

Opportunities for reducing packaging waste are included in Section 10.0 - Reducing the impacts of packaging.

4.8 Circular Economy

Traditionally the economy can be viewed as linear – take, make, use, dispose. This process results in resources being used only once before being disposed of. The Circular Economy (Figure 4.4) attempts to mimic nature with no build-up of waste as raw materials are extracted from a 'waste' stream to be used in another product.

Figure 4.4: Circular Economy model
(Green Industries SA, n.d.)

Circular economies are fully integrated with products designed for disassembly, reuse and recycling.

For the dairy industry the focus, within a circular economy is to use resources effectively in the production of the dairy products and ensure packaging is designed in a way to facilitate reuse and recycling. Further opportunities to "close the loop" in the context of dairy manufacturing include the irrigation/dispersal of water and nutrients in wastewater/bio-solids back to surrounding farmland to encourage pasture/crop growth - which in turn feeds dairy cattle.

4.9 Biodiversity

The International Dairy Federation (IDF) has produced a Guide on Biodiversity for the Dairy Sector (IDF, 2017). Dairy Australia has also produced the Biodiversity Action Plan (http://biodiversity.dairyaustralia.com.au/#/). Whilst these guidelines are mainly focussed on dairy farming, as stakeholders in the dairy supply chain, dairy processors have a role to play in supporting biodiversity initiatives and protecting their own environments with respect to waste management. This is highlighted by the UK dairy sector in their 2018 Roadmap (Dairy UK, 2018) with contributions to include but not be limited to:

- Complementary planting using native species.
- Erecting nesting facilities for birds where not contrary to food hygiene/safety requirements.
- Allowing natural regeneration.
- The removal of non-native species.
- Avoidance of light pollution in wildlife sensitive corridors.

4.10 The Digital Economy

The digital economy and its impact on manufacturing is known as the 'Fourth Industrial Revolution' or Industry 4.0. It is a trend that is permeating and impacting all areas of business including financial transactions, business operating processes and advanced manufacturing processes.

The digitisation of manufacturing and business processes will revolutionise the way manufacturers do business with great potential to improve efficiencies. Dairy processors can embrace and capitalise on the digital economy from simple measures such as digital accounting systems which can reduce office paper use to more advanced examples such as real time monitoring to reduce energy peak demand and resource use or product labelling showing product history, use of robots, the use of 3D printers, block chain and smart contracts. Further information on opportunities for manufacturers out of the digital economy can be found in Prasad, et. al. (Prasad, et al., 2017).

Industry 4.0

Industry 4.0 refers to the current trend of improved automation, machine-to-machine and human-to-machine communication, artificial intelligence, continued technological improvements and digitalisation in manufacturing. This trend is enabled by four key drivers:

1. Rising data volumes, computational power and connectivity.
2. The emergence of analytics and business-intelligence capabilities.
3. New forms of human-machine interaction, such as touch interfaces and augmented-reality systems.
4. Improvements in transferring digital instructions to the physical world, such as robotics and 3D printing (DIIS, 2017).

The Internet of Things

Internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.

Virtual Microgrid

The Australian Renewable Energy Agency (ARENA) provided $370,000 in funding for a feasibility study into a 'virtual microgrid' for the Latrobe Valley. The $775,000 project focuses on the feasibility of creating a 'virtual microgrid' across up to 200 dairy farms, over 100 household consumers and around 20 other commercial and industrial customers in the Gippsland region.

A 'virtual microgrid' is a local marketplace of connected energy users who can buy and sell electricity within a localised area.

The virtual microgrid will incorporate solar PV, battery storage, smart appliances and enabling technologies combined with a peer-to-peer energy trading platform which uses blockchain technology to allow participants to securely buy and sell locally produced renewable energy.

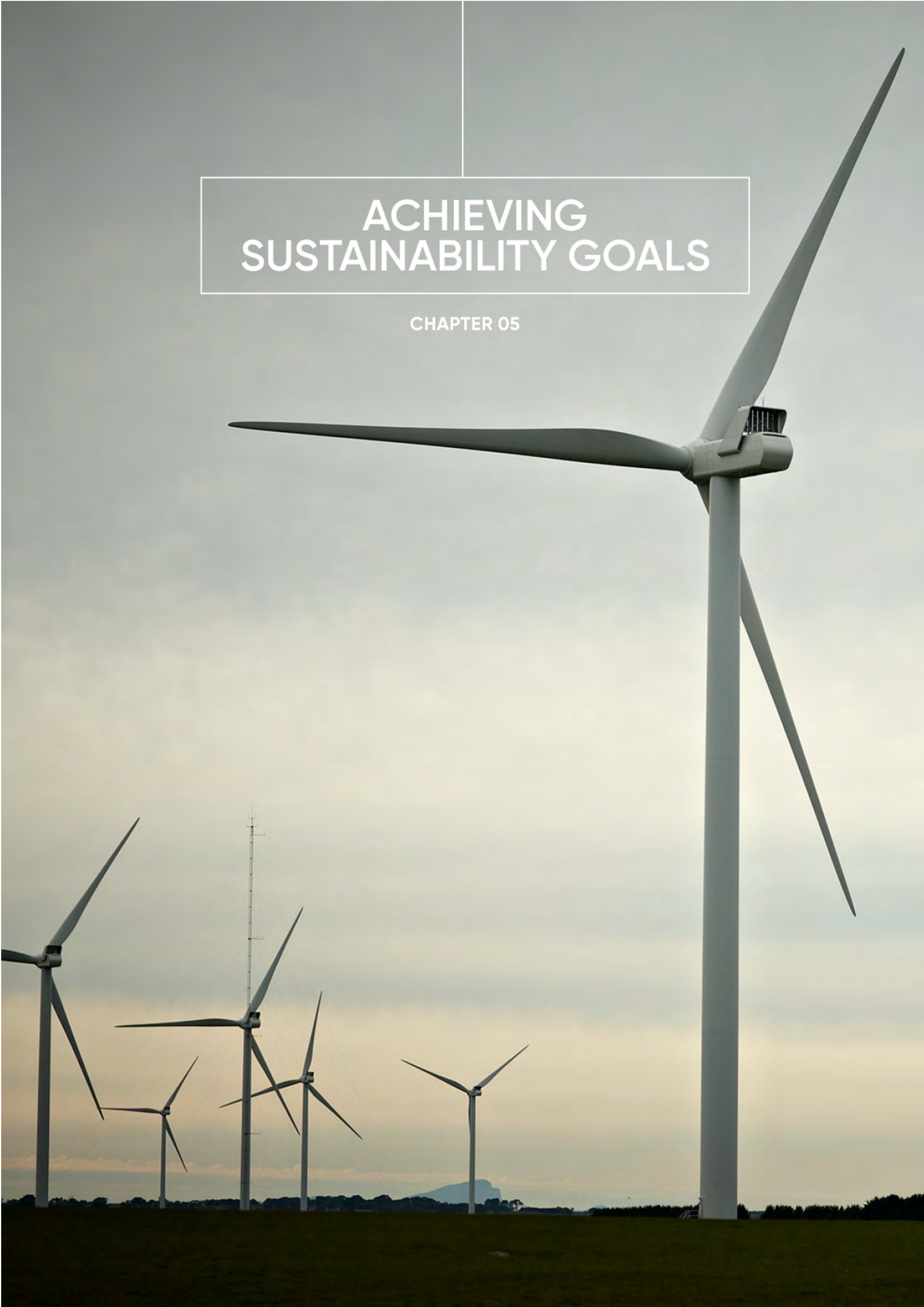
If the feasibility study is successful, this marketplace will allow Gippsland farmers to take greater control of their energy use, providing the opportunity to sell their solar power back to the grid, delivering savings on their energy bills.

Participants will be linked in an internet-of-things-based marketplace while using AusNet's distribution network. Participants will have a combination of solar, battery and smart devices to generate and store energy and manage usage.

A benefit of the feasibility study is that farmers will be offered the opportunity to opt-in for solar PV assessments and installations at no upfront cost through loans provided by the Sustainable Melbourne Fund, repaid through council rates. (ARENA, 2018)

ACHIEVING SUSTAINABILITY GOALS

CHAPTER 05



5.0 Achieving Sustainability Goals

5.1 All about eco-efficiency

5.1.1 Origins

Eco-efficiency is a 'win–win' business strategy that helps companies save money and reduce their environmental impact. It is considered as a first step towards a more sustainable business. The original eco-efficiency concept was put forward by The World Business Council for Sustainable Development in 1991 (WBCSD, n.d.). It is about increasing process efficiencies and reducing environmental impact, for example by reducing the use of goods and services, enhancing recyclability, and maximising the use of renewable resources. There are a range of ways companies can improve their eco-efficiency. Companies can:

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

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

5.1.2 Carrying out an assessment

A method for carrying out an eco-efficiency assessment is shown schematically in Figure 5.1. This method has been adapted from the UNEP Environmental management tools — cleaner production (UNEPTIE, 2003) and outlines six main steps: planning and organisation, pre-assessment, assessment, evaluation and feasibility, implementation and continuous improvement.

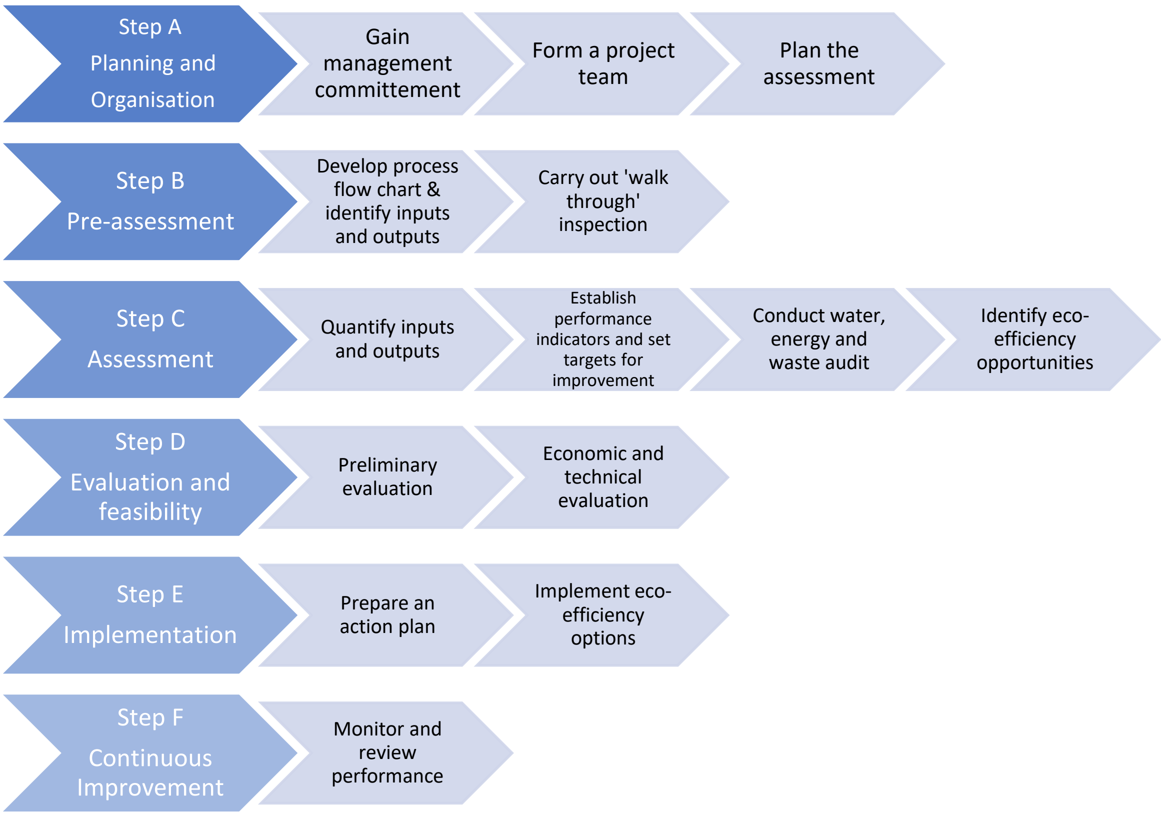


Figure 5.1: Cleaner Production Assessment Process
(Adapted from UNEP, Environmental Management Tools – Cleaner Production Assessment 2003)

5.1.3 Barriers

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

The key barriers to the implementation of eco-efficiency are typically:

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

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

- **Develop management awareness, commitment and support for projects -** this is important from the beginning, and throughout projects, to ensure there is time allocated to hold team meetings, perform process trials and implement solutions.

- **Establish a cross-functional working group -** this should include a range of staff likely to be impacted by the project, including cleaners, operators, engineers and managers.
- **Hold regular team meetings -** to maintain focus and to ensure continued progress.
- **Determine baseline information on resource consumption and waste generation -** when you achieve savings it is important that you can clearly communicate exactly what those savings are. There must be a clear picture of the situation before the savings were made.
- **Development of the business case -** this should include clearly communicating additional benefits such as positive publicity, improved involvement with the local community, safety, and operational benefits.

5.2 Achieving best practise in dairy processing

While the question of 'best practice in dairy processing' cannot be directly quantified within the scope of this document, the following points attempt to describe the characteristics of a dairy processing company and operation that is headed towards best practice. Ideally, the adoption of best-practice technologies, procedures and initiatives should be considered during the design and planning stages of a plant. A holistic approach should also be taken in deciding what is the most appropriate technology or plant design. For example, if a factory in a regional area has the option to irrigate, it may not be sensible for it to treat wastewater to potable water standards.

5.2.1 Characteristics of a company that is aiming for best practise

General:

- Integrated process control software that enables trending of key variables and generates customised reports for different purposes; able to be accessed by management from office workstations; use of mobile devices that can send alerts and warnings where set levels are reached; and uses programs that interface with accounting, inventory, maintenance and quality systems.
- A multi-use clean-in-place (CIP) system with the use of membranes to recover product, chemicals and water.
- Membrane plants for the recovery of condensate, cleaning chemicals and whey proteins.

Product yield:

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

Water usage:

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

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

Energy usage:

- A detailed energy balance or model that identifies energy consumption in each area.
- A system for the real time monitoring and reporting of energy consumption.
- The use of alternative renewable fuels such as solar and wind energy. In particular, solar PV and battery storage with demand management control capabilities.
- In powder plants, mechanical vapour recompression evaporators and multi-stage dryers.
- High-efficiency boilers with recuperators and economisers for recovery of heat to pre-heat flue gas and boiler feed water.
- Biogas recovery, with biogas used to supplement energy consumption.
- Cogeneration plants that export excess electricity to the grid.
- Efficient demand-management systems, including load shedding, to reduce peak demand.
- Efficient refrigeration systems that utilise state-of-the-art control systems, variable speed drive (VSD) compressors and heat recovery.
- High-efficiency motors of at least 90% efficiency.
- Efficient lighting systems that take advantage of natural light and automatically switch off or dim according to lighting needs.
- Pinch analysis of dairy factories to identify possible areas for improvement in heating and cooling duties.

Waste and packaging:

- Identification of all waste streams with a management plan to reduce, reuse or recycle wastes.
- No organic waste sent to landfill.
- Sustainable procurement policy.
- All packaging made from recyclable, compostable or reusable material.
- Incorporation of recycled materials in packaging.
- Operator training to ensure separation of waste streams at source.
- Contractual requirements for waste service providers to ensure efficient management and measurement of waste.

Chemicals:

- Clean-in-place systems incorporating chemical recovery.

- The use of enzyme-based and chemicals with reduced toxicity and reduced rates of phosphate and nitrogen.
- The holistic use of chemicals with consideration of the impact of wastewater disposal, particularly in regard to irrigation and salinity issues.
- Operator training and systems to ensure correct (not excessive) chemical dosing

Process Control

- Model Predictive Control systems

Note that several UK documents list Best Available Technologies for Dairy Processors (Natural Resources Wales, 2014) (UK Environment Agency, 2009), much of which includes what is listed above.

5.2.2 Future or emerging technologies

High pressure processing

High Pressure Processing (HPP) is a cold pasteurization technique by which products, already sealed in their final packaging, are introduced into a vessel and subjected to a high level of isostatic pressure transmitted by water (Hiperbaric, 2018). Isostatic pressure is where force is applied equally in all directions on the product surface. The high pressures destroy spoiling microorganisms. The technology is potentially more energy efficient than traditional pasteurisation, however thermal energy requirements for steam pasteurisation are replaced by electrical energy requirements and total energy consumption is dependent on holding times. There is currently one Australian example of a dairy processor using this technology for a liquid milk product (Made by Cow, n.d.). The technology is reported to have an impact on the texture of yoghurt and cheese (Barber & Cumming, 2017).

High temperature heat pumps

Though not a new technology, heat pumps are becoming more commercially viable as energy prices increase. Heat pumps use a refrigerant to upgrade low grade heat to high grade heat. At an industrial scale, high temperature heat pumps are a proven technology with potential for application by dairy processors. They are economically feasible where they can be used to upgrade heat from waste streams and/or capture latent heat e.g. from wastewater, dryers or refrigeration systems. Heat pumps are listed as a technology of note in the Sustainable Milk Project. Further information is provided in Section 7.0 - Energy and Carbon Emissions.

Absorption chillers

An absorption chiller is another form of heat pump. Where a mechanical heat pump is driven by electric energy, an absorption heat pump is driven by thermal energy. Absorption chillers use a source of waste heat to produce a chilled product with typical refrigerants being ammonia/water and more recently lithium bromide/water. As with high temperature heat pumps, absorption chillers are becoming commercially viable as energy prices increase. Further information is provided in Section 7.0 - Energy and Carbon Emissions.

5.3 Effecting Change

5.3.1 Avenues for supporting implementation

One of the most effective means of implementing eco-efficiency is through site-based cross-functional teams. Ways in which dairy processing companies can support and implement eco-efficiency projects are as follows:

Appointing designated managers and supervisors. Most dairy processing companies have appointed Sustainability or Environment Managers which may act a corporate level. It is beneficial to ensure a relevant operational, engineering or process improvement manager is assigned responsibility for a project.

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

Including eco-efficiency aspects in tender and proposal documents. If it is specified in tender documents that resource consumption must be considered during the design stages of projects, it can go a long way towards improving process yields and reducing environmental impacts. Examples might include the installation of metering devices during commissioning stages, the selection of less resource-intensive equipment, or improved process layout design. Similarly, including sustainability clauses in contracts with service providers can help share the responsibility of reducing environmental impacts.

Developing and maintaining Environmental management systems. If the company has established an environmental management system (EMS), this can also provide an opportunity to integrate eco-efficiency into the organisation. An EMS provides a management structure that allows for setting targets, clarifying responsibilities, training, and raising awareness to achieve environmental improvement. A focus within the EMS on continuous improvement will allow it to be used to go beyond mere compliance and achieve many of the environmental improvement opportunities discussed in this manual. An EMS can also provide legitimacy within an organisation for a focus on eco-efficiency — particularly where the organisation also has an environmental policy that commits it to a high level of environmental performance.

Grants and partnerships with government bodies. There are opportunities to obtain national and state government grants, which can provide encouragement and financial support for improving efficiency through the use of more efficient technology and research. Some of these are listed on the Australian Dairy Manufacturing Resource Centre[2].

[2] http://manufacturing.dairyaustralia.com.au/support-programs/current-grant-programs

Support from industry associations. Organisations such as Dairy Australia[3], the Dairy Manufacturers Sustainability Council[4] and the International Dairy Federation (IDF)[5] provide valuable resources in the form of publications, training and advice that can be used to support an eco-efficiency program.

5.3.2 Building the business case

Eco-efficiency projects will generally not be pursued by management unless there is a compelling business case to support their implementation. However, depending on the cost of resources, this is not always straight forward. For example, water supply costs are relatively cheap and can make it difficult to justify recycling or reuse projects. The following chapters in this manual discuss the concept of the 'true cost' of water or waste and this is very useful for helping to determine actual project savings. Other aspects to consider in helping to 'build the business case' include:

- **Driving competitive advantage** - resource and production costs are reduced through improving efficiencies. Inherent in eco-efficiency projects is looking for ways to reduce environmental impacts through reduced resource consumption. Dairy manufacturing companies can reduce resource and production costs by tens of thousands of dollars per year as demonstrated in case studies throughout this manual.
- **Improving risk management** - addressing environmental issues and making these integral to how a company operates reduces business risk. Such companies are viewed more favourably by the community, stakeholders and investors. This is displayed by the environmental targets and case studies that are included in many company and sector sustainability reports (e.g. the Australian Dairy Manufacturers Sustainability Reports and Environmental Scorecards[6]). Such companies also have a greater chance of being successful in government bids for tenders and grants. In addition, improving chemical management can reduce health and safety risks for staff.
- ***Reduced costs of compliance*** - in Queensland, companies that are involved with the state funded ecoBiz program, are eligible for a 10% discount on their environmentally relevant activity fees. Companies which have a certified Environmental Management System can gain a further 20% reduction (Qld Govt., 2016a). A further reduction of 20% can be made when a lower emission score is met. This can save companies in the order of thousands of dollars per year.

5.3.3 Stakeholder engagement

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

[3] https://www.dairyaustralia.com.au/

[4] http://manufacturing.dairyaustralia.com.au/support-programs/dairy-manufacturers-sustainability-council

[5] https://www.fil-idf.org/

[6] http://manufacturing.dairyaustralia.com.au/resource-library/sustainability-reports

Supply chain

Engaging with the broader supply chain is an essential part of striving to achieve sustainability goals. Dairy processors have the capacity to influence their suppliers e.g. farmers, packaging providers, utilities, and work with them to help reduce the overall environmental footprint of the dairy industry. Similarly, there are opportunities upstream of processors to do likewise.

Bega Cheese, Environmental Management System (Bega Cheese, 2016)

In 2005, the Bega Environmental Management System (BEMS) was piloted on 20 farms in Bega to help improve the long-term sustainability of their milk supply base. By 2016, 93 % of Bega Cheese milk suppliers had completed a BEMS Sustainability Assessment as part of the program. BEMS is a voluntary continuous improvement program. Sustainability risks on dairy farms are identified and the information used to develop extension programs and secure resources to support farmers to reduce the risks and improve long term viability of dairying. In addition to BEMS, Bega Cheese works closely with its suppliers to identify and address key issues that are important to them. Such issues include:

- DPI Water IPART water pricing review.
- Representing suppliers in Murray Darling Basin Senate inquiry.
- The repair to the Cochrane Dam near Bega, and water access.

Staff engagement

Engaged and motivated staff provide fertile ground for organisations to continuously improve and innovate. Staff engagement includes informing staff about company values and its long term purpose and how their role contributes to the big picture. It includes open communications and encouraging new ideas and input. Site-based teams provide an excellent mechanism for improving staff engagement. They build a sense of ownership and awareness of environmental issues at the site level. This is demonstrated by the Murray Goulburn case study where a cross functional team was formed to tackle an energy management project (see below). Ideas for involving staff in eco-efficiency projects include:

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

‘It is important to set targets and allow operators active involvement in developing improvements.’

‘One of the main issues is operator awareness and training. With such a large number of casual and seasonal staff, training and awareness has to be maintained so that eco-efficient projects are continually generated from the floor and maintained.’

The Saputo Dairy Australia[7] experience (2004 Ed)

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

Key learning

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

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

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

Key learning

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

The first project the team implemented was achieved through improved communication between the boiler house and process operators. It did not require any capital outlay but led to annual savings of $180,000 and 1,536 tonnes of CO_2 (which contributes to global warming). The following different perspectives and the team approach contributed in various ways to identifying and implementing this project:

Process operator perspective

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

Boiler operator perspective

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

Eco-efficiency perspective

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

Benefits of a team approach

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

[7] Formerly Devondale Murray Goulburn

5.3.4 *Supplier performance contracts*

Supplier performance contracts are becoming increasingly prevalent and are a potential incentive for processors to invest in resource efficiency projects. These include energy and water performance contracts, power purchase or solar leasing agreements as well as wastewater treatment systems. With such models, both third-party ownership and financing are available in a 'performance contract', whereby a third party takes responsibility for the risk and maintenance and the project is refinanced through the efficiency savings. Projected savings are guaranteed by the provider and either part or zero up-front investment is required which can make certain projects more economically attractive. Further reading on Energy Performance Contracts can be found at A Best Practise Guide to Energy Performance Contracts (ISR, 2000).

Waterwerx STREAMWISE Project, Fonterra, Spreyton (2018)

In 2017 Fonterra's Spreyton factory conducted a trial of Waterwerx's STREAMWISE technology.

Waterwerx is a specialist in water and wastewater treatment and the STREAMWISE technology is an automated system for optimising the chemistry of industrial wastewater solid-liquid separators, such as dissolved air flotation (DAF) units, induced air flotation units and clarifiers.

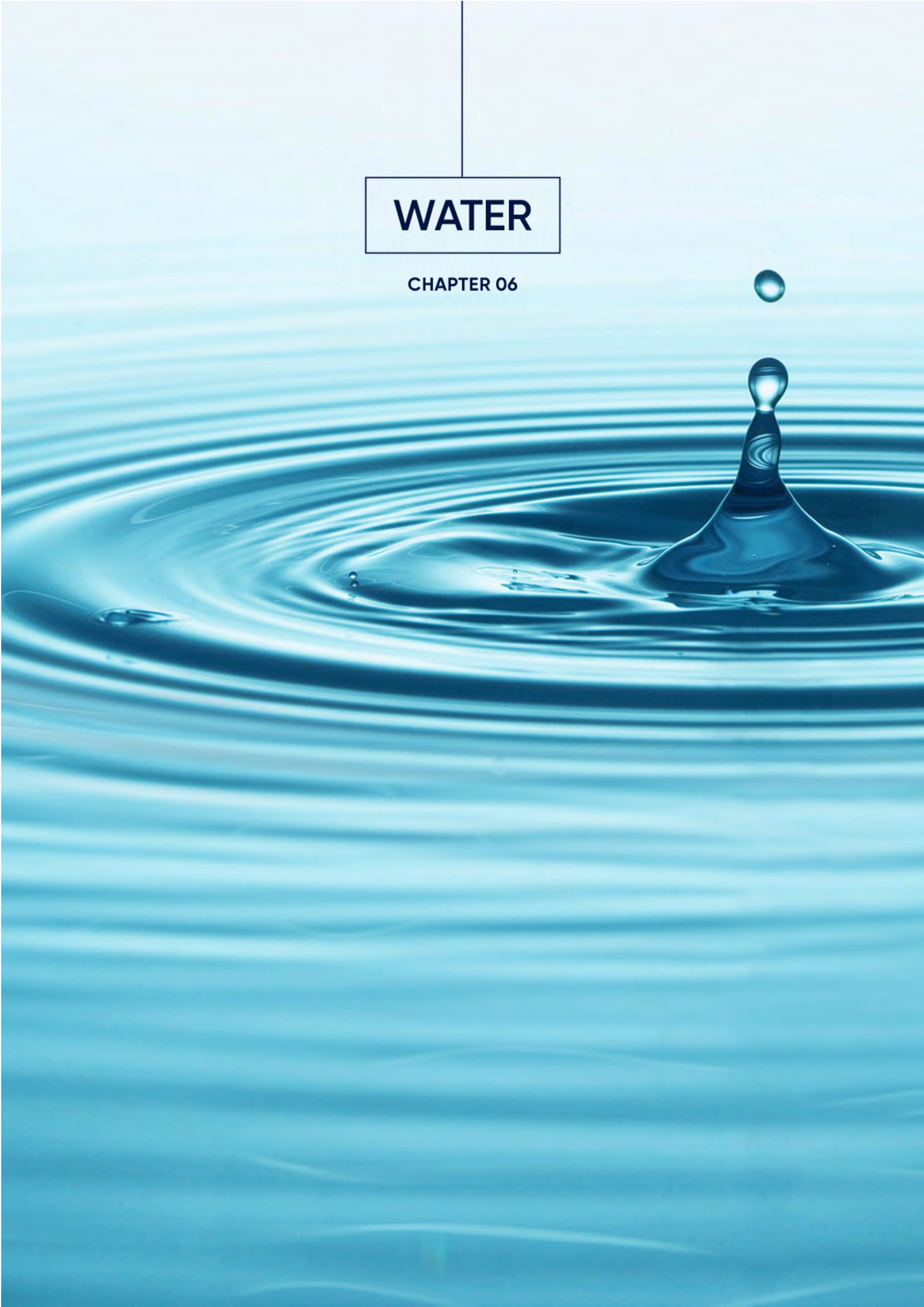
As part of the trial, Waterwerx installed the STREAMWISE system at the Spreyton site and then monitored the performance of the site's DAF unit against a typical baseline. The trial established that the STREAMWISE system could save Fonterra approximately 30% of its wastewater treatment and disposal costs through a combination of chemical, energy, labour and trade waste savings. This translated to a cost reduction of approx. $260,000 p.a.

Waterwerx's business model is such that they lease the STREAMWISE equipment to a site and then take a portion of the savings to help pay off their asset.

In 2018 Fonterra entered into a leasing agreement with Waterwerx to supply the STREAMWISE system at their Spreyton site for the management of the waste water treatment plant.

WATER

CHAPTER 06



6.0 Water

6.1 Overview of water use

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

6.1.1 Water use in dairy factories

In 2015/16, the dairy industry used approximately 1506 GL of water, (1489 GL for farming (ABS 4610) and 17 GL for manufacturing (Pers Comm, 2019) which is equivalent to 9% of Australia's total freshwater consumption (16,131 GL ABS 4610). Of this, 99% is attributed to on-farm use, indicating that the main opportunities for reducing water consumption in the dairy industry are to be found in improving the efficiency of milk production at the farm (Lunde, et al., 2003). Nevertheless, there are still gains to be made and it is important that dairy processors minimise water consumption within factories. Most often they use town water, but other sources include river water, irrigation channel water, bore water and reclaimed condensate. Water shortages in both regional and urban areas are leading processors to review the source and efficiency of their onsite water use, both of their own accord and in response to pressure from local authorities and communities.

Water Stewardship is a management practise which is growing in importance in the management of water resources. It is a useful framework to allow organisations to understand their water use and impacts, and to work collaboratively and transparently for sustainable water management within a catchment context. An example is shown here of an Australian dairy processors that is using the Water Stewardship framework.

Water Stewardship (Lion Co, 2017)

Lion Co. will soon be mapping water risk and impact throughout their supply chain. A Water Stress Study is planned for 2018 and a targeted Water Stewardship Plan will be developed in 2019. More information on an international standard for water stewardship can be found at waterstewardship.org.au/.

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

Water is used in dairy factories for processing and cleaning, for the operation of utilities such as cooling water and steam production, and for ancillary purposes such as amenities and gardens. Figure 6.1 shows an example of water use in a dairy processing factory that produces market milk.

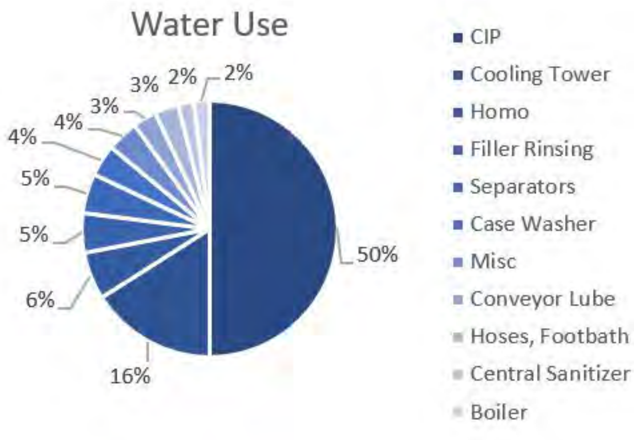


Figure 6.1: Breakdown of water use for a market milk processor (Price, 2015)

Many dairy processors track the overall consumption of water by monitoring the ratio of water to raw milk intake. Trends in water use intensity for the Australian dairy manufacturing industry are shown in Figure 6.2. In 2016/17, ratios for Australian processors producing any combination of white milk, cheese, powders or yoghurts ranged from 0.8 to 3.2 L/L milk, with the average being around 1.85 L/L milk (Figure 6.2) (DMSC, 2017). This is higher than the water benchmarks for the UK ranging from 0.6-1.8 L/L raw milk for liquid milk plants and 0.8-1.7 L/L raw milk for powdered milk plants (Natural Resources Wales, 2014) (WRAP, 2013). Effluent volumes per raw milk intake are often in the same range.

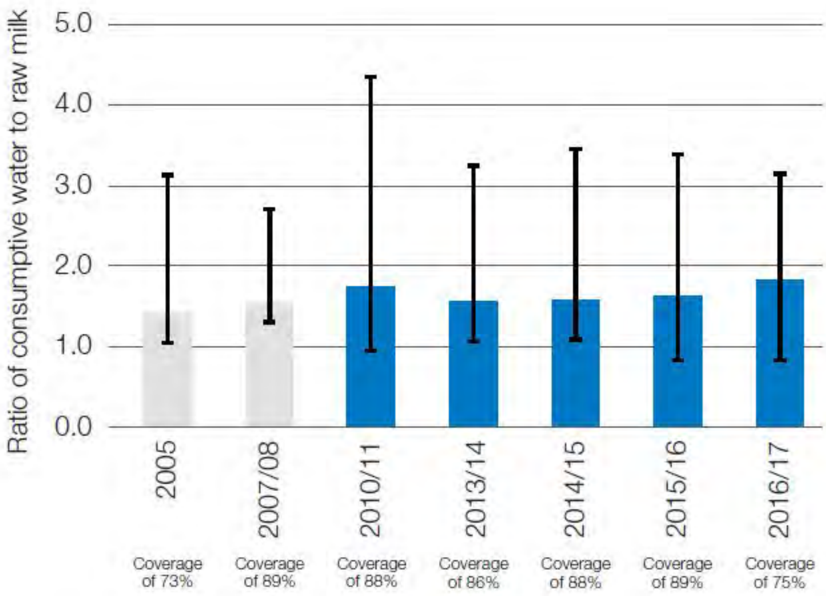


Figure 6.2: Water use intensity – Australian dairy processors (DMSC, 2017)

Table 6.1 shows the range of ratios for factories producing white or flavoured milks, mostly cheese and mostly powdered products. For factories that produce powdered products, there is the potential for the majority of water (>95%) to be supplied from treated condensate, also known as 'cow water'. However, the potential for recovering condensate depends on the scale of a particular powder plant and the ratio of supply to demand on a given day. For example, if the production rate is reduced during the off-peak season there will consequently be less condensate available for recovery.

The range in water to milk intake ratios indicates there is potential for some dairy processing plants to decrease water consumption significantly. The table also shows benchmark data for UK dairy processors. UK processors are encouraged to achieve these benchmarks in order to comply with their environmental permits (UK Environment Agency, 2009) and (Natural Resources Wales, 2014).

Table 6.1: Water to milk intake ratios Australian dairy processors (L/L)2015/2016

Component	Min	Max	Average	No. plants providing data	UK benchmark#
White and flavoured milk*	0.98	2.98	1.9	10	0.6-1.8
Mostly cheese (some powders)	1.6	2.28	1.87	3	-
Mostly powders (some cheese/butter)	0.62	1.05	0.6	3	0.8-1.7
Mixed products	0.90	1.70	1.30	2	-
All dairy processors	0.62	4.51	1.9	22	-

*Excludes UHT in white milk. # (UK Environment Agency, 2009) and (Natural Resources Wales, 2014)

Bega Cheese Ltd, Bega, NSW (Pers Comm, 2018)

Bega Cheese was aiming to reduce its water consumption at its Lagoon St site by almost 40% from 1.3 ML per day in FY2016 to 0.8 ML per day in FY2018. Between 2007 and 2018, water intensity has reduced from 8.5kL/tonne to 7.946kL/tonne product. The reduction in water use has been achieved as a result of recovering and recycling spent water for non-product contact use such as cooling towers and boilers, and an emphasis on improving line efficiencies.

Water mapping, Parmalat, Lidcombe (Parmalat, 2015)

Parmalat's Lidcombe site undertook a water mapping exercise to understand the different points of use through their manufacturing process. This allowed them to optimise their consumption in particular areas. The manufacturing sites track and report on water consumed per kg of finished product.

Zero water milk processing plant, Nestle, Mexico (Nestle, 2017)

Nestle, Mexico has installed a zero water dairy processing plant, which saves 1.6 ML of water per year. The company has invested in another zero water milk plant in California, which it projects could save some 63 million gallons of water (238 ML) every year. During 2015, Nestle's factories — in every product category, not just dairy — withdrew 41.2% less water per tonne of product than they did 10 years previously. The next goal, for 2020, is to achieve an overall reduction of water withdrawal of 35% compared with 2010.

There are increasing numbers of 'zero water' dairy processing plants in countries including Mexico and Brazil (six to be on-line by 2018) with similar plans in South Africa, India, Pakistan, China and California (Nestlé, 2018). The milk powder plants do not extract any local freshwater resources and obtain all of their water needs through reuse of recovered condensate or 'cow' water (Nestlé, 2018).

6.1.2 The true cost of water

Relative to other processing inputs, such as labour or energy, water in Australia is a relatively cheap resource. For this reason, water recycling or reuse projects often cannot be justified once capital expenditure is included and paybacks are calculated. Conversely, water security and availability is increasingly a conservation driver with the occurrence of drought and competition for water sources. Local councils and water authorities continue to move towards full cost recovery for the supply of fresh water and treatment of wastewater. Table 6.2 shows the cost of town water supply for a number of regions where there are dairy processing plants. These costs range from about $1.22c/kL for water supplied from Taswater to $4.27/kL for the South East Queensland regions.

*Table 6.2: Water supply charges in dairy processing regions**

Council	State	City/town	Water supply charge ($/kL) 2004	Water supply charge* ($/kL) 2018	Additional service charges** ($/kL) 2018
Sydney Water	NSW	Penrith	0.94	$2.04	<4%
Hunter Water	NSW	Hexham	0.85	$1.94	<4%
South Australia Water	SA	Mount Gambier	1.00	$3.37	-
Citiwest Water	Vic	Melbourne		$2.59	-
South East Water	Vic	Melbourne	-	$3.12	-
Gippsland Water	Vic.	Maffra	0.54	$2.04	<3%
Goulburn Valley Water	Vic.	Tatura	0.47	$1.17	<10%
Wannon Water	Vic.	Warrnambool	0.58	$2.24	<3%
Queensland Urban Utilities (prev Brisbane Water)	Qld	Brisbane	1.13	$1.45	$2.82 bulk charge
Queensland Urban Utilities (prev) Ipswich City Council	Qld	Booval	1.28	As above	As above
Taswater	Tas.	Devonport	0.70	$1.06	15%

*Excludes meter charges **Additional set charges based on meter size

Despite relatively cheap supply costs, the consideration of the true cost of water is useful in helping develop a business case for water conservation projects. The components making up the total true cost of water for dairy processors include:

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

Table 6.3 provides an example of the full cost of ambient and hot water. It indicates that, while the purchase cost of the water was $2.10 /kL, the true cost was actually $6.87/kL for water at ambient temperature and $10.81/kL for hot water. The cost of wastewater discharge in different regions is discussed more fully in Section 8.0 - Yield optimisation and product recovery.

Table 6.3: Example of the true cost of ambient and hot water ($/kL)

Purchase[a]	$2.10
Supply water treatment	n.a.
Wastewater treatment [b]	$0.75
Wastewater pumping	$0.15
Wastewater discharge (volume charge)	$3.87
True cost of ambient water	**$6.87**
Heating to 80°C [c]	$3.94
True cost of hot water	**$10.81**

[a] Purchase and discharge costs based on Gippsland Water, 2018 charges
[b] Wastewater treatment is based on an estimate for an anaerobic digester
[c] Cost for heating to 80°C using steam produced by a gas boiler. Assumes 1.45 c/MJ

6.1.3 Measuring water consumption

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

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

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

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

Many dairy processors developed water balances and water management plans several years ago particularly during specific drought periods in their region. Often once the period of specific drought has passed these management plans are still in place but the implementation has slipped due to the lack of external (regulatory) pressure to maintain savings. Frequent revisiting of these balances and plan to ensure the information is still accurate and initiatives are still in place can be useful.

Flow meters

Flow meters on equipment with high water consumption, incoming water inlets and wastewater discharge outlets will allow regular recording and monitoring of water use. Flow meters are also useful for measuring 'standing still' water consumption during periods when equipment is not operating, to detect any leaks.

When installing a meter ensure that the meter is tailored to meet the application (e.g. measurement of product wastewater or clean-in-place volumes). The cost of installing or hiring flow meters will vary according to the meter size and functionality. Factors to consider include pipe size, flow rate (L/min), fluid quality (e.g. incoming potable water, wastewater, process water), type of power supply required (mains, battery or solar), accuracy required and piping installation costs.

The digital economy is also impacting on measurement and monitoring with the latest devices using wireless transfer of data from sensors to microcontrollers and modems so that data is transferred in real time to smart phones or PCs. A challenge with metering can be the quantity of data obtained in terms of storing large files and then using the data. A balance between the level of detail metered (e.g. time interval) and the ability to manipulate and draw conclusions from the data should be considered. For example, some meters may be able to provide flow data in intervals of seconds but if the flow is fairly steady then intervals of minutes or half hourly may be sufficient.

Water saving initiatives developed through EPA Victoria's EREP and WaterMAP programs, Lion Co. (DMSC, 2011)

Lion's Chelsea plant in Melbourne was able to identify a series of water reduction opportunities in 2009 through its participation in EPA Victoria's Environment and Resource Efficiency Plan (EREP) program. Many opportunities were implemented almost immediately leading to a saving of 29 ML of fresh water annually. Initiatives implemented included moving to a 6-day production schedule, which eliminated one clean-in-place (CIP) wash a week (saving 6.76 ML each year), installing improved sprays on carton fillers (saving 10 ML per year), and reducing the amount of water used to flush milk pasteurisers during cleaning whilst still maintaining required levels of hygiene. The various water efficiency projects have managed to drive water usage per litre of milk produced down to 0.66L/L – better than world-class standard, which in dairy is typically 1L/L.

'Every Drop Counts' Improved water management: Parmalat, Lidcombe, 2004 Ed

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

Improved water management: Lion Co., Penrith, 2004 Ed

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

6.1.4 Process Models

A number of excel based process models have been developed for Australian dairy processors with Victorian Government Resource Smart Funding. This includes the Closing the Loop Dairy Factor Model which can be accessed through Dairy Australia.

6.2 Reducing demand for water: processing

6.2.1 Optimising rate of water flow

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

Optimising homogeniser cooling water: Beston Global Food Co, Mount Gambier, 2004 Ed

Beston's Mount Gambier site reduced water costs by $10,800/yr, by reducing the flow of cooling water to the homogeniser to the optimum rate. The cost was only $250 for the installation of a flow regulation valve.

6.2.2 Efficient process control

Installing automatic monitoring and control devices in key sites can lower production costs. A wide variety of devices are used in dairy factories to detect operating parameters such as level, flow, temperature, pH, conductivity and turbidity. These are particularly important for detecting the quality of processing and waste streams to enable the maximum recovery of product, chemical and water. Refer to Section 8.0 - Yield optimisation and product recovery for more details.

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

6.2.3 Leaks

Leaking equipment such as pumps, valves and hoses should be promptly repaired, not only to save water, but also to set a good example to staff on the importance of water conservation and good housekeeping. Equipment that is left leaking over lengthy periods can waste significant amounts of water or product. Table 6.4 gives some examples of the cost of water loss from leaking equipment.

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

For equipment items that use large volumes of water, the cost of installing and regularly monitoring meters to detect leaks can be well justified. If possible, it is a good idea to take supply water meter readings during non-production hours to highlight any unusual water consumption or even leaking pipes. A system for reporting and promptly repairing leaks should also be established.

Table 6.4: Cost of water loss from leaking equipment

Equipment	Hourly loss (L)	Annual loss (kL)	Water cost ($/yr)
Union/flange (1 drop/s)	0.5	5	34
Valve (0.1 L/min)	6	53	364
Pump shaft seal (0–4 L/min)	0-240	0–2100	0-14,427
Ball valve (7–14 L/min)	420–840	3680–7360	25,282–50,563
1-inch hose (30–66 L/min)	1800–4000	15,770–34,690	108,340–238,320

Assumptions: purchase cost of water = $2.10/kL; total cost of water = $6.87/kL (Section 6.1.2). Table derived from hourly and annual water loss figures in (Envirowise, 2003).

6.3 Reducing demand for water: cleaning

Cleaning accounts for a large proportion of the water consumed by dairy processors, with as much as 50% used for cleaning equipment and surrounding areas of the plant (Figure 6.1). There are numerous opportunities for reducing water use for cleaning, as outlined in the following section. The Australian Dairy Hygiene Handbook discusses the principles of cleaning, cleaning regimes, water quality and volumes for effective cleaning (Hakim, 2016) and is a useful reference, however, it should be noted that much of the discussion applies to soiling on cold surfaces and to dairy farming.

6.3.1 Dry cleaning

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

Dry floors save water, Parmalat (Parmalat, 2015)

Parmalat's manufacturing sites reduced fresh water use by 23 kL through implementation of water efficiency projects. One of the most significant projects was implementation of the 'dry floors' mandate across the manufacturing sites during 2014.

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

6.3.2 Trigger-operated controls for hoses

Hoses left on unnecessarily waste water. For example, a hose left unattended for a total of one hour each day can lose between 470 kL and 940 kL annually, equating to \$3,200–\$6,400 every year for each hose.[8] The cost of a trigger gun can be up to \$200 for a good quality heavy-duty unit. Developments in trigger nozzles include 'fan shaped' sprays giving broader water coverage as opposed to a narrow jet (Numedic, 2018).

A hose left unattended for a total of an hour a day can waste as much as \$3200–\$6400/yr.

Reuse of pasteuriser water, and hose water-saving devices: Parmalat, Nambour, 2004 Ed

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

6.3.3 High-pressure cleaning systems

High-pressure water cleaners are typically used to clean floors and some equipment. They can use up to 60% less water than hoses attached to mains water as they achieve the clean much more quickly (Müller, 2017) and are considered a 'best available technology' (WRAP, 2013). Mobile high-pressure cleaners can have flow rates up to 20 L/min and pressures of up to 20,000 kPa. In a dairy processing plant, high-pressure cleaners may be useful for cleaning areas such as around wastewater treatment plants, cooling towers and some floor areas. They may not be useful around some processing areas due to the possibility of creating aerosols.

6.3.4 Clean-in-place systems

'When optimising CIP systems, take one step at a time and don't try to make too many changes at once.'

Clean-in-place (CIP) systems are commonly used in dairy processing plants for cleaning tanks, piping, filling machines, pasteurisers, homogenisers and other items of equipment. A well-designed system minimises the use of water, energy and chemicals. The most eco-efficient CIP systems are located close to processing equipment to minimise pipe runs and are properly sized to avoid excessive use of resources. They are also multi-use, where rinse water and chemicals are recovered and stored for reuse. Chemicals and water used in some CIP systems are recovered using membrane filtration. This is discussed further in Section 11.0 - Chemical Use. Design considerations for CIP include ((Tetrapak, 2015) and (DFSV, 2014)):

- all surfaces accessible to the detergent solution
- no dead ends that the detergent cannot reach
- all pipes and machines can be drained
- material choices including stainless steel, plastics and elastomers must be of such quality that they do not transmit any odour or taste to the product.

[8] Assumptions: \$6.87/kL for true water cost; 260 days each year; hose flow rate of 0.5–1.0 L/s

- Material choices must withstand detergents or disinfectants in use at the cleaning temperatures.
- Pump capacity must be able to ensure turbulent flow and adequate pressure to remove soil deposits
- Effective control system including the management of the interface between product, chemical and wash water through a selection of timing devices, conductivity and turbidity meters.

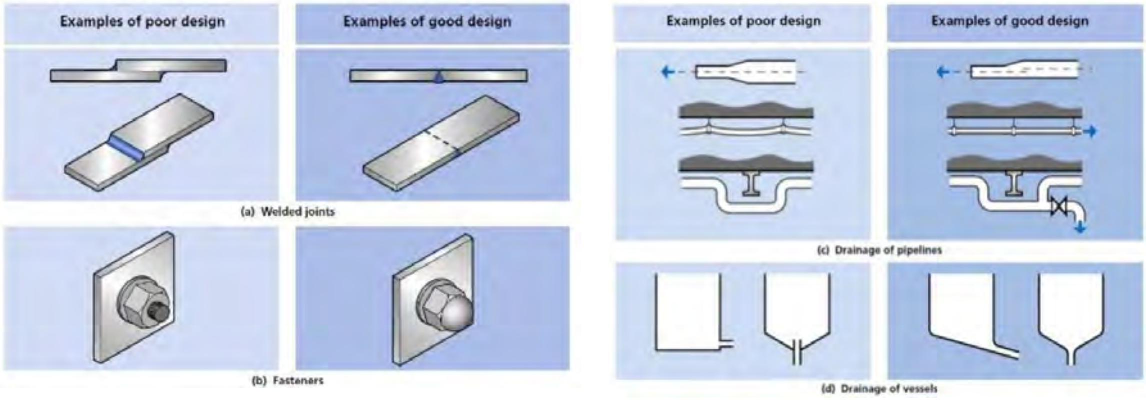


Figure 6.3 Examples of good and poor design for efficient cleaning (WRAP, 2012)

In most systems, interfaces between product, chemical and rinse water are detected using conductivity or turbidity meters; other systems use timers. The effectiveness of conductivity and turbidity meters compared with timers is a topic of debate. Recent designs utilise turbidity sensors for milk product/water interfaces and for pre-rinses with conductivity meters used for CIP solution/water interfaces and for post rinse and final rinse steps (Price, 2015). Timers may not provide a consistent or repeatable quality of clean due to factors such as varying flow rates, pressures, and pump or valve wear; meters can fail, causing operating delays or unnecessary loss of product, chemicals or water to the waste stream. In addition, instrumentation can ‘drift’ out of calibration over time; and timers can be adjusted to compensate for operational factors. Regardless of which system is used, it is important to regularly verify chemical strengths and temperatures as well as carrying out visual checks, if possible, to ensure equipment is clean. These checks may be done every day, shift or clean. It is also important to carry out longer-term monitoring — for example, every 12 months to validate CIP system settings and review timers, chemical concentrations, temperatures and general cleaning effectiveness. This is discussed further in Section 11.0 - Chemical Use

For further reading on CIP systems see

- AS 1162:2000, Cleaning and Sanitizing Dairy Factory Equipment;
- AS/NZS 2541:1998, Guide to the Cleaning-in-Place of Dairy Factory Equipment.
- Closing The Loop Project - investigation of alternative CIP chemicals and practices for reduction in sodium in dairy processor waste streams (Weeks, et al., 2007);
- Clean in Place – A Review of Current Technology and its Use in the Food and Beverage Industry (Palmowski, et al., 2005)

Section 11.0 - Chemical Use outlines methods to reduce chemicals which often also leads to water reduction.

Mapping water use, Fonterra, Darnum site (Monash University, 2017)

Fonterra, Darnum undertook a project via the Gardiner Foundation which involved mapping water use and discharge across the plant to identify major contributors of wastewater and to explore options for recovery/recycling of water. An upgrade to the CIP system was undertaken which included the recovery of final rinse water as well as optimised CIP programs which were adjusted without affecting quality of final product.

CIP upgrade: Bega Cheese (Tatura) (Bega Cheese, 2016))

Tatura Milk relocated and upgraded its lactoferrin and separators kitchen in a project which reduced water use and sodium lost to wastewater. The original clean in place (CIP) kitchens servicing the lactoferrin and separator areas at TMI were antiquated single-use satellite systems, using large volumes of caustic soda and possessing a number of inherent safety issues. The company approved capital of $1 million to install new cleaning infrastructure in a centralised CIP area to service the lactoferrin process and milk separators. The new system will include a re-use system and result in an annualised reduction of sodium of 54 tonnes and an annual water use reduction of 36 ML.

CIP Relocation saves water and energy (Price, 2015)

A dairy relocated it's CIP skid closer to the point of use. The reduced pipe length and more efficient use of water, chemicals, and energy, along with reduced wastewater treatment resulted in water savings of 1.6 million gallons/yr, time savings of 330 cleaning hrs/yr and cost savings of $124,000/yr. This effected 11,500 cleaning circuits per year.

Optimisation of CIP washes (Price, 2015)

A dairy manufacturer undertook approximately 22,500 cleaning circuits per year across 10 CIP sets. A review of the CIP sets found that, on average, 150 gallons (570L) of excess water was being used per circuit. Optimising the water use saved $82,000 and 680 hours of cleaning time per year.

Fine-tuning of CIP system: Lion Co, Penrith, 2004 Ed

Lion Co's Penrith site, as part of a regular audit of CIP systems, reviewed the flush time of their pasteuriser. They were able to reduce the flush time by 12 min/day, which resulted in water savings of 15 ML/yr.

Validation of CIP System: Lion Co, Morwell, 2004 Ed

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

Spray balls and nozzles

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

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

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

Water-efficient spray nozzles: milk and beverage processor, USA , (University of Minnesota, 2003) 2004 Ed

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

Burst rinsing

Burst rinsing is frequently used for the pre-cleaning of tanks and tankers to maximise product recovery before CIP. Depending on the characteristics of the product being cleaned (e.g. its viscosity), a series of bursts rather than a continuous rinse can minimise water use. Burst rinsing is reported to save as much as 15% of cleaning water use (Price, 2015). One disadvantage is that it can add time to a cleaning cycle.

Burst rinsing of tankers: Saputo Dairy Australia, Leongatha. 2004 Ed

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

Burst rinsing: Brownes Dairy, Balcatta. 2004 Ed

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

6.3.5 Scheduling or modifying product changeovers

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

Greater efficiency achieved through longer production runs & reduction in cleaning cycles, Saputo Dairy Australia, Allansford (WCBF, est 2012)

Saputo Dairy Australia's Allansford site actively seeks to run its plant at capacity for as long as possible when milk is available. Milk processed has increased by 170ML (25%) over the past 5yrs. The cheese plant has increased run lengths by 20% (20h to 24h), the powder plant has increased run lengths 50% (20h to 30h). This is achieved by careful hygiene & manufacturing practices. All this reduces energy, water and waste.

Product scheduling improvements save energy: Lion Co, Penrith, 2004 Ed

Lion Co's Penrith site improved product scheduling and increased throughput of the factory which saved energy and water for washing the pasteuriser. Operating procedures dictated that the pasteuriser was cleaned every 9–14 hours, depending on the type of product. The product scheduling improvements reduced the time for which the pasteuriser switched to recirculation mode (effectively not producing product), thereby reducing energy and water consumption per unit of product.

'Pigging' systems

Pigging is a method of removing product from pipes; it can reduce the volume of water required for cleaning by minimising residual product left in the system, and therefore reduce rinse times. Pigging systems, including case studies, are discussed further in Section 8.0 - Yield optimisation and product recovery. One such case study is reported to reduce water consumption during CIP by 80%.

6.3.6 Crate washers

Crate washers can use a significant volume of water in a plant producing short shelf-life milk. The breakdown of water consumption in Figure 6.1shows crate washing as accounting for about 4% of the total water used. Crate washers can be prone to leaks and it is important that they are well maintained. Recirculating water in crate washers is a relatively easy method of reducing consumption. It is useful to investigate adjusting the washer speed and length of cleaning cycles, to achieve the most efficient clean while still meeting hygiene standards. For large dairy processors which operate several sites, it is useful to benchmark water, energy and chemical use between crate washers to identify opportunities for improvement as well as obtain water consumption specifications from potential suppliers.

Redesign of crate wash system: Lion Co, Penrith. 2004 Ed.

Lion Co's Penrith site redesigned its crate wash system to allow the recirculation of water. The improvement saved 60 kL/day of water and $105,000/yr, based on water supply and discharge costs. The cost of implementation was $50,000.

6.4 Reducing demand for water: utilities

6.4.1 Cooling tower operation

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

Opportunities to conserve water in cooling towers include minimising water loss, optimising blowdown, using alternate water supplies and reusing blowdown. Information on the efficient operation of cooling towers can be found at Cooling Towers – Eco-efficiency Opportunities for Queensland Manufacturers (Qld Govt, 2006) or US Federal Energy Management Program (USDOE, 2011).

Cooling towers can be a source of microbial contamination, or can use excessive water, if they are not well maintained. A regular maintenance schedule will enhance the tower's efficiency and maximise its lifespan. Requirements for microbial control measures are set out in AS/NZS 3666.1:2011, Air-Handling and Water Systems of Buildings — Microbial Control — Design, Installation and Commissioning, and in guidelines issued by state health departments.

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

Overflow of water on cooling tower: Saputo Dairy Australia, Leongatha. 2004 Ed.

Saputo's Leongatha site conducted a water audit, which identified that one of the cooling towers was intermittently overflowing. The leak was measured at 120 L/min, which equated to around 57,000 L/day, assuming the leak occurred 30% of the time.

6.4.2 Blowdown in cooling towers and boilers

Blowdown prevents the build-up of dissolved solids deposits in cooling towers and boilers, which reduces operating efficiency. Older cooling towers may be designed to operate with a constant blowdown flow or via timed water release at regular intervals. At minimum, modern systems should have a dedicated water meter and a total dissolved solids (TDS) meter/controller to maintain proper bleed-off rates. The controller then initiates blowdown only when the conductivity in the water exceeds a set value. It may be possible to reuse boiler blowdown water for non-product uses such as floor cleaning or possibly toilet flushing. Blowdown can also be a good source of recovered heat, as discussed in Section 7.0 - Energy and Carbon Emissions – Heat Recovery.

6.4.3 Equipment sealing water

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

Upgrade of cheese plant vacuum pumps, Saputo Dairy Australia, Allansford (WCBF, est 2012)

In 2005, Saputo Dairy Australia's Allansford site upgraded their cheese plant from 6.5 to 8 tonne per hour. This included an upgrade to the vacuum pump room to allow capture and recycle of pump seal water instead of going to drain. This resulted in an 8% reduction in water consumption with savings of 110 kL/day and $630,000 per year.

6.5 Ancillary water use

Water use in amenities, kitchens/cafeterias and gardens may be a small percentage of a factory's overall water use but there can still be significant savings. Practising water conservation, often by implementing simple and low-cost measures, also sends a strong message to staff. Australia has a Water Efficiency Labelling and Standards (WELS) scheme (see www.waterrating.gov.au) which provides a star rating water consumption information for taps, showers, toilets, urinals, flow controllers and dish washers. Table 6.5 shows water efficiency ratings and corresponding flow rates of various appliances.

Table 6.5: Water appliance ratings

Rating	Flow rates for basin taps (L/min)	Flow rates for showers (L/min)	Flow rates for toilets L (average flush volume)*
zero stars	> 16	>16	n/a
★	>12 <16	>12 <16	9.5/4.5 <5.5
★★	>9 <12	> 9.0 <12	9.5/4.5 <4.5
★★★	>7.5 <9	>7.5 < 9.0	6.5/3.5 <4.0
★★★★	>6 <7.5	>4.5 <7.5	4.7/3.2 <3.5
★★★★★	>4.5 <6	n/a	4.7/nd <3.0
★★★★★★	>1.1 <4.5	n/a	4.7/nd <2.5

Source: AS/NZS 6400:2016, Water Efficient Products — Rating and Labelling.
*Full flush/half flush (not greater than) and average flush. nd – not defined

Water saving device for taps, Waterblade (Isle Utilities, 2017)

Waterblade enables hand washing with half the water consumption of standard taps. It is suitable for use in bathroom basins and is easy to install. The Waterblade can be fitted to 95% of European mixer taps and requires only a low flow rate of 2.5 L/m compared with other aerators which operate at 6 L/m, standard taps at 10 L/m. Return on investment depends on usage and utility costs. In an office trial a saving of $75 per tap per year was calculated ($50 water and $25 energy). The Waterblade retails at $12.50, which corresponds to a payback period of just 2 months.

6.6 Stormwater

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

Use of stormwater: Lion Co, Penrith. 2004 Ed.

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

6.7 Water recycling and reuse

There are varying opportunities for water recycling and reuse, depending on the dairy products being produced. In liquid milk factories, water recycle and reuse mostly occurs via the recycle of CIP water and collection of equipment flush and sealing water. Milk powder plants have the opportunity to recycle greater volumes of water (relative to intake) due to the availability of evaporator condensate or 'cow water'. There are increasing examples of powder plants achieving 'zero water' intake.

Cheese plants produce whey as a by-product. The whey is often concentrated using multi-effect evaporators and/or membrane processes and dried to produce a powder so there is potential to recover condensate for reuse. Though it is technically feasible for 'end of pipe' wastewater to be treated for full potable recycle, it is not always cost effective. Water security, as opposed to water costs are more likely to be a driver in increasing levels of recycle and reuse.

Depending on their source, some wastewater streams are relatively clean and can be recycled or reused onsite generally with some form of further treatment. This may be simple filtration and disinfection or via more advanced processes. In some cases, it may be necessary to segregate wastewater streams to allow for reuse. Generally, water that will be in contact with product must be of drinking water quality and meet the Australian Drinking Water Guidelines (HMRC&NRMMC, 2011). Water that is recovered for use as boiler and cooling tower make-up must also generally be of high quality, as excessive organics or salts in the water will become concentrated and cause damage through excessive scaling or corrosion. Advice on the quality of water that can be reused in boilers and cooling towers should be sought from relevant experts.

Conductivity is usually used as an indicator of boiler feed-water quality and a maximum acceptable conductivity of 25 µS/cm has been cited (IDF, 1988). A more recent example described water quality for boiler reuse as follows:

- pH 7–10,
- conductivity (25 °C) <40 mS/cm,
- COD <10 mg/L,
- total organic carbon (TOC) <4mg/L,
- biological oxygen demand (BOD5) 1–50mg/L,
- Ca^{2+} <0.4 mg/L and
- total suspended solids (TSS) 0.5–10 mg/L) (Kitou, 2015).

Reuse of pasteuriser flush water: Lion Co, Chelsea Heights. 2004 Ed

Lion Co's Chelsea Heights site reduced water use by 3 kL/day by recovering water from the pasteuriser flush. Estimated savings per year are greater than 1 ML.

Reuse of instrument cleaning water: Lion Co, Malanda. 2004 Ed

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

6.7.1 Condensate recovery

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

Drying and evaporation processes

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

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

Condensates from evaporation of milk and whey contain various levels of low molar mass organic molecules, traces of lactic acid, alcohols, acetoines and non-protein-nitrogen. These components enhance microbiological growth (often associated with slimy by-products) and create odours which require advanced treatment (Möslang, 2017). The quality of vapour condensate depends on the type of product that is being evaporated, the evaporator installation, the place of extraction, the efficiency of operating personnel and the care they take. For example, it has been shown that the BOD of vapour condensate produced from concentrating acid whey can be almost 14 times that of condensate produced from concentrating skim milk, therefore limiting the opportunities for reuse: 'In general it has been found that the condensate from the earlier stages (effects) of an evaporator can be used after monitoring as boiler feed water, with that from the later stages being suitable for washing floors and the exterior of plant and vehicles' (IDF, 1988). Generally, without further treatment condensate is classified as non-potable.

Typical characteristics of cow water are shown in Table 6.6.

Table 6.6: Characteristics of cow water

Origin	Milk FR (ZA)	Sweet whey (DE)	Acid whey (DE)	NF & RO Permeates
Conductivity (uS/cm)	10-15 (100)	8-40	30-120	20-500
TSS (mg/L)	2-3 (20)	2-3	2-10	1-3
COD (mg/L)	10-50 (100)	30-45	50-300	20-300
TKN (mg/L)	0-2	0-3	0-5	2-10
Ethanol (ug/L)	50-800 (5000)	100-2500		
Acetoines (ug/L)	50-2,000	50-400		
TOC (mg/L)	1-4 (15)	1-9		

- Strong tendency for bacterial growth (> 200,000 CFU/mL)
- Strong concentration changes of constituents over time
- Development of slimy byproducts
- Volatile Organic Compounds (VOC) due to TOC and MO activity resulting in odour

Source: (Möslang, 2015)

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

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

If disinfection is required, condensate should be adequately and properly dosed with disinfectant, with time allowed for additives to react.

These requirements are valid where simple, relatively cheap treatment methods are employed prior to reuse of the condensate. Such methods include the addition of disinfectants such as chlorine and chlorine compounds, and hydrogen peroxide/peracetic acid, as well as technologies such as ion exchange. However, more advanced treatment methods are available and commonly employed by dairy processors. Membranes such as reverse osmosis, ultrafiltration and combinations of these, are used as a higher level of treatment, to remove unwanted components and produce water that can be reused in most areas of a dairy processing plant. This is discussed further in Section 6.7.2 - Use of membranes for water recovery below. Condensate is also often acidic and may require caustic addition to increase the pH — for example to prevent boiler corrosion if used as boiler feed water.

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

Condensate is a good source of heat energy and should be utilised. Significant savings in heating costs can be realised by recovering the heat energy for purposes such as pre-heating product or boiler feed water. For best results, condensate recovery should be integrated into the process at design stage to gain maximum economic benefit from energy and water recovery. Further information can be found in Section 7.0 - Energy and Carbon Emissions.

Reuse of condendate water: Saputo Dairy Australia, Allansford (WCBF, est 2012)

Condensate is produced when skim milk is concentrated in the powder plant evaporator from approximately 10% to 50% milk solids. Water vapour is drawn off and condensed, the pH adjusted & chlorinated ready for use. Previously only 87% of condensate was utilised. Saputo Dairy Australia's Allansford site has now achieved 100% utilisation as of Feb 2010 saving $1,110,000 per year in water costs.

Water recycling, Saputo Dairy Australia, Leongatha (Devondaler, 2013)

Saputo's Leongatha site undertook a water recycling project which involved the installation of plant and equipment to recycle, treat and reuse water. The project reduced reliance and demand on town water and reduced the amount and load of wastewater being discharged from the plant. The project delivered water savings of 390 ML in 2010/11 and 404 ML in 2011/12.

Biological and membrane treatment of condensate water, Veolia Technologies (Möslang, 2017)

A more recent process uses biological treatment of cow water to remove nutrients prior to the membrane filtration. The process consists of a fluidised and fixed bed bioreactor (polishing step) which removes nutrients and helps prevent fouling of membranes. The bioreactor converts very small organic molecules into gases and microorganisms which can be separated easily with ultrafiltration technology. UF membranes separate components with particle sizes > 0.05 µm. Next, reverse osmosis is used for elimination of dissolved, non-biodegradable components. The resulting permeate is treated with chlorine dioxide ready for reuse, while the retentate (15-20% of feed) is typically utilised as process water for less critical applications (e.g. water for cooling towers). The process meets all limits of the German drinking water regulations except for mineral content (pH and solubility for calcite).

Challenges with recovery of condensate water: Fonterra, Spreyton. 2004 Ed

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

Recovery of condensate water: Bega Cheese, Koroit. 2004 Ed

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

Boiler condensate return systems

Water produced from the boiler system in the form of steam condensate should be recovered wherever possible. Minimising condensate loss significantly reduces make-up 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. Steam traps, condensate pumps and lines should be routinely inspected, while boiler systems should be maintained to reduce blowdown and maintain boiler efficiency. More information on boiler condensate return systems can be found in Section 7.0 - Energy and Carbon Emissions .

Reuse of whey evaporation condensate water, Bega Cheese, Southern NSW (Bega Cheese, 2016)

At Bega Cheese, southern NSW, steam condensate from the whey evaporating process is returned to the boiler feed water tank, saving approximately another 70 kilolitres of bore water per day.

6.7.2 Use of membranes for water recovery

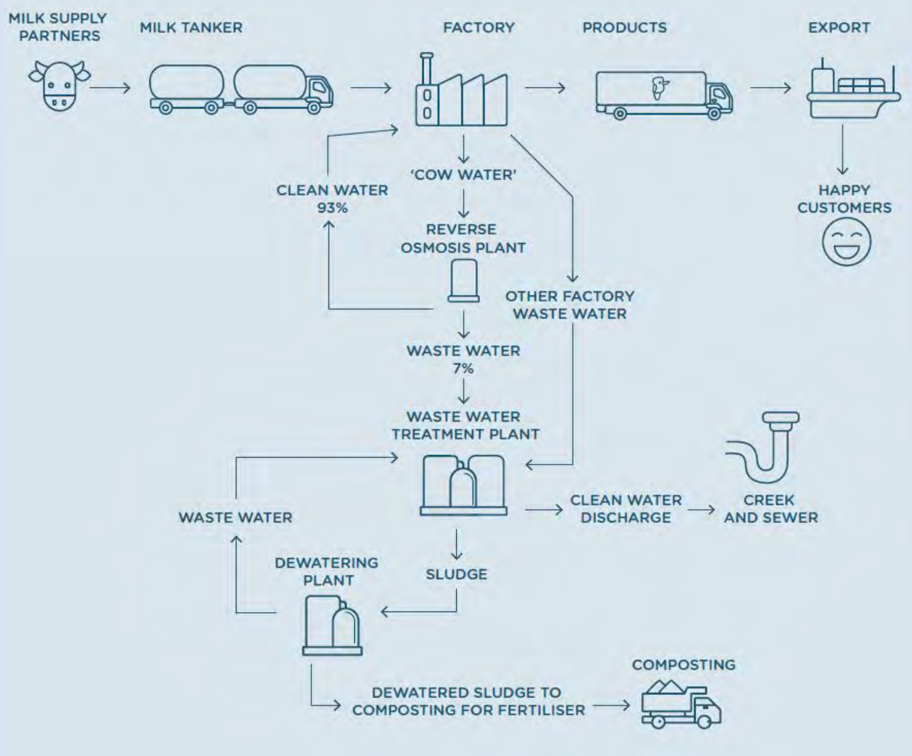
Membranes are commonly used within the dairy industry for the recovery of product, chemicals or water. Since the early 1990s, when the first membrane plants were installed to recover water from evaporator condensate, the technology has become a common feature for all new installations (GEA, 2012). This section looks at the use of membranes to recover and reduce the consumption of water. The use of membranes in dairy processing plants is covered further in Section 8.0 - Yield optimisation and product recovery while the use of membranes for chemical recovery is addressed in Section 11.0 - Chemical Use.

There are many examples of dairy processing plants using membrane filtration (to polish evaporator condensate (cow water); for whey concentration; and for recovering CIP solutions. Reverse osmosis is commonly used to recycle cow water for uses such as cleaning, and for other non-product-contact operations such as for boiler or cooling tower makeup water. Select or combinations of membranes (reverse osmosis, (RO), nanofiltration (NF), Ultrafiltration (UF) and microfiltration (MF) – See 8.7) with pre or post treatment are used to obtain potable water quality which can be used in direct contact or even as part of dairy products (Kitou, 2015). Further advances include the introduction of biological treatment (membrane bioreactors) in conjunction with standard membranes and post treatment processes including carbon (necessary to remove unwanted odours), disinfection (UV and chlorine dioxide) and mineral dosing to make water that is potable and less aggressive to plant (Braun, 2016) (Möslang, 2017). Rather than the treatment of individual wastewater streams, membranes may also be part of a complete wastewater treatment train forming a tertiary treatment step as described in the following section.

Though it is technically feasible to use membranes to produce potable water, it is not always cost effective as membranes can be very energy intensive to operate and treatment methods need to be determined based on the purpose it will be re-used for.

Recovery of cow water from milk powder plant, Burra Foods, Korumburra (Burra Foods, 2017)

Burra Foods milk powder plant treats cow water and recovers up to 80 kL/hr (previously 40 kL/hr) through the installation of a pre-concentrating RO plant. They now have the capability to recover 'cow water' from both the evaporators and the RO plant, which is as high as 800 kL/day during peak season. Burra has now reached the point where, on any one day, 70% of water requirements are produced in house. Burra has invested over $580,000 in its water treatment systems over the past three years. By recovering water, there is less wastewater to treat and, therefore, greatly reduced waste volumes leaving the site.



Membrane treatment of process water for reuse: Cheese, Southern NSW (Bega Cheese, 2016)

At Bega Cheese, southern NSW, water is recovered from the whey concentrating process for reuse in cooling towers. Approximately 125-150 kL of water is recovered each day from cheese processing and used in five cooling towers at the factory. Permeate from the NF process goes through a RO membrane and is then pumped to the five cooling towers. This reduces the use of bore water. In addition, steam condensate from the whey evaporating process is returned to the boiler feed water tank, saving approximately another 70 kL of bore water per day.

Water reclaim system, Fonterra, Pahiatua, NZ (Foodbev Media, 2018a)

Fonterra NZ also has a target to reduce water consumption in its manufacturing plants by 20% by 2020. The P3 milk powder plant at Pahiatua (built in 2015) was already 100 per cent self-sufficient for water, meaning it does not use any groundwater in the manufacturing process. However, the evaporators often produced more water than was required and the excess was typically irrigated onto surrounding farmland. Now, rather than irrigate the excess water, the new reclaimed water system treats the excess water via RO and chlorination before combining it with the site's main water supply for general use. This is saving about half a million litres of groundwater (about the same as 18 milk tanker loads) every day thanks to the development and installation of the new water reclaim system. The Pahiatua site is Fonterra's most water efficient.

Biological and membrane treatment of dairy wastewater, Brazil (Braun, 2016)

A Brazilian dairy producing UHT milk, yogurt, cheese, cottage cheese and petit Suisse undertook treatment trials of its wastewater. The treatment steps included sieving and DAF treatment, a bench scale membrane bioreactor to remove COD and nutrients (nitrogen and phosphorus), and a nano-filtration step. Treated water (permeate) from the membrane bioreactor alone did not produce suitable quality water. The NF step produced permeate which met standards for cooling water feed and low-pressure steam generation, proving that it may be reused for these applications as well as for washing floors, external areas and trucks, that require a lower quality water. The resulting COD concentration of 73 mg/L was well below discharge parameters of environmental legislation in the state of Minas Gerais, Brazil (180 mg COD/L).

Novel use of reverse osmosis water: Lion Co, Malanda. 2004 Ed.

Whey proteins are processed in an RO plant at Lion Co's Malanda site. The company installed pipework to allow water from the RO plant to be used in the laboratory. This eliminated the need to produce 60 kL/week of distilled water (3 ML/yr), and saved $600 in water supply costs. The pipework installation cost $500.

6.8 Wastewater

This section outlines typical wastewater treatment systems used in Australian dairy processing plants. Further information on wastewater management, trade waste discharge costs, yield optimisation and product recovery is presented in Section 8.0 - Yield optimisation and product recovery.

6.8.1 Treatment of wastewater

Dairy processing effluents include:

- milk or milk products lost during processing e.g. via spills;
- by-products of processing operations e.g. evaporator condensates or milk and whey permeates;
- wastewater from the washing of milk trucks, tanks, cans, equipment, bottles and floors;
- starter cultures used in manufacturing; and
- waste chemicals used in CIP processes.

Dairy processing wastewater can contain high concentrations of organics (measured as biochemical or chemical oxygen demand, BOD or COD respectively), nutrients (nitrogen and phosphorous), fats, oils and grease (FOG) and total dissolved solids (TDS) (salinity). The degree of treatment necessary to treat wastewater from a dairy processing plant is determined by the end use and criteria set by regulatory authorities — that is, whether the wastewater is to be discharged to sewer, reused on or off the site, discharged to surface water or used for irrigation. Processes used to treat wastewater fall into three main categories:

- Primary Treatment – physical/chemical treatment to remove fat, oil, grease and solids
- Secondary Treatment – biological treatment to reduce organic matter
- Tertiary treatment – advanced biological treatment, polishing and disinfection.

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

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

Primary treatment

Primary treatments commonly used by the dairy industry are screening, equalisation, neutralisation, and dissolved or induced air flotation (DAF or IAF) to remove fats and suspended solids. The large variation in wastewater volume and quality is a challenge for dairy processors and ensuring that the wastewater is equalised or balanced is important for effective primary treatment.

Secondary treatment

Secondary treatment may incorporate the removal of organic matter and in some cases nutrients such as nitrogen and phosphorus. It typically uses a series of anaerobic and aerobic biological treatment processes. Secondary treatment relies on micro-organisms consuming and converting organic material in the wastewater into either carbon dioxide or methane (biogas), or into more cell matter (sludge) which can be removed and usually dewatered, stabilised and disposed offsite.

In 2015, there were seven anaerobic digesters installed in Australia in dairy processing sites, four of which were tank reactors and three constructed lagoons. Given the significant increase in energy costs, there is growing interest in biogas capture to supplement energy supplies (Chen, 2017).

Further information on biogas capture and sludge utilisation can be found in Section 7.0 - Energy and Carbon Emissions and Section 9.0 - Solid waste reduction Chapter 4, ‘.

Tertiary treatment

Tertiary treatments use biological, physical and/or chemical separation processes to remove organic and inorganic substances that resist primary and secondary treatment; they produce very high-quality effluent, possibly to potable water standard. The most common form of tertiary treatment used by the dairy industry involves the use of membranes, followed by disinfection steps.

6.8.2 Selection of a wastewater treatment system

Selection of a wastewater treatment system will depend on:

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

For dairy processing plants that have the option to discharge waste to the sewer, primary treatment is often the highest level of treatment utilised. Plants in regional locations typically treat wastewater by secondary and tertiary methods to a level suitable for irrigation. However, given the increasing energy costs, anaerobic digestion with biogas capture has become more attractive regardless of location.

An eco-efficiency approach to selecting and operating a wastewater treatment system considers:

- the resources consumed by the treatment system, such as electricity, chemicals and oxygen.
- opportunities for the system to recover valuable materials contained in the waste stream (including biogas).
- opportunities to reuse water after treatment.
- opportunities to recycle biosolids or effluent after treatment.
- the ease with which the system can be operated.
- the efficiency of the wastewater treatment system in meeting regulatory requirements.
- the complexity of the process and risk of system failure.

Where financially viable, wastewater treatments should be selected that enable existing and future opportunities for water reuse, product and energy recovery, and effluent or biosolid recycling. Again, from an eco-efficiency perspective, the most important step is to minimise the volume of wastewater and prevent waste from entering the wastewater stream in the first place. This is discussed in more detail in Section 8.0 - Yield optimisation and product recovery.

Reducing wastewater discharge, Bega Cheese, Tatura (Bega Cheese, 2016)

In FY2016, Bega Cheese's Tatura site conducted an audit of the condensate system and found several opportunities to increase the recycling of condensate on-site, reducing the need for town water and also reducing the volume discharged to Cussen Park. The audit also identified opportunities to reduce the nutrient content of the condensate discharged to the wetland. As a result of work undertaken, condensate volume discharged to Cussen Park in FY2016 was 17% lower than FY2015 (a reduction of 45ML/yr). In addition, the total load of nutrients (nitrogen, phosphorous and BOD) discharged to Cussen Park was reduced by 80% in FY2016 compared to FY2015.

Balancing tank reduces wastewater risk, Lidcombe, Parmalat (Parmalat, 2017)

In 2015, Parmalat Australia installed a 500kL balance tank with biological treatment at their Lidcombe site. The primary reason was to reduce COD, BOD and reduce the risk of odour that could affect nearby residents.

6.8.3 *Management of saline waste streams*

A 2018 report reviews disposal options for saline waste streams from dairy processing in Northern Victoria. Disposal methods and management are very dependent on location, particularly with respect to irrigation and capacity of the receiving environment to manage salt levels. Saline waste streams are classified as shown in Table 6.7.

Table 6.7: Sources of saline wastewater in dairy processing

Waste Stream	Typical source	Primary contaminants	Current management methods
Highly Saline (4000-40,000 EC)	Brine produced by cheese processing Brine produced by NF treatment of cheese brine Brine produced by ROtreatment of groundwater	whey, sodium chloride	Offsite evaporation ponds/basins
Saline (1500 – 4000 EC)	Clean in place (>80%) Brine from product (approx. 10%) Additional product process (approx. 5%) Product loses (approx. 5%)	sodium hydroxide sodium chloride	Irrigation, shandying with fresh water
Salty (< 1500 EC)	Generally non-dairy processing waste	Sodium chloride	Irrigation, shandying with fresh water
Source: (RMCG, 2018)			

The report describes treatment methods for a modern cheese making facility which utilises membrane filtration as shown in Figure 6.4. For further information on current and proposed management of saline waste streams see Saline Wastes in Northern Victoria-Management Strategy (RMCG, 2018).

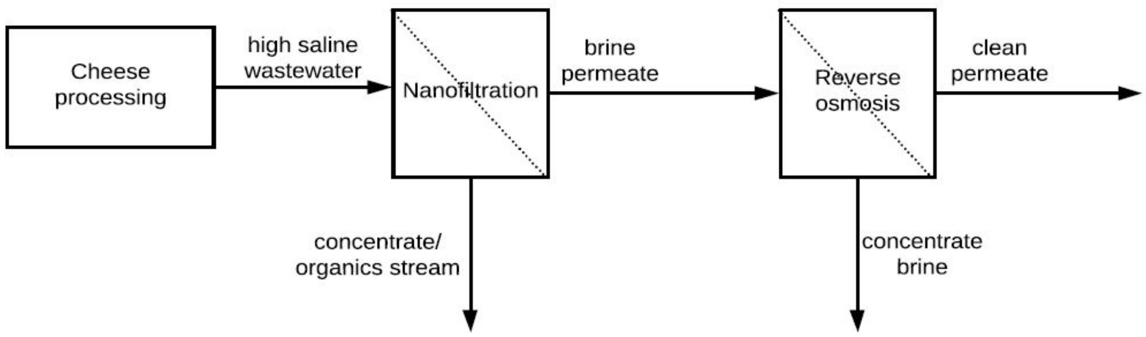


Figure 6.4: Treatment of high saline wastewater in cheese processing (RMCG, 2018)

Minimising sodium discharge in irrigated water, Bega Cheese, Strathmerton (RMCG, 2018)

In 2014/15, a graduate student at Bega Cheese's Strathmerton site investigated options for minimising sodium discharge in irrigated water. A mass balance of sodium was completed and found that 91% of the sodium came from the CIP systems. Historically, the CIP control programming had not been written with concern for the minimisation of sodium hydroxide consumption. Also, process changes over time had added to the sodium hydroxide consumption and therefore adjustment of all CIP circuits was recommended. Recommendations included:

- Increasing the lag time on the return valve to the caustic tank during the pre-rinse cycle of the hold tube circuit. A drop in conductivity shortly after changing from pre-rinse to caustic resulted in an over-dosing. The location of the dosing sensor caused the control system to see this change in conductivity, resulting in the unnecessary dosing.
- Installing a filter on the cooker filler circuit to ensure that all residual cheese pieces are removed from the line. This prevents solids entering the caustic tank, where they degrade the caustic for future cleaning cycles.

- Installing variable speed drives on CIP supply pumps to reduce the mixing of the caustic cleaning solution and the rinse water. This reduces fluctuations in conductivity measurements which result in unnecessary dosing of sodium hydroxide.
- Re-timing of each CIP circuit to ensure that the pump and valve operating times are correct for the length and size of the pipelines in each circuit.

6.8.4 Reuse of treated wastewater for irrigation

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

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

Table 6.7 indicates the sources of saline wastewater. The uptake of salts by crops and pasture can reduce growth, discolour or scorch leaves, or cause foliage death, so it is essential that the salinity level of wastewater used for irrigation is routinely monitored. High sodium salt levels (measured as sodicity) impacts on soil structure and ability to receive water and nutrients.

A risk assessment that includes a water, nutrient and salt model should be developed to fully assess the hydraulic and nutrient salt loadings of the soil, and the likely impact of irrigation. It is also important to prevent runoff and contamination of waterways, and spray drift onto neighbouring lands. Figure 6.5 shows a flowchart for evaluating impacts of salinity and sodicity on soils. For explanation and further information see the ANZECC Guidelines for fresh and marine water quality for information on quality of water that can be used for irrigation (ANZECC, 2000).

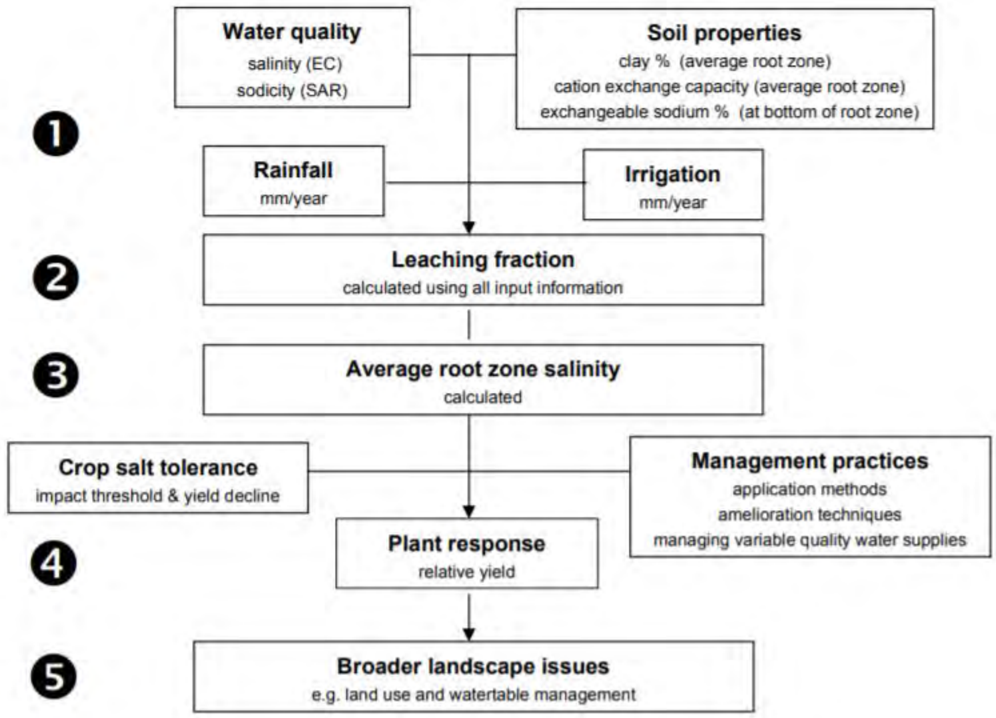


Figure 6.5: Flow diagram for evaluating salinity and sodicity impacts of irrigation water (ANZECC, 2000)

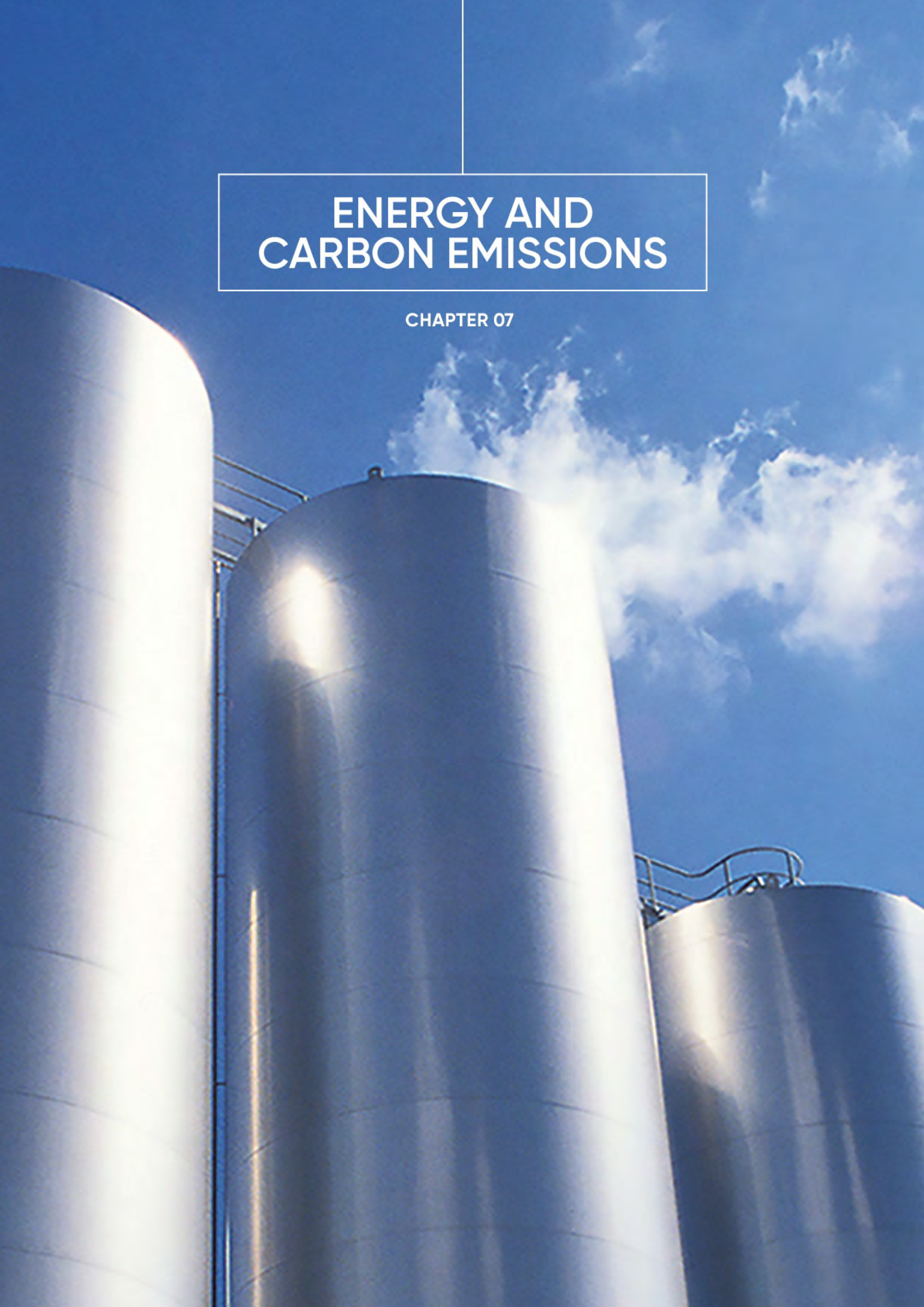
Irrigation of wastewater, Bega Cheese (Bega Cheese, 2016)

Bega and Strathmerton sites irrigated 656ML of wastewater onto surrounding farms.

Farmers welcome the water and buy less fertilizer thanks to the beneficial nutrients and minerals in the water. Bega Cheese studies the health of irrigated soil as part of the sustainable irrigation program. 29 per cent of water consumed by the Group is irrigated to farms.

ENERGY AND CARBON EMISSIONS

CHAPTER 07



7.0 Energy and Carbon Emissions

7.1 Overview

Dairy factories use variable amounts of energy, depending on the types of products manufactured. Dairy factories producing mainly market milk use energy for heating and pasteurisation, cooling and refrigeration, lighting, air conditioning, pumping, and operating processing and auxiliary equipment. Factories producing concentrated milk products, cheese, whey or powders require additional energy for churning, pressing, separation, concentration, evaporation and drying.

The sources of energy in Australian dairy processing plants are generally electricity and thermal energy from fossil fuels including coal, oil, natural gas and LPG, while increasing numbers of processors are supplementing fuel supplies with biogas. There are also growing numbers of food processors utilising renewable energy sources, mainly solar PV. The Australian dairy processing industry has been tracking carbon emissions over the last decade and has recently been reporting on energy consumption (Figure 7.1 and Figure 7.2). These trends represent about 80-90% of the entire industry (DMSC, 2017)

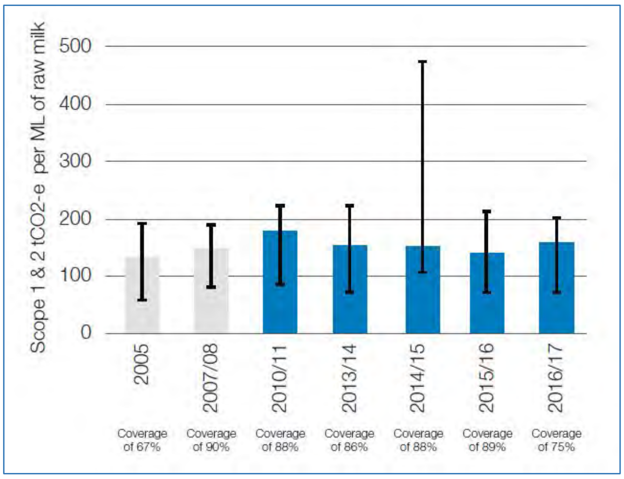


Figure 7.1: Scope 1 & 2 Carbon Emissions Australian Dairy Processors (DMSC, 2017)

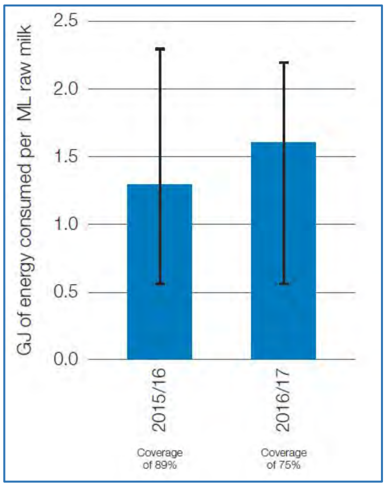


Figure 7.2: Energy consumption Australian Dairy Processors (DMSC, 2017)

Table 7.1 shows typical percentages of energy supplied from electricity and other fuels used to produce thermal energy (i.e. steam for Australian dairy plants surveyed during this project).

Table 7.1: Proportions of electricity and thermal energy use (2015/16)

	Electricity (%)	Thermal (%)
White and flavoured milk#	49	51
Mostly cheese (some powders)	21	79
Mostly powders (some cheese)	16	84
Mixed products	16	84
# excluding UHT milk		

Table 7.2 shows total use of energy (electrical and thermal) per kL of raw milk intake for Australian dairy processors (2015/16). The table also shows 2008 data for 23 UK dairy processors as well as 2014 data which is the expected benchmark range that UK processors must meet in order to retain their environmental permits (UK Environment Agency, 2009) and (Natural Resources Wales, 2014). Energy consumption of Australian liquid milk and cheese

plants is similar to the UK benchmarks. The average energy consumption for Australian powder plants (1.50 GJ/kL) is higher than the expected benchmark for Welsh processors (1.08 -1.44 GJ/kL). This could be attributed to economies of scale.

Table 7.2: Total energy use — electrical and thermal (2015/16)

	Australian data (2015/16)				UK (2014)[1]	UK (2008)[2]
GJ/kL raw milk intake	**Min.**	**Max.**	**Average**	**No. plants providing data**	**Benchmark range**	**Min-Max (Ave)**
White and flavoured only	0.38	0.87	0.53	10	0.25-0.72	0.12-1.41 (0.63)
Mostly cheese (and some powders)	0.52	1.99	1.46	3	-	0.46-1.74 (1.48)
Mainly powders	1.30	2.78	1.50	4	1.08-1.44	-
Mixed products	0.84	1.69	1.26	2	-	0.20-3.69 (1.34)
All dairy processors	0.38	2.78	1.02	22	-	-

[1] (UK Environment Agency, 2009) (Natural Resources Wales, 2014)[2] (Carbon Trust, est 2010)

Figure 7.3 and Figure 7.4 show the typical breakdown of energy costs in two UK dairy processing plants, one producing mainly white milk and the other producing cheese and powders. For a short shelf-life milk plant, energy costs are relatively evenly distributed between refrigeration, general services, processing, clean-in-place, bottling and cartoning. For plants producing cheese, whey and powders, the main energy costs are in drying and evaporating, followed by general services, refrigeration and clean-in-place.

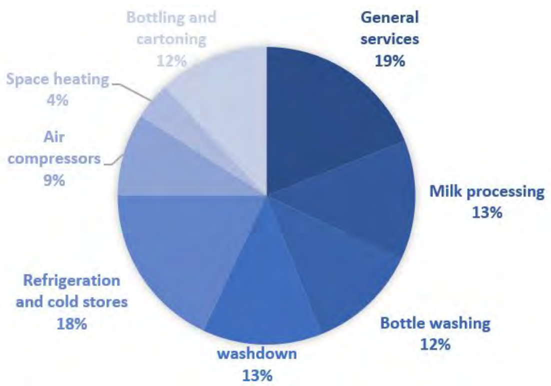


Figure 7.3: Energy cost breakdown by area – milk plant

Source: (ETSU, 1998)

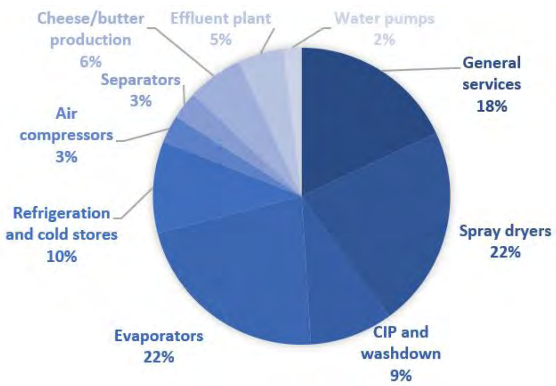


Figure 7.4: Energy cost breakdown by area – powder, cheese and whey plant

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

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

7.1.1 The cost of energy

Table 7.3 shows typical costs for the energy sources commonly used in dairy factories, which vary between approximately $4.70 per GJ for black coal and around $19 per GJ for electricity. There is variation in the price paid for fuels and electricity within the industry, depending on the source, the supplier and the negotiating power of the business. Dairy processing plants choose their electricity supplier and purchase electricity on the contestable market where this is available.

For electricity, there are additional demand related charges that are not included in these costs and which can contribute a further 30-50% of an electricity bill. Australian dairy processors have experienced steep increases in energy costs as a result of retiring aging infrastructure, managing the rise of renewable energy sources and domestic markets (in the case of electricity supply) and managing supplies and volatility in the domestic and international gas market (in the case of gas) (Wood, et al., 2017) (CEFC, 2018). As an indication of energy expenditure for a dairy processing company, the combined electricity and gas bill for Burra Foods increased by almost $4 million per annum from 2016 to 2018 (DMSC, 2017). In relation to total operating costs, in 2016/17, 5% of Bega's non-milk expenditure was on energy and 12.5% was on packaging (Bega Cheese, 2017).

Table 7.3: Typical costs for primary energy sources

Fuel costs	Calorific value[a]		Typical fuel cost			
			($/quantity of fuel)[b]		($/GJ)	CO_2 emissions kg CO_2 eq/GJ[a]
Black (bituminous) coal	27.0	GJ/t	$126	/t	$4.67	90
Heating oil	37.3	GJ/kL	$0.77	/l	$20.62	69.7
Natural gas (town)	39.0	MJ/m3	$8-15	/GJ	$8-15	60.2
Biomass (municipal and industrial)	12.2	GJ/t	-	-	-	1.8
Grid Electricity (Vic/NSW)	3.6	MJ/kWh	$0.07	/kWh	$19.40	219-300

a (Aust Govt, 2017)
b Coal price (KPMG, 2018), Heating Oil price (Indexmundi, 2018), Natural gas price (Oakley Greenwood, 2018), (Momentum Energy, 2018)

Table 7.4 shows example fuel costs for steam production in coal, natural gas and oil-fired boilers. These costs do not include the operating costs of chemicals, labour, maintenance and ash disposal. The fuel costs for producing steam from coal is considerably lower than for gas and for fuel oil. As shown, the cost per tonne of steam is around $15.40 for a coal-fired boiler (85% efficiency) to around $43 per tonne for a natural gas boiler (95% efficiency). (Note: this does not include costs of labour or ash handling.)

Table 7.4: Example fuel costs for steam production [a]

	Coal boiler (85% efficiency)		Natural gas boiler (95% efficiency)		Fuel oil boiler (90% efficiency)	
Energy content of steam	2.8	GJ/t steam	2.8	GJ/t steam	2.8	GJ/t steam
Fuel energy input	3.3	GJ/t steam	2.9	GJ/t steam	3.1	GJ/t steam
Quantity of fuel	122	kg coal/ t steam	2.9	GJ/t steam	83	litre oil/t steam
Cost	$15.40	/t steam	$43.5	/t steam	$63.90	/t steam

[a] Based on a system producing steam at 11 bar and 184°C, with a steam enthalpy of 2.8 GJ/kg steam and pricing in Table 7.3

Hot water is also used for heating and sterilisation. Table 7.5 shows example fuel costs for water heating. Other heating options are the use of solar PV, solar evacuated tubes and also heat pumps. The costs of producing hot water and steam for these options is very much site and location specific as they are impacted by solar irradiance (in the case of solar PV) and also temperature requirement. In the case of heat pumps, there is also the potential to utilise waste heat sources to improve efficiencies. Heat pumps and solar technology are discussed later in this chapter.

Table 7.5: Example fuel costs for direct heating of water with electricity or gas from 20°C to 84°C [a]

	Direct water heating			
	Electricity		Gas	
	95% efficiency		95% efficiency	
Heat input required (MJ)	282	MJ/kL	282	MJ/kL
Quantity of fuel / power	78.2	kWh/kL	7.1	m^3 gas/kL
Cost	$6.26	/kL	$2.41	/kL

[a] Based on electricity price of $0.08/kW h and gas price of $0.34/$m^3$

Replacement of electric heaters with steam heaters, Bega Cheese, Koroit, 2004 Ed

Electric dryer bar heaters were replaced with heaters fuelled by steam at Bega Cheese's Koroit site. Savings in fuel were estimated at $156,000/yr (including 1938 tonnes CO_2 emissions) for an installation cost of $80,000.

7.1.2 Carbon emissions

Carbon emissions from dairy processing (farmgate to supermarket door) are around 15% of total carbon emissions over the entire life cycle (Figure 7.5) with 54% related to on-farm emissions (Lunde, et al., 2003). Emissions during processing are related to the carbon intensity of the energy sources with fossil fuels being most carbon intensive as shown in Figure 7.6. Figure 7.7 shows the trend in emission intensity for Australian dairy processors from 2005 to 2016/17 with averages ranging between about 120 and 160 kg CO_{2e}/kL milk.

Installation of solar PV, (Lion Co, 2017)

Lion have a target to reduce carbon emissions on FY2015 levels by 30% by 2026 and will install 10 MW of solar PV generation by 2025. By the end of 2017, they had reduced Scope 1 and 2 carbon emissions by 12.8%.

Table 7.6 shows carbon emissions for different dairy products. As shown in Table 7.1, cheese and powdered dairy products use more thermal energy than for liquid milk processing which impacts on carbon emissions due to the variation in fuel sources. Table 7.6 also includes 2008 data for 23 UK dairy processors. Based on this data, average carbon emissions for Australian processors for all products falls with the range of figures for the UK processors. There are growing examples of dairy processors utilising renewable energy sources as discussed later in this chapter.

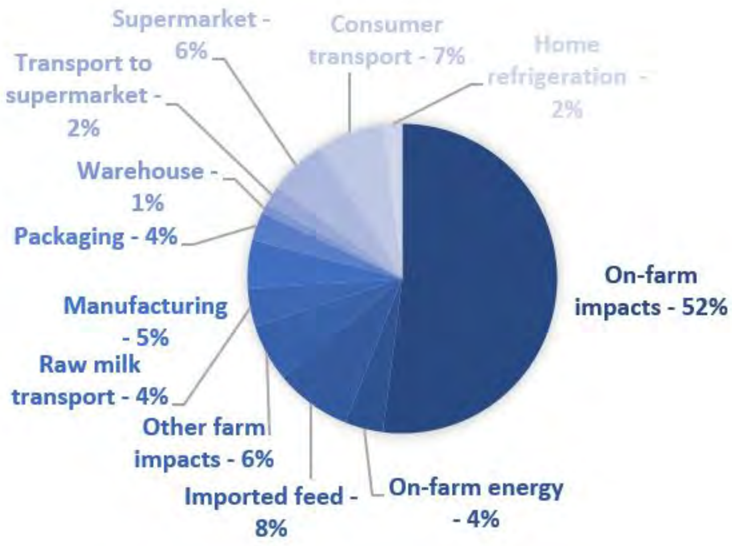


Figure 7.5: Australian Dairy Industry life cycle carbon emissions. Source: (Lunde, et al., 2003)

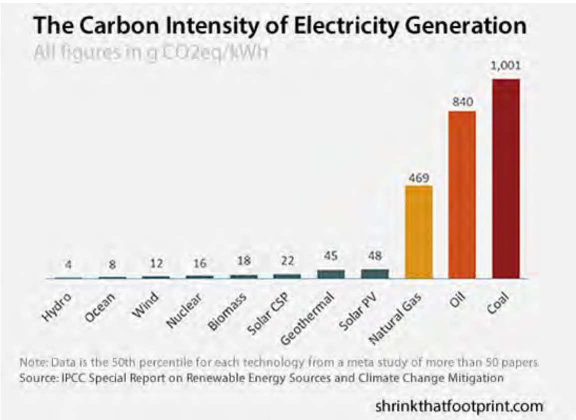


Figure 7.6: Carbon intensity of electricity generation by type. Source: www.shrinkthatfootprint.com. Data obtained from (Moomaw, et al., 2011)

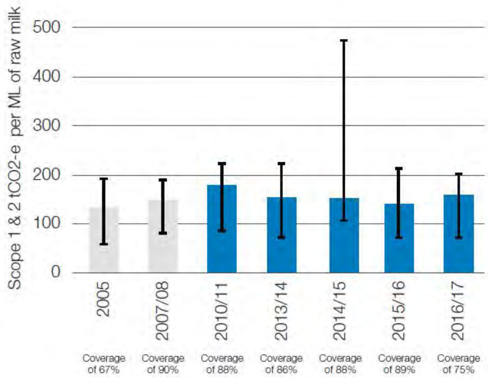


Figure 7.7: Scope 1 and 2 carbon emissions – Australian Dairy Processors (DMSC, 2017)

Table 7.6: Scope 1 and 2 carbon emissions

kg/kL raw milk intake	Australian data (2015/16) Min.	Max.	Average	No. plants providing data	UK data (2008)1 Min-Max (Ave)
White and flavoured only	48.2	111.8	74.5	10	18-111 (53)
Mostly cheese (and some powders)	62.4	205.0	109.9	3	49-151 (81)
Mainly powders	142.1	275	142.6	4	15-362 (83)
Mixed products	88.6	155.1	121.9	2	
All dairy processors	48.2	205.0	109.4	22	

[1] (Carbon Trust, est 2010)

7.2 Energy management

A good energy management program will identify uses of energy for a factory and highlight areas for improvement. One of the first steps in an energy management program is to find out where energy is being used across the site, which may require the installation of additional instrumentation such as steam, gas and electricity sub-meters. Measuring and monitoring energy use will highlight opportunities for savings and in turn reduce greenhouse gas emissions.

The formation of an energy management team, involving a wide cross-section of staff, is a proven way of identifying opportunities to reduce energy consumption. International standards that can be used as a guideline for energy management are the *ISO 50001:2018 – Energy Management System.* These are based on the model for continual improvement used for other standards such as ISO 9001 (Quality Management Systems) and ISO 14001 (Environmental Management Systems). Standards for energy auditing are described in *ISO 50002:2014 Energy Audits: Requirements with guidance for use* and the *ASNZS 3598:2014 Energy Audits* which includes three parts for Commercial Buildings; Industrial and Related Activities and Transport Related Activities.

Burra Foods Energy Management (DMSC, 2017)

As with all Australian dairy processors, Burra Foods is facing increasing utility costs. From 2016 to 2018, their combined electricity and gas bill increased by almost $4 million per annum. With the support of Sustainability Victoria, Burra Foods commenced a detailed study of the energy usage.

An early initiative included the design and installation of an energy management system to control peak load demand and collect minute-by-minute data by department. This enables tracking of energy demand against production so Burra Foods can better manage supply. The company installed 600 m^2 of solar PV which was expected to deliver 2.4% of electricity needs with a five-year payback. More solar, wind turbine, gas tri-generation turbines, renewable energy fed boilers and other options are being evaluated.

CASE STUDY

energy use efficiency

Tatura: "Meterman" project to improve energy efficiency in powder dryers

In 2010, Tatura Milk Industries (TMI) developed a project to assess the benefit of using real time energy data to improve operational efficiency in their powder dryers. Real time monitoring had previously been adopted elsewhere but with mixed results.

Using a major investment of $600k of Government and industry funding, including from the Geoffrey Gardiner Foundation, technicians installed two dozen meters on one dryer, to capture data on air and liquid flows, humidity, steam, and associated electricity consumption over an 18 month period.

Throughout 2010/11, a small group of employees developed a program for step-by-step improvement in the dryer operation as data became available. This process also revealed that highly experienced dryer operators already had different (and entrenched) ways of managing the dryer performance. A key element of the TMI approach was anticipating this outcome and engaging a consultant to assist with people-related aspects of the project, ensuring greater implementation / behavioural change.

Different operating options were tested and the most effective ones used in developing a set of procedures that were subsequently accepted by all of the individual operators as moving towards both consistent and optimum (energy efficient) performance. It was projected that on completion of the project after 2010/11 improvements in productivity would be >5%. Tatura Milk Industries is now looking into how these lessons can be applied to its other dryers, to further improve productivity and related energy savings.

7.2.1 Real time energy monitoring

Real time energy monitoring/management systems are widely available and accessible to industry. Such systems can be set up to monitor real time energy or water consumption on individual items of equipment or finite areas of processing. Modern energy management systems feature cloud-based monitoring dashboards showing consumption to the minute and can be equipped with alerts if energy use is outside typical operating parameters or approaching peak demand set points. They can also incorporate control mechanisms to turn on or off equipment items or adjust settings. A study of 103 industrial/factory energy management systems indicated that in 2014, yearly annual savings were about 10% with individual equipment items savings (HVAC and other) being at about 16% (Lee & Cheng, 2016).

7.2.2 Demand management

There are substantial savings possible through managing the electricity demand of the plant. Demand charges are based on the largest amount of electricity consumed in any single demand period (generally 15 minutes) during a month and are typically charged in $/kVA. Demand charges can make up as much as 50% of total electricity costs. They can be reduced by managing the operation of equipment to utilise off-peak supplies, load shedding, and staggering the start-up times of large equipment items such as compressors or dryers. Soft starters on motors will help flatten out power demand during start-up while variable speed drives can also help reduce overall demand. Real time energy monitoring systems can help reduce peak demand by ramping back equipment (where production is not affected) when pre-selected set points are reached.

Demand is usually charged as total power used by the site (kVA) which is the power used (kWh) multiplied by the power factor. Power factor is explained in the following section.

Lidcombe Utilities Sub-Metering (Parmalat, 2015)

The ability to measure energy consumption is the first step to be able to identify and control inefficiencies. Parmalat's Lidcombe site was fitted with 19 electricity meters to measure refrigeration and air compressors, packaging moulding machines and large equipment on the processing floor. Five steam, natural gas and compressed air flow meters were also installed. The data collected is used to create efficiency ratios that are used daily by the site to measure utilities efficiency. The project won a 2014 National Energy Efficiency award from the Energy Efficiency Council, in the category of Best Industrial Energy Efficiency Project 2014.

Reducing power demand: Saputo Dairy Australia, Leongatha 2004 Ed

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

Improved start-up procedures: Bega Cheese, Koroit 2004 Ed

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

Load shedding, California dairy (Homan, et al., 2015)

A California dairy participating in an auto demand response program achieved an 80% load reduction in their cheese production line for a 2 hour event. The dairy reduced demand by turning off compressors and allowing temperatures to "float" in the cold storage section of the operation without affecting product quality. A demand curtailment of 160 kWh was reported (average of 80 kW over the 2 hour period).

Transferring this to Australian context would save around $23,000/yr (80 kW x 19.90 $/kW x 12 mnths/yr = $19,000/yr in demand charges & 160 kWh x 365 d/yr x 7 c/kWh = $4000/yr)

7.2.3 Power factor correction

Power factor is the ratio of the total or apparent power (kVA) demanded by the site and the real power used by the site, or more simply how efficiently a site uses the electricity provided to them. A PF close to unity (1) means energy is used effectively and the demand is equal to the use. A poor PF will give a higher kVA reading and will cost a site more.

Generally, the demand of the site is greater than the real power leading to a PF less than 1. A PF less than 0.8 should be investigated, however any PF less than 1 will have an impact on the demand charge. Poor PF is generally caused by

- Inductive loads such as transformers
- AC motors
- Welding equipment
- Fluorescent lighting (Energy Queensland Group, 2018).

PF can be improved at the source of the problem by:

- Installing the correct size motors (i.e. not oversized)
- Installing equipment with variable speed drives (VSDs),
- Retrofitting VSD's
- Retrofitting with LEDs and
- Choosing equipment that has good power factor (Energy Queensland Group, 2018).

Alternatively, Power Factor Correction (PFC) can also be installed either on the main switch or at the problematic equipment. PFC are a bank of capacitors that store and provide reactive power as required.

7.2.4 Voltage optimisation

Australian standards require electricity to be supplied at 230 V (+10% to -6%), therefore providing an allowable voltage supply range between 253 V to 216 V. Voltage optimisation aims to adjust the voltage levels from a wider range (i.e. supplied between 253 V and 216 V) to a narrower range (e.g. 230 V +\- 1%) that is optimal for a company's particular electrical equipment. In some cases, an adjustment in supply voltage levels may lead to a reduction in electricity consumption and associated costs. For further information see 'I am your guide to Voltage Optimisation' (NSW OEH, 2016).

7.2.5 Process models

A number of excel based process models have been developed for Australian dairy processors with Victorian Government Resource Smart Funding. These can be accessed through Dairy Australia and include the following:

- Dryer System Mass and Energy Balance Tool
- Evaporator System Mass and Energy Balance Tool
- Boiler Model
- Butter Model
- Cheese Model
- Compressed Air Model
- Liquid Milk Model
- Powder Model
- Refrigeration Model

7.3 Reducing thermal energy demand

In 2018, the Australian Manufacturing Gas Efficiency Guide was released to guide manufacturers on gas saving opportunities to reduce use and operating costs (CEFC, 2018). Gas is currently the main energy source used to produce steam and hot water and for process heating. The report indicates the potential for Australian industry to reduce gas consumption by at least 25% on 2018 levels through greater efficiency or fuel switching. Opportunities are listed based on upfront cost, payback and readiness to adopt the opportunity. Many of the opportunities are discussed in detail in this manual.

7.3.1 Evaporation

Evaporators are commonly used in dairy processing plants to concentrate whole milk, skim milk, whey, whey protein concentrate and permeate from membrane filtration. They are often used as a concentration step before drying of milk product, for example, concentrating heat-treated milk from approximately 10% to around 50% total solids or whey from 6% to 60%. To minimize the thermal impact on the products from the heat applied, evaporation takes place in a vacuum at pressures of 160 – 320 kPa, equivalent to water boiling temperatures of 55 – 70 °C (Tetrapak, 2015). There are various types of evaporators available to the industry including circulation evaporators, falling film (plate and tubular types) and others (Tetrapak, 2015; APV, 2009)

Figure 7.8 and Figure 7.9 show schematics of falling film evaporators typically used by the industry. Evaporators may be single- or multiple-stage (effect) where energy savings are made by using the vapour from the first effect to heat product in the second, and so on. Thermal vapour recompressors (TVRs) further reduce energy usage by using a steam ejector to compress the vapour, increasing its temperature and pressure before utilising its evaporative energy. Mechanical vapour recompressors (MVRs), which use a motor or mechanically driven compressor, are even more energy-efficient than TVRs, even though additional electrical energy is required to operate the compressor.

The most energy-efficient evaporators use a combination of multi-stage design and mechanical vapour recompression. Table 7.7shows a comparison of energy requirements for four combinations of evaporators. Australian milk powder factories generally use a combination of TVRs, MVRs, multiple-stage evaporators (up to five) and multiple-stage dryers.

Process models and simulators are extremely useful tools in monitoring and predicting the efficiency of evaporators. The results of one such study, which predicted profiles similar to an existing evaporator, were consistent with a known fact that a three-effect falling-film evaporator with MVR could consume 60% less energy than a conventional five effect evaporator (Zhang, et al., 2018).

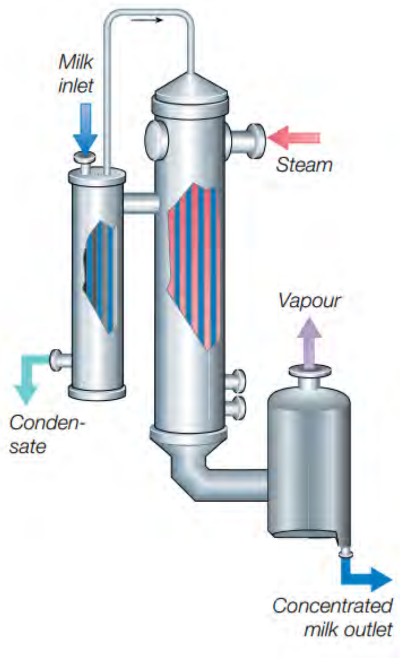


Figure 7.8: Single-effect falling film evaporator schematic
Source: (Tetra Pak, 1995)

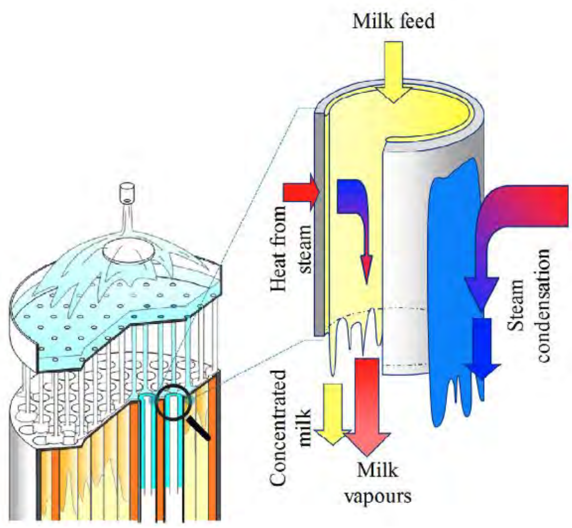


Figure 7.9: Falling film evaporator basic principle
(Zhang, et al., 2018)

Table 7.7: Energy consumption of multi-effect evaporators and vapour recompression

Technology	Typical specific energy consumption (energy /kg water evaporated
Triple-effect evaporation	0.14 kWh [a]
Five-effect evaporation	0.085 kWh [a]
TVR + triple-effect evaporation	0.12–0.15 kWh [b]
MVR + triple-effect evaporation	0.01–0.02 kWh [b]
MVR	0.01-0.0125 kWh [c]
Two effect falling film with TVR	0.32 kg steam [c]
Two effect falling film no TVR	0.55 kg steam [c]
Five effect falling film with TVR	0.09 kg steam [c]
Five effect falling film no TVR	0.2 kg steam [c]

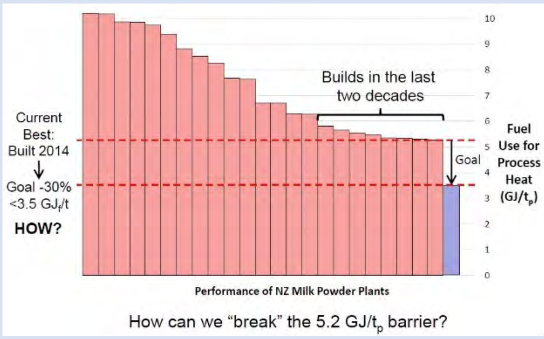
[a] (Joyce, 1993) [b] (ETSU, 1998) [c] (Tetrapak, 2015)

Optimisation of spray drying process, Bega Cheese, (Bega Cheese, 2016)

At Bega Cheese's Lagoon Street site, particulate emissions from the whey powder drying process have been reduced by optimising the crystallisation process and balancing equipment. This has increased the solids content of whey powder, reducing the drying cycle by two-hours and saving 15 per cent of steam energy used for drying.

Energy Consumption of Milk Powder Plants, New Zealand (Walmsley, et al., 2015)

In 2014, best practise energy consumption for whole milk and skim milk powder plants in New Zealand was 5.2 GJ per tonne product with a goal to reduce this by 30% to 3.2 GJ per tonne product. This is achievable through further optimising heating and heat recovery process, specifically, thermal vapour recompression combined with direct steam injection for milk preheat stage; replacing thermal vapour recompression with mechanical vapour recompression and optimising all evaporator temperatures and pressures



7.3.2 Membrane concentration

Membranes are commonly used to concentrate dairy streams in preparation for further processing. The type of membranes (and pore size) is suited to the removal or concentration of different milk components (refer to Section 8.0 - Yield optimisation and product recovery for further information).

Reverse osmosis (RO) is a cost-effective way to remove water and is often used as a pre-concentration step prior to thermal evaporation processes. Along with demineralisation, nanofiltration (NF) can be used for the volume reduction of whey and permeates e.g. for transport purposes. Microfiltration (MF) and ultrafiltration (UF) are more suited to concentrate milk components such as milk or whey proteins as opposed to water removal or volume reduction (GEA, 2012).

RO can achieve a milk solids concentration of 35%, however membrane fouling is an issue (caused by proteins) with higher solids concentrations requiring higher pressures and energy consumption. Using combinations of membranes e.g. UF, RO and NF to remove proteins can reduce the incidence of fouling and can be a more energy efficient alternative than RO membranes alone as a pre-concentration step before evaporation. For example, a combination of RO and UF has been found to be more than 20% more energy efficient than RO on its own. (Nickels, 2014) (Kulozik & Grunow, n.d.) .

Membrane processes are energy-efficient for concentration, with typical energy consumption around 0.004–0.01 kWh per kg of water removed (ETSU, 1998), which is significantly more economical than using evaporation methods Table 7.7. However, there are economic limitations to the level of concentration that can be attained, to the point where it is financially preferable to use traditional evaporation methods. For example, whey is concentrated up to 18–27% because beyond that range process performance is reduced, due to the high osmotic pressure, high retentate viscosity, lactose crystallisation and calcium phosphate precipitation (Daufin, et al., 2001). The more concentrated the retentate, the higher is the pressure required to induce filtration and the more robust the membranes need to be.

Membranes have been used to concentrate streams to up 55% total solids (PCI-Memtech, 2000) and (Barber & Cumming, 2017)), primarily determined by viscosity and fouling considerations. Pumping equipment will also be more energy-intensive, which will lead to higher operating costs. Forward osmosis with utilisation of saline solutions is another potential technology described in the case study below.

There is also an optimum temperature and pressure for membrane separation with increased separation (flux) and energy efficiency occurring at increased processing temperatures despite the additional thermal energy requirement (Méthot-Hains, et al., 2016). Further information on membranes can be found in ‘Cost-effective membrane technologies for minimising wastes and effluents’ (WS_Atkins_Consultants_Ltd, 1997).

Thickening and desalinating whey in the dairy industry: dairy processor, The Netherlands (CADDET, 1999) 2004 Ed

Before food ingredients can be made out of whey, the original thin liquid must be concentrated and desalinated. A whey processing plant in The Netherlands has installed a NF unit to perform part of the total thickening process. The membrane filter replaces an evaporator and ion exchanger; this increases the solids content of the whey from 5.5% to 17%, and removes 70% of the salt content with the permeate.

Steam consumption for the old system was 436 m^3 natural gas equivalent (NGE) per tonne dry solids, and electricity consumption was 11.5 m^3 NGE/t. Steam use for the new system has decreased to 120 m^3 NGE/t but electricity consumption has increased to 19.2 m^3 NGE/t. Net energy savings are 308 m^3 NGE/t, which equates to around 70% of the original energy consumption. In addition there were savings in chemical and water use for cleaning. The payback period was 1.3 years.[1]

Forward osmosis utilises salty streams and reduces energy for milk concentration (Barber & Cumming, 2017)

Forward osmosis uses the osmotic pressure of a saline draw solution to drive water across a membrane and thus concentrate product in the feed stream. The membrane is permeable to water but not salts and product. There is the potential to using salty waste streams (i.e. ion exchange brines, salty whey) to provide a driving force for the concentration of milk or other dilute dairy streams via forward osmosis membranes.

Work done by CSIRO suggests that a 20% saving in gas and a 60% saving in electricity can be achieved with FO in comparison with a conventional evaporator. 50% solids can be achieved in the product stream and concentration without evaporation Other advantages are lower capital cost. Energy requirements for traditional evaporation are 0.56 MJ/kg (0.16 kWh/kg) compared with 0.208 MJ/kg (0.058 kWh/kg) for FO.

7.3.3 Spray drying

Spray drying is used extensively by the dairy industry for producing milk, whey and cheese powders. Powder production is carried out in two phases with pre-treated milk evaporated to a solids content of around 48 – 52 % (whey is typically concentrated to 58 – 62 %) and then concentrate is turned into powder in a spray dryer (Tetrapak, 2015). The concentrate is atomized into a spray of droplets which are put into contact with hot air in a drying chamber. Dryers may be co-current, counter-current and mixed flow, with sprays produced by a rotary (wheel) atomiser or nozzle atomiser. Spray dryers may be single, two-stage or multi-stage, with the latter being the most energy-efficient but also the most capital-intensive. Second and later stages use fluidised bed drying, which is more energy-efficient.

The energy consumption of spray dryers can be measured based on energy use per amount of water removed (known as specific energy consumption kJ/kg water, see below) or alternatively energy use per amount of powdered product (kJ/kg product).

Specific Energy Consumption (SEC)

Measures how much energy is required per kilogram of water evaporated from the feed, where:

$$\text{SEC (kJ/kg)} = \frac{\text{rate of energy consumption of dryer (kW)}}{\text{rate of evaporation(E) of dryer (kg/s)}}$$

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

$E = W_S (X_1 – X_0)$

where

W_S = dry solids feed rate

X_1 = moisture content of the input stream / dry solids weight

X_0 = moisture content of the output stream/ dry solids weight

The rate of energy consumption should be routinely monitored and compared against other similar spray dryers. Energy consumption is dependent on the type of dryer and characteristics of the product being dried.

Shuck et al describe a complete set of equations for evaluating evaporation and drying of milk powders (Shuck, et al., 2015). The evaporation of 1 kg of water from a product requires the condensation of 1.1 kg of primary steam. The energy cost is therefore about 2,700 kJ/kg evaporated water. For example, the energy consumption of different spray-drying configurations in the production of skim milk powder using a 48% dry matter concentrate is provided in Table 7.8 (Shuck, et al., 2015).

Table 7.8: Energy consumption of spray dryers of skim milk

Spray Dryer Configuration	Energy consumption kJ/kg
Single-stage dryer	6,677
Two-stage dryer with a vibrofluidizer	5,362
Compact two-stage dryer with a static bed	4,602
multi-stage dryer (MSD) with a static bed	4,020

Source: (Shuck, et al., 2015).

Further tips for the efficient operation of a spray dryer include:

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

- recovering waste heat by installing a recuperator that uses exhaust air to pre-heat the inlet air.
- investigating ways of pre-heating the milk concentrate.
- Dehumidifying dry air intake (see case study below).

There can be problems with recuperating waste heat, due to the presence of particulates in the exhaust air stream and the tendency for fouling, which causes hygiene problems. To date, this technology has been investigated but not adopted by Australian dairy factories for this reason.

Overall, the energy efficiency of the dryer can be maximised by maximising the solids content of the feed — for example, operating at 40% solids instead of 30% reduces the heat input by 36% (ETSU, 1996). As a rule of thumb, every 0.5% increase in feedstock solids reduces energy consumption by 2% (ETSU, 1996).

The optimum drying temperature should also be determined. It is useful to check on what basis a spray dryer's inlet feed temperature has been set as it may not be optimum. An increase in the feed temperature can significantly reduce energy consumption of the spray dryer (USEPA, 2011).

A detailed discussion on heat recovery systems and the efficient operation of spray dryers can be found in Good practice guide 185 of the UK Energy Efficiency Best Practice Programme, *Spray drying* (ETSU, 1996) and (GEA, 2010). These and more recent papers (Walmsley, et al., 2015) (Moejes, et al., 2018) discuss the increase in efficiency through heat recovery of spray dryer exhaust – typically a 10-20% increase. Walmsley (Walmsley, et al., 2015) concludes that heat recovery is economically justifiable for the given case study presented in his research. There is also discussion on retrofit considerations for individual processors.

Heat recovery from spray dryer: Tatura Milk, Tatura (Niro, 2003) 2004 Ed

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

Lichfield: Investing in new technologies, Fonterra, New Zealand (Fonterra, 2017)

Fonterra use the opportunity of building new capacity to invest in improving the resource efficiency of their sites. In 2016 they invested in the expansion of the Lichfield site with a new milk powder dryer, distribution centre and wastewater treatment plant. The new 30 tonne-an hour dryer is fuelled by natural gas. It is Fonterra's most efficient milk dryer to date.

The dryer is capable of processing 4.4 million litres of milk each day, making it the largest milk powder dryer in the world alongside the dryer at Fonterra's site at Darfield in Canterbury, New Zealand.

Dehumidification of dryer air intake (Barber & Cumming, 2017)

Dehumidifiers can be installed on dryer air intake which can potentially reduce energy costs by 5% but is case specific. Along with energy savings, a prime benefit is increased dryer production output and easier plant operation in high humidity environments or weather events. There is reduced risk of 'stickiness' related operational problems and fouling and possibly improved product consistency. One such system uses a rotating desiccant wheel.

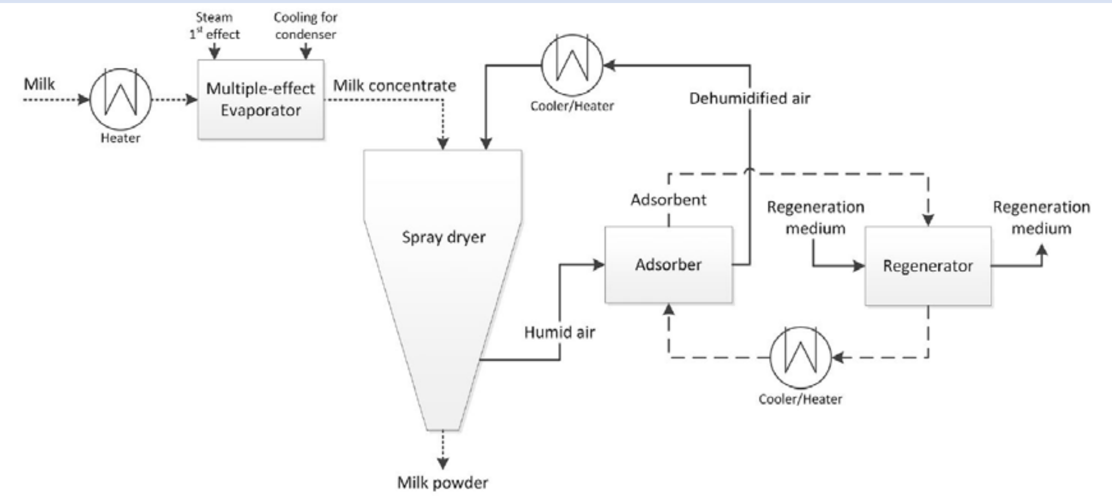
Achieving a step change in spray drying efficiency (Moejes, et al., 2018)

Energy reduction by closed-loop drying is not possible in current spray drying systems. This is because energy from the dryer exhaust air cannot be recovered due to the fines present in the air, which causes fouling of heat exchangers. Typically this exhaust air is cooled and passed through bag filters to remove fines with heat energy left unrecovered.

A study was undertaken to evaluate a step change in spray drying efficiency through improved heat recovery of dryer air exhaust. The study involved using monodisperse droplet atomizers to produce exhaust air free of fines. Four systems were then evaluated for the dehumidification of the air exhaust prior to heat recovery resulting in potential energy savings of 11 to 42% compared to current practice of milk powder production with no heat recovery. The systems are:

- a membrane contactor with superheated steam to regenerate absorption medium;
- a membrane contactor with no superheated steam;
- a zeolite adsorbent with superheated steam and
- a zeolite adsorbent without superheated steam.

The study indicates that the treatment of vapour with a membrane contactor with superheated steam as regeneration medium leads to the lowest energy requirements of 4.9 MJ heat per kg powder while the zeolite absorbent required 5.1 MJ heat per kg powder. This is compared with conventional systems which require over 8 MJ heat per kg powder. The dehumidification technology that is closer to commercialisation is the zeolite adsorbent.



7.3.4 *Boiler operation*

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

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

The efficiency of a boiler can be monitored by measuring the excess air and the composition of flue gas. Insufficient excess air will lead to incomplete fuel combustion, while too much causes a loss of heat in the boiler and a decrease in efficiency. Optimum percentages of oxygen (O_2), carbon dioxide (CO_2) and excess air in exhaust gases are shown in Table 7.9. The ratio of boiler air to fuel can be adjusted to obtain the optimum mix of flue gases, using oxygen trim systems. Table 7.10 shows the potential fuel savings resulting from the installation of online oxygen trim control. Digital control systems can be connected to the site's SCADA system to provide monitoring and control of the boiler. The Australian Manufacturing Gas

Efficiency Guide (CEFC, 2018) suggests such a digital control system can be adopted for a cost in excess of $50,000 with a payback of less than 5 years.

Table 7.9: 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 7.10: Fuel savings from installing online oxygen trim control

Boiler capacity (MW)	Fuel savings (GJ/yr)	Fuel savings ($/yr)	CO_2 (t/yr)	Simple payback (yr)
1	635	10,795	37	4.6
2	1270	21,590	75	2.3
4	2540	43,180	150	1.2
6	3810	64,770	224	0.8
8	5080	86,360	299	0.6
10	6350	107,950	374	0.5

Source: Adapted from (SEAV, 2002a) and updated with 2018 costs
Assumptions: gas costs $17/GJ; boilers operate 24 h/day, 350 days/year; installation cost of the boiler trim system $50,000

Lidcombe Boiler House, Blowdown Heat Recovery, and Burner Control (Parmalat, 2015).

Blowdown heat recovery was achieved by installing a heat exchanger on the exhaust of the blowdown with the recovered heat used to pre-heat the make-up water. The burner control included a probe to measure oxygen levels in the exhaust stack and control excess air accordingly. The project resulted in natural gas savings of 1900 GJ/yr and a 98 tonne reduction in carbon emissions (CO_{2e}).

Regularly record the flue gas temperature

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

Operate the boiler at the design working pressure

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

Monitor and clean boiler tubes to remove scaling

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

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

Match steam supply with demand

If the steam production at the boiler house is too high compared to the plant's actual steam demand, the excess may need to be vented, resulting in unnecessary fuel wastage. The use of metering instrumentation (steam, water and fuel meters) will help match steam supply with demand. If appropriate, meter the steam flow to different sections of the plant separately.

Improving communication between boiler operators and end users can lead to significant savings in boiler operating costs. It is not uncommon for boilers to be operated inefficiently at low load or on standby ready to meet process demands. Improving communications can allow the boilers to be operated more efficiently at higher loads for the periods required, thereby reducing operating costs (CEFC, 2018). Boilers should be started up as late and shut down as early as possible while still meeting process demands. This is more difficult to manage with solid fuel boilers than with gas or oil, due to the slower response time.

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

7.3.5 Steam delivery

Rectification of steam leaks

Leaks allow live steam to be wasted, requiring more steam to be produced to meet the plant's needs. As replacement feedwater is required, more fuel is used for heating and more chemicals are needed for treatment. For example, a hole 1 mm in diameter in a steam line at 700 kPa will lead to an annual loss of 3000 L of fuel oil or 4300 m^3 of natural gas, equating to around \$1500-\$2000 (SEAV, 2002b)(assumed 2018 gas price of 0.34 \$/m3).

Elimination of steam leaks: Fonterra, Spreyton 2004 Ed.

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

Boiler condensate return systems

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

Condensate return systems are often designed with flash vessels to allow for the re-evaporation of condensate into steam (referred to as flashing). The flash vessels also remove non-condensable gases such as air and CO_2. If these gases remain in the equipment being heated, the gases form pockets that insulate the heat transfer surface and decrease boiler efficiency (Smith, 2004) and (CEFC, 2018)). The steam in the flash vessels can be used as a low-grade heat source.

Condensate return: Beston's Global Food Company, Murray Bridge, 2004 Ed

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

Improved condensate return: Saputo Dairy Australia, Rochester (Aust Govt, 2003) 2004 Ed

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

Maintenance of steam traps

A steam trap is an automatic valve for removal of condensate from a steam system. In the presence of steam it closes, preventing steam from passing through it and being wasted before it has given up its heat and condensed. In the presence of water it opens, allowing the discharge of condensate. Depending on its type, it may also open to discharge non-condensable gases.

Where feasible, condensate removed from steam traps should be returned to the boiler feed tank as previously discussed. Regular testing and maintenance of steam traps and condensate lines saves money and time as well as improving operating efficiency. Traps can be checked by plant staff or an outside contractor. Traps that are losing steam can waste thousands of dollars a year, usually far more than the cost of their replacement or repair (Smith, 2004). A scheduled maintenance program for steam traps should be implemented on a 6 or 12 monthly cycle. This should include an ultrasonic and temperature based survey of all traps followed by replacement of failed traps (CEFC, 2018).

Steam system audit: Saputo Dairy Australia, Leongatha 2004 Ed

Saputo's Leongatha site undertook a steam system audit to review the efficiency of the many steam traps. It cost the plant $10,000 to eliminate the faulty/leaking traps.

'Be proactive. The savings are the result of fixing a large number of small out-of-the-way items.'

Rationalisation of boiler use and steam lines

For some older factories that have progressively expanded over the years, steam supply lines may not take the most direct route from the boiler to the point of use. This results in a greater length of steam pipework than is really required and greater potential for heat loss and leaks. Rationalising steam and condensate pipework can lead to savings in boiler operating costs (CEFC, 2018). A review of boiler use may also identify the need for a boiler upgrade or even replacement.

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 7.11. Insulation that is damaged should be repaired and sources of moisture should be removed to prevent insulation from deteriorating. It is estimated that 35% of the heat energy supply is lost during the manufacture and distribution of steam, while approximately 2000 kWh is lost in a year from a 1-metre length of 5cm steam pipe with a surface temperature of 170°C (Kjaergaard-Jensen, 1999). Thermal imaging can be used to identify areas where additional insulation is necessary and assist with quantifying the energy loss for business case development (CEFC, 2018). There are innovations with the use of flexible and removable high temperature fabrics for processing equipment such as heat exchangers as highlighted in the case study below.

Table 7.11: 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	$ 4811
Insulated with mineral fibre	0.138	0.05	$ 235

Source: Adapted from (USDOE, 2002) and updated with 2018 costs
Assumptions: 125 mm steel pipe at 150˚C; natural gas cost of $0.017/MJ of boiler operating 8 h/day, 250 days/ year.

Insulation of steam, hot water and chilled product pipes, (Bega Cheese, 2017)

Bega Cheese has undertaken a program of upgrading insulating of hot and cold surfaces (lines and tanks) across many of its NSW plants. As a result, energy intensity has reduced from 11.5 GJ/tonne to 10.1 GJ/tonne for these sites.

Use of flexible, easily removable insulation covers (Barber & Cumming, 2017)

A Victorian processor upgraded insulation with the use of flexible, easily removable insulation covers on heat exchangers, valves and piping. The company invested capital expenditure of $42,000 which resulted in energy savings of 225 GJ per $1K CAPEX and a 7 month payback.

7.3.6 High-efficiency boilers

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

Walmsley, et al. describes benefits of an additional condensing economiser - 'Standard industrial steam boilers for milk powder production operate at 40 bar (250 °C saturated) and are fitted with an economiser. The economiser preheats pressurised boiler feed water before it enters the main evaporation tubes. Depending on the boiler design the flue gas enters the economiser at up to 350 °C and leaves above the acid dew point at 140 °C. An additional condensing economiser can be installed to capture more flue gas heat. There is also a water dew point, which for a natural gas boiler is about 60 °C while a coal fired boiler is 40°C. Extracting additional heat, both sensible and latent (if useful), maximises boiler efficiency and minimises fuel use.' Very few sites in New Zealand have steam boilers equipped with condensing economisers and this is also likely to be the case for Australian processors, indicating a potential energy efficiency opportunity. (Walmsley, et al., 2016)

Another efficiency option is the use of variable speed drives on combustion air blowers which can be retrofitted to continually match the load on the boiler. Average project costs are in excess of $50,000 with a five year payback (CEFC, 2018).

When replacing or upgrading boilers, many dairy processing companies are also investigating the option of converting to a more efficient and cleaner fuel (e.g. changing from coal or fuel oil to gas). The installation of these energy-saving measures can mean an improvement in boiler efficiency from around 90 to 94% for a new boiler. The environmental impacts of switching fuels will be reduced (fewer greenhouse gas emissions) (CEFC, 2018), but the disadvantage is the higher cost of natural gas as shown previously in Table 7.4.

Richmond Dairies, High Efficiency Boiler (AGL, est, 2012)

Richmond Dairies installed a high efficiency 8 MW AGL boiler unit with economiser, state-of-the-art combustion control, and the ability to co-fire multiple fuels. The online gas flow meter monitors consumption and boiler efficiency. The boiler has an efficiency of 85%. The project cost $700,000 with gas savings of 10% and a 3.5 year payback.

Energy-efficiency in boiler design: Fonterra, Darnum Park (AGO, 2002a), 2004 Ed

Fonterra's Darnum Park site increased the efficiency of their four 10 MW boilers by installing economisers, oxygen trim control, variable-speed drives and automatic blowdown control. Around 80% of the condensate is returned to the boilers, utilising heat in the condensate and reducing water consumption, chemical consumption and wastewater generation.

7.4 Reducing the demand for electricity

7.4.1 Industrial refrigeration systems

The energy cost of a refrigeration system can approach 20% of the total energy costs in a liquid milk processing plant (Figure 7.3). Dairy processors typically use the vapour compression cycle refrigeration system consisting of a compressor, condenser, evaporator and expansion valve (Figure 7.10). In small commercial scale refrigeration plants these components are generally split into two locations with the evaporator and compressor located inside a cool room or freezer room and the condenser located outside of the building. These generally have a single refrigerant gas and are mostly air cooled, so a good air flow is needed around the condenser unit.

For large scale industrial systems, these individual components are significantly larger in size and there is typically a primary and secondary refrigerant circuit. The primary refrigerant e.g. ammonia is generally contained in the refrigeration utility area of the factory and is most often cooled with water circulating via an evaporative cooling tower (Figure 7.10). The secondary refrigerant e.g. glycol or chilled water is circulated throughout the dairy plant to the location that requires cooling. Supplementary refrigerants can be used for dedicated refrigeration uses or to extend refrigeration capacity of primary/secondary refrigerants e.g. CO_2 cascade systems (Barber & Cumming, 2017).

High efficiency refrigeration systems will include high efficiency compressors, variable speed motors, heat recovery features and digital control systems discussed further in this section.

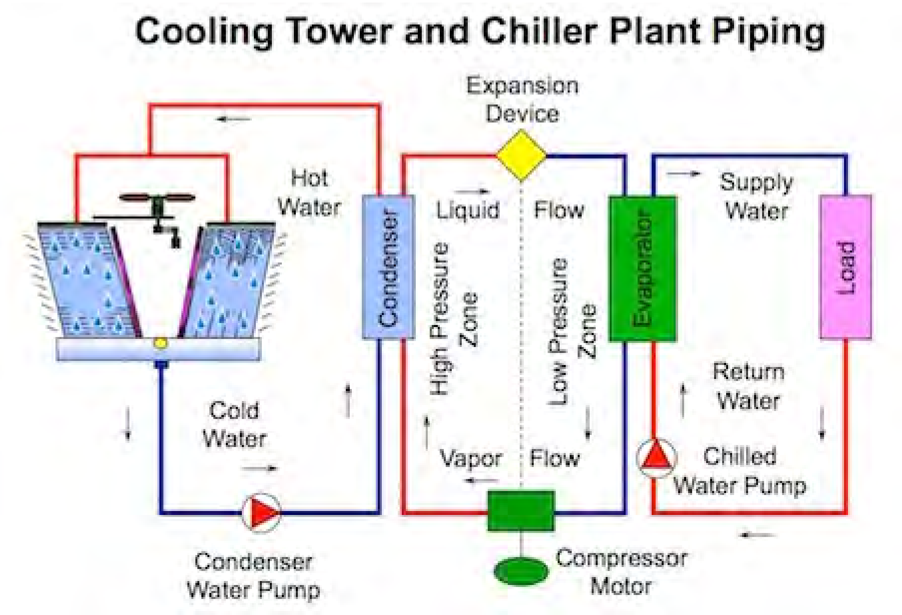


Figure 7.10: Refrigeration circuit with primary and secondary refrigerant (chilled water)
Source: (Edmondson, 2014)

The efficiency of a refrigeration system is measured by the coefficient of performance (COP) which is the quantity of refrigeration produced (cooling output in kilowatts) divided by the total energy required by the system (energy input in kilowatts). The higher the COP, the higher the efficiency of the system. Refrigeration systems have increased in efficiency so that the cooling effect is now 5 or 6 times that of the energy input (Barber & Cumming, 2017).

Refrigeration efficiency is measured in terms of Coefficient of Performance (COP)

$$COP = \frac{\text{quantity of cooling (kW)}}{\text{total energy input (kW)}}$$

Compressors

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

- type of compressor
- compressor load

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

Compressor selection

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

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

High efficiency screw compressor (Barber & Cumming, 2017)

A high efficiency screw compressor (high stage thermosiphon) with variable speed and ammonia refrigerant has a potential payback of 0.65 years based on improved COP of 1.5 to 5.65, energy savings of 1028 MWh/yr or $123,360/yr (at 12 c/kWh electricity costs) and $80,000 capital expenditure.

Compressor load

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

Ice banks where thermal energy is stored then utilised when needed can be an effective way of meeting peak demands without the need for large compressor capacity. They are best used in applications where there are short to medium peak loads but a much lower average load during a production day. Ice can be formed during the night to take advantage of cheaper off-peak electricity. It could be used as an option to spread the load to reduce electricity peak demand. Note however, that though it can lead to dollar savings, it is not a particularly efficient use of energy.

Variable Head Pressure Control, Refrigeration System Upgrade, (Parmalat, 2015)

The Lidcombe refrigeration system was upgraded to include variable head pressure control and compressor staging. The process of refrigeration relies on a large fan capability to remove heat from a fluid by evaporating water sprayed on a heat exchanger. The system measures the outside temperature condition to control the load on the condenser and compressors, this results into a more efficient overall refrigeration system. By the middle of 2016, the plant was saving 2444 GJ of energy, 727 tonnes CO_{2e} and an estimated \$98,000 per year. This represents 4% of the overall electricity used at the site with a simple payback of 1.3 years. Parmalat, with partners Minus 40, won the 2016 Energy Efficiency Council Award for Best Industrial Energy Efficiency Project.

Minimising temperature difference

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

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

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

Alternatively, the condensing temperature can be decreased by ensuring that the condenser, which may be a water- or air-cooled cooling tower, is operating efficiently. Condensers should be sized correctly to maintain the optimum condensing temperature within the capabilities of the refrigeration system. If the condenser is too large, however, the refrigerant can actually sub-cool[9] and this will affect the function of the expansion valve.

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

An increase of 1°C in evaporating temperature or a reduction of 1°C in condensing temperature will increase the compressor efficiency by 2–4%.[10]

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

[10] (ETSU, 2000)

Energy management control system: Nestlé, Victoria (SEAV, 2002b) 2004 Ed

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

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

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

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

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

Hot gas bypass defrost

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

Reducing load on refrigeration systems

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

Lights and fans also add to the heat load. Sensors and timers can be used to ensure that lights are used only when necessary. Upgrading to LED lighting can also reduce heat load (Section 7.4.5 - Lighting). Variable speed drives, coupled with a programmable controller, can cycle off fans and refrigerant feed during low load times.

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

Nambour Cold Store Forklift Access Door Curtain, (Parmalat, 2017)

The Nambour cool room has a forklift access door that is opened for at least 5 minutes in every hour, allowing the chilled air to escape and therefore increasing the energy usage, wet floors, condensate build up on roof and costs required to cool the room. A plastic curtain was installed to reduce the volume of cool air escaping when the forklifts entered and exited the room. The result was a 16.5 kWh energy reduction and $5,000 in savings each year.

Absorption chilling

Absorption chillers allow cooling to be produced from heat sources such as clean fossil fuels, biofuels, low-grade steam, hot water, exhaust gas or even solar energy, (Susmilk, 2016) (Dixit, 2018). An absorption chiller is another form of heat pump (Section 7.5.5 - Heat pumps). Where a mechanical heat pump is driven by electric energy, an absorption heat pump is driven by thermal energy (De Kleijn, 2018).

Absorption chillers use a source of waste heat to produce a chilled product with typical refrigerants being ammonia/water and more recently lithium bromide/water. The COP of absorption refrigeration is relatively low compared with vapour compression refrigeration systems with the best absorption chillers generating just over 1 kW of refrigeration for 1 kW of energy. However, this does not transfer to higher operating costs as a low grade or waste heat source can be utilised which can displace the use of more expensive fuels. The higher the temperature of the waste heat the more effective the refrigeration will be. Dixit, provides a detailed analysis of operating costs of an absorption chiller. This indicates a 26% reduction in operating costs for an absorption chiller fired on natural gas compared with a convention electric chiller (Dixit, 2018). Absorption chilling is promoted as a suitable technology for sustainable milk processing (Susmilk, 2016).

Use of absorption refrigeration: milk processing plant, USA (CADDET, 1996), 2004 Ed.

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

Phase out of refrigerants

In order to meet the requirements of the Montreal Protocol there is a phase out of ozone depleting and high Global Warming Potential (GWP) refrigerants (Aus Govt, 2018). R22 is a type of synthetic refrigerant which is commonly used in refrigeration systems in the dairy industry. It is a HCFC (hydro-chlorofluorocarbon) which is a substance with high ozone-depleting characteristics and an extremely high Global Warming Potential (GWP) of 1780 which is 1780 times greater than that of carbon dioxide with GWP of 1. R22 is part of a family of refrigerants which include HCFC and CFCs and which are more commonly known as Freon. These can be replaced with natural refrigerants with zero or low global warming potential such as ammonia, carbon dioxide or glycol (AMIC, 2016).

R22 Chiller Replacement – Fonterra, Wagga Wagga (Minus 40, 2018)

Fonterra, Wagga Wagga site needed to upgrade their R22 chiller to meet increased production capacity. The existing R22 chiller was required to act as an “ice bank” – a practice in which the chiller produces ice during periods of low load, so that it can use this stored energy during peak load. This is a particularly inefficient practice, in this case, as it is preferable to operate a chiller with capacity for peak load. Upgrade of the R22 chiller removed the risk of leakage of an ozone depleting substance with high global warming potential. The replacement chiller operates with ammonia refrigerant. Although the unit is larger than the original unit, it is more efficient and has a far smaller environmental footprint.

Further reading

See Sustainability Victoria Best Practice Guide: Industrial Refrigeration (Sustainability Victoria, 2009) and the NSW Office of Environment and Heritage guideline on the optimisation of industrial refrigeration systems (NSW OEH, 2017). The NSW guideline lists 15 opportunities for energy efficiency in industrial refrigeration systems. These energy-saving technologies are applicable to most industrial refrigeration facilities and primarily involve control modifications that can be implemented on the plant's programmable logic controller (PLC) software. A number of these technologies have been previously discussed and are listed as follows:

- Variable plant pressure control
- Automated compressor staging and capacity control
- Remote control optimisation of refrigeration plant
- Heat recovery from discharge gas and oil cooling
- Variable cold store temperatures
- Variable evaporator fan speeds
- Condensate sub-cooling
- Refrigeration plant design review
- Chiller efficiency – full and part load
- Chilled water/glycol circuit design and control
- Heat recovery from chillers and chiller/heat pumps units
- Variable chilled fluid temperatures
- Variable cooling water temperatures

Another extremely useful resource is a toolkit and set of fact sheets produced via the Energy Efficiency Information Grants Program for the Australian Meat Industry Council, see www.amic.org.au/content_common/pg-energy-efficiency.seo.

7.4.2 Compressed air systems

Compressed air is used extensively in dairy processing plants, mainly for the operation of valves, filling and packing machines, and for cleaning spray dryer bag filters. The cost of operating a compressed air system in a dairy processing plant can approach 10% of total electricity costs (Figure 7.3). Compressed air systems are very energy-inefficient, with around 80% of electricity input lost as waste heat. Over the life of an air compressor, the upfront capital costs contribute around 15-20% of life cycle costs, compared with operational costs at around 70-80% and the remainder maintenance costs ((Mousavi, et al., 2014) and (Sustainability Victoria, 2006)).

Compressor efficiency ranges from around 5.8-8.5 kW/m^3/min (Sustainability Victoria, 2006). Selecting and efficiently operating the correct type of compressor for the application can substantially reduce operating costs, as discussed in the sections that follow.

Installing a control sequencing system on multiple compressors will help the system to respond more efficiently to varying loads. Variable-speed compressors can reduce power with reduced demand. If compressors operate at variable rates or are oversized to cater for higher than usual loads, consider installing a variable speed drive (see section 7.4.4 - Motors and drives).

Large dairy factories can have a combination of fixed and variable speed compressors jointly and efficiently operated via a centralised control system (Mousavi, et al., 2014). However, depending on the system it can also be more efficient and cost effective to consolidate compressors (Marshall, 2011) so it is important that dairy processors assess their individual needs.

Lead-lag system for compressors: Murray Goulburn Cooperative, Koroit, 2004 Ed

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

Replacement of Air Agitation with Mechanical Agitation, Parmalat, Bendigo (Parmalat, 2017)

Three silos at the Bendigo, Parmalat dairy plant relied on compressed air agitation. This process is very energy intensive and the company planned to replace the current air agitation with mechanical agitation. Mechanical agitators were mounted to the side of all three silos. The overall project saved 40 kW in total energy usage and saved $17,000 per year.

Compressed air leaks

Leaks in a compressed air system can contribute 20–50% of total air compression output (SEAV, 2002b). Table 7.12 indicates the cost of compressed air leaks. Ultrasonic detectors can be used to check for leaks; the traditional method of using soapy water on pipework is also effective. It is best to check for air leaks when the plant is shut down and background noise is minimal. It is also a good housekeeping measure to isolate compressed air on items of equipment that are shut down for extended periods (e.g. overnight or on weekends).

Table 7.12: Cost of compressed-air leaks

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

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

Optimising air pressure

Air pressure should be kept to the minimum required for the end use application. Sometimes operating pressures are set high to meet the demand of just one or two items of equipment. It may be possible to redesign individual items of equipment to enable pressure reduction across the rest of the plant. Alternatively, determine whether it is cost-effective to use a second compressor to service these equipment items.

Table 7.13 illustrates the cost and energy savings that can be made by reducing air pressure. Compressed air is an expensive medium and its use should be avoided for activities such as cleaning or drying, where other methods such as fans or blowers could be used. It is estimated that every 50 kPa increase in pressure increases energy use by 4% (SEDA, 2003).

Table 7.13: Cost and energy savings that can be made by reducing air pressure

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

Source: (SEAV, 2002b)
Assumptions: 700 kPa system operating for 2000 h each year; electricity tariff 8 cents/kW h

Reducing inlet air temperature

Up to 6% of a compressor's power can be saved by using cooler air (SEAV, 2002b). When the inlet air entering a compressor is cold, less energy is required to compress it. It is estimated that every 3˚C drop in inlet air temperature decreases electricity consumption by 1% (SEDA, 2003).Compressed air systems should be well ventilated and any hot compressor room air ducted away, perhaps to a heat recovery system for space heating. The air should also be clean, as clogged filters at the inlet will cause a drop in pressure, reducing compressor efficiency. Table 7.14 shows energy and cost savings that can be made by reducing the temperature of compressor intake air.

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

(SEDA, 2003)

Table 7.14: Energy and cost savings from reducing the temperature of compressor inlet air

Reduction to intake air temperature	3˚C		6˚C		10˚C		20˚C	
Average load (kW)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)	Energy saving (kW h/yr)	Cost savings ($/yr)
4	80	6	160	13	264	21	528	42
7.5	150	12	300	24	495	40	990	79
15	300	24	600	48	990	79	1980	158
30	600	48	1200	96	1980	158	3960	317
55	1100	88	2200	176	3625	290	7251	580
110	2200	176	4400	352	7260	581	14,520	1162
160	3200	256	6400	512	10,550	844	21,100	1688

Source: (SEAV, 2002b)
Assumptions: 700 kPa system operating for 2000 hours each year; electricity tariff 8 cents/kW h

Heat recovery from air compressors

As previously mentioned, as much as 80% of the energy used to operate an air compressor is lost as heat. There are heat recovery units available that will recover heat from both water- and air-cooled compressors. However, heat recovery units for water-cooled compressors are more efficient and can provide a more significant payback on capital outlay.

The energy recovery system consists of a plate heat exchanger, which transfers heat from the compressor's lubricating oil to the water. This can heat water to up to 90°C and recover up to 70% of the compression heat without any adverse influence on the compressor performance. For example, a heat recovery unit for a 37 kW single-stage, oil-injected rotary screw compressor unit has the capacity to produce 36 L/min of 73°C hot water (Atlas Copco, 2003).

Compressed air savings at milk, cheese and ice cream plants, Winnipeg, Canada (Marshall, 2011)

A Canadian dairy processor saved 625MWh and 87 kW peak load equating to $US 29,700 per year through reviewing and upgrading its compressed air system. Improvements included consolidating two compressors and replacing with a variable speed compressor, identifying and repairing filling machine exhaust valves that had failed open thereby reducing compressed airy system load and replacing chilled water cooling of the compressors with air cooling which reduced load on the plant refrigeration system.

Further information and case studies on improving compressed air system efficiency can be found at www.compressedairchallenge.org/library.

7.4.3 Homogenisers

The control of homogeniser pressures, in particular pressure drop, will affect the efficiency of the homogeniser and the quality of the product. Confusion in terminology for measuring pressure (e.g. gauge, absolute and differential pressure) can lead to homogeniser pressure settings that are less than optimum. Once an optimal pressure control strategy is established and understood, the energy consumption of the homogeniser can also be calculated and incorporated into plant energy-management programs. These aspects are explained further in the DPEC publication *Homogeniser performance evaluation guide manual 1996/97* (DPEC, 1997). Energy consumption in homogenisers is dependent on flow rate and pressure as shown in the equation below (Tetrapak, 2015):

$$E = \frac{Qin\ x\ (P1 - Pin)}{36{,}000\ x\ \eta pump\ x\ \eta\ el.motor}\ kW$$

Where

E = Electrical energy consumption kW

Qin = feed rate, L/h

P_1 = Homogenization pressure, bar

P_{in} = Pressure to the pump, bar

η_{pump} = Efficiency coefficient of the pump (0.85)

$\eta_{el.\ motor}$ = Efficiency coefficient of the electrical motor (0.95)

For a system running at 10,000 L/h, P_1 = 200 bar, P_{in} = 2 bar, energy consumption would be 68 kW.

Energy reductions will arise through reducing homogenization pressure through more efficient equipment design. Homogenisation pressure should therefore be a consideration in selection of equipment. Pressures commonly used in the dairy industry are up to 30 MPa (high pressure homogeniser) with units ranging from 100-400 MPa classed as 'ultra-high pressure' (Wilbey, 2011).

Optimising CIP of homogenisers (Carbon Trust, est 2010)

Studies of homogeniser operation by the UK Carbon Trust indicated that the clean-in-place stage of homogeniser operation used between 45-63% of power demand (kW) and was between 9-27% of electricity consumption (kWh). Optimising the clean-in-place cycle by minimising cycle times will help reduce energy costs.

Another opportunity for energy savings for liquid milk producers is through partial homogenisation of liquid milk. Rather than homogenisation of the full volume of skim milk and cream, only part of the skim milk volume is homogenised which is then blended with the full volume. This reduces the load on the homogeniser and can result in energy savings of up to 80% (Tetrapak, 2015) (Carbon Trust, est 2010).

7.4.4 Motors and drives

Selecting a motor

An electric motor uses 4–10 times its purchase price in electricity annually (AGO, 2002b). When choosing a motor, it is therefore wise to consider the operating costs as well as the initial purchase price. High-efficiency motors cost up to 40% more than standard motors; however, energy savings quickly recover the extra cost, usually within two years. Table 7.15 illustrates the payback periods for motors with different ratings.

Table 7.15: Payback periods for purchasing high-efficiency motors

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

Source: (Teco Australia, 2003)

In 2008 the International Electrotechnical Commission (IEC) motor efficiency classification standard was introduced. This classifies motor efficiency according to the labels IE1, IE2, IE3, IE4, and the recently introduced IE5, where IE5 is the most efficient. The standard now includes 8-pole motors, and an extended power range. The efficiency standards still apply to any single or three phases line motor (regardless of technology) operating at 50 or 60Hz. Figure 7.11 shows efficiency for bands IE1-4.

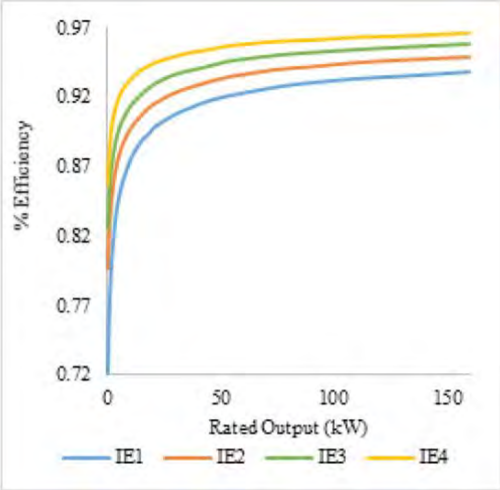


Figure 7.11: IE1 to IE4 bands for 4 pole motors
(Carbon Trust, 2018)

Sizing a motor

It is best to avoid purchasing oversized motors to cater for future production increases, either as insurance against motor failure or simply to override load fluctuations in the production processes. Motors that are oversized run with lower efficiency and power factor. If the load is constant, size the motor as closely as possible to the load, with a small safety margin. Table 7.16 illustrates savings to be made by replacing oversized motors with motors of the correct size to meet the load — for example in Case 1 the installation of a 3.7 kW motor which is 80% loaded, compared to 7.5 kW which is 40% loaded, saves $722/yr.

Table 7.16: Cost comparison for oversized motors

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

Source: Adapted from (USDOE, 2004)
[a] Operating 2500 h/yr
[b] Operating 6000 h/yr
Assumption: electricity cost $0.08/kW h

Information on determining electric motor load and efficiency can be found at this reference - (USDOE, 2014).

Rewinding Motors

Although failed motors can be rewound, it is often better to take the opportunity to replace the motor with an energy-efficient model. It is recommended that a high efficiency model be purchased in preference to rewinding when the motor is between 5.5 kW – 11 kW. It can be cost effective to have large motors rewound, however this should not be done more than twice. A failed motor that has been rewound will be 0.5%-2% less efficient than it was previously (Carbon Trust, 2018).

Variable speed drives

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

The energy consumed by fans and pumps is proportional to the cube of the motor speed. For example, if a VSD on a refrigeration compressor reduced its speed by 20% the power consumed would drop by 49%. The installation of VSDs can be financially viable but depends on the motor application and operating hours. VSDs are most economically viable for large motors. Table 7.17 shows the potential savings through the installation of a VSD for a 5.5 kW and a 18.5 kW motor operating for 8000 h/yr. In these cases, the payback can be from 18 months to 2 years. Variable speed drives also reduce operating costs through reductions in peak demand (See 7.2.2).

Table 7.17: Savings due to installation of variable speed drives

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

Source: (Teco Australia, 2003)
Assumptions: 8000 operating hours per year; 20% reduction in energy consumption due to VSD; electricity cost $0.08/kW h

Review and upgrade of pumping systems, Saputo Dairy Australia, Koroit (Sustainability Victoria, est 2010)

As a part of the overall plant energy improvement programs, the engineering group at Saputo's Koroit site undertook a detailed analysis of their existing milk separation pump systems. The main focus of the review was to determine potential for:

- reduction in the size of existing motors with smaller capacity motors having the same frame sizes
- replacement of complete pumps with smaller units
- modification of some existing pump units.

The review included an analysis of the pressure drop and power absorbed for two separator banks and found excessive pressure differentials for some pumps which meant that operators were having to throttle valves to obtain balance in feed to each unit – a very inefficient practise.

The outcome of the review and upgrade were:

- reduced pump system running costs by 42% for separator bank no.1
- reduced carbon emissions through lower power consumption
- improved process control
- reduced piping system component wear by reducing friction losses through the system.

The total cost of replacement equipment was $24,878 (pumps, modifications and controls) with total savings of $7869 made up of energy savings ($6029 p.a.), and GHG reduction ($1840 p.a.). Further details on the analysis can be found at Sustainability Victoria Best Practise Guides - www.sustainability.vic.gov.au/Business/Efficient-business-operations/Energy-efficiency-for-business/Energy-efficiency-best-practice-guidelines.

7.4.5 Lighting

Improvements in efficiency

Lighting energy efficiency has improved significantly over the last decade, particularly with the efficiency and reliability of light emitting diode (LED) technology. Benefits of LED lights in addition to reduced energy consumption include reduced heat output, which reduces loads on air conditioning systems as well as extended life and lower maintenance requirements.

Examples of lower efficiency lights that are commonly found in manufacturing plants include fluorescent tubes for lighting of small spaces such as offices and corridors; and metal halide or mercury vapour high bay lights which are often found in processing and warehousing areas. Table 7.18 gives an indication of potential upgrade options and savings for upgrade of light fittings that are commonly found in manufacturing sites.

Table 7.18: Energy savings through lighting upgrades

Original light fitting	Upgrade option	Quantity	Typical capital cost	Energy saving kWh/yr	Payback	Energy reduction %
Twin 36 Watt T8 fluorescent l	30 Watt integrated LED luminaire	100	$9,000	15,600	2.4	67%
400 Watt metal halide	210 Watt LED	180	$63,000	63,440	4.5	54%
500 Watt box floodlight	110 W LED	10	$5000	14,196	1.6	78%

Source: (NSW OEH, 2014)

Light use, design and maintenance

Lighting can be as high as 10% of a dairy processor’s total energy costs, savings can often be made at little or no cost. Significant savings can often be made by simply turning off lights in areas that are not in use and making better use of daylight. Opportunities for reducing lighting costs include:

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

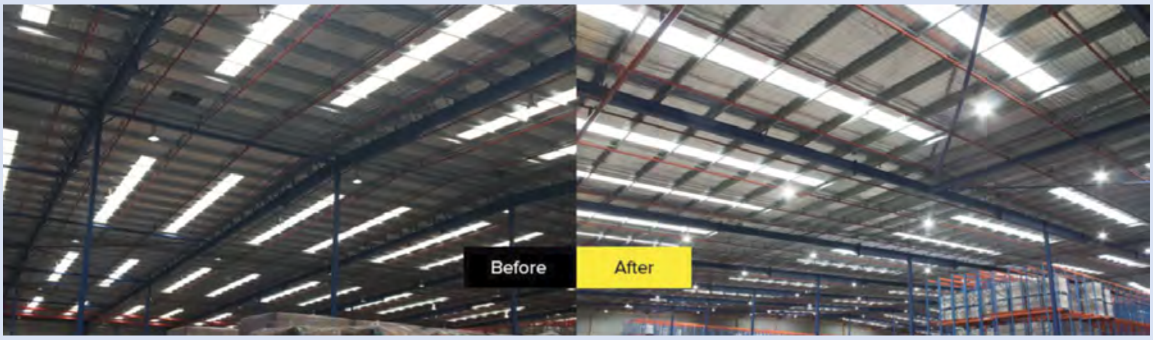
LED high bay lights with movement sensors are very efficient options for manufacturing facilities.

Lighting upgrade, Parmalat Lidcombe (Parmalat, 2017)

Lights at Parmalat's Lidcombe site used 1624 MWh/yr, representing 9.5% of the total annual bill and costing $230,000 per year. Following a site energy audit a lighting upgrade was undertaken. The project reduced overall energy use by 660 MWh, saving $105,000 per annum in energy costs with a capital cost of $268,000.

Warehouse lighting upgrade, Bega Cheese, Derrimut (LEDified, 2018).

Bega Cheese's Derrimut warehouse facility operated around the clock with 130 inefficient metal halide lights. A lighting upgrade saw the installation of more efficient high bay LED lights. Along with a reduction in energy use, there were added benefits in less heat generation, less maintenance and higher lux levels throughout the facility (meeting AS/NZS1680 lighting standards). Savings of $40,000 per year in operating costs were made ($60,337 operating and $4534 maintenance pre-upgrade and $18,984 per year operating cost post upgrade).



Warehouse lighting rationalisation: Fonterra, Spreyton, 2004

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

7.4.6 HVAC

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

Direct expansion

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

Chilled water

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

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

Choosing energy-efficient systems

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

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

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

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

Further reading:

A very useful resource is the NSW Office of Environment and Heritage HVAC guide (NSW OEH, 2015).

7.4.7 Heat recovery

There are many opportunities for recovering heat in dairy processing plants; however, the feasibility of implementing such systems depends on the location of the heat source in relation to the potential area of use, the capital cost of heat recovery equipment, and the potential energy savings. In addition to the commonly used regenerative pasteurisers and sterilisers, examples of heat recovery opportunities in dairy processing plants include using heated whey during cheese processing to preheat incoming milk, from boiler flue gases, boiler blowdown and condensate recovery systems and from the heated air from spray dryers.

Walmsley et al discusses heat recovery from chillers. 'In most instances this opportunity requires an additional compressor unit to increase the pressure of the chiller's condenser, thereby upgrading its heat so that it may be integrated to fulfil process heat demands. Pinch technology (Section 7.4.8) 'can aid the selection of the condenser pressure and identify the method for its integration, either direct with process stream and/or via the hot water utility network, using the appropriate placement principle for heat pumps' (Walmsley, et al., 2016).

Stratified storage tank and heat recovery from wastewater: Saputo Dairy Australia, 2004 Ed

A dairy processing site reclaimed heat from its warm whey through a water medium. The water was pumped into the bottom of a 200,000 L hot water bank. The hot water in the tank was transferred from the top of the tank for the pre-heat of the pasteuriser. The cost of implementation consisted of labour costs for programming and optimising several cascade loops. The system maintained cold whey temperatures for the whole day and improved the performance of the membrane plant. The processing plant also recovered heat from its cleaning wastewater that could not otherwise be recycled or reused. The heat reclaimed from the wastewater was used to heat incoming mains water.

Heat recovery from cheese whey: Fonterra, Wynyard, 2004 Ed

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

Heat recovery and reduction in steam usage: Beston Global Food Company, Mount Gambier, 2004 Ed

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

Heat recovery from refrigeration compressors: Lion Co., Penrith, 2004 Ed

Lion Co's Penrith site recover heat from the refrigeration compressors to pre-heat site process water. The system allows water used for cleaning to be heated to 50°C. Heated water for hosing was previously provided by a boiler.

7.4.8 Pinch technology

A strategic method for looking at the opportunities for heat recovery is through a procedure known as 'pinch technology'. This involves analysing the heating or cooling requirements of various process streams and matching these requirements to determine the minimum amount of heat energy input into a system. The original term was introduced by Linhoff and Vredeveld. The document *Introduction to pinch technology* by Linhoff March has further information and can be downloaded from the Oklahoma University website (Linhoff March, 1998). Pinch technology continues to be utilised to help with the efficient design of future milk processing facilities as described in the research by Walmsley.

7.4.8).

Energy efficient design of future milk powder plants, (Walmsley, et al., 2016)

Walmsley et al has been applying pinch technology (Total Site Heat Integration) to investigate potential improvements in energy efficiency of milk powder production. The work is intended to inform the design of future milk production plants. Three energy reduction opportunities are investigated:

1. increasing boiler efficiency through condensing economisers,
2. waste heat recovery from the chiller unit, and
3. Combined Heat and Power (CHP) for electricity production.

The study indicates potential reduction in energy requirements of 227 MJ/tonne product and 101 MJ/tonne product for items 1 and 2 along with 51% of site energy production being met by a CHP system.

7.4.9 Pasteurisers and sterilisers

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

Potential energy savings arise through increasing the regeneration efficiency of the pasteuriser through more efficient heat exchange. Other opportunities to conserve energy during pasteurisation is to analyse and minimise times of extended circulation. A hibernation mode can be included where the cooling section is turned off and heating reduced by 90% (Carbon Trust, est 2010). There are also low temperature alternatives such as UV light, pulsed traditional light and pulsed electric field pasteurisation. High pressure processing is also a growing trend in the food industry.

7.4.10 Wastewater treatment aerators

Aerators in wastewater treatment ponds use a substantial amount of electrical energy. The use of variable speed drives can potentially reduce this energy consumption as well as the use of efficient aerator models as per the case study below.

Venturi Aerator, (Barber & Cumming, 2017)

Venturi aeration is achieved by pumping water through a venturi jet and sucking air into the water stream. The Andzac Aerator uses four Venturi jets and pumps aerated water back into the water body. As a comparison, a 22 kW aerator operating 12 hours per day for a year gives 1.8 kg O_2/kWh. Operating at 60% motor load it uses 57.8 MWh for 80.9 tonne O_2. The Andzac model 2.2 kW aerator x 5 operating 12 hours per day uses 31.5 MWh and gives 73 tonne O_2. For 5 units, this is a 26.3 MWh energy saving (22%).

7.5 Renewable Energy Sources

Renewable energy is becoming increasingly attractive to dairy processors as the energy delivered by these technologies is reaching cost parity with traditional energy sources. In particular, biogas, biomass and solar PV are becoming more frequently used to supplement existing energy supplies. While renewable energy sources currently only provide a portion of total energy requirements, the industry is looking to the future with research undertaken by Walmsley describing a process for sustainable milk powder production using improved energy efficiency and 100% renewable energy sources (see below). Other processors are utilising power purchase agreements to reach targets of 100% of supply from renewable sources (see 7.5.6).

Factory of the future with 100% renewable energy sources, (Walmsley, et al., 2016)

Walmsley undertook an analysis of requirements to integrate 100 % renewable energy into a 10 t/h ultra-low energy milk power factory of the future in New Zealand and California. Three case studies from three different locations are reported. In New Zealand the best option is to use renewable electricity from wind, hydro and geothermal for the factory electrical needs, and high temperature geothermal energy when available for process heating up to 210 °C and low temperature geothermal energy with MVR technology upgrading for process heating up to 180 °C. When no geothermal energy is available the best option is renewable electricity driven heat pumps for heating up to 85 °C, and biomass (wood residue) for high temperature heating up to 210 °C. Biomass production, however, will require 35 % more land than the farms require for producing the milk. In California renewable energy is best met using biogas from anaerobic digestion of cow manure and solar thermal. Biogas converted into biomethane on farm fuels a combine cycle gas turbine with a heat recover steam generator (HRSG) to meet process heating needs above 80 °C and all factory and biogas compression electrical needs. Solar thermal with day-night storage provides hot water utility. A cow manure collection rate of 37 % is required to meet both process heat and electricity needs.

7.5.1 Biofuels

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

Use of wood waste at Meredith Dairy (RIRDC, 2017)

Well renowned goat and sheep dairy ‘Meredith Dairy’ installed a 240 kW biomass boiler to reduce reliance on LPG providing hot water for pasteurisation, washdown and domestic hot water within the factory.

LPG is still required for the factory’s water heating, but the biomass boiler has reduced Meredith Dairy’s LPG consumption by an estimated 1,600 litres per week ($76,500/year). The cost of producing their own woodchips is estimated to be around $31,200 annually (including diesel, maintenance and depreciation on the machines and labour costs) giving an overall cost saving of $45,300/year. This equates to a simple payback period of 2 years, 8 months and has reduced the dairy’s emissions of greenhouse gases by approximately 230 tonnes per year.

7.5.2 Biogas (Anaerobic digestion)

Anaerobic digestion and the utilisation of methane (biogas) is an opportunity that is of increasing interest to Australian dairy processors due to the rise in energy and trade waste discharge costs. Biogas is significantly cheaper than other fuels, in the order of $5-$15 per GJ (Energetics, 2017) compared with natural gas at $8-$15 per GJ (Table 7.3). In 2017, there were seven anaerobic digesters installed at Australian dairy processing plants with numerous other examples of their use around the world (GHD, 2017). Dairy Australia has commissioned a report on the feasibility of a range of anaerobic treatment technologies in dairy plants including cost estimates of a covered anaerobic lagoon (CAL). Determination of requirements and the viability of implementing a CAL is dependent on:

Anaerobic digestion of food-processing wastewater produces biogas that can supplement energy requirements.

- Quantity and load of wastewater stream e.g. from liquid milk, cheese or powder plant

- Space availability
- Location and proximity to plant / residential area
- Presence of skilled operators or willingness to train
- Cost associated with infrastructure requirements
- Ability to utilise biogas for heating or electricity
- Energy costs and requirement for generation rather than flaring

Generally, the driver for covered anaerobic lagoons is to utilise biogas as an energy source as well as reduce carbon emission. The prerequisites for the successful use of biogas include ensuring:

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

Table 7.19 shows a range of loading rates and design criteria for an anaerobic digestion system for dairy processors. Table 7.20 gives an example of methane and energy yields from anaerobic digestion at an ice-cream plant in Minto, New South Wales.

Table 7.19: Design criteria for covered anaerobic lagoon treating dairy wastewater

	Low-rate digestion of effluent (lagoon digester)
Influent characteristics	Temperature: 30- 35 ºC BOD 2,500 – 25,000 mg/L Alkalinity > 1,500 mg/L as $CaCO_3$
Organic load	0.03-0.4 kg COD/m^3/day
BOD/COD removal rate	60-90%
Pond hydraulic retention time	10-40 days
Pond depth	5-7 m
Pond freeboard	0.5 m
Pond geometry	2.3:1 Length:width
Pond slope	3:1 sand soils, 2:1 clay soils
Effluent characteristics	pH: 7-7.6, Volatile Fatty Acids: 50-500 ppm as acetic acid, Alkalinity:2000-3000 as $CaCO_3$ VFA/Alkalinity ratio:0.1-0.5
Biogas generation	0.5 m^3 biogas/kg COD & 0.25-0.35 m^3 CH_4/kg COD

Source: (GHD, 2017)

Table 7.20: Sample methane and energy yields from biogas digestion for an ice-cream factory in New South Wales

	Low-rate digestion of effluent (lagoon digester)
Material available for digestion	3060 kg COD/day
Organic load available	0.34 kg COD/m^3/day
Methane conversion rate	0.352 m^3/kg COD removed
Organic removal rate	70%
Methane yield	754 m^3 CH_4/day
Energy yield	27,000 MJ/day
Equivalent natural gas savings	$324/day @ $12/GJ

Source: (UNEP Working Group for Cleaner Production, 1999)

Business case for anerobic digestion: Dairy Manufacturer, Victoria (Dairy Australia)

Although very common in Europe, Anaerobic Digesters are still scarce in Australia. In 2018, an Australian dairy manufacturer undertook a detailed feasibility assessment to build a business case for Anaerobic Digestion in Victoria. The scope of the project included dairy input from operations (trade waste, whey and other by-products) as well as community impacts and environmental outcomes. The purpose of the business case was to prove the economic viability of an anaerobic digestion process in the dairy industry. In order to optimize the prospects of success, the Manufacturer looked into different scenarios to assess available options around operation, capital and space requirements. The outcomes of the business case were extremely positive. The volumes of whey and trade waste generated on site and their methanogenic potential would allow the production of enough biogas to power all operations, including biogas but also electricity through co-generation. Given the closed loop system, the costs associated with trade waste discharge could be reduced by up to 47% and whey disposal costs could be cut by 40% or eliminated altogether in the case of a built-owned-operated digester. In addition to securing a sustainable source of renewable energy, utility costs could potentially be reduced by 25% and about 30,000 tCO_{2eq} could be abated. Further points around long term planning capital and space availability are being assessed by the manufacturer.

Utilisation of biogas: Warrnambool Cheese and Butter, Allansford. 2004 Ed

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

Anaerobic Digestion, Saputo Dairy Australia, Leongatha (RIRDC, n.d) and (DMSC, 2011)

Capital was invested in bioenergy and wastewater treatment upgrades at Saputo's Leongatha plant. In 2009, $20 million was spent on upgrading the existing wastewater treatment plant so all treated waste could be safely discharged to the ocean. The treatment reduced the organic and nitrogen load in the wastewater and generated approx. 9,000 m^3 of biogas.

In mid-2010, two biogas engines (760 kW combined energy) were installed with help of Sustainability Victoria ($140,000) and SP Austnet. The engines have capacity to generate 5000 MWh/yr and were projected to reduce grid electricity demand by 9%, saving $600,000 per year in energy costs as well as renewable energy certificates. Final commissioning post 2010/11 was expected to reduce carbon emissions by 11,000 tonnes CO_{2e} annually. Payback on the biogas engines was expected to be 3 years. The project suffered issues, however, due to poor process design for the scrubbing of impurities from the biogas. This led to damage to the generator sets and a re-think of the system design.

7.5.3 Solar PV and battery storage

There is a number of dairy processors utilising solar PV systems to supplement energy supplies. This is currently most common in non-processing areas such as offices and distribution buildings where solar PV can form a significant proportion of energy requirements. The increased interest in solar energy is driven both by rapid increases in energy costs (refer to charts above) and gradual reductions in the cost of installed PV systems. Figure 7.12 illustrates the reduction in pricing for a 50 kW solar PV system in Australia with a decrease from around $1.50 per watt in 2014 to around $1.24 per watt in 2018.

Battery storage is also becoming commercially viable. In the last two decades, lithium ion batteries used for portable electronics have decreased in price from around $3000 USD/kWh to around $400 USD/kWh in 2015 (Figure 7.13). In 2017, lithium ion batteries are competitive on a commercial scale at a cost of 216 $AU/MWh compared with gas peaking plants at ($218/MWh), pumped hydro at $161/MWh and solar thermal at 137/MWh (ARENA, 2017).

Into the future, it will not be uncommon for dairy processors to take advantage of solar PV and/or off peak rates and battery storage with capacity for demand management and peak shaving.

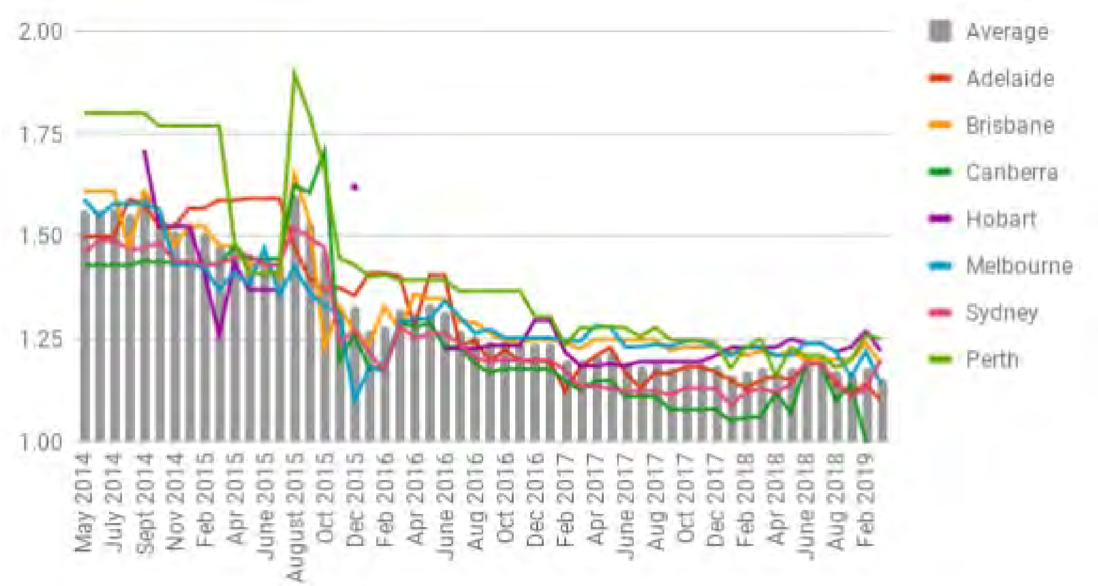


Figure 7.12: 50 kW commercial solar system prices (Solar Choice, 2018)

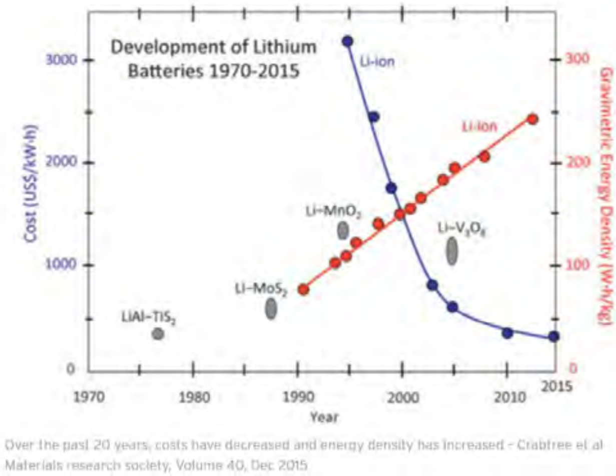


Figure 7.13: Cost reduction in Lithium Batteries (ARENA, 2017)

Burra Foods, Solar PV Installation, 2017 (DMSC, 2017) and (Burra Foods, 2017)

With the help of LaTrobe Valley based Energis Pty Ltd, Burra Foods installed 600 square metres of solar PV in September 2017, with the 100 kWh generation expecting to deliver 2.4% of electricity needs. This project has a five-year payback. Initially the solar power will be fed into the electrical supply to use it within the factory; however, Burra Foods expects it is only a matter of time before they adopt battery storage to get better value from their own power generation.

Distribution centre, Solar PV Installation, Lionco, Chullora (Lion Co, 2017)

Lionco, Chullora have built a new Dairy & Drinks distribution centre in a joint initiative with their landlord, Charter Hall. The building features a 600 kW solar PV system.

7.5.4 Solar thermal

Solar thermal power systems use solar energy for heating water and even for steam generation. Solar thermal systems are technically feasible as an alternative to gas for industrial uses and for a wide range of temperatures. An advantage of solar thermal systems is that, although they can have high initial costs, operating costs are low if they are well designed and properly installed and maintained. Dairy processing plants have large amounts of roof space that could be utilised for solar collectors, however, this is likely to be a trade off with solar PV installations.

Possible uses of solar heat energy are hot water for cleaning, to pre-heat boiler feedwater or even steam generation. Performance is linked to the level of solar radiation. At a site with a reasonable solar resource, solar thermal is likely to be economically viable for temperatures up to 150°C and possibly viable up to around 250°C (IT Power, 2015). There are a number of examples of solar thermal technology used in Australian dairy farming sites (Dairy_Australia, 2018)

Evacuated solar tubes for process hot water, B.-d Farm Paris Creek (Greenland Systems, 2014)

B.-d Farm Paris Creek export biodynamic-organic dairy products including milk, yogurt, quark, butter, and soft and hard cheeses. The company installed solar PV to reduce grid electricity and in 2014 installed evacuated solar thermal tubes to replace LPG for hot water and steam production.

Sixty solar thermal collectors (150 kW) were installed which heat process water up to 80-85 º C. The system met the high temperature needs of the facility, while ensuring the production process was not disrupted irrespective of solar conditions. This was achieved by providing 6,000 L of hot water storage and utilising the existing boiler configuration as a back-up source.

The solar system displaced about 70% of the annual LPG consumption prior to installation and has a 40 year service life. Expected payback was approx 5.5 – 6 years. The system was expected to supply 90% of all heating energy required in summer and approximately 50% in winter.

Solar Trough Collector, Cheese Manufacturing Plant, Switzerland (IT Power, 2015)

NEP Solar have installed a 627m^2 trough solar collector field on the roof of the Emmis Tete de Moine cheese manufacturing plant in Switzerland. This system produces over 50% of the daily heat demand of the dairy process on sunny days. The site averages 12 MJ/m^2/day solar irradiance. Construction time was about 2 months.

In Australia, NEP Solar have installed a 330m^2 trough collector field in Newcastle. This field can reach temperatures of 330ºC. The Newcastle Granite Power project received funding from ARENA and generates 30 kWe and produces over 150 kWth of heat for the Wallsend swimming complex.

7.5.5 Heat pumps

Heat pumps use a refrigeration cycle (refrigerant) to upgrade low grade heat to high grade heat. Domestic versions of the technology are frequently seen as reverse cycle air conditioning units. At an industrial scale, high temperature heat pumps are a proven technology with potential for dairy processors. Thousands of units are now in service, in Japan, South Korea and (to a lesser extent) Europe to supply heat at up to 95°C. The technology has also extended to development of heat pumps delivering steam at up to 150°C.

Currently, there are barely a handful of high temperature (over 65°C) industrial installations in Australia (Jutsen, et al., 2017). Heat pumps are economically feasible where they can be used to upgrade heat from waste streams and/or capture latent heat, (like waste water, hot humid air (e.g. from dryers), condenser heat from refrigeration systems), and where simultaneous heating and cooling duties can be delivered. The efficiency of the heat pump depends on the selection of refrigerant. Further information can be found in *High Temperature Heat Pumps for the Australian Food Industry* (Jutsen, et al., 2017). Numerous case studies can be found at http://heatpumptechnologies.org including two dairy industry case studies below.

Dairy Cooperative Tine, Norway: Heat recovery for hot water generation (Jutsen, et al., 2017)

The heat recovery system utilises waste heat from the dairy's refrigeration system to fulfil the dairy's demand for CIP water at 73°C (COP 5.8). The system is also connected to a local heating network which supplies heat to nearby greenhouses at 58°C (COP 9.0). The system uses an Ammonia refrigerant. /

Dairy processing, US: High temperature short time (HTST) pasteurisation (Jutsen, et al., 2017)

The HTST pasteurisation process in this Wisconsin dairy factory utilises an efficient two stage heat pump to deliver the 90°C water temperature required. Entering water temperature is 10°C and refrigeration is the heat source. The two stage heat pump system cost US$1,250,000 and delivers 60,507 MMBTU of heat per year. The heat pump system has a COP of 4.2 (compared to gas boiler system COP of 0.85).

7.5.6 Wind

Wind generators are a possible future source of alternative energy for those companies that have a constant source of 'clean wind' (i.e. wind coming from a constant direction and not made turbulent by nearby obstacles). In 2017, Australia's wind farms produced 33.8% of the country's clean energy and supplied 5.7% of Australia's overall electricity during the year. For the first time ever, 2017 saw wind contribute an almost identical amount of Australian electricity as hydro energy with total generating capacity at 4816 MW (CEC, 2018). The levelised cost of wind energy is around 8 cents/kWh (Diesendorf, 2015). There are numerous examples of wind turbines owned and operated by dairy farmers. Wind energy can also be part of the energy mix for processors via contract agreements for renewable energy.

Burra Foods, Power Purchase Agreement, Wind Energy, (Burra Foods, 2018)

Gippsland based dairy processor Burra Foods, has entered into a large-scale Renewable Corporate Power Purchase Agreement (PPA) with Melbourne-based energy retailer Flow Power. The deal will bring Burra Foods closer to meeting its ambitious energy efficiency goals and give the business direct access to secure low-cost renewable energy over a ten year period. The renewable power, sourced from Ararat Wind Farm, is expected to deliver annual savings in excess of 20% and can be used in real time to offset grid electricity consumption. Partnering with Flow Power and sourcing a steady supply of clean, renewable energy is a major step toward the facility being powered by 100% renewable energy.

Wind generator: dairy processor, UK (HoTT, 2016)

Longley Dairy in West Yorkshire, UK have retired their 18 kW and 90 kW wind generators which were originally installed in 1986. The dairy has set up a community energy company and is replacing them with a larger turbine of approximately 225kW capacity. The project became operational in September 2015. The new turbine is anticipated to produce around 582 MWh per year of green electricity – the equivalent demand of 188 homes. This will offset approximately 286 tonnes per year of CO_2 emissions at the grid average emissions factor of

0.45kg/kWh. Power generated is fed into Longley Farm's distribution system from where the energy will either be consumed by the dairy or exported to the grid depending on dairy demand and wind speed.

7.5.7 Geothermal

Geothermal energy is a possible energy source for dairy processor depending on their location. It can be used for direct heating, typically for temperatures below 150 ºC, but also higher. For a large energy user (in excess of 50,000 GJ) it can be a competitive energy source and potentially cost effective compared to gas at even $5/GJ. Further information can be found in Renewable Energy Options for Australian Gas Users (IT Power, 2015). Examples of geothermal energy supply in food processing are relatively uncommon in Australia, however, there are several examples in New Zealand.

7.6 Combined heat and power

Combined heat and power (CHP) systems use a single source of fuel to cogenerate both electrical and thermal energy. The main advantage of a cogeneration system is the overall system efficiency, which can be as high as 80%. In contrast, the conversion efficiency of a conventional power station producing only power is only about 36%, with the remainder lost as unrecovered heat. Payback on a cogeneration system in Europe is reported to be less than three years (Thomson, 2016) with upfront capital cost, labour and operational costs recovered by savings on energy prices. Cogeneration plants that produce power in excess of factory requirements can export the power to the grid.

Types of CHP systems

There are four 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.
- **Trigeneration systems** combine cooling, heat and power by using an absorption chiller to convert waste heat into cooling energy. This eliminates greenhouse intensive refrigerants and reduces overall air emissions.

Applicability to dairy processing

The purpose of cogeneration is to produce electricity and heat together at a specific site more cheaply than they can be produced separately. Small-scale cogeneration plants, which could be used by dairy processors, compete with retail electricity prices; however, electricity and gas prices greatly affect the economic viability of a cogeneration plant. For a typical multi-product dairy manufacturing plant in Australia, greenhouse gas emissions could be reduced by 30–40% by adopting cogeneration technology (Lunde, et al., 2003)(Lunde et al. 2003). Walmsley, et al. describe a possible CHP system which could provide 51% of the electricity requirements for a milk powder plant (Walmsley, et al., 2016).

Both third-party ownership and sophisticated financing are available in an 'energy performance contract', whereby a third party takes the risk and maintenance of the project and is refinanced through the energy savings; this may make certain projects more economically attractive.

Te Rapa Cogeneration Plant, Fonterra (Contact Energy, 2018)

The Te Rapa cogeneration plant is a 45 MW cogeneration plant owned and operated by Contact Energy. It is located at the Fonterra dairy factory at Te Rapa near Hamilton in New Zealand.

The plant is based on a gas turbine which can produce up to 45 MW of electricity. Hot exhaust gases from this gas turbine are ducted to a heat recovery steam generator (HRSG) to raise steam. This HRSG has duct burners to increase steam output, which can be up to 180 tons of steam per hour. The plant was commissioned in 1999 and is still in operation in 2018. The cogeneration plant is designed for flexible operation, and can provide electricity to the dairy factory, export electricity to the local network or import electricity for use in the dairy factory. A common operating mode is 30 MW of electricity exported and 15 MW plus 120 tons per hour of steam provided to the dairy factory.

YIELD OPTIMISATION AND PRODUCT RECOVERY

CHAPTER 08

8.0 Yield optimisation and product recovery

8.1 Overview

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

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

8.1.1 Sources of product loss

Sources of product loss in dairy processing plants are summarised in Table 8.1. Some sources of loss are unavoidable or inherent due to equipment design (e.g. separator de-sludge), while others may be due to poor operating procedures or process control. Opportunities to minimise loss are discussed throughout the chapter.

Table 8.1: Sources of product loss in dairy processing plants

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

8.1.2 The cost of lost product

The true cost of waste product consists not only of raw material costs but also:

- the cost of processing (heating, pasteurising, cooling, pumping);
- labour costs involved with re-testing, storage and handling;
- the cost of wasted packaging, and of wastewater treatment; and

- discharge or solid waste disposal costs.

However, there are opportunities for substantial savings on the cost of raw ingredients in the wastewater stream alone, as explained below.

Table 8.2 shows typical wastewater characteristics from a survey of 10 Australian Dairy processing sites as well as some additional data from literature. Britz, et al. includes data on BOD and COD for selected milk products as well as concentration of selected elements in dairy wastewater streams e.g. phosphorus, sodium or calcium (Britz, et al., 2006).

Table 8.2: Indicative wastewater characteristics from dairy processing plants

Wastewater characteristics pre-treatment	Typical value[a]	Range for all processor types[a]	Example Milk plant[b]	14 Cheese/ whey plants[b]	Example Powder plant[b]
BOD_5, mg/L	2500	700-15,000		565-5722	
COD, mg/L	4500	500-80,000	713-1410	785-7619	1908
TSS, mg/L	1500	250-12,000	360-920	326-3560	
TDS, mg/L	3000	700-7,000			
TN, mg/L	100	30-300			
TP, mg/L	50	10-150			
FOG mg/L	500	100-1200			
pH		4-12	7.1-8.1	6.2-11.3	5.8
Sources: a)Dairy Australia survey of 10 processing sites (GHD, 2017) b) (Britz, et al., 2006)					

Dairy processors typically undertake primary treatment of wastewater through flow equalisation followed by induced air flotation (IAF) or dissolved air flotation (DAF) to remove oil and grease before discharge to trade waste (GHD, 2017) or irrigation. A number of processors undertake secondary treatment through anaerobic treatment systems. Typical target quality of wastewater prior to trade waste discharge to sewer is shown in Table 8.3.

Table 8.3: Indicative wastewater characteristics from dairy processing plants

Parameter	Typical Quality Target (post treatment, to discharge)
BOD_5, mg/L	600-1000
TSS, mg/L	500-600
TDS, mg/L	2000
TN, mg/L	200
TP, mg/L	50
FOG mg/L	100-150
Temp deg C	38
Source: (GHD, 2017)	

A mass balance calculation on milk solids loss to wastewater is defined as:

$$Q\text{milk} = \frac{Q\ x\ B}{B\ milk}$$

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

Q = total flow to treatment (ML/yr)

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

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

Source: (Morgan, 1999)

Assuming a BOD_5 strength for undiluted milk of 100,000 mg/L, a wastewater flow of 300 ML/yr and a typical BOD_5 of untreated waste of 2000 mg/L (Table 8.2), the volume of lost milk to the waste stream is 6 ML/yr. For an indicative cost of $0.40–0.50/L milk, this equates to milk losses of $4–5 million per year. Even a 5–10% improvement in yields can therefore lead to substantial savings of $400k-$500k.

Table 8.4 shows the wastewater to raw milk intake ratio from 2004 survey data from Australian processors. The data indicates that wastewater flow per tonne of milk for a market milk processor ranges from 0.96 to 2.43 L/L milk processed, with an average of 1.60 L/L processed, suggesting there is opportunity for improvement in reducing wastewater volumes in Australia plants that produce mainly market milk.[11]

A UK publication suggests that COD levels in wastewater streams for market milk plants should be less than 3.8 kg COD/t milk processed with 1.5 kg COD/t of milk achievable, while for cheese and butter production COD should be less than 3 kg COD/t of product (Envirowise, 1999b). Insufficient data was available to compare the Australian COD load with the UK benchmark.

Table 8.4: Wastewater to milk ratio (L/L)

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

Source: Original data 2004 edition of this manual

Trade waste discharge costs

Trade waste (wastewater) discharge costs vary significantly according to the region and charging structure of the receiving authority. Most local councils or water authorities have adopted a ‘user pays’ charging structure where customers must pay for the volume and quality of the wastewater discharged, thereby contributing to the operating (and sometimes capital) costs of the waste treatment facilities.

As previously mentioned, a high wastewater load not only represents a loss of valuable product but also results in additional discharge fees. Table 8.5 shows the trade waste discharge costs for a number of local councils that host dairy processing plants. The charges are for the highest category of trade waste (i.e. relatively high-strength and high-volume waste that is typically produced by dairy processors). Table 8.6, Figure 8.1 and Figure 8.2 compares the cost of discharge in the different regions, based on an assumed wastewater volume and quality. The BOD and SS charge typically make up the highest proportion of the total charge. Total effluent charges can vary by as much as 300%, depending on the overall discharge costs for each region.

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

Table 8.5: Trade waste charges in various regions [a]

Wastewater load	Brisbane Water	Ipswich Water	Sydney Water	SA Water	Goulburn Valley Water (Tatura)	Citiwest water
Volume	$1.00/kL	$1.50/kL	$/kL Quarterly fee	$0.19/kL ($1.42 fcr)	$0.9021/kL	$0.8152/kL
BOD_5	$0.98/kg	$1.26/kg	$2.001+ (0.133 x [BOD mg/L]/600)/kg	$0.312 /kg < 1000 mg/L and $0.471/kg > 1000 mg/L	$0.1982/kg	$0.9953/kg
SS	$0.90/kg	$1.77/kg	$1.619/kg	$0.277/kg	–	$0.5392/kg
Nitrogen	$2.22/kg	$2.00/kg	$1.834/kg	$0.488/kg	$0.9816/kg	$1.9154/kg
Phosphorus	$1.76/kg	$4.45/kg	$6.577/kg	$2.373/kg	$2.2302/kg	–
Grease	–	–	$1.546/kg	–	–	
Sodium	–	–	–	–	$1.2472/kg	–
TDS				$0.157/kg		0.0194

[a] (2018/2019 charges)
[b] Incorporates quality charges

Table 8.6: Comparison of trade waste charges for Plant A [a]

Wastewater characteristic	Assumed load	Load kg/d	Brisbane Water ($/day)	Ipswich Water ($/day)	Sydney Water ($/day)	SA Water ($/day)	Goulburn Valley Water ($/day)	Citiwest Water ($/day)
Volume	1 ML/d	-	1000	1500	quarterly fee	190	902	815
BOD5	2000 mg/L	2000	1960	2520	4889	942	396	1991
SS	500 mg/L	500	450	885	810	139	0	270
Nitrogen	100 mg/L	100	222	200	183	49	98	192
Phosphorus	100 mg/L	100	176	445	658	237	223	0
Grease	500 mg/L	500	0	0	773	0	0	0
Sodium	500 mg/L	500	0	0	0	0	624	0
TDS		0	0	0	0	0	0	0
Total charge for Plant A ($/d)			3,808	5,550	7,312	1,557	846	2,900
Total annual charge for Plant A ($/yr)			1,066,240	1,554,000	2,047,435	435,848	236,880	812,000

[a] Based on 2018/19 charges

Figure 8.1: Annual trade waste charge for 1 ML/d of typical dairy wastewater

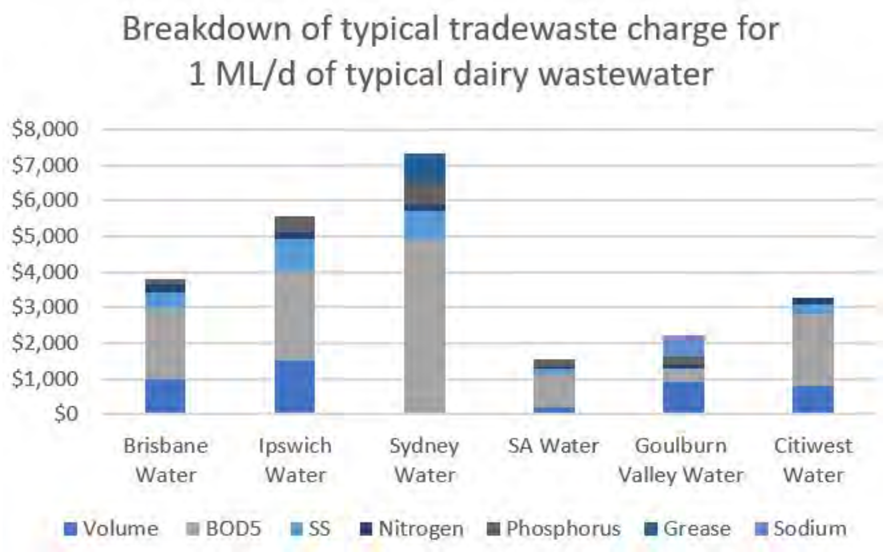


Figure 8.2: Breakdown of daily tradewaste charges for 1 ML typical dairy wastewater

Permeate and whey losses during tanker loading, Bega Cheese, Tatura. (Bega Cheese, 2016)

Toward completion of tanker loading, fresh water was pushed into the transfer line to clean it, but because the tanker would typically fill before the water pushed through the entire length of the transfer line, this often resulted in permeate and whey being lost to trade waste. A simple solution of installing opacity meters in the transfer line now enables the operators to fill the tankers completely with product and avoids discharge to trade waste. The system was installed in late Sep 2016 and resulted in a 29% reduction in lactose lost to trade waste (212 tonnes down to 151 tonnes) compared with the previous 12 months.

Milk waste reduction at Rowville, Parmalat (DMSC, 2011)

In 2007, Parmalat's Rowville factory began a multi-year project to reduce the amount of milk lost during production and cleaning. Detailed analysis of milk losses around the plant were followed by the development of a new daily production schedule to minimise the number of product changeovers required during each processing and filling run. Since the project began, the volume of milk rinsed into the drains during cleaning has been reduced by 45% without changing the hygienic integrity of the plant. This reduction was projected to total 2.7 ML of milk during 2011, equivalent to 100 farm-milk collection tankers and a saving of $1.3 million.

In addition to the recovered milk value, the reduction in milk rinsed to drain was projected to reduce the BOD in factory effluent by 44% or 288,000 kg, representing potential savings of $226,000 in avoided waste treatment charges.

Tatura Loss Tracking Project, Bega (Bega Cheese, 2016)

A cross-site multifunctional team was established in April 2015 to critically review all processes in all plants with the aim of identifying sources of milk product loss to the trade waste system. The team consisted of staff from operations management, production, engineering, environment, maintenance, and process improvement. More than 60 opportunities (large and small) were identified during FY2016 to reduce the loss of fat, protein and lactose to trade waste. As a result, the following reductions were achieved in FY2016 compared to FY2015:

- Fat – 12 % reduction
- Protein – 3% reduction
- Solids (mainly lactose) – 6% reduction.
- The project is also continuing in FY2017, with many identified improvements still to be completed.

8.2 Improving plant layout and design

Waste can be generated as a result of poorly designed processes or processing equipment. Plants should be designed to have a direct and logical flow of materials and processes. Waste should not be accepted as normal practice, and each process step should be designed to keep waste at an absolute minimum. The relocation or modification of existing factories provides a good opportunity to consider possible sources of waste and how they can be eliminated or reduced.

Areas of waste in dairy processing plants include insufficient sloping of pipes, installation of pumps in a configuration that does not facilitate complete drainage, and failure to allow adequate drainage time for equipment. Ensuring optimum pipe sizing is also important with oversized pipes contributing to higher product losses and requiring additional resources to clean (Price, 2015).

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

Product loss due to pipe oversizing (Price, 2015)

An ice cream manufacturer installed piping in their processing facility that was oversized for the requirement. Piping installation costs were $105,000 higher than required and additional costs of cleaning and wasted product were calculated at $250,000 per year.

8.3 Efficient process control

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

The use of online instrumentation for measuring components such as phosphorus, nitrogen, fat, protein, pH, BOD and COD has great potential for improving product yields.

Typical instrumentation includes pH and temperature measurement, flow meters (e.g. Coriolis flow meters) that are capable of measuring when there is entrained air or bubbles (particularly during milk tanker delivery), automated self-cleaning pH monitors which can detect possible spoilage of raw milk via pH variation and optical sensors, which utilise nephelometry or turbidimetry (near infra-red and UV extinction) to detect milk/water interfaces. Online density measurement is also used for standardisation of milk products (Endress+Hauser Australia, 2018). Total Organic Carbon (TOC) is now often used as a surrogate for BOD/COD detection in waste streams (Pryde Measurement, 2009). There are also on-line biofilm monitoring systems which are able to detect growth of biofilm (Isle Utilities, n.d.).

Inline fat and protein monitoring systems that can monitor and control the composition of milk products including powders by measuring the viscosity of concentrated feed milk are also available. The monitors allow for improved quality control, reduced product loss and better energy utilisation. The use of closed-circuit television on main effluent streams has been adopted by many Australian dairy processors, along with audible factory alarms to notify operators of abnormal waste flows.

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

Advanced process control

Advanced process control (APC) systems use sophisticated software to fine-tune operating processes, using such elements as feed-forward or cascade control schemes; time-delay compensators; self-tuning or adaptive algorithms; and Model Predictive Control (MPC). The end result is to increase product yield by increasing process stability and reducing product variability, with the additional benefits of reducing energy consumption and process wastes. Dairy processors have used advanced process control systems to fine-tune the operation of equipment including pasteurisers, dryers and evaporators. Advances in digital technology and real time monitoring has greatly improved the capacity and efficiency of APC systems.

Model Predictive Control (MPC) has a role to play in dairy processing, particularly for large processors. MPC is an algorithm that utilises a ‘model’ of the process to predict future behaviour. The algorithms optimise performance by dynamically adjusting the model and predicting changes to the final control element based on previous performance.

It is reported that large milk powder plants typically see a payback in six months to one year, based on between 0.2-1.0% higher residual moisture in the final powder (Labs, 2015). That is, the more moisture that is sold as powder, the less moisture has to be evaporated, while staying within the specifications. The reduced variation of the process allows the plant to operate closer to the specification. Processors can realise an extra capacity of 3-10% and 5-10% reduced energy consumption. Two other advantages are the plant produces a more uniform product, and MPC reduces the risk of fouling through more stable process control (Labs, 2015).

Real time monitoring of biofilm growth, (Isle Utilities, n.d.)

The ALVIM real-time, on line biofilm monitoring system is able to detect bacterial colonisation of surfaces from the initial phase (down to 1% of surface coverage). Biofilm growth is detected when it grows directly on the surface of the sensor, therefore positioning in the process is crucial. There is an increase in signal once 1% of the surface is covered by biofilm. The system costs in the order of $5000.

On-line monitoring of COD and TSS, (Isle Utilities, 2017)

Arenal PCS produce an analyser for the online monitoring of COD and TSS in industrial wastewater (both organic and inorganic contaminants). The analyser incorporates sensors based on two techniques: ultrasonic sonochemistry and conductivity measurement. The system can be used for 24/7 monitoring of CIP and other process discharges. Measurement of COD and TSS loading can also be used to control tank contact time and optimise aeration processes in waste treatment. In combination with additional sensors connected upstream, the device can be used for detection and prevention of liquid leakage (milk, cream etc) and hence reduce costs as well as waste.

Real time monitoring of TOC reduces waste costs, Saputo Dairy Australia, Maffra (Pryde Measurement, 2009)

Saputo's Maffra site installed a Total Organic Carbon analyser which samples effluent 24/7 and every 12 minutes. The analyser limits COD discharge levels outside the trade waste agreement, thus minimising additional charges previously incurred. The analyser was installed as part of a SCADA system controlling plant effluent. TOC analysis is a far more reliable method of analysis than milk-water interface (turbidity) analysers, as the latter do not respond to dissolved substances such as proteins, lactose or sugars. Murray Goulburn were considering extending the use of the analyser to detect leaks upstream of the waste treatment plant.

Process Control web interface and diagnostics, Chobani, 2011 (Rockwell Automation, 2018)

In 2011, Chobani upgraded its new Victorian manufacturing facility with a new process control system that featured a web interface with diagnostics. This allowed operators remote access to the system, making it easy to find diagnostic information and identify areas that needed attention. The biggest help to Chobani to reduce downtime during the infancy of the plant was the ability for operators to quickly gain remote access to any device and find detailed information fast, which in turn allowed them to reduce downtime.

Advanced process control: Bega Cheese, Koroit, (Mackay, 2002) 2004 Ed

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

8.4 Milk receival, initial processing and storage

Use of isolating valves: Lion Co, Salisbury, 2004 Ed

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

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

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

8.5 Minimising product waste during processing

8.5.1 Optimising start-up and shutdown procedures and changeovers

There are waste-reduction opportunities in improving start-up and shutdown procedures, by fine-tuning timers and accurately detecting product interfaces (as discussed in Section 8.3). Start-up times, in particular, have the greatest potential for loss because operating processes have not reached a stable mode. Procedures to accommodate unexpected shutdowns (e.g. due to loss of power or steam) will also minimise the potential for loss. Machine maintenance and operator training also plays a part in reducing waste during processing.

Reducing milk losses, Parmalat (Parmalat, 2017)

Parmalat's manufacturing sites reduced their wastes to sewer by reducing milk losses in tank wash outs, leaks in transfer lines, spills on the filling line, optimising production runs and equipment cleaning. Overall, waste to sewer was reduced with a 9.3% reduction in Chemical Oxygen Demand (COD) from 2013 to 2014.

Optimising product streams to reduce waste, (Bega Cheese, 2016)

Bega Cheese have been working hard to reduce milk lost to wastewater streams. Given the cost implications of trade waste treatment on top of the loss of a valuable raw material, milk recovery represents a significant opportunity for the company with each of the milk processing sites continually exploring options to reduce losses through small initiatives and large projects. Specifically, Bega Cheese is reviewing the way it treats and manages milk solids within the various product streams, exploring opportunities to optimise fat, protein and lactose within the process. Optimisation is an effective waste minimisation strategy, reducing COD levels in wastewater and ensuring maximum productivity from raw milk supplied.

In 2016, the Coburg processing site increased the recovery of whey (reducing discharges to drain) whilst Tatura reduced discharges of condensate, milk product, and sodium. The milk loss expressed as Chemical Oxygen Demand (COD) increased by 5-6 per cent from 2015-2016. This was partly attributed to the loss of significant amounts of whey at the Lagoon Street site but was also due to improvements in wastewater testing methods.

Reclaim system for power loss: Bega Cheese, Koroit, 2004 Ed

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

Fine-tuning start-up and shutdown: Lion Co, Crestmead, 2004 Ed

Lion Co's Crestmead site fine-tuned its product start-up and shutdown operation by reviewing product interfaces and reducing timers to maximise product recovery. The review led to annual savings of $40,000 or around 60,000 L of milk.

8.5.2 Optimising product formulation

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

Optimising product formulation: Beston Global Food Company, Mount Gambier, 2004 Ed

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

Use of milk permeate for standardisation of powders: Warrnambool Cheese and Butter, Allansford, 2004 Ed

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

Optimising batch make-up: Lion Co, Salisbury, 2004 Ed

Lion Co's Salisbury site improved the running efficiency of its flavoured milk pasteuriser and reduced waste by running a specific volume of white milk either side of flavour mixes (slurries) based on batch size. This improved the batch preparation process by removing the need to flush the pipelines with water between batches.

8.5.3 Production scheduling

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

Improving process control and product scheduling: Lion Co, Morwell, 2004 Ed

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

Improving process control: Lion Co, Salisbury, 2004 Ed

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

8.5.4 Separator de-sludge optimisation

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

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

In certain circumstances, separator de-sludges are recycled into the process to recover useful components. For example, in anhydrous milk fat processing, milk fat has been recovered by recycling separator sludge to the process. The sludge and effluent is collected, filtered and run through a separator to recover the fat. In these cases, it is important to ensure that the sediment levels do not become excessive. If separator sludge cannot be recycled in the process it can be recovered and sold as stock feed, as discussed in Section 9.0 - Solid waste reduction.

Optimising separator de-sludge times: Beston, Mount Gambier, 2004 Ed

Beston's Mount Gambier site extended the separator de-sludge times to prevent usable milk going down the drain. As a result the plant now saves $3900/yr in reduced milk loss.

Milk filters reduce product loss: Bega Cheese, Koroit, 2004 Ed

Bega Cheese's Koroit site installed milk filters prior to separators to reduce discharge frequency. The initiative increased the length of time between discharges from 20 minutes to 50 minutes, saving $40,000/yr with a payback period of 1 year.

8.5.5 Minimising loss of cheese fines

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

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

Recovery of cheese fines and whey from separator de-sludge: Fonterra, Stanhope, 2004 Ed

Fonterra's Stanhope plant use cyclones to recover cheese fines and liquid whey from whey room separator de-sludge. It is estimated that the initiative saved the plant $170,000/yr, with a payback period of 3 months. Challenges included keeping the product and separator cyclones clean.

Recovery of cheese fines: Fonterra, Stanhope[1], 2004 Ed

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

Recovery of cheese product from Cheddar Masters: Lion Co, Murray Bridge, 2004 Ed

Lion Co's Murray Bridge factory fitted knockers to the draining conveyors of two Cheddar Masters. It has been estimated that the initiative achieved a 75% reduction in waste for cheeses with a high moisture content that required washing and a 95% in waste for Cheddar.

8.5.6 Spray dryers and evaporation

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

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

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

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

Filtering of spray dryer exhaust: Bega Cheese, Tatura, (Niro, 2003) 2004 Ed

A milk powder plant recently installed by Niro at Bega Cheese's Tatura plant has the facility to filter the exhaust air using a CIP-able bag filter. The fines product fraction is returned to the process, thus recovering the valuable powder and discharging clean air to the atmosphere.

Optimising spray drying reduces waste and emissions, Bega, (Bega Cheese, 2016)

At Bega Cheese's Lagoon Street site, particulate emissions from the whey powder drying process have been reduced by optimising the crystallisation process and balancing equipment. This has increased the solids content of whey powder, reducing the drying cycle by two-hours and saves 15% of steam energy used for drying.

8.5.7 Product recovery during filling

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

8.6 Maximising product recovery during cleaning

Poor or inefficient cleaning procedures can be a major source of product loss, particularly if product is not recovered towards the end of production. The publication *Performance evaluation guide manual — cleaning systems* (DPEC, 1999) outlines a process for the performance evaluation of cleaning procedures and systems for each unit operation of a dairy processing plant.

8.6.1 Clean-in-place (CIP) systems

The detection of product–water interfaces is the most important aspect of product recovery during cleaning. As discussed previously in section 8.3, they are usually detected using turbidity or conductivity meters or timers. Process equipment should be emptied as far as possible before commencing CIP; the mixing of product and cleaning solutions should be avoided, as it only prolongs cleaning time and adds to wastage of product and cleaning solution. First flush of process equipment should be collected and, where possible, blended back into the process or treated and disposed of as animal feed. Some CIP systems are designed so that pipes are drained of water at the end of the cleaning cycle, which eliminates a water–product interface and minimises the loss of product on start-up. Many factories also use filters to remove gross solids (e.g. fruit pieces, cheese) on supply or return CIP lines.

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

Flush or burst rinsing of tanks and tankers (discussed Section 6.0 - Water) has now been adopted by Australian dairy processing companies. The procedure can save not only in recovered product but also in water usage.

Recovery of cream and oil from AMF CIP: Fonterra, Stanhope, 2004 Ed

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

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

CIP systems are discussed in more detail in Section 6.0 - Water and Section 11.0 - Chemical Use.

8.6.2 Pigging

Source: LC Thomsen Product Recovery

Pigging systems utilise an inert plug which is propelled through a pipeline to push out remaining product in preparation for cleaning. The plug can be a solid flexible food grade material, while other examples include the use of ice slurries and sterilised air. Pigging is generally used for viscous products such as yoghurts, dairy desserts or cream. The advantage is that minimal water is used during cleaning, so that maximum product recovery can be achieved. The design of pigging systems is extremely important, to prevent the pig from being lodged mid-pipe, delaying production and causing hygiene problems. These issues are eliminated where ice slurries are used.

Ice pigging was originally developed by Bristol University (UK) as a solution for pipe cleaning in the potable water industry (Carbon Trust, 2015). The technology has been proven in the Food and Beverage industry in Europe, though there have been no applications in this area in Australia (Carbon Trust, 2015) (Isle Utilities, n.d.).

Ice pigging trial, Yeo Valley Dairy, UK (Carbon Trust, 2015)

An ice pigging trial was undertaken at the Yeo Valley dairy. Two scenarios were costed – a stand-alone pigging system and a system that was integrated with the facility control systems. The results indicated that £132,000 ($AU232,500)in additional revenue per year can be achieved for a single dairy site by recovering saleable product from production lines. When fully integrated into a dairy facility, ice pigging could deliver a further £115,000 ($AU202,500) per year through increased productivity by reducing the time needed for cleaning, thus allowing for increased production. An integrated system requires additional capital costs with payback on a standalone versus and integrated system were 1.6 years compared with 2.2 years.

Vortex air pigging, Babcock (Isle Utilities, n.d.)

Vector is a patented recovery system for the removal of liquefied product within a distribution system through the use of an 'air vortex'. Product removal occurs in two-phases with an initial air phase. The second phase can also introduce atomised rinse water into the air flow (where CIP water flushing is necessary) and this is reported to reduce the dairy producers waste water usage by a minimum of 80%.

Princes foods (UK) installed a system at their soft drinks manufacturing centre. The objectives of this installation were to improve yield, reduce water usage and waste production, to come as close as possible to a zero-loss manufacturing facility. The initial aim was to save 49kg per batch, which would result in recovering 1400 tonnes/year of syrup. The project was expanded though and an additional 201 – 276kg of syrup was saved per batch. Within the original scope the process saved 10,600m^3 of water and 12,000m3 of wastewater per annum. The initial savings were estimated at $1M per annum which equated to a payback of less than one year.

8.7 Use of membranes for recovery of resources

Membranes are commonly used within the dairy industry to produce value-added products and to recover product, chemicals or water. A major advantage of membrane separation technology is that the separated substances can be recovered in a chemically unchanged form. Types of membrane separation technology commonly used in the dairy industry are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). They are used in the following ways (GEA, 2012):

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

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

Membranes used in dairy processing are typically 'cross-flow' where two streams are produced — a 'permeate' and concentrated 'retentate'. Table 8.7shows the relative sizes of membranes and their typical application in dairy processing. In reality, the boundaries between the four types of membrane are not uniform, as performance specifications vary from supplier to supplier.

Table 8.7: Membranes used in the dairy industry

Membrane type	Molecular weight (Dalton)	Approximate pore size	Application in dairy industry
Microfiltration	-	0.1–1.0 (μm)	• Solution clarification; • removal of bacteria
Ultrafiltration	1,000 Da to 300,000 Da	0.01–0.1 (μm)	• Protein, whey, milk concentration/standardisation; • clarification
Nanofiltration	200 Da to 1,000 Da	1 nm – 10 nm	• Lactose rejection, • Protein, whey, milk concentration; • recovery of caustic from CIP; • standardisation of protein; • desalinisation of salty whey
Reverse osmosis	<100 Depends on solubility	Depends on solubility	• Whey, milk, lactose concentration; • polishing RO permeate; • de-ashing whey, lactose; • clarification. Salt and water recovery

Source: Adapted from (GEA, 2012) and (Yoon, 2016)

The choice of membrane depends on what is to be extracted from the feed stream, and what the resulting permeate and retentate streams are to be used for. Some dairy processing plants use RO to polish evaporator condensate; this is discussed further in Section 6.0 - Water.

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

Spent CIP solutions can also be regenerated using MF, UF or NF, as discussed in Section 11.0 - Chemical Use.

8.8 Whey products

Whey, a by-product of cheese manufacture, has in past years been considered a waste stream. From 100L of milk used in the cheese manufacturing process approximately 80-90L of whey is produced (Božanić, et al., 2014). There are generally three classes of whey:

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

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

Membrane processes have provided the dairy processing industry with the means to produce value-added by-products that were previously sent to waste or used as stockfeed. Membrane processes are used to separate whey into permeate (lactose-rich) and retentate (protein-rich) streams. Permeate can be used to produce crystalline lactose — a valuable ingredient with uses in milk powder standardisation, baking, infant formula and pharmaceuticals.

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

The retentate may be processed to form such products as whey protein concentrate (WPC) or demineralised whey powder. WPC is used extensively as a food ingredient in the manufacture of ice cream, baking products, beverages and processed meat as well as in cosmetics and detergents (Dairy Australia, 2018). There are many possible products that can be obtained from whey as shown in Figure 8.3

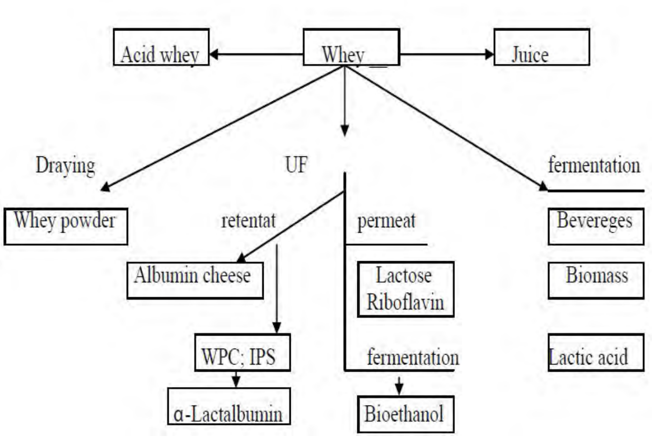


Figure 8.3: Possible products derived from Whey.
(Božanić, et al., 2014)

Some dairy processors generate a salty effluent stream (cheese brine) from cheese production which cannot be reused without further treatment such as MF. The high salt content in cheese brine makes it unsuitable for disposal onto land or as animal feed.

In order to guide dairy processors on operational and commercial options for cheese whey, Dairy Australia have produced and recently updated the Whey Utilisation Tool. The Web Tool provides indications of investment and operating costs, as well as the net value of operation and investment. Users can select from a range of whey production options as well as whey by-products. There is also option for variation of the inputs for capital, labour, overheads, product yield, and utilities usage and cost. See wheyapp.dairyinnovation.com.au/Demonstration.

Whey drying plant: Beston Global Dairy Foods Jervois, 2004 Ed

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

SOLID WASTE REDUCTION

CHAPTER 09

9.0 Solid waste reduction

9.1 Overview

Dairy processors produce significant quantities of solid waste that must be managed and disposed of responsibly to eliminate environmental risks and reduce environmental impacts and costs. The following chapter looks at sources of solid waste in dairy processing plants and the opportunities for reducing such waste.

9.1.1 Sources of solid waste

The types of solid waste typically produced by dairy processors include packaging waste such as cardboard, paper, cartons and plastic; organic wastes such as sludge and reject product; and office waste. Sources of solid waste from dairy processing plants are shown in Table 9.1. They can be generated during processing, or when raw materials and products are being transported, stored and handled.

Table 9.1: Sources of solid waste in dairy processing plants

Category	Type of waste	Disposal stream
Non-organic	Cardboard boxes, paper, slip sheets	Recyclable
	Plastic wrap	Recyclable, depending on cleanliness and plastic type
	Plastic/paper powder bags	
	Used packaging from off-spec/returned/out of date product	
	HDPE bottles and caps	Recyclable
	Foil seals	Non-recyclable
	Liquid paperboard	Recyclable
	Labels	Generally non-recyclable
	Plastic and metal drums and containers	Returned to supplier, reused or recycled
	Polystyrene	Recyclable in some areas
	Office waste (e.g. toner cartridges, paper)	Recyclable
	Canteen waste (e.g. aluminium cans, polystyrene cups)	Recyclable in some areas
	Metal and/or obsolete equipment	Saleable/Recyclable
	Timber/pallets	Recyclable
	Miscellaneous (e.g. waste oil, oily rags, damaged pallets)	Recycled or landfill
Organic	Reject product including in-process	Animal feed
	Returned or out of date final product	Animal feed
	Off-spec raw material (e.g. liquid flavours)	Rework
	Obsolete or out-of-date raw materials	Animal feed
	Lab samples and samples for online testing	Animal feed
	Separator de-sludge	Animal feed
	Baghouse fines, dryer sweepings	Animal feed
	Effluent sludge	Animal feed or compost
	Membrane retentate sludge	Animal feed or compost
	Cheese fines	Animal feed
	Fat recovered from effluent	Animal feed

9.1.2 Solid waste generation and targets

The Australian Dairy Processing Industry has set a target of 40% reduction in solid waste to landfill compared with 2010/11 levels. As of 2014/15 this target has already been exceeded (DMSC, 2015). Some companies have set higher waste reduction targets while others have reported 100% waste diversion from specific sites. The UK Dairy Industry have set a target of zero ex-factory waste to landfill by 2020 and currently achieve 4% to landfill (Dairy UK, 2018). (Note that this is supported by disposal options currently unavailable to Australian dairy processors such as waste to energy plants).

In 2015/16, ratios for Australian processors producing any combination of milk, cheese, powders or yoghurts ranged from zero waste to landfill to 13.79 kg/kL of raw milk intake and averaging at 2.2kg/kL (Table 9.2). The DMSC has tracked the waste to landfill intensity (tonnes of waste per ML of milk processed) of dairy processors since 2007/08 as shown in (DMSC, 2017). This reduction in waste to landfill results from both better monitoring and better management practices including improved recording of waste generated through weighing waste rather than estimating; reduction in waste generation; improved segregation and recycling.

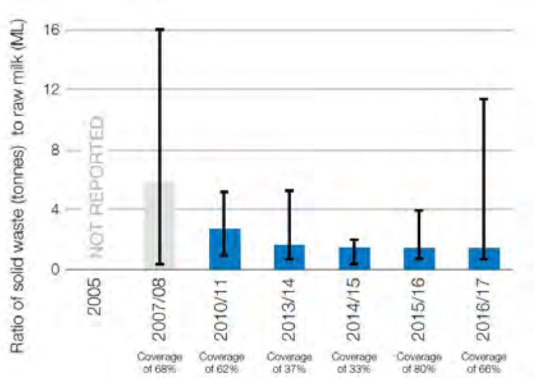


Figure 9.1: DMSC Waste to landfill performance indicator
(DMSC, 2017)

Much of this success has come from staff engagement programs with behaviour change resulting in a reduction of waste and recycling generation.

Table 9.2: Waste production per raw milk intake for Australian Dairy processors (2015/16)

	Australian data (2015/16)			
kg/kL raw milk intake	**Min.**	**Max.**	**Average**	**No. plants providing data**
White and flavoured only	0.18	13.79	2.2	9
Mostly cheese (and some powders)	0.94	1.98	1.29	3
Mainly powders	0	1.57	0.4	4
Mixed products	0.69	0.81	0.7	2
All dairy processors	0	13.79	2.2	22

9.1.3 *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. As the push to minimise waste to landfill continues, costs are likely to keep increasing. The cost of generating and disposing of solid waste includes:

- loss of raw materials
- loss of product (including processing costs).
- treatment costs
- storage and handling
- collection and transport costs
- disposal costs

Similarly, the cost of disposal of organic waste has also increased through

- increased costs for volume/load based charges for trade waste, landfill or compost.
- de-packaging, transport and/or off-take agreement costs for stock feed.
- increased pumping/transport and environmental monitoring/testing costs for irrigation/compost disposal. (Isle Utilities, n.d.).

9.2 Solid waste management

Unless a processor has achieved Zero Waste to Landfill there is always more that can be achieved. Reducing the loss of materials and improving the rate of reuse, recovery and recycling of valuable resources is a very important aspect of eco-efficiency. The many economic, environmental and social incentives for reducing and utilising solid waste more efficiently include:

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

100% recycling achieved, Bega Cheese (Bega Cheese, 2016)

Nearly all waste at Derrimut is recycled with monthly percentages close to 100%. Most waste streams are picked up at no cost while only co-mingling has a pick up cost.

Manufacturer achieves Zero Waste to Landfill (CCIQ ecoBiz, n.d.)

Keystone Foods Australia is a red meat manufacturing food processing facility that supplies the quick-service restaurants across Australia, Asia and the Middle East. Keystone has achieved Zero Waste to Landfill since 2013.

The company started with a waste audit to determine why and how much waste was generated and possible alternative opportunities to landfill.

Ideas from staff resulted in a 70% reduction in inedible food waste through a low-cost equipment redesign with remaining inedible by-products on-sold for further processing. Cardboard, plastics and metals are recycled. Blood-contaminated plastic waste is incinerated offsite to generate electricity.

The waste management hierarchy in Figure 9.2 represents a sequential approach to reducing solid waste.

- Avoidance e.g. through light weighting of packaging or buying in bulk.
- Reuse e.g. the reuse of milk crates or waste product used for stockfeed.
- Recycling e.g. through ensuring all packaging components can be recycled
- Energy recovery e.g. waste to energy options or biogas recovery from wastewater treatment.
- Treatment as required
- Disposal – as a last resort after all avenues in the waste hierarchy have been explored.

Figure 9.2: Waste Management Hierarchy (NSW EPA, 2017)

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

In keeping with product stewardship, dairy processors have a responsibility to investigate the waste they produce on their site and through the consumption of dairy products. Using packaging that can be recycled and has recycled content in it are two ways of reducing product footprints. Other ways include minimising the amount of secondary packaging used during transport and sale of goods as well as exploring ways that make it easy for consumers to recycle. Each of these initiatives help create a sustainable supply chain. This is discussed further in Section 10.0.

There are several ways to reduce waste and improve efficiency.

One way is to investigate each product line and determine where the wastes occur.

- Review each step of the product process.
- Determine what wastes are occurring.
- Drill down into each waste to work out why they are occurring.
- Look at options to reduce waste.

Waste minimisation through staff involvement (Qld Govt, 2009)

Priestley Gourmet Delights (a bakery product manufacturer based in Queensland) reviews each product line with all staff involved. They work through each step of the process to determine where waste occurs and drill down to the cause of the waste. As a team they determine strategies to prevent waste. This has saved them over $99,500 in raw material.

Alternatively, undertake a waste audit and identify all the different waste streams. Choose one waste stream at a time and determine what is occurring to produce the waste and how it can be reduced.

Once the waste streams and solutions have been identified, an effective management system requires good planning and monitoring. A successful system relies on segregation of waste streams to prevent cross contamination. The following steps will help establish a successful solid waste management system:

1. Design the waste management system carefully and ensure all staff are involved and trained in the implementation of the system.
2. Determine the number of waste/recycling streams required.
3. Set up one or more bins for each waste stream. Clearly label each bin with the types of waste to be collected. Use of colour coding and images of the wastes on each bin can be helpful for workspaces with large numbers of staff with English as a second language.
4. Try to locate bins near to where the waste is being generated. Co-locate recycling and general waste bins where more than one waste stream is produced to encourage the use of the correct bin. If staff have to walk further to use the right bin, then there is a high chance of cross contamination.
5. Monitor how well the system is working. Keep records of the quantities of each waste stream collected.
6. Keep staff motivated and informed on their recycling efforts, and on the economic and environmental benefits.

Segregation improves recycling leading to 100% landfill free (Parmalat, 2017)

Parmalat has 32 different segregated waste streams including batteries, aluminium, electronic waste, organics, ink cartridges and timber (pallets). In 2016 they improved their total waste diverted from landfill to recycle streams from 88% to 94%. Their South Australian Clarence Gardens site is proudly landfill free. They continue to work with their waste service provider to further improve their results.

9.3 Avoid and reduce waste

The best way to reduce waste costs is to not produce the waste in the first. Yield optimisation and product recovery (refer to Section 8.0 - Yield optimisation and product recovery) will assist manufacturers reduce the amount of waste resulting through the process. Waste can also be reduced through:

- Better staff engagement for human error problems such as reject product
- Better inventory control for out of data or obsolete raw materials
- Better supply chain management for returned or out of date final product.

Reducing construction waste at Fonterra, Stanhope (DMSC, 2017)

The reconstruction of the Stanhope site following a fire had the potential to create a lot of construction waste. Large wooden crates were used during construction to protect equipment while it was stored and moved into place. These crates would have been sent to landfill once the equipment was in place except that through discussions with the Stanhope and District Men's Shed found that they could reuse this resource. The Men's Shed were able to turn these crates into toys and Christmas decorations like cars, trains and dolls.

Pallet recycling can be profitable, Bega Cheese (Bega Cheese, 2016)

All wooden, non-returnable pallets and pallet boards are recycled at Bega's Strathmerton and Coburg plants. It is cost neural at Strathmerton and they actually get paid for the pallets at Coburg.

9.3.1 Supply chain management

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

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

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

9.3.2 Value adding

In dairy processing, opportunities exist for recovering valuable by-products. These by-products may be reused in onsite processes, or perhaps sold. Thus, any waste streams should be analysed for their potential to add value by being utilised in some other way with the added benefit of reducing or eliminating disposal costs.

Lion Co. circular economy (Lion Co, 2017)

In 2017 Lion diverted 97% or 361,053 tonnes of by-product waste from landfill. As part of their supply chain by-product process, some of their dairy farmers can purchase spent grain from the brewing process for stock feed at discount rates. This reduces the disposal costs of the spent grain and provides a feed source for dairy cows.

Whey is a valuable by-product as discussed in Section 8.8 - Whey products. Recent research has also found that whey permeate can be used successfully in wheat fermentation to produce ethanol. This could provide a value-added solution for whey permeate through the biofuels industry (Pararshar, et al., 2016).

9.3.3 Sustainable Procurement

Sustainable procurement attempts to reduce adverse environmental, social and economic impacts of products over its life. Rather than just choosing a product based on the initial cost, all aspects of the products is considered including operating and maintenance costs, disposal, recyclability, and initial resource consumption during manufacturing. The Department of Sustainability, Environment, Water, Population and Communities commissioned the *Sustainable Procurement Guide* to assist companies to include sustainability considerations in all stages of the procurement process (ECObuy, 2013).

Strategies that can be implemented by dairy processors include:

- Ensuring sustainability is included in the procurement policy
- Working with suppliers to obtain products with recycled content.
- Working with suppliers to obtain products with minimal packaging.
- Working with suppliers to obtain products with packaging that is recyclable, reusable or compostable.
- Returning packaging where possible.
- Choosing goods that can be recycled at the end of their useful life.
- Managing inventory to minimise or co-ordinate deliveries to save transport costs and emissions.
- Working with suppliers to incorporate waste minimisation initiatives.
- Choosing products which are non-toxic (often plant based) and bio-degradable e.g. cleaning chemicals and paints.
- Looking for products that are socially responsible.
- Considering ways to work across the entire supply chain with a view to eliminating or reducing waste.

Which copy paper? (WWF, 2010)

There are so many different copy paper choices from carbon neutral, recycled and sustainable forest paper that the choice is difficult. WWF has produced a guide to buying paper which suggests a purchasing policy and to look for:

- Paper with 100% recycled content ideally and ISO14021 verification; then
- A label from a recognized sustainable forest management verification body e.g. FSC or PEFC; then
- Carbon neutral or carbon reduced which has been certified by a recognized 3rd Party e.g. National Carbon Offset Council.

9.4 Reuse of waste

There may be opportunities to reuse waste within the plant, depending on its type and quality.

Often the reuse options involve third parties who can take the waste stream and reuse. Opportunities to involve the local community and supply chain in waste reuse can improve dairy processor's social sustainability. For example, wood and construction materials could be used by local Men's Shed Groups. Similarly, pallets could be repaired and reused.

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

- animal feed

Beneficial reuse of treatment sludge, Saputo Dairy Australia, Allansford, 2005-2010 (WCBF, est 2012)

Saputo Dairy Australia saves $250k in trade waste charges a year by spreading 30-40ML per year of sludge from their anaerobic lagoon on local pastures as beneficial fertiliser.

- composting
- soil injection or direct landspreading.

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

9.4.1 Animal feed

Dairy processing wastes such as separator de-sludge, whey and product returns provide a good source of protein and fat, and are often used as animal feed. Waste milk powder, such as that collected from the dry cleaning of a spray dryer, can be collected in bags and sold to farmers as calf food. Farmers may accept stockfeed for free or charge a low cost compared with traditional waste disposal costs.

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

Transport costs are possibly the biggest expense associated with this means of disposal. Compactors are also used to separate out liquid product from packaging before sending it for stock food. Compactors not only reduce transport costs but also lower landfill costs, with only a small amount of solid waste remaining after compaction.

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

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

The Australian Pesticides and Veterinary Medicines Authority (APVMA) has guidelines for the type and quality of animal stockfeed, including exposure levels for various chemicals potentially found in feed including antibiotics (See apvma.gov.au/node/10631). Information can also be obtained from the Stock Feed Manufacturers Association of Australia (www.sfmca.com.au/).

A clear managerial procedure should be in place between dairy processor and farmer to reduce risks to both by ensuring the waste is suitable for, and is used as stockfeed. This will reduce the risk of regulatory fines, public backlash, environmental damage and animal health.

9.4.2 Composting and Vermicomposting

Effluent treatment plants in dairy factories can generate a large amount of sludge as a by-product of the water treatment processes. Due to the high nutrient value of sludge it is often used as a fertiliser, compost or soil conditioner. Composting is usually only viable for dairy processing plants in regional areas that have sufficient space, and where the potential odour will not upset neighbouring businesses or communities. Transporting organic waste to offsite large-scale facilities for composting may be a good alternative to landfill if transport costs are not too high.

Sludge thickening is used to increase the sludge concentration and reduce transport costs. Processes such as belt or screw presses or centrifuges are often used to reduce the water content in the sludge.

Recovery of separator de-sludge and dryer wet scrubber solids: Saputo Dairy Australia, Maffra, 2004 Ed

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

Sludge can be turned into pellets, for use as fertilisers, through use of a mechanical dryer e.g. rotary drum operated on natural gas, LPG or biogas. The capital and operating costs can be high. However, for a site that has anaerobic digestion the biogas generated may be a cheap source of energy. While this technology can be applied on a small scale the financial benefits come from larger scale operation s (ANZBP, n.d.). Solar sludge drying is generally undertaken in a greenhouse type construction to prevent water ingress. Alternatively it can be undertaken in open ponds and requires a large amount of land and is more difficult to control (Yoo, et al., 2017). New technology is combining solar drying with a rotation system to aerate the sludge and reduce drying time. However, currently applications are for large municipal sewage sludge plants.

Disposal of sludge as compost: Bega Cheese, Koroit, 2004 Ed

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

9.4.3 Soil injection and direct landspreading

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

The obvious advantages of direct landspreading are that there is no need for further processing and the product does not need to be stored for any great length of time. Suitable organic wastes that have been dewatered or dried can be used directly for landspreading, using a conventional manure spreader. Liquid biosolids can be transported by tanker to an application site and then injected into the soil.

There are different requirements in each state for the utilisation of sludge as a fertiliser or compost additive. Table 9.3 provides links to the guidelines for each local regulatory authority.

The Australian and New Zealand Biosolids Partnership has been set up to support sustainable biosolids management - www.biosolids.com.au.

Table 9.3: Guidelines for Biosolids

Location	Guideline
ACT	ACT Waste Management Strategy: Towards a sustainable Canberra 2011–2025 www.environment.act.gov.au/__data/assets/pdf_file/0007/576916/ACT-Waste-Strategy-Policy_access.pdf
NSW	Environmental Guidelines. Use and disposal of Biosolids Products www.environment.nsw.gov.au/resources/water/BiosolidsGuidelinesNSW.pdf
NT	Applies the national guidelines
Qld	General beneficial use approval for Biosolids ehp.qld.gov.au/assets/documents/regulation/wr-ga-biosolids.pdf
SA	South Australian Biosolids Guidelines www.epa.sa.gov.au/files/7700_guide_biosolids_1997.pdf
TAS	Biosolids Reuse Guidelines August 1999 epa.tas.gov.au/regulation-site/Pages/Document.aspx?docid=37 The Approved Management Method for Biosolids Reuse epa.tas.gov.au/regulation-site/Pages/Document.aspx?docid=38
Vic	Guidelines for Environmental Management. Biosolids Land application www.epa.vic.gov.au/~/media/Publications/943.pdf
WA	Western Australian guidelines for biosolids management www.der.wa.gov.au/images/documents/our-services/approvals-and-licences/western-australian-guidelines-for-biosolids-management-dec-2012.pdf

9.5 Maximising solid waste recycling

Most dairy processors have recycling systems in place and achieve good rates of recycling. The limiting factor in further recycling can be the lack of financially viable disposal services in the region. Other limiting factors include the quantity of recyclable waste produced, the cleanliness of the waste, and the level of staff engagement with the recycling system. For example, waste packaging that is heavily contaminated with milk or milk powder may not be suitable for recycling without rinsing. Product packaging should be designed in the first place with end-of-life disposal in mind (refer to Section 10.0 - Reducing the impacts of packaging).

Bega Cheese waste plastic become stadium seats (Bega Cheese, 2015)

No plastic waste from the Bega Strathmerton site goes to landfill. Bega have forged an alliance with a small Melbourne recycling company called Polymer Holding. They accept all plastic waste from the site and separate, clean and chip it then sell it to a manufacturing site to make a range of products such as plastic pallets, film sheets and stadium seats. This not only reduces landfill but saves Bega Cheese landfill costs.

Saputo Dairy Australia, Allansford : Reduction of solid waste to landfill (WCBF, est 2012)

Between 2007/08 to 2010/2011 Saputo Dairy Australia, Allansford, improved their recycling from just cardboard packaging from the cheese plant to diverting 306 tonnes of waste a year saving $145k in annual landfill costs. This was achieved by a series of skip bin audits to identify wastes followed by a slow roll out of recycling cages to capture the recycling stream when a recycling/collection vendor was identified. As of 2012 they were recycling 43% of their waste including cardboard, plastics and paper.

\Clearly label general waste and recycling bins

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

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

‘It is important to ensure that the message to all staff is clear on what is to be recycled; and set up appropriate areas without impacting on operator duties.’

Recycling program: Lion Co, Malanda 2004 Ed

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

9.6 Waste to Energy

Waste to energy plants may be an option when solid waste cannot be reused or recycled. For example, this can be the case for plastic contaminated with food waste or if there are no recycling facilities in the vicinity of the company. If the contaminant cannot be washed off then sending it to a waste to energy facility may be a method of retrieving the energy from the waste generally through incineration. There are currently only a few Waste to Energy facilities around Australia.

Energy recovery from organic solid waste (particularly sludge) through anaerobic digesters can be a good way to reduce total solid organic waste for disposal and as a means to extract biogas for use in boilers or other equipment (Tetrapak, 2015) which reduces carbon emissions. The sludge resulting from this method can often then be disposed of through land-spreading or composting. However, the process has relatively high capital costs, long retention times and high pollutant supernatant (Gray, et al., 2012).

Lab testing of pyrolysis of dried sludge has found it produces sufficient energy to be worth further investigation. Pyrolysis allows energy recovery in the form of a high calorific value pyrolysis gas and a char that may be used as soil amendment or an adsorbing media (Kwapinska & Leahy, 2017). Where dairy processors have access to such a facility i.e. through third party investment, this is a potential means of utilising the sludge.

REDUCING THE IMPACTS OF PACKAGING

CHAPTER 10

10.0 Reducing the impacts of packaging

Packaging is a large cost to dairy processors. It is also one of the most visible ways for the industry to promote their sustainable practices to consumers. With an increasing focus of consumers on reducing waste to landfill, processors have an opportunity to play a leading role in reducing the impact of packaging and making it easier for consumers to recycle.

The cost of packaging (Bega Cheese, 2016)

In 2016, Bega reported that 12.5% of their non-milk expenditure was on packaging.

Packaging considerations for dairy processors include packaging used for product as well as that used for general supply of materials.

Industry Working Group on Sustainable Packaging

Australian dairy manufacturers are taking the lead in minimising the amount of dairy product packaging that ends up in landfill after national packaging targets were set in late 2018.

The Dairy Manufacturers Sustainability Council, a collection of leading dairy processors, has formed a Dairy Australia-supported Industry Working Group on Sustainable Packaging to drive its consideration of sustainable options. Comprised of dairy processors including Bega, Bulla, Saputo, Fonterra, Lion, Chobani and Parmalat, as well as the Australian Dairy Products Federation, the working group is led by Dairy Australia.

The group aims to ensure that dairy provides leadership on packaging and continues to provide consumers with ‘permission to buy’ dairy products. The initiative will enable the dairy industry to respond to changing consumer expectations, set the agenda, and move quickly on funding and government support.

In addition to developing industry-wide packaging targets and an annual reporting structure, the working group is exploring the development of dairy-specific ‘sustainable packaging guidelines’. The guidelines would provide insight into how packaging can be better designed to ensure it is correctly sorted at Australia’s waste management facilities.

The working group is also investigating harmonised labelling to better communicate how consumers sort their packaging waste, such as the Australasian Packaging Label system.

10.1 Australian Packaging Covenant Organisation

In April 2018, Australia’s federal, state and territory environment ministers endorsed a target of 100 percent of Australian packaging being recyclable, compostable or reusable by 2025 or earlier. The Australian Packaging Covenant Organisation (APCO), represents over 900 leading companies, and is the leading organisation endorsed by government to help deliver this target. APCO is a co-regulatory, not-for-profit organisation that partners with government and industry to reduce the harmful impact of packaging on the environment. It promotes and assists companies with sustainable packaging activities including:

- Sustainable design
- Recycling initiatives including labelling.
- Waste to landfill reduction
- Circular economy

Most dairy processing companies are signatories to APC and report annually on their progress in improving their packaging.

Sustainable practices acknowledged through APCO (Bega Cheese, 2016)

Since signing up to APC in 2002, Bega updates its action plan each year. In 2016 it improved from a 3 out of 5 rating to 3.8 and was commended for working collaboratively with suppliers during the year.

Using the SPG (Parmalat, 2017)

Since signing up to APC, Parmalat have been assessing new and existing packaging against the Sustainable Packaging Guidelines. Using the SPG they have improved their packaging by:

- Lightweighting of packaging (bottle caps, milk cartons and boxes)
- Using more efficient pack formats
- Incorporating the use of recycled materials such as eHDPE resin in the manufacture of milk bottles.

APCO have developed sustainable packaging guidelines (SPGs) and companies that sign up to APCO must adopt the guidelines (APCO, n.d.). The guidelines assist companies to work within their supply chain to implement product stewardship of packaging. It promotes sustainable design, manufacture and end-of-life management of the packaging while meeting the needs of product safety, consumer protection, market performance and cost.

The SPGs provide guidance on:

- Maximising water and energy efficiency during packaging manufacturing.
- Minimising resource use in packaging (Section 10.2).
- Considering source material including using recycled and/or renewable materials (Section 10.2).
- Reducing the use of toxic and hazardous materials including inks and dyes.
- Choosing materials from responsible suppliers.
- Designing for efficient transport through lightweighting, fully using shipping space and using bulk packaging for distribution.
- Considering if the packaging can be designed to be reused, e.g. packaging sent to wholesaler returned for reuse.
- Designing for reduced litter if the product is likely to be consumed away from home.
- Designing to assist consumers to recycle (Section 10.2.1).

Local supplier reduces transport greenhouse gases (Parmalat, 2017)

Parmalat found that they could shorten the supply chain and reduce greenhouse gases and other transport related impacts by using a local supplier for their small plastic tubs. Previously they had several suppliers with the tubs travelling long distances to arrive at site.

Lightweighting saves 720 tonnes of HDPE per year (Lion Co, 2017)

Lion Co have reduced the weight of their 2L high density polyethylene (HDPE) milk bottles by 8g. This has reduced the amount of HDPE in use by 720 tonnes per year.

They also made alterations to their 3L milk bottle blow moulding packaging lines which reduced polyethylene resin use by 14%, saving them approximately 44 tonnes a year.

Parmalat improved design saves 3.2m bottles *(Parmalat, 2017)*

Parmalat in Queensland redesigned and optimised existing technology for the HDPE blow moulded bottles for their Ice Break and Breaka lines to improve the efficiency of resin use. This reduced packaging weights by around 1.9-2.8 grams per bottle saving 95.63 tonnes of blown plastic (equivalent to 3.2 million bottles) in 2015-2016.

A similar lightweighting and optimisation project on the clear plastic Farmhouse Gold bottle reduced the 750mL bottle from 50g to 35g and the 1.5L bottle from 70g to 60g saving 1500 tonnes of plastic.

APCO Reporting Tool assesses members against the Packaging Sustainability Criteria (Figure 10.2). All members are required to report against all core criteria in their annual reports (Figure 10.2).

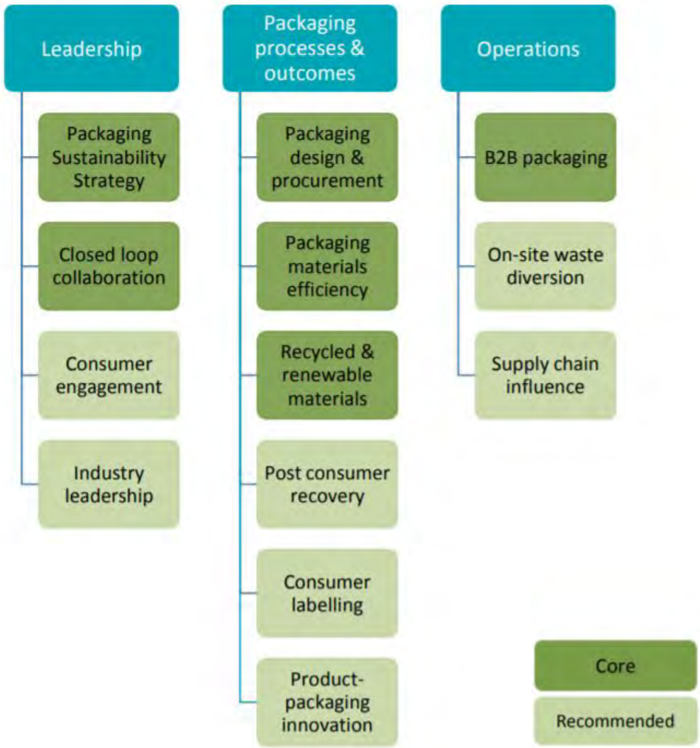


Figure 10.1: APCO Packaging Sustainability Framework Criteria (APCO, 2017)

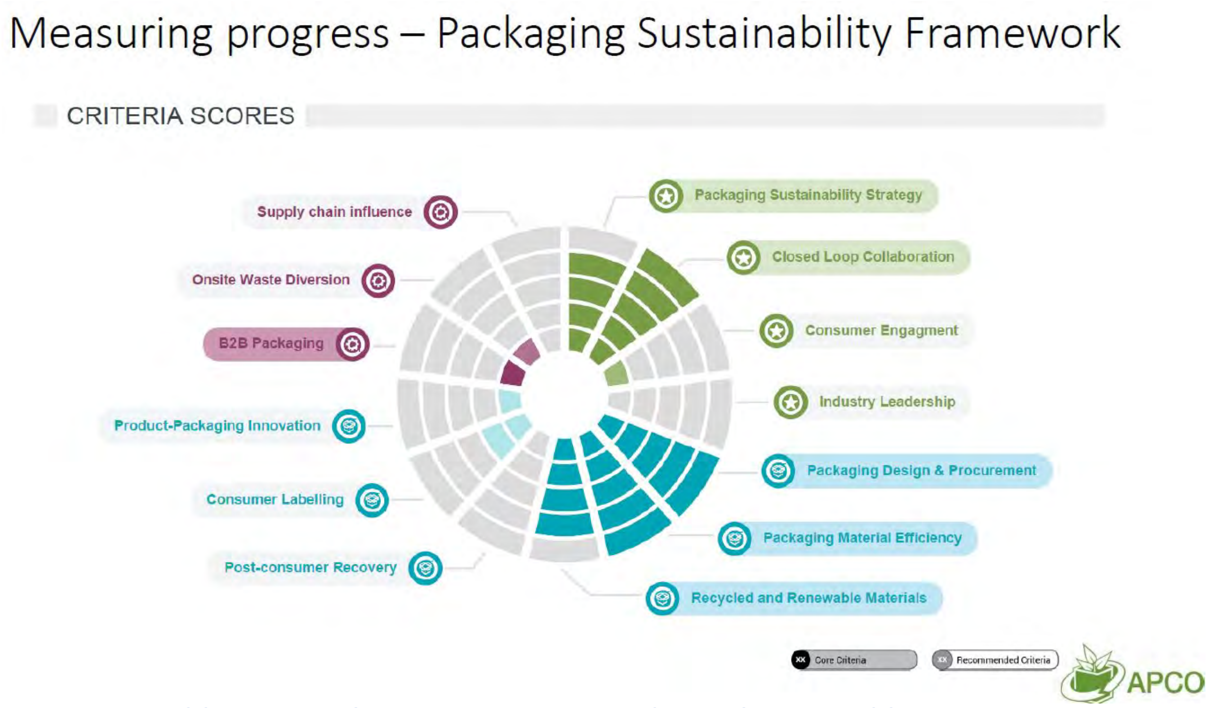


Figure 10.2: APCO Packaging Sustainability Framework Criteria Scores (APCO, 2018a)

The main objectives of packaging is to maintain or extend shelf life, be tamper resistant and market the product. This needs to be balanced against recyclability of the packaging.

One area of research is into aseptic packaging to further extend the shelf life of non-refrigerated dairy products beyond six months. This allows products to be stored without refrigeration before being opened reducing the energy requirements. Other packaging trends include packaging with materials that offer sustainability benefits and stronger barrier properties to increase stability throughout the supply chain (O'Halloran, 2013).

10.2 Packaging design and content

APCO have joined with PREP design and Planet Ark to develop a voluntary labelling system that allows companies to evaluate, and validate the recyclability of their packaging material. The PREP or Packaging Recyclability Evaluation Portal allows companies to assess their current packaging material and investigate alternative design (e.g. evaluate the impact of adding a new label or changing the material type of components) and print out validated self-assessments. This assessment can then be used in conjunction with Planet Ark's Australasian Recycling Label to obtain better packaging design and content.

Other providers may have their own design tool such as the AMCOR ASSET LCA program.

AMCOR ASSET LCA tool helps develop sustainable packaging options (AMCOR, 2018)

AMCOR has developed their Advanced Sustainability Stewardship Evaluation Tool (ASSET) to assess the life cycle performance of packaging. It allows packaging options to be compared across the supply chain from cradle to grave to assist in sustainable packaging choices.

The tool provides information on material selection, product protection, recyclability and licycle impacts.

10.2.1 Supporting consumer recycling

Dairy processors can play a role in improving post-consumer recycling through educating consumers on what and how they can recycle. Though many consumers want to recycle there is confusion about what packaging can be recycled and what should go to general waste. By 2025, it will become compulsory for all packaging material to be recyclable.

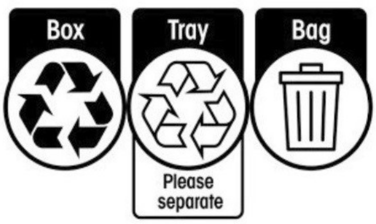


Figure 10.3: Example of Australasian Recycling Label
(APCO, n.d.)

Currently there are no legislated labels that must be used on packaging. However, there are voluntary labels. For example, Planet Ark in conjunction with APCO have developed an evidence-based labelling system that allows consumers to immediately determine if the packaging is recyclable. The Australasian Recycling Label can be applied to each component of the packaging. The PREP system can be used by manufacturers to determine which label can be used.

Closing the loop – Fonterra Mile for Schools pack (Fonterra, 2017)

In New Zealand, Fonterra runs a Milk for Schools program providing 200mL milks to children. The package is made from Tetra Pak manufactured from sources certified by the Forestry Stewardship Council.

The program provides the schools with recycling bins, liners and training material. The schools recycle all used packaging which is collected with each milk delivery. The packaging is shipped overseas to recycling facilities and turned into products such as school books and roofing tiles.

The program also teaches the next generation about the importance of recycling using games and competitions such as the fastest folder to improve engagement and success.

10.3 Creating a market for recycled product

Designing packaging to be recycled is a great start for the dairy industry. However, to encourage a circular economy it is also necessary to generate a market for recycled materials. Use of post-consumer recycled (PCR) content in plastic food packaging is increasing. Companies such as PepsiCo and Nestle are using up to 100% of recycled polyethylene terephthalate (rPET) in bottled beverage products. Using rPET feedstock for bottle production saved Naked Juice 25% of the typical energy consumption during the manufacturing process. (Dreizen, 2017). There is potential for these savings in bottle costs to be achieved by dairy processors.

Dairy UK target 50% recycled content in packaging (Dairy UK, 2018)

The UK Dairy industry has set a target of 50% recycled material in HDPE milk bottles, or its carbon equivalent reduction by 2020. They have currently achieved a 31% recycling content in HDPE milk containers.

Nestle creates market through demand

Nestle have found that using rPET has an economic benefit of creating a market for the recycled plastic and so recycling programs were developed to meet that demand with the programs encouraged to supply a high-quality rPET to meet Nestle's demands (Dreizen, 2017).

Lion Co contribution to circular economy, (Lion Co, 2017)

Lion Co have set targets to have 100% of their consumer packaging made from recyclable material by 2025 with at least 50% of it produced using recycled content. They also plan to make recycling easier for their consumers by simplifying recycling information.

Currently 90% of their consumer packaging is recyclable through existing schemes and they will have established a baseline for recycled content by the end of 2018.

Similarly, replacing materials from non-renewable sources with renewable sources, such as paper, cardboard and bio-polymers, can increase the sustainability of packaging. Packaging company Seventh Generation (a Unilever subsidiary) have committed to manufacturing all packaging from recycled or bio-based materials by 2020.

Increasing recycled content in cardboard saves (Parmalat, 2017)

Parmalat have re-designed all their carboard cartons to maintain the current strength while increasing the recycled content and reducing the total amount of cardboard used. They have managed to use 100% recycled content for most of their plain cartons. The project has saved approximately 400 tonnes of cardboard.

Many dairy processors are investigating or have started to incorporate recycled material within packaging (generally starting with cardboard). For others, a starting place could be to ensure all non-food contact packaging such as boxes, reusable crates, and wrap contain recycled content. Similarly, a sustainable procurement policy could

Visy provide recycled plastic for use in food containers (Visy, 2015)

Visy has a plastics plant in Australia that can produce recycled PET and HDPE containers for food and beverage customers. The recycled content for their plastic containers can be provided at 15%, 30%, 50% or 100% recycled content.

include investment in products with recycled content such as rubbish bins, containers and pallets. This will help drive a market for recycled plastics.

Fonterra designed the packaging for recycling (Fonterra, 2017)

Since 2004 Fonterra has produced the outer packaging of their 25kg milk powder bag from plastic sandwiched between four layers of paper to plastic between two. This outer layer of paper is generally removed for hygiene purposes at the customer's facility prior to taking the plastic inner bag into the food production area. This allows both the paper and the plastic to be recycled.

Further Reference:

Hansen-Knarhoi's report into Maximising the Recyclability of Dairy Product Packaging has reviewed opportunities for Dairy Processors including lightweighting, increased recycled content and colour choice to increase recyclability of packaging (Hansen-Knarhoi, 2018).

CHEMICAL USE

CHAPTER 11

11.0 Chemical Use

11.1 Overview of chemical use

The cost of chemicals for dairy processing plants can be several hundred thousand dollars per year and a significant proportion of total operating costs. The dairy processing industry uses a wide variety of chemicals for cleaning, pH control of process and waste streams, and treating water for process and auxiliary uses such as boiler and cooling tower feed.

It also has an impact on the components in the wastewater stream. The minimisation of chemicals in the discharge streams is important in meeting discharge limits and requirements for irrigation and composting.

This chapter discusses the use of chemicals in dairy processing plants, in particular for cleaning, and looks at opportunities to reduce or optimise chemical use with the aim of lowering operating costs and minimising environmental impacts.

Closing the Loop on Chemical Use

The Closing the Loop report by DISC found dairy processors did not fully understand chemical use within CIP systems. The main findings included:

- Optimum sodium hydroxide (NaOH) concentration for CIP systems is a 1% w/v solution.
- Concentrations above optimum do not improve cleaning effectiveness.
- Alternatives to NaOH with reduced sodium can be at least as effective as full NaOH.
- Reductions in sodium in effluent streams can be achieved by using potassium hydoxide (KOH) or KOH/NaOH blends (Weeks, et al., 2007a).

11.1.1 Cleaning

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

A CIP system is a fully enclosed automated system that delivers a number of wash and rinse cycles to the internal surfaces of processing equipment. CIP systems largely remove human contact with cleaning agents, thus reducing the risk of harmful exposure. They also reduce labour costs, as well as the wear involved in dismantling equipment. One of the main advantages of CIP systems is that they can recirculate chemicals and rinse water, thereby substantially reducing the consumption of water and chemicals.

Typical CIP cycles consist of a water rinse followed by a caustic wash, a second water rinse, an acid wash, a third water rinse, and often a final sanitiser rinse. Caustic washes are usually carried out at least once a day; acid washes are less frequent, and may be carried out once or twice per week. CIP systems may be classified as single-use, multi-use or full recovery. Single-use (SU) systems dispose of rinse waters and spent solution to drain after one use, while multi-use (MU) systems recover final rinse waters and suitable-quality spent solution for reuse. Full recovery systems typically use membrane technology to recover chemicals, water and, potentially, product.

11.1.2 What standard of cleaning is required?

As explained in Dairy Processing Handbook (Tetrapak, 2015), four levels of cleaning can be identified:

- **Physically clean.** All visible dirt has been removed from the surface but chemical residues may remain.
- **Chemically clean.** The surface is rendered totally free from any trace visible dirt and chemical residue.
- **Bacteriological clean.** The surface has been disinfected and the number of bacteria has been reduced to an acceptable level.
- **Sterile** where all microorganisms have been destroyed (e.g. in ultra-high-temperature [UHT] processes).

A surface that is sterile may not be physically or chemically clean. Surfaces are therefore first cleaned with chemical detergents and then disinfected to be both chemically and bacteriologically clean (Tetrapak, 2015). Poor cleaning can cause substandard quality of the milk products resulting in spoiled product, off flavours, waste and increased processing costs.

11.1.3 Types of fouling

Efficient cleaning requires a good understanding of the types of fouling and the chemicals (detergents and sanitisers) used in their removal. Fouling occurs on both hot and cold surfaces. On hot surfaces, fouling starts to form when milk is heated above 60^{o}C. Calcium and magnesium phosphates, proteins and fats deposits stick to the surface and change from whitish to brownish after runs of over eight hours.

On cold surfaces, a milk film can adhere to the walls of pipes, pumps, tanks etc. If the film dries out it is harder to remove so starting the cleaning cycles as soon as possible after the system is emptied will reduce cleaning requirements (Tetrapak, 2015).

Fouling can be divided under two general headings:

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

Most soils are a combination of organic and inorganic deposits; for example 'milkstone' is a combination of calcium caseinate and calcium phosphate (Romney, 1990). A comparison of the solubility and ease of cleaning of various surface deposits found in the dairy industry is shown in Table 11.1.

Table 11.1: Characteristics of typical soiling found in the dairy industry

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

Source: (Schmidt, 2015)

Milk proteins can range from those that are relatively easy to remove, to casein, which is particularly difficult. Casein has good adhesive properties and in fact is used in many glues and paints (Schmidt, 2015). The nature of milk protein residue can vary greatly according to the temperature at which it is deposited; thus different equipment will require different cleaning regimes. For example, the heated surface of a pasteuriser will require a more rigorous cleaning regime than will a cold raw milk line or tank. Proteins broken down by heat can be particularly difficult to remove and require the use of highly alkaline detergents with peptising and wetting ingredients that disperse and increase the suspendability of the proteins. The attributes of detergents are explained further in the next section.

Biofilms develop on surfaces in aqueous environments and are a community of microorganisms which attach and become embedded in a matrix of extracellular polymers of microbial origin which for dairy processors is the milk proteins or polysaccharides. Figure 11.1 shows how a biofilm is formed. Biofilm contribute to product contamination if not controlled by regular cleaning (Knight, 2015).

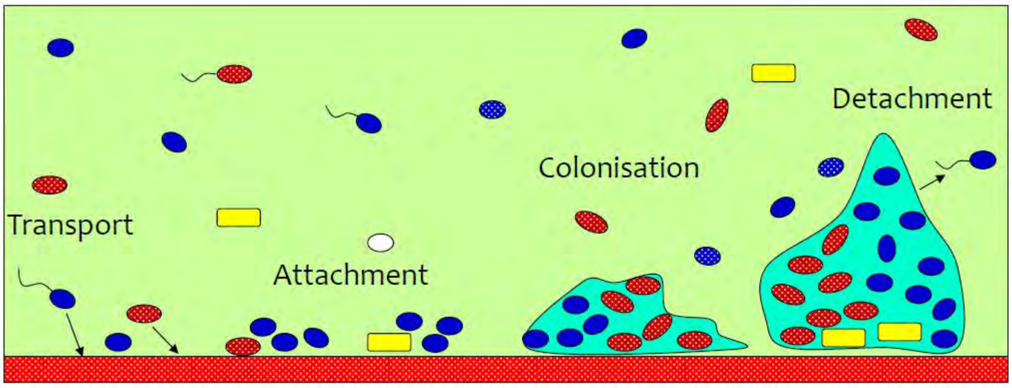


Figure 11.1: Formation of biofilm on a surface
(Knight, 2015)

11.1.4 Cleansers and sanitisers

The distinction between cleansers and sanitisers is shown below (Figure 11.2) (Hakim, 2016).

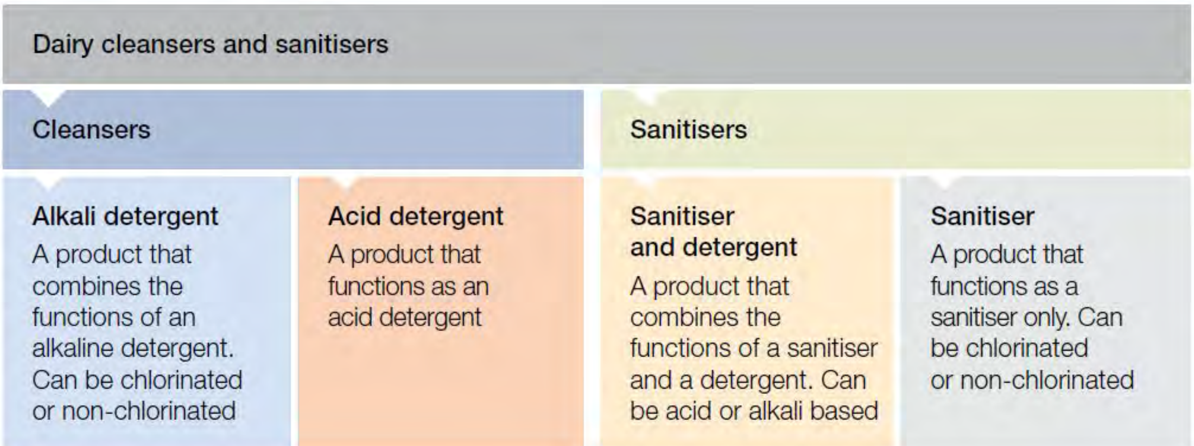


Figure 11.2: Distinction between cleansers and sanitisers (Hakim, 2016)

Detergents

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

- organic dissolving power, to solubilise proteins, fats and sugars.
- dispersing and suspending power, to bring insoluble soils into suspension and prevent their redeposition on cleaned surfaces.

- emulsifying power, to hold oils and fats dispersed within the cleaning solution.
- sequestering power — the ability to combine with calcium and magnesium salts and form water-soluble compounds.
- wetting power, to reduce surface tension and aid penetration of the soil.
- rinsing power — the ability to rinse away clearly without leaving a trace of soil or chemical on the surface.

Detergents are formulated from a wide range of materials, which usually fall within the groups of inorganic alkalis, acids and sanitisers (Hakim, 2016). Detergents can also contain peptising agents, which have the ability to disperse protein. Enzyme-based detergents are another option for Australian dairy processors. This is discussed further in Section 11.3 - Chemical alternatives.

Alkali detergents

Examples of inorganic alkalis include sodium hydroxide (caustic soda), potassium hydroxide, sodium carbonate and sodium bicarbonate. They are commonly used in CIP systems or bottle wash applications and are effective in removing fats.

Water hardness does affect alkali detergents so the dose rates need to be adjusted depending on water hardness for pH, chlorine level and active alkalinity. Active alkalinity is the alkaline concentration within the solution. A heavier soil load requires a higher active alkalinity either by increasing the dose rate or selecting detergents better formulated to cope with heavier loads (Hakim, 2016).

Acid detergents

Acid ingredients can be inorganic (e.g. phosphoric, nitric and hydrochloric acid) or organic (e.g. hydroxyacetic and citric acid). They are designed to remove tenacious soil, such as mineral deposits, that cannot be removed using alkali detergents. The low pH also make bacterial growth more difficult. Water hardness does not have an impact on dosing rate. However, if the water pH is too alkaline or has a large buffer capacity (ability to resist pH change) a higher acid dose rate may be required (Hakim, 2016).

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

Sanitisers

Sanitisers are used to reduce micro-organisms to a level that is safe for public health and enhances product quality. Sanitisation can be achieved through:

- Thermal sanitisation using hot water or steam for a specified temperature and contact time.
- Chemical sanitisation using approved chemical sanitiser such as chlorine-based compounds (e.g. chlorine dioxide) and peroxides (e.g peroxyacetic acid) at a specified concentration and contact time (Schmidt, 2015).

Many sanitisers are significantly affected by pH and water quality. Chlorine compounds are broad-spectrum germicides which are relatively cheap and less affected by water hardness than many other sanitisers. They are, however, corrosive to many metal surfaces and are the subject of some health and safety concerns.

Table 11.2 shows the types of cleaning chemicals typically used in dairy processing.

Table 11.2: Types of chemicals used in the dairy industry

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

Sources: (AS 4709:2001, 2001); (Melrose Chemicals, 2003), (Parker & Longmuir, 1999), (Romney, 1990) (Schmidt, 2015)

11.1.5 Water quality

As mentioned in Section 6.0 - Water, water supply for dairy processors can include town, river, irrigation channel and bore water, as well as reclaimed condensate, and can vary markedly in quality. The quality of water required will also be determined by its end use. For example, water that will be in contact with product must be of drinking water quality and meet the Australian Drinking Water Guidelines (HMRC&NRMMC, 2011).

Water is the primary constituent of all dairy processing cleaners and thus all cleaning chemicals should be tailored to the plant's water supply. While milk also contains minerals such as calcium, phosphorous, sodium and magnesium it is mainly the cleaning water that dictates the acid required for the wash program (Hakim, 2016). Hard water containing substantial amounts of calcium, magnesium and iron can result in scale build-up; this affects the ability of detergents and sanitisers to contact the surface, requiring cleaning, and can lead to excessive scaling in boilers and cooling towers. Hard water may require treatment such as ion exchange, or alternatively the use of detergents and sanitisers that are specially formulated for hard water. The harder the water the less suited it is to cleaning and the more corrosive to equipment.

Water conditioning saves chemicals: dairy processor, UK (Manufacturingtalk, 2003), 2004 Ed

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

11.1.6 True cost of chemicals

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

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

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

11.1.7 Environmental impact of chemicals

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

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

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

RMCG investigation into saline wastes

A study undertaken in 2018 by RMCG for Dairy Australia developed a saline waste disposal management plan for northern Victoria prompted by concerns that

- the current disposal system may lead to long-term damage to productive land through raised sodicity and
- the future economic development opportuniteis of the region may be limited by the current disposal options.

The study found that processors need to first look for opportunities to reduce the amount of salt entering the waste stream. The best management option is then to segregate the saline waste streams by the total salinity into three categories each with different management solutions.

Highly saline flows (4,000 - 40,000 EC):

This waste stream has the most significant salinity challenges and should be avoided and minimied where possible. This stream should be further segregated into high and low organic streams. High organic streams could potentially be used for agriculture (e.g. pig food) while currently the only solution for the low organic streams is onsite treatment and disposal e.g. evaporation pond with landfill disposal.

Saline flows (1,500 – 4,000 EC)

Resulting mostly from cleaning products in the processing plants, reducing the loads through better cleaning processes can reduce salt concentrations in this waste stream. Disposal through a well managed long-term sustainable application to pasture is possible for this stream.

Salty wastes (<1,500 EC)

These flows can be disposed of to sewer through trade-waste dischrages managed by the regional water corporation or through Standard irrigation approaches for 'saline' wastes involving shandying and disposal to land (RMCG, 2018).

There are additional resources available on the Manufacturing Resource Centre manufacturing.dairyaustralia.com.au.

11.2 Optimising chemical use

The high nutrient value in milk makes it an ideal growth medium for biological material. Ineffective cleaning is one of the main sources of microbial contamination which in turn is the major cause of poor quality milk (Hakim, 2016). The degree of chemical use, therefore, is largely determined by food safety requirements and quality specifications from both the domestic and export market. Good design is the first step to minimising cleaning requirements and is outlined in Section 6.3.4 - Clean-in-place systems.

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

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

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

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

Validation or review of cleaning systems is necessary to prove the cleaning effectiveness of a system and can be done as part of the contract obligation of the plant's chemical supplier. Improvements are usually achieved by extensive trials to ensure sufficient cleaning without compromising product quality. Refer to Section 5.3.4 for further information on supplier performance contracts.

Review of CIP cycle frequency and chemical recovery: Lion Co, Salisbury, 2004 Ed

Lion Co's South Salisbury site reduced chemical use by 11% by auditing its CIP flip cycle (valve operation), recovering chemicals from its pasteuriser wash and decreasing the frequency of acid washes.

Annual CIP audit: Lion Co, Penrith, 2004 Ed

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

TMI reduced sodium in discharge wastewater by 21% (Bega Cheese, 2016)

Wastewater discharged from Tatura Milk Industries (TMI) goes to the Goulburn Valley Water trade waste system which is ultimately irrigated onto local farmland. The sodium in wastewater can have a negative impact on the soil structure and groundwater. The majority of sodium discharged results from caustic soda used in the cleaning process.

From FY2010-2015 sodium levels in the wastewater discharge were increasing so TMI put together a multi-disciplined team to investigate the CIP system to reduce sodium consumption and water use at all sites.

Changes made to the systems included:

- reduction in cleaning times,
- standardisation and reduction in caustic strengths between plants,
- improved re-use of caustic solutions and
- modification to inconsistent software programs.

In the first year it reduced the total sodium discharged to tradewaste by 98 tonnes from 468 tonnes in FY2015 to 370 tonnes FY2016.

11.2.1 Chemical types and blends

Ideally a cleaning chemical will meet all cleaning requirements as well as being economical, non-corrosive, non-toxic, stable, non-dusting, effective in softening water, highly soluble and able to withstand a broad range of environmental conditions. Chemical suppliers can provide advice on the most appropriate chemicals for each cleaning task, which clean effectively while also minimising environmental impacts and ensuring operator safety. Table 11.3 indicates some differences between commonly used cleaning chemicals.

Table 11.3: Chemical types.

Type	Advantages	Disadvantages
Alkaline detergent types		
Raw Caustic (Sodium Hydroxide)	Low cost commodity	Poor soil removal / penetration Increased CIP time High Impact on Waste Treatment High levels required for performance
Fully built alkaline detergents containing Surfactants and Wetting Agents Chelating Agents Emulsifiers	Better for soil removal / Penetration Decreased CIP time Reduced caustic levels required Reduced impact on waste treatment	Additional cost of cleaning chemicals
Additive program with bulk Caustic Mix additives with caustic on site	Better for cost / efficiency ratio Provide 'fit for purpose' on site formulated detergents for different areas throughout the process Decreased CIP time Reduced caustic levels required	Some additional cost of chemicals Additional requirements for bulk storage / mixing equipment

	Reduced impact on waste treatment
Acid detergent types	
Raw or blended acids	Can include wetting agents and surfactants for improved cleaning with reduced concentrations
Source: (Ellis, 2015)	

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

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

Alternative detergent use increased productivity: Fonterra, Stanhope (Aust Govt, 1999) 2004 Ed

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

11.2.2 Chemical concentrations and temperature

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

The Closing the Loop Report into CIP Chemical use and reduction in sodium wastewater streams found that the optimised concentration of sodium hydroxide (NaOH) was 1% w/v for dairy processors. Concentration above this were found to have no additional cleaning effectiveness and the rate of cleaning was actually found to decrease. Potassium and potassium/sodium blend chemicals were found to provide an effective clean with a reduced concentration (or absence of) sodium in the effluent stream (Weeks, et al., 2007a). The KOH and KOH/NaOH blend cleaners are more expensive than bulk caustic however, this needs to be offset by reduce wastewater treatment and disposal costs if it allows wastewater streams to be irrigated.

Review of CIP chemical concentrations: Lion Co, Morwell, 2004 Ed

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

11.2.3 Cleaning cycle times

Jude & Lemaire found that an optimised CIP system can reduce cleaning times by up to 20%. If a CIP program takes 5 hours that is a saving of 1 hour that can be used in production (Jude & Lemaire, 2013).

Operation of the CIP system is production downtime. Minimisation of this downtime will allow increase in production and increase profitability. Optimisation of CIP systems can also reduce chemical, water and energy consumption. Systems may be optimised at one point in time and then over time become less efficient as changes are made to the program in response to events such as:

- a problem in the CIP system. Avoidance of the root cause of the problem in favour of starting the system back up in case additional maintenance work is required leading to further downtime.
- fear of contamination and not meeting hygiene standards leading to overcompensation through increased cleaning times. This can be particularly true if the system is not well understood (Jude & Lemaire, 2013).

An optimised CIP system is a balance of cleaning cycle time, temperature, chemical concentration and mechanical action. Some strategies to optimise include:

- reducing time between CIPs by increasing the time of production runs.
- increasing cleaning chemical strength (however may cause increased chemical costs and chemicals in the effluent stream but can decrease cycle time.)
- increase CIP step times
- Introducing intermediate cleans which allows production lengths to be extended but increases soil loading at CIP.
- adopting pre-treatment regimes to produce better cleans at the same CIP timing (Ellis, 2015).

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

Regular audits of CIP systems help to ensure that the efficiency and effectiveness of the cleaning system is maintained. Such audits are carried out by internal staff or on a contract basis by chemical suppliers.

Auditing of dosing equipment: Lion Co, Morwell, 2004 Ed

Lion Co's Morwell site reduced caustic and acid cycle times on its CIP system. During the early stages of commissioning the plant significant issues were experienced and cleaning times were increased. As the many design issues were resolved it was found that the times were longer than recommended and could be reduced without comprising product quality.

Reduced cleaning by combining acid and sanitiser step: Lion Co, Malanda, 2004 Ed

Lion Co's Malanda site have been working in partnership with their supplier and have removed a rinse cycle and a sanitation step from all its cleaning circuits by changing from a caustic/acid/sanitation cycle to a caustic/acid-sanitiser one shot cycle. The initiative has saved the factory 15,000 kL/yr in rinse water with additional savings in chemical costs.

11.2.4 Control instrumentation

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

More sophisticated integrated program control allows problem identification and can significantly reduce trouble-shooting times in the event of a problem with the system allowing diagnosis within a few minutes. Components of an enhanced CIP system can include:

- **Supply side flow transmitter** – to precisely control the total amounts of liquid delivered to each CIP circuit in each rinse and wash step
- **Variable frequency drive on the supply pump** – to precisely control flow rates and achieve minimum liquid flow velocities for surface contact in the various pipe diameters and sufficient flow through the spray balls for tank circuits.
- **Supply side line pressure transmitter** – to monitor and detect an obstruction in the circuit if the pressure is too high or a break in the circuit if the pressure is too low.
- **Level transmitter or level probes on the tanks** – to signify when action needs to be taken.
- **pH transmitters for alkaline and acid tank makeup** – to monitor pH levels and achieve desired concentrations
- **Proximity sensors** – to ensure all manual hook-up stations are properly in place.
- **Return side temperature transmitter** – to ensure the entire circuit is being cleaned at the required minimum temperature.
- **Return side liquid flow switch** – to detect liquid is returning to the skid or kitchen from the circuit being cleaned.
- **Return side conductivity transmitters** – to detect the absence or presence of chemicals in returning rinse and wash water. Wash times can be shortened if there is no chemical in the returned liquid stream.
- **Return side turbidity meter** – to detect the amount of solids in return liquid stream and prevent liquids with high solids content entering recovery tank.
- **Human-machine interface (HMI)** – operator's window into the system for control and monitoring process while operating (Malyszko, 2014).

Instrumentation for cleaning improvements: Lion Co, Malanda, 2004 Ed

Lion Co's Malanda site audited all its CIP processes. Optic sensors were used to fine-tune water and milk interfaces and conductivity and turbidity meters for cleaning improvements. Estimated savings for the improvements were $211,500/yr.

11.2.5 Chemical recovery

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

CIP systems used in dairy processing plants may be classified as single-use, multi-use or full recovery. Single-use systems dispose of rinse waters and spent solution to drain after one use, while multi-use systems recover final rinse waters and appropriate-quality spent solution for reuse. Multi-use systems are particularly efficient when the soiling is only light and the spent chemical still retains most of its active agent (DPEC, 1999). Rinsing and recovering product before CIP will minimise contamination and enable the chemical solution to retain its quality characteristics for a longer period of time. Full recovery systems typically use membrane systems to recover product, chemicals and water. The advantages and disadvantages of these three systems are shown in Table 11.4.

Table 11.4: Types of CIP systems

Type of system	Features	Advantages	Disadvantages
Single Use	All solutions used once All used cleaning solutions go to drain	Equipment cost is low Flexible CIP regimes to suit individual requirements CIP with fresh solutions	High use of CIP chemicals High impact on waste treatment
Multi-use	Rinse solutions are reclaimed for pre-rinse at next CIP	Equipment cost is low Flexible CIP regimes to suit individual requirements Reduce water use Improved initial rinse	Some additional equipment cost Reduced use of CIP chemicals High impact on waste treatment
Full recovery	High soil load portions of cleaning solutions go to drain Low soil load solutions are reclaimed and adjusted for concentration Post rinses reclaimed for pre-rinsing at next CIP	Reduced CIP chemical costs Reduced water use Improved initial rinse Lower impact on waste treatment	High initial equipment cost
Source: (Ellis, 2015)			

The use of full recovery membrane filtration systems is becoming more financially viable, allowing even greater recovery of resources. Spent CIP solutions can be regenerated using microfiltration, ultrafiltration and nanofiltration, with the potential to recover as much as 99% of cleaning solution, and with substantial water savings (DFSV, 2014). The retentate from chemical recovery systems is usually disposed of to the wastewater treatment plant or sewer. Membrane factors to consider for CIP chemical recovery include:

- Membrane material
- Module type
- Fouling composition
- Water quality
- Chemical use.

- Pressure, temperature, solids concentration, pH and VCF (Makardij, 2015).

Section 6.7.2 - Use of membranes for water recovery provides more detail on membranes for removal.

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

CIP Nanofiltration Re-use Project – Saputo Dairy Australia, Allansford (WCBF, 2018)

In 2010, with some assistance through funding from Sustainability Victoria, Saputo Dairy Australia's Allansford site installed a collection and filtration system to treat cleaning solutions that were traditionally too dirty to re-use. These caustic solutions were used once and then dumped to drain. Achieving Kosher accreditation across the manufacturing site enabled this project to proceed, whereby cleaning solutions from different plants across the site could be mixed together, cleaned using nano-filtration and redistributed to plants for re-use. The project saves more than 300t/y of caustic and more than 20ML/y water.

Bega Cheese Upgrade to Caustic recovery plant (DMSC, est, 2012)

An existing caustic (sodium hydroxide) recovery plant at Bega Cheese's Koroit site was upgraded increasing the amount of spent caustic suitable for re-use. This reduced chemical costs and also lowered salt loadings in the wastewater used to irrigate MG's nearby farm.

The project team calculated the savings from reducing the amount of caustic that went down the drain, the quantity that could be recovered and the benefits from reducing salt loadings on soil heath. Pilot trials predicted that a nano-filtration membrane plant would provide 95% recovery rates of caustic at a purity well above the quality standard for reuse. Financial savings were predicted at $350,000 per annum in chemical savings and wastewater treatment savings.

The system was installed in 2011 with a 100kL storage tank for dirty caustic. It also required an upgrade to supply / recovery lines and valves around the site. The project was also predicted to provide additional efficiency savings through reduced cleaning times on some equipment.

11.2.6 Operator competency and safety

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

11.2.7 Equipment operation and maintenance

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

It is also important to regularly check and calibrate instrumentation (e.g. for measurement of temperature, conductivity or flow). Similarly, regular checks of chemical dosing equipment are required to ensure proper function.

11.3 Chemical alternatives

Several alternatives to the traditional chemicals are becoming more popular as they provide additional benefits such as reduced load on wastewater treatment and reduced health and safety risk.

11.3.1 Biodegradable chemicals

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

Peroxyacetic acid is used in the dairy industry as a biodegradable and non-toxic sanitising agent that is as effective as chlorine and can be used at low concentrations. The advantages of peroxyacetic acid over chlorine-based compounds include:

- its relatively stable at use strengths of 100 to 200ppm,
- absence of foam or phosphates.
- Low corrosiveness
- Tolerance to hard water
- No water temperature sensitivity
- Biodegradability (Schmidt, 2015).

A number of factors do need to be considered, however, when using peroxyacetic acid. In the concentrated form (40%) it is highly toxic, a powerful oxidiser and is a potential irritant thus safe handling needs to be undertaken. It has a pungent odour and its germicidal activity is reduced by pH particularly that above 7-8 (Schmidt, 2015). When peroxyacetic acid is added to water it creates a solution of peroxyacetic acid, acetic acid and hydrogen peroxide. The breakdown into acetic acid can increase the BOD loading of wastewater, potentially increasing wastewater disposal costs. The acetic acid can also lower the pH of the wastewater (to pH 4–5), depending on the initial concentration of the acetic acid in the peroxyacetic acid product and the dosage of peroxyacetic acid added to the water. In dairy processing, the pH of the wastewater is not significant because the volume of water containing acetic acid is mixed with much larger volumes of wastewater.

Table 11.5: Comparison of inorganic and organic acids

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

Examples: hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid.	Examples: acetic acid, lactic acid, hydroxyacetic acid, citric acid, peroxyacetic acid
Source: (Harper & Spillan, 2004)	

Brewery develops own cleaning chemicals (Qld Govt, 2017)

Beard and Brau, a boutique brewery in Queensland, worked with a chemical manufacturer to develop a range of biodegradable cleaning chemicals for the brewing and wine manufacturing and service sectors. Their wastewater is treated onsite in a biological system. Water consumption has been reduced by 24% by using biodegradable cleaning chemicals. In addition, energy savings have been achieved through using lower temperature water for cleaning.

Traditional vs biodegradable cleaning

Traditional cleaning and sanitising chemicals for washing brewing tanks			Biodegradable cleaning and sanitising chemicals brewing tanks		
Product	Temp of water (^0C)	Amount (L)	Product	Temp of water (^0C)	Amount (L)
Caustic wash	80	100	Caustic substitute (Beerox (sodium carbonate/hydrogen peroxide or Cleanskin (Sodium based)	40	40
Rinse		30	Rinse		10
Phosphoric wash	60	100			
Rinse		30			
Peroxide wash	Ambient	100	Vinisan (broad spectrum biocide - PHMB)	40	40
Rinse		60	Rinse		10
Total		420	Total		100

There is also a significant reduction in freight costs as B&B no longer have to pay for their chemicals to be delivered in a Dangerous Goods Truck.

11.3.2 Enzyme-based detergents

Enzyme-based detergents are finding acceptance in dairy processing industry for both foam cleaning and CIP applications. Enzymes speed up specific chemical reactions in mild conditions of temperature and pH. The primary advantages of enzyme detergents are that they are environmentally friendly and non-corrosive, they require less energy input in the form of heat, they can reduce wastewater costs, and they can reduce the salt levels of effluent through the reduced use of caustic-based cleaners (Boyce, et al., 2010).

Enzymes have been found to be effective in removing biofilms including thermo-resistant streptococci from stainless steel. The enzymes remove the extracellular polymeric substances which protect the cells of the bacteria in the biofilm more efficiently than NaOH. Using enzymes require less water for rinsing leading to reduced water consumption and costs and reduced wastewater volumes. In addition, the wastewater is less contaminated and does not require neutralisation (Boyce, et al., 2010).

While most enzyme cleaners are limited to unheated surfaces some trials on heat transfer surfaces have found that specific enzymes can be used in CIP systems to effectively remove contaminants and can replace the caustic detergent solution cycle. With the enzymes cycle operating at 40ºC compared to the 70-80ºC caustic cycle there are significant energy savings are achieved (Boyce, et al., 2010). This also leads to reduced transport and handling of hazardous and corrosive chemicals.

Enzymes can also be used as a periodic solution to remove biofilm rather than to be used during every CIP cycle (Novozymes, n.d.).

Single phase cleaning and enzyme technology: ice-cream processor, Asia (Kidd & Stiff, 2003) , 2004 Ed

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

11.3.3 Reduced phosphate, nitric and sodium blends

Many conventional cleaning chemicals contain phosphates in the form of phosphoric acid and tri-sodium phosphate, and nitrogen in the form of nitric acid. Many dairy effluents also contain high levels of phosphates from product residues. Phosphates and nitrates need to be removed from wastewater streams, as they can contribute to eutrophication causing algal blooms and oxygen starvation in waterways. As a result, some local councils include a levy on the concentration of phosphates and nitrogen in wastewater. Products with less than 0.5% by weight of phosphorus are available to replace conventional cleaning chemicals for most duties (MnTAP, 2008).

Many cleaning chemicals also contain sodium in the form of sodium hydroxide (NaOH), which contributes to the salt load of wastewater and exacerbates salinity levels in soil if the water is irrigated. Some dairy processors are using blends of sodium hydroxide and potassium hydroxide to reduce the sodium levels in wastewater. Water authorities are therefore introducing sodium-based charges (like phosphorus and nitrogen charges) on wastewater disposal. However, the use of potassium hydroxide in CIP systems to replace sodium hydroxide has the disadvantage that it is more expensive, less effective due to the reduced solubility and cleaning efficiency compared with NaOH resulting that 40% more potassium hydroxide is required for the same level of clean (Ref RM Consulting Report – when merged). This increase in potassium hydroxide in the wastewater stream has its own treatment and disposal problems as a larger area for irrigation is required or a higher fee charged.

As mentioned in Sections above and below the addition of chelating agents, additives, detergents and enzymes and other alternatives listed in this document can be used instead of traditional caustics.

Change to nitric acid blend: Beston Global Dairy Foods, Jervois, 2004 Ed

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

Replacement of phosphoric acid with citric acid: Saputo Dairy Australia, Rochester, 2004 Ed

Saputo Dairy Australia's Rochester site reduced the use of phosphoric acid, due to the resultant high level of nutrients (phosphates) in the effluent which is used for irrigation.

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

A plant recovery system for reclaiming cleaning chemicals reduced the total dissolved salts in the plant effluent and reduced plant effluent conductivity by 15%.

Neutral cleaners for cold surfaces: Saputo Dairy Australia, Maffra, 2004 Ed

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

11.4 Chemical treatment of boilers, cooling water and condensate water

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

11.4.1 Boiler water treatment

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

11.4.2 Cooling water treatment

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

11.4.3 Condensate water treatment

Information on condensate reuse and condensate water treatment can be found in Section 6.0 - Water.

11.5 Alternatives to chemical use

11.5.1 Ozone

Ozone is a powerful oxidising agent that destroys micro-organisms by oxidising their cell membrane. Ozone is usually generated on demand by creating an electrical discharge across an oxygen or air stream. The bonds that hold the O_2 together are broken and three O_2

molecules are combined to form two O_3 molecules (ozone). The ozone quickly breaks down and reverts to O_2. The O_3 molecules destroy micro-organisms by oxidising their cell membranes. For use in a CIP system, ozone enriched water can be directly injected into the system and circulated for a set duration. It has the advantage of reducing overall chemical and wastewater treatment costs. It is applied in cold water as it is less stable at higher temperatures reducing both energy consumption and overall system deterioration that occurs using traditional hot water with anti-microbial chemicals (Canut & Oascual, 2007). Ozone is a cost-effective alternative to chlorine as it is applied in cold water, leaves no residue and is less dependent on pH and temperature. This reduces:

- energy for heating water or steam generation for cleaning.
- water use as multiple rinse cycles are not required to wash out residual chemical. In addition ozonated water that has been used for disinfection can be reused as initial cleaning water as it has no residual ozone.
- wastewater generation and contamination as less water is used with reduced salt levels.

A disadvantage is that it can be difficult to maintain consistent dosage rates, because the breakdown of ozone back into oxygen occurs rapidly.

A study comparing the effectiveness of warm water (40ºC) and ozonated cold water (10ºC) as a pre-rinse to remove the bulk of milk residues found that the ozonated water was more effective removing 84% of milk residue compared with warm water at 51% (Varga & Szigeti, 2016). A separate study found that both aqueous and gaseous ozonation facilitated desorption of whey protein from stainless steel surfaces.

Ozonated water was found to be more effective against biofilm at 100ppm for 2 mins compared with commercial chlorinated sanitiser. It was also found that a combined application of ozone and power ultrasound was even more effective for bacterial biofilm removal then either of them separately (Varga & Szigeti, 2016). Ozone can have a detrimental impact on systems containing copper or carbon steel parts.

Ozone to treat cooling towers: Fonterra, Stanhope, 2004 Ed

Fonterra's Stanhope site trialled the use of ozone in its cooling towers. The ozone proved to be very cost-effective and was predicted to save the plant around $120,000/yr in reduced chemicals. Each ozone unit cost around $5500 and was economical to operate, using a 0.5 kW generator.

11.5.2 Ultraviolet light

Ultraviolet (UV) disinfection systems destroy micro-organisms through interaction with microbe DNA. The degree of inactivation of microbes is related to the UV dose, which is linked to UV light intensity and contact time. Factors that can affect dosage include turbidity and organic load. Some micro-organisms, such as *Giardia* or *Cryptosporidium*, may not be affected at average doses. UV light has the advantage of

- not introducing toxins
- leaves no residue
- not change chemical composition, taste, odour or pH of the fluid being disinfected.
- not causing off-flavours.
- and is not affected by water chemistry.
- being low maintenance and environmentally friendly (Berson UV-Techniek, 2005).

A UV system generally consists of a UV lamp housed in a protective quartz sleeve within a cylindrical stainless steel chamber. The water passes through the chamber. Applications for the dairy industry include:

- direct contact with water or ingredient. This can also allow the reuse of process water without risking the quality of the product.
- pre-treatment disinfection prior to reverse osmosis or carbon filtration that may be adversely affected by microbial contamination.
- CIP water and wash water disinfectant without the use of chemicals.
- cooling media and chiller disinfection to prevent contamination by contact-cooling fluids for heated products.
- packaging and surface disinfection to reduce microbial counts,
- wastewater to ensure discharge meets environmental regulations (Berson UV-Techniek, 2005).

UV light has been used by some Australian dairy processors to disinfect water used for cleaning, and for treating condensate.

Ultraviolet disinfection of feta cheese brine: cheese processor, South Africa (Manufacturingtalk, 2003), 2004 Ed

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

11.5.3 Carbon dioxide

Thought there are no current examples of its use in dairy processing, dry ice (CO_2) blasting can be used for surface cleaning in food processing. Solid carbon dioxide is accelerated in a pressurised dry air stream either manufactured on site or by a vendor. CO_2 is nonconductive, chemically inert, nontoxic and non-flammable which leaves no residue and is non-abrasive. Cleaning works by the use of kinetic energy as the pellets contact the solid surface then the dry ice loosens soiling as CO_2 changes from solid to gas instantly through sublimation. Sublimation increases the volume of the gas particles by 400% creating a mini-explosion (Powitz, 2014).

11.6 Supply and handling of chemicals

11.6.1 Supply agreements and performance-based contracts

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

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

1.1.1 Bulk supply of chemicals

Purchasing chemicals in bulk or at higher concentration may be more economical and can save on packaging. If chemicals are purchased in more concentrated form, appropriate training should be provided to ensure safety of operators and to avoid wastage. All chemicals should be properly labelled and stored in a dry, well-ventilated and appropriately designed area and measures in place to ensure legislative requirements are met for the safe use and storage of chemicals.

Consolidation of suppliers and bulk purchasing: Dairy Processor, Bomaderry, 2004 Ed

A Bomaderry dairy processor previously used nine different chemical suppliers to meet its chemical needs. The plant then changed to just one supplier. It took a few months for the plant and the supplier to come up with a range of chemicals equivalent to those they were previously using. They negotiated a reduced price. The plant also received a 'group discount' for buying in bulk for several processing plants.

11.7 Further reading

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

- AS 1398:1998, Iodophors for Use in the Dairying Industry
- AS 1162:2000, Cleaning and Sanitising Dairy Factory Equipment
- AS 1536:2000, General Purpose Detergents for Use in the Dairying Industry
- AS 1087:2003, Sodium Hypochlorite Solutions for Use in the Dairying Industry
- AS/NZS 1389:1997, Acidic Detergents for Use in the Dairying Industry
- AS/NZS 1400:1997, Heavy-Duty Alkaline Detergents for 'In-Place' Cleaning in Dairy Factories
- AS/NZS 2541:1998, Guide to the Cleaning-in-Place of Dairy Factory Equipment.

Other dairy industry reports include:

- Closing The Loop Project - investigation of alternative CIP chemicals and practices for reduction in sodium in dairy processor waste streams (Weeks, et al., 2007);
- Closing The Loop Project - an holistic approach to the management of dairy processor waste streams: inactivation of thermophilic spores by NaOH solutions (Issa, et al., 2007)
- Clean in Place – A Review of Current Technology and its Use in the Food and Beverage Industry (Palmowski, et al., 2005)

12.0 References

ADIC, 2016. *Australian Dairy Industry Sustainability Report,* Australian Dairy Industry Council http://www.sustainabledairyoz.com.au: s.n.

AGL, est, 2012. *Richmond Dairies High Efficiency Boiler. AGL case study www.agl.com.au,* s.l.: AGL Energy Ltd.

AGO, 2002a. *Greenhouse Challenge. Bonlac Foods, Success Stories,* s.l.: Australian Greenhouse Office.

AGO, 2002b. *Motor solutions online: selecting the best motor and equipment.* [Online]
Available at: www.greenhouse.gov.au/motors/case-studies/index.html
[Accessed 9 April 2004].

Aither, 2017. *Urban Water Pricing Reform. National urban water pricing standards and implementation pathway,* s.l.: Infrastructure Australia.

AMCOR, 2018. *The Environment - Packaging that's better for the planet, and good for business.* Melbourne, DMSC Workshop 19 July 2018.

AMIC, 2016. *Freon vs Ammonia and Glycol Refrigeration Systems - Fact Sheet. Energy Efficiency Information Grants Program,* s.l.: Australian Meat Industry Council.

ANZBP, n.d. *Australian and New Zealand Biosolids Partnership - Plate 11 Heat Drying.* [Online]
Available at: www.biosolids.com.au/wp-content/uploads/DSE-Thermal-Drying.pdf
[Accessed 02 11 2018].

ANZECC, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1. Figure 4.2.1,* s.l.: Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

APCO, 2017. *Summary of APCO's Packaging Sustainability Framework,* Sydney: Australian Packaging Covenant Organisation.

APCO, 2018a. *Working together towards packaging sustainability.* Melbourne, Australian Packaging Covenant Organisation. Presentation to DMSC, 2018.

APCO, 2018. *News: Australia's environment ministers commit to eliminating all packaging going to landfill by 2025.* [Online]
Available at: www.packagingcovenant.org.au/news/australias-environment-ministers-commit-to-eliminating-all-packaging-g

APCO, n.d.. *Sustainable Packaging Guidelines,* s.l.: Australian Packaging Covenant Organisation. https://www.packagingcovenant.org.au.

APV, 2009. *Evaporator Handbook. EHP-599.* 4th Edition ed. www.apv.com: APV an SPX Brand.

ARENA, 2017. *Four charts that show the future of battery storage,* s.l.: Australian Renewble Energy Agency. Ketan Joshi Blog.

ARENA, 2018. *Australian Renewable Energy Agency.* [Online]
Available at: arena.gov.au/news/latrobe-valley-virtual-microgrid-allow-dairy-farms-trade-energy-via-blockchain/

AS 4709:2001, 2001. *Guide to Cleaning and Sanitising of Plant and Equipment in the Food Industry,* Viewed 25 November 2003: Australian Standards.

Atlas Copco, 2003. *Energy recovery systems.* BRISBANE: Fax provided by Atls Corpco April 2003.

Aus Govt, 2018. *HFC Phase Down - Frequently Asked Questions and The phase out of R22 - Factsheet.* [Online]
Available at: www.environment.gov.au/protection/ozone/hfc-phase-down/hfc-phase-down-faqs

Aust Govt, 1999. *Cleaner production — anhydrous milk fat: serum fat recovery — Bonlac Foods.* [Online]
Available at: www.deh.gov.au/industry/corporate/eecp/case-studies/bonlac1.html
[Accessed 13 November 2003].

Aust Govt, 2003. *Case study dairy processing sector, Murray Goulburn Rochester, Energy Efficiency Best Practice Program,,* s.l.: Australian Government Department of Industry, Tourism and Resources.

Aust Govt, 2017. *National Greenhouse Accounts Factors. Australian National Greenhouse Accounts,* s.l.: Australian Government Department of Environment and Energy.

Barber, M. & Cumming, J., 2017. *Opportunities for Reducing Greenhouse Gas Emissions Intensity in the Australian Dairy Processing Sector,* s.l.: Dairy Australia.

Bega Cheese, 2015. *Sustainability Report,* s.l.: s.n.

Bega Cheese, 2016. *Sustainability Report,* s.l.: Bega.

Bega Cheese, 2017. *Creating a better tomorrow. Bega Cheese Sustainability Report,* s.l.: s.n.

Berson UV-Techniek, 2005. *UV disinfection in the dairy industry.* [Online]
Available at: www.foodprocessing.com.au/content/processing/article/uv-disinfection-in-the-dairy-industry-1290411837

Boyce, A., Piterina, A. V. & Walsh, G., 2010. Assessment of the potential suitability of selected commercially available enzymes for cleaning-in-place (CIP) in the dairy industry. *Biofouling,* October, 26(7), pp. 837-850.

Božanić, R., Barukčić, I. & Lisak, K., 2014. Posibilities of Whey Utilisation. *Austin Journal of Nutrition and Food Sciences*, 25 July, 2(7), p. 1036.

Braun, M., 2016. *The Zero Water Milk Processing Plant.,* s.l.: GEA. Food Marketing & Technology Magazine, p. 28..

Britz, T. J., van Schalkwyk, C. & Hung, Y.-T., 2006. Treatment of Dairy Processing Wastewaters. In: *Handbook of Industrial and Hazardous Wastes Treatment, Second Edition.* s.l.:Taylor & Francis Group, p. Chapter 1.

Burra Foods, 2017. *The Common Ground - Burra Foods Community Report - December 2017,* s.l.:
http://www.burrafoods.com.au/public/files/files/Burra%20Foods%20Community%20Report%202017.pdf.

Burra Foods, 2018. Burra Foods commits to long-term sustainability through renewable energy. *Media Release*, May.

Burra Foods, 2019. *Burra Foods Community Report, Issue 10 Summer 2018/2019.* [Online] Available at: www.burrafoods.com.au/public/files/files/Burra%20Common%20Ground%20December%202018%20FINAL.pdf

CADDET, 1996. *Retrofit cogeneration system at milk processing plant.* [Online] Available at: www.portalenergy.com/caddet/eetb_eut/R257.pdf
[Accessed Feruary 2004].

CADDET, 1999. *Thickening and desalinating whey in the dairy industry.* [Online] Available at: www.caddet-ee.org
[Accessed July 2003].

Canut, A. & Oascual, A., 2007. *OzoneCip: Ozone Cleaning in Place in Food Industries.* Valencia, Spain, IOA Conference and Exhibition, pp. 6.6-1 to 6.6-18.

Carbon Trust, 2015. *Ice pigging technology offers dairy industry significant savings.* [Online] Available at: www.carbontrust.com/news/2015/04/ice-pigging-technology-offers-dairy-industry-significant-savings/
[Accessed 6th Nov 2018].

Carbon Trust, 2018. *Motors and Drives. Introducing energy saving opportunities for business. CTV048v3,* UK: www.carbontrust.com.

Carbon Trust, est 2010. *Industrial Energy Efficiency Accelerator - Guide to the dairy sector,* s.l.: Carbon Trust UK. Department for Environment and Climate Change.

CCIQ ecoBiz, n.d.. *Case Study - Food Processing - Keystone Foods Australia.* [Online] Available at: www.cciqecobiz.com.au/assets/PDFs/CCIQ-ecoBiz-Case-Study-Keystone-Foods-Australia.pdf

CEC, 2017. *Renewable Energy Target.* [Online]
Available at: www.cleanenergycouncil.org.au/policy-advocacy/renewable-energy-target.html

CEC, 2018. *Clean Energy Council.* [Online]
Available at: www.cleanenergycouncil.org.au/technologies/wind-energy.html#

CEFC, 2018. *Australian Manufacturing Gas Efficiency Guide,* s.l.: Clean Energy Finance Corporation, Energy Efficiency Council and The Australian Industry Group. https://www.energy.gov.au/news-media/news/australian-manufacturing-gas-efficiency-guide.

Chen, M., 2017. *Anaerobic Digestion as a Treatment and Energy Recovery Technology for Dairy Processing Waste Streams,* s.l.: GHD. Dairy Australia. https://manufacturing.dairyaustralia.com.au.

Contact Energy, 2018. *Contact Energy.* [Online]
Available at: contact.co.nz/aboutus/our-story/our-powerstations

COWI, 2000. *Cleaner production assessment in dairy processing - Industrial section guide,* France : UNEP.

Dairy Australia, 2017. *Australian Dairy Industry in Focus,* Melbourne: Dairy Australia. www.dairyaustralia.com.au.

Dairy Australia, 2017. *Briefing note: 2017/18 energy price implications,* s.l.: Dairy Australia. www.dairyaustralia.com.au.

Dairy Australia, 2018a. *Dairy Situation and Outlook,* Melbourne: Dairy Australia.

Dairy Australia, 2018. *Casein and Whey.* [Online]
Available at: www.dairyaustralia.com.au/industry/production-and-sales/casein-and-whey

Dairy UK, 2018. *The UK Dairy Roadmap. Showcasing ten years of Environmental Commitment,* s.l.: s.n.

Dairy_Australia, 2018. *Saving energy on dairy farms - Booklet,* https://www.dairyingfortomorrow.com.au/wp-content/uploads/1437-Saving-energy-on-dairy-farms-Booklet-2018_FA_DIGITAL_20181210.pdf: Dairy Australia.

Daufin, G. et al., 2001. *Recent and emerging applications of membrane processes in the food and dairy industry.,* s.l.: Transactions of the Institute of Chemical Engineers, Vol 79 (C2), pp. 89-102.

De Kleijn, 2018. *Absorption Heat Pump, De Kleijn Energy Consultants & Engineers.* [Online]
Available at: industrialheatpumps.nl/en/how_it_works/absorption_heat_pump/
[Accessed 14th Nov 2018].

Devondaler, 2013. Leongatha project a 'boost' for community. *Devondaler*, Volume 28 No. 10 (Issue No. 332).

DFSV, 2014. *Technical information - Cleaning in place (CIP) systems,* Melbourne: Dairy Food Safety Victoria.

Diesendorf, M., 2015. *100% Renewable Electricity for South Australia. Conservation Council of South Australia, Adelaide. ,* s.l.: Conservation Council of South Australia, Adelaide. .

DIIS, 2017. *Industry 4.0. Department of Industry, Innovation and Science.* [Online]
Available at: industry.gov.au/industry/Industry-4-0/Pages/default.aspx. Accessed 10/6/17

Dixit, R., 2018. *The New Era of Absorption Chillers.* [Online]
Available at: www.power-eng.com/articles/2018/08/the-new-era-of-absorption-chillers.html
[Accessed 10th November 2018].

DMSC, 2011. *Australian Dairy Manufacturing Environmental Sustainability Report 2010/2011,* s.l.: Dairy Australia.

DMSC, 2015. *Environmental Sustainability Scorecard 2014/15,* Melbourne: Dairy Manufacturers Sustainability Council.

DMSC, 2017. *Environmental Sustainability Scorecard 2016-17,* s.l.: Dairy Australia, Dairy Manufacturers Sustainability Council.

DMSC, 2018. *Case Study - Chemical Use - MG @ Koroit.* [Online]
Available at: www.dmsc.com.au/cs-chemicals-mg-koroit

DMSC, est, 2012. *Case Study - Chemical Use - MG @ Koroit.* [Online]
Available at: www.dmsc.com.au/cs-chemicals-mg-koroit
[Accessed Accessed Dec 2018].

DPEC, 1997. *Homogeniser performance evaluation guide manual 1996/97 ,* s.l.: s.n.

DPEC, 1999. *Performance evaluation guide manual:cleaning systems 98/99,* s.l.: Dairy Process Engineering Centre, Australia.

Dreizen, C., 2017. *The race to increase recycled content in packaging.* [Online] Available at: www.packagingdigest.com/sustainable-packaging/the-race-to-increase-recycled-content-in-packaging-2017-12-04

ECObuy, 2013. *Sustainable Procurement Guide,* Canberra: Department of Sustainability, Environment, Water, Population and Communities.

Edmondson, C., 2014. *Cooling Tower and Condenser Water Design Part 1: The Refrigeration Cycle.* [Online]
Available at: jmpcoblog.com/hvac-blog/cooling-tower-and-condenser-water-design-part-1-the-refrigeration-cycle
[Accessed 25 November 2018].

EEC, 2018. *Navigating a dynamic energy landscape: a briefing for Australia's businesses,* s.l.: Energy Efficiency Council.

Ellis, R., 2015. *CIP for Hot Surfaces - Conference Presentation. Robert Ellis Technical Support Coordinator, Food and Beverage, Ecolab.* s.l., s.n.

Endress+Hauser Australia, 2018. Quality monitoring in milk processing — Part 1 and Part 2. *Process Online - Process Technology*, March.

Energetics, 2017. *Waste to energy options: the business case looks better and better. A2EP - 2XEP Energy Productivity Summit. Australian National Maritime Museum. Sydney. Leigh Rostron.* s.l., s.n.

Energy Queensland Group, 2018. *Understanding Power Factor.* [Online]
Available at: www.ergon.com.au/network/manage-your-energy/business-resources/understanding-power-factor
[Accessed 25 November 2018].

Envirowise, 1999b. *Reducing waste for profit in the dairy industry, ,* s.l.: ETBPP Good Practice Guide 242, www.envirowise.gov.uk.

Envirowise, 1999. *Reducing waste for profit in the dairy industry, ETBPP GG 242,,* s.l.: s.n.

Envirowise, 2003. *Water loss from leaking equipment,* s.l.: viewed 7 March 2003. www.envirowise.gov.uk.

ETSU, 1996. *Good Practice Guide No. 185, Spray Drying,* s.l.: Energy Technology Support Unit, UK Energy Efficiency Best Practice Programme.

ETSU, 1998. *Reducing energy costs in dairies - a guide to improed profitability, Good Practice Guide 280,* Oxfordshire: UK Energy Efficiency Best Practice Programme.

ETSU, 2000. *Energy efficiency refrigeration technology - the fundamentals, Best Practice Guide 280,* Oxfordshire: UK Energy Best Practice Programme.

Fonterra, 2017. *Sustainability Report,* s.l.: s.n.

Foodbev Media, 2018a. *Fonterra boosts water efficiency at milk powder drying operation.* [Online]
Available at: www.foodbev.com/news/fonterra-boosts-water-recovery-at-milk-powder-drying-

operation/
[Accessed 25 November 2018].

GEA, 2010. *Milk Powder Technology Evaporation and Spray Drying (Reprinted),* Copenhagen: GEA Process Engineering.

GEA, 2012. *Membrane Filtration in the Dairy Industry,* s.l.: GEA Process Engineering.

GHD, 2017. *Anaerobic Digestion as a Treatment and Energy Recovery Technology for Dairy Processing Waste Streams,* s.l.: Dairy Australia.

Gray, J., Mitchell, L. & Pierce, E., 2012. *Disposal of Dairy Sludge.* https://www.slideserve.com/donny/disposal-of-dairy-sludge, s.n.

Green Industries SA, n.d.. *What is a Circular Economy?.* [Online]
Available at: www.greenindustries.sa.gov.au/circular-economy
[Accessed 8 10 2018].

Greenland Systems, 2014. *Dairy manufacturer goes solar as an alternative to escalating LPG costs,* s.l.: Manufacturers Monthly.

GRI, 2017b. *G4 Online Materiality. Global Reporting Initiative.* [Online]
Available at: g4.globalreporting.org Accessed 19/5/17

GRI, 2018. *GRI Empowering Sustainable Decisions. Global Reporting Initiative.* [Online]
Available at: www.globalreporting.org/Pages/default.aspx
[Accessed Nov 14th 2018].

Hakim, G., 2016. *Australian Dairy Hygiene Handbook,* s.l.: Dairy Australia.

Hale, N., Bertsch, R., Barnett, J. & Duddleston, W., 2003. *Sources of wastage in the dairy industry, Bulletin of the International Dairy Federation, no. 382,* Brussels: IDF.

Hansen-Knarhoi, B., 2018. *Maximising the Recyclability of Dairy Product Packaging,* Melbourne: Dairy Australia.

Harper, W. J. & Spillan, M., 2004. *Cleaning and sanitizing food plant equipment — cleaning compounds: characteristics and functions.* [Online]
Available at: class.fst.ohio-state.edu/FST401/Information/Cleaning%20and%20Sanitizing.doc
[Accessed 22 April 2004].

Hiperbaric, 2018. *HPP Technology.* [Online]
Available at: www.hiperbaric.com/en/high-pressure
[Accessed 14th Nov 2018].

HMRC&NRMMC, 2011. *Australian Drinking Water Guidelines Paper 6. National Water Quality Management Strategy.,* Canberra: National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia..

Homan, G., Aghajanzadeh, A. & McKane, A., 2015. *Opportunities for Automated Demand Response in California's Dairy Processing Industry,* s.l.: Ernest Orlando Lawrence Berkeley National Laboratory.

HoTT, 2016. *Holmfirth Transition Town.* [Online]
Available at: hott.org.uk/projects/#

IDF, 1988. *The quality, treatment and use of condensate and reverse osmosis permeates. Bulletin no. 232/1988,* Brussels: International Dairy Federation.

IDF, 2017. *The IDF Guide on Biodiversity for the Dairy Sector. Bulletin No. 488/2017,* s.l.: International Dairy Federation.

Indexmundi, 2018. *Commodity Price Index, Heating Oil.* [Online]
Available at: www.indexmundi.com/commodities/?commodity=heating-oil&months=360&currency=aud

Isle Utilities, 2017. *Opportunities for Reducing the Intensity of Water Consumption in the Australian Dairy Processing Sector,* s.l.: Dairy Australia.

Isle Utilities, n.d.. *Opportunities for Reducing Cost and Intensity of Waste Production in the Australian Dairy Processing Sector,* s.l.: Dairy Australia.

ISR, 2000. *A Best Practice Guide to Energy Performance Contracts,* s.l.: Australian Department of Industry Science and Resources and Australasian Energy Performance Contracting Association.

Issa, J., Weeks, M., Knight, G. & Jamil, K., 2007. *Closing The Loop Project - an holistic approach to the management of dairy processor waste streams : inactivation of thermophilic spores by NaOH solutions ,* s.l.: Gardiner Foundation; Food Science Australia (FSA); Victoria. Department of Primary Industries (DPI); DISCover Sub-project Research Team; Victoria University (Melbourne, Vic.); RMIT; Dairy Process.

IT Power, 2015. *Renewable Energy Options for Australian Industrial Gas Users,* s.l.: ARENA. Australian Renewable Energy Agency.

Joyce, K. M., 1993. *Energy efficiency in Australian dairy factories,* s.l.: Dairy Research and Development Corporation Australia, Melbourne.

Jude, B. & Lemaire, E., 2013. *How to Optimize Clean-in-Place (CIP) Processes in Food and Beverage Operations,* s.l.: Schneider Electric.

Jutsen, J., Pears, A. & Hutton, L., 2017. *High Temperature Heat Pumps for the Australian Food Industry: an opportunities assessment,* s.l.: Australian Alliance for Energy Productivity.

Kidd, C. & Stiff, M., 2003. *Ecolab* [Interview] 2003.

Kitou, A., 2015. *A review in reuse of water in dairy: possible solutions. https://www.slideshare.net/ANNAKITOU/reuse-of-water-in-dairy-products,* s.l.: s.n.

Kjaergaard-Jensen, G., 1999. *Energy consumption,,* s.l.: Bulletin of the International Dairy Federation, no. 340, pp. 34-41.

Knight, G., 2015. *Hygienic Design of Dairy Processing Equipment.* Melbourne, Dairy Innovation Australia.

KPMG, 2018. *Coal price and FX market forecasts June/July 2018 Edition,* s.l.: KPMG.

Kulozik, U. & Grunow, M., n.d.. *Processing milk – how concentrates help to save energy.* [Online]
Available at: www.tum.de/en/about-tum/news/press-releases/detail/article/31876/

Kwapinska, M. & Leahy, J. J., 2017. *Pyrolysis - a way of recovering energy from wastewate sludge from milk processing factories.* s.l., 5th International Conference on Sustainable Solid Waste Management.

Labs, W., 2015. Tech Update: Model Predictive Control - Predict the future: Get control of your process.. *Food Engineering*, 6th April, pp. www.foodengineeringmag.com/articles/93726-predict-the-future-get-control-of-your-process.

LEDified, 2018. *LEDified.* [Online]
Available at: www.ledified.com.au/bega-cheese-derrimut/

Lee, D. & Cheng, C.-C., 2016. Energy savings by energy management systems: A review. *Renewable and Sustainable Energy Reviews,* pp. Volume 56, April 2016, Pages 760-777.

Linhoff March, 1998. *Introduction to Pinch Technology,* Northwich, Cheshire UK: Linhoff March.

Lion Co, 2017. *2017 Sustainability Report. Lion Dairy and Drinks,* s.l.: Lion Co.

Lion Co, 2017. *Reduce, reuse, recycle.* [Online]
Available at: sustainability.lionco.com/reduce-reuse-recycle/
[Accessed 28 09 2018].

Lunde, S. et al., 2003. *Evaluation of the environmental performance of the Australian dairy processing industry using life cycle assessment,* s.l.: Dairy Research Development Corporation.

Lundie, S., 2013. *Carbon Footprint of the Australian Dairy Industry,* s.l.: PE Australasia and UNSW Water Research Centre for Dairy Australia. Confidential Report.

Mackay, M., 2002. *Investigation of the ability of model predictive control to increase powder production capacity at Murray Goulburn's Koroit Plant,,* s.l.: Dairy Research Development Corporation Internal document.

Made by Cow, n.d.. *About Us.* [Online]
Available at: www.madebycow.com.au/about-1/
[Accessed 25 November 2018].

Makardij, A., 2015. *Membrane Cleaning: Science or Art!.* Melbourne, Dairy Innovation Australia.

Malyszko, S., 2014. *Best Practice of Automated CIP Systems.* [Online]
Available at: www.foodqualityandsafety.com/article/best-practices-of-automated-cip-systems/

Manufacturingtalk, 2003. *UV disinfection protects cheese from contamination.* [Online]
Available at: www.manufacturingtalk.com/news/ric/ric101.html
[Accessed 12 December 2003].

Marshall, R., 2011. *Energy savings at milk, cheese and ice cream plants,* s.l.: Compressed Air Best Practices, Compressed Air Challenge.

Melrose Chemicals, 2003. *Cleaning.* [Online]
Available at: www.melrosechem.com/english/publicat/general/cleaning.pdf
[Accessed 11 November 2003].

Méthot-Hains, S. et al., 2016. Effect of transmembrane pressure control on energy efficiency during skim milk concentration by ultrafiltration at 10 and 50°C. *Journal of Dairy Science,* 99(11), pp. 8655-8664.

Minus 40, 2018. *Fonterra Wagga Wagga Chiller Upgrade.* [Online]
Available at: www.minus40.com.au/engineers/wp-content/uploads/2017/05/Fonterra-Wagga-Wagga-Case-Study.pdf
[Accessed 2019].

MLA, 1997. *Steam Generation Systems,* s.l.: Meat Livestock Australia and Meat Research Corporation.

MnTAP, 2008. *Phosphorus: reducing releases from industrial cleaning and sanatizing operations.* [Online]
Available at: www.mntap.umn.edu/focusareas/water/phosphorus/

Moejes, S. N., Visser, Q., Bitter, J. H. & van Boxtel, A. J., 2018. Closed-loop spray drying solutions for energy efficient powder production. *Innovative Food Science and Emerging Technologies,* pp. Edition 47 Pg 24-37.

Momentum Energy, 2018. *Energy Price Fact Sheet - Gas,* Pricing for Melbourne Metro and Yarra Valley Region: s.n.

Monash University, 2017. *Monash Industry Team Initiative 2016/17, Water Efficiency and Optimisation Study,* s.l.: Project Poster.

Moomaw, W. et al., 2011. *Annex II: Methodology. In Special Report on Renewable Energy Sources and Climate Change Mitigation,* s.l.: IPCC Intergovernmental Panel on Climate Change.

Morgan, S., 1999. *Milk processing effluent stream characterisation and utilisation, Project CMP121,* s.l.: Dairy Research and Development Corporation..

Möslang, H., 2015. *Cost Saving by Upgrading of Evaporator Condensates and NF-/ RO Permeates (Cow Water) for Reuse in Dairy Processes.* Cologn, 2nd International Conference on Separation + Drying Technologies for Milk and Whey.

Möslang, H., 2017. *The Daireuse Process, Biological treatment of evaporator condensates (Cow Water).,* s.l.: International-dairy-com.

Mousavi, S., Kara, S. & Kornfeld, B., 2014. *Energy Efficiency of Compressed Air Systems.* s.l., Procedia CIRP Science Direct, pp. 313-318.

Müller, K.-U., 2017. *High pressure cleaners - effective and water-saving.* [Online]
Available at: www.europeancleaningjournal.com/magazine/articles/product-features/high-pressure-cleaners-effectiveand-watersaving

Muller, M., Simek, M., Mak, J. & Mitrovic, G., 2001. *Modern Industrial Assessments: a training manual, Version 2.0.,* s.l.: Rutgers University, New Jersey, USA. Viewed November 2018.

Natural Resources Wales, 2014. *How to comply with your environmental permit. Additional guidance for Dairy and Milk Processing Sector (EPR 6.13),* s.l.: Natural Resources Wales.

Nestle, 2017. *Nestle in Society. Creating shared value and meeting our commitments. Full Report Corporate Social Responsibility,* s.l.: Nestle.

Nestlé, 2018. *Zero water - It's possible to use 'zero water' in manufacturing - here's how.* [Online]
Available at: www.nestle.com/stories/zero-water-factory
[Accessed 25 November 2018].

Nickels, L., 2014. *Membrane process increases energy efficiency in milk production.* [Online] Available at: www.filtsep.com/food-and-beverage/news/membrane-process-increases-energy-efficiency-in/

Niro, 2003. *New NIRO Milk Powder Plant.* [Online]
Available at: www.niro.com.au/News%20TMI.html>
[Accessed 2004].

Novozymes, n.d.. *Say goodbye to biofilm, with enzymes.* [Online]
Available at: www.dairyfoods.com/ext/resources/White_Papers/Novozymes-Realco-BioTimes-article.pdf

NSW EPA, 2017. *The Waste Hierarchy.* [Online]
Available at: www.epa.nsw.gov.au/your-environment/recycling-and-reuse/warr-strategy/the-waste-hierarchy

NSW OEH, 2014. *Energy Saver, Energy Efficient Lighting Technology Report,* s.l.: NSW Office of Environment and Heritage.

NSW OEH, 2015. *I am your optimisation guide: Heating, Ventilation and Air Conditioning Systems,* s.l.: NSW Office of Environment and Heritage.

NSW OEH, 2016. *I am your guide to Voltage Optimisation,* www.environment.nsw.gov.au: NSW Office of Environment and Heritage.

NSW OEH, 2017. *I am your refrigeration guide,* s.l.: NSW Office Environment and Heritage. Produced by Consultancy Minus 40.

Numedic, 2018. *Hydrofan.* [Online]
Available at: numedic.co.nz/products/hand-held-hydrofan-nozzle/
[Accessed 13th Nov 2018].

Oakley Greenwood, 2018. *Gas Price Trends Review 2017,* s.l.: Department of Environment and Energy.

O'Halloran, S., 2013. *Looking ahead: Dairy industry trends & challenges.* [Online]
Available at: www.foodengineeringmag.com/articles/91280-looking-ahead-dairy-industry-trends-challenges
[Accessed 24 November 2018].

Palmowski, L., Baskaran, K., Wilson, H. & Watson, B., 2005. *Clean in Place – A Review of Current Technology and its Use in the Food and Beverage Industry,* s.l.: School of Engineering and Technology Deakin University.

Pararshar, A. et al., 2016. Incorporation of whey permeate, a dairy effluent, in ethanol fermentation to provide a zero waste solution for the dairy industry. *Journal of Dairy Science,* 99(3), pp. 1859-1867.

Parker, J. & Longmuir, W., 1999. *Cleaner Production in the Australian dairy processing industry, WSL Consultants Pty Ltd.* Hobart, Tasmania, Australian Water and Wastewater Association and Waste Management Association of Australia.

Parmalat, 2015. *Sustainability Report,* s.l.: Parmalat.

Parmalat, 2017. *Sustainability Report,* s.l.: Parmalat.

PCI-Memtech, 2000. *Factsheets: Preconcentration of milk for soft cheeses and yoghurt using membrane technology; 2. Increased cheese vat utilization;,* viewed March 2004: PCI-Memtech.

PCI-Memtech, 2000. *Factsheets:1. Preconcentration of milk for soft cheeses and yoghurt using membrane technology; 2. Increased cheese vat utilisation; 3. Membrane technology for whey protein concentrate production. 4. Evaporator condensate recovery.* [Online] Available at: www.pci-memtech.com
[Accessed March 2004].

Pers Comm, 2004. *Manfred Schneider.* s.I.:Steam Link Queensland.

Pers Comm, 2004. *Phillip Carruthers.* s.I.:Norman, Disney and Young.

Pers Comm, 2018. *Neil Rosier,* s.I.: Bega Cheese Ltd. Group Manager Safety and Sustainability.

Pers Comm, 2019. *Ian Olmstead,* s.I.: Dairy Australia Program Manager - Manufacturing Innovation & Sustainability - Trade & Industry Strategy.

Powitz, R. W., 2014. *Chemical-free Cleaning: Revisited.* [Online]
Available at: www.foodsafetymagazine.com/magazine-archive1/octobernovember-2014/chemical-free-cleaning-revisited/

Prasad, P., Pagan, R., Kauter, M. & Price, N., 2004. *Ecoefficiency for the Dairy Processing Industry,* Melbourne: Dairy Australia.

Prasad, P., Price, N. & Gaffel, J., 2017. *Sustainable Manufacturing – a literature review with case studies,* Brisbane: Queensland Departement of State Development.

Price, B., 2015. *Water Reduction in Food Processing Facilities.* s.I., Food Processing Suppliers Association (FPSA) 2015 Conference.

Pryde Measurement, 2009. Dairy reduces effluent and increases yield with TOC analysis. *Process Online - Process Technology*, 4th June, pp. www.processonline.com.au/content/instrumentation/article/dairy-reduces-effluent-and-increases-yield-with-toc-analysis-738534479.

Qld Govt., 2016a. *Information sheet, Environmental Protection Regulation 2008, Paying a reduced annual fee.* [Online]
Available at: www.ehp.qld.gov.au/assets/documents/regulation/era-is-reduced-annual-fee.pdf

Qld Govt, 2006. *Cooling Towers - Ecoefficiency Opportunities for Queensland Manufacturers,* www.ecoefficiencygroup.com.au: Queensland Government..

Qld Govt, 2009. *Reducing Solid Waste - Eco-efficiency resources for the food processing industry,* Brisbane: Queensland Government.

Qld Govt, 2017. *Beard & Brau Farmhouse Brewery - Case Study.* [Online]
Available at: www.ecoefficiencygroup.com.au/wp-content/uploads/2018/07/Case_Study_BB.pdf

RIRDC, 2017. *Biomass Producer - Meredith Dairy heats up with Wood Waste. Rural Industry Research and Development Corporation.* [Online]
Available at: biomassproducer.com.au/project/meredith-dairy-heats-up-with-wood-waste
[Accessed 4th Feb 2019].

RIRDC, n.d. *Power from dairy manufacturing waste.* [Online]
Available at: biomassproducer.com.au/case_study/power-from-dairy-manufacturing-waste/#.W9FZDExuLIX

RMCG, 2018. *Saline Wastes in Northern Victoria-Management Strategy.,* s.l.: Dairy Australia. RM Consulting Group Pty Ltd.

Rockwell Automation, 2018. Automating yoghurt production in Chobani's new plant. *Process Online, Process Technology*, 2nd March, pp. www.processonline.com.au/content/industrial-networks-buses/case-study/automating-yoghurt-production-in-chobani-s-new-plant-338495663.

Romney, A., 1990. Chapter 1, Principles of cleaning. In: *CIP: cleaning in place,.* s.l.:Society of Dairy Technology, Cambridgeshire, UK.

Schmidt, R. H., 2015. *Basic elements of equipment cleaning and sanitising in food processing and handling operations,* s.l.: University of Florida - IFAS Extension.

SEAV, 2002a. *Infosheet: Combustion trim for boilers,* s.l.: Sustainable Energy Authority Victoria..

SEAV, 2002b. *Energy and Greenhouse Management Toolkit. Module 5,* www.seav.viv.gov.au/advice/business/EGMToolkit.html: Sustainable Energy Authority Victoria.

SEDA, 2003. *Enerrgy smart compressed air calculator.* [Online]
Available at: www.energysmart.com.au/wes/DisplayPage.asp?PageID=53
[Accessed March 2004].

Shuck, P. et al., 2015. Energy Consumption in the Processing of Dairy and Feed Powders by Evaporation and Drying. *Drying Technology,* pp. 33: 176–184, 2015.

Smith, G., 2004. *Personal communication.* Queensland: Spirax Sarco Queensland,.

Solar Choice, 2018. *Commercial solar PV price index.* [Online]
Available at: www.solarchoice.net.au/blog/commercial-solar-pv-price-index-for-august-2018

Somsen, D. & Capelle, A., 2002. Introduction to production yield analysis - a new tool for improvement of raw material yield. *Trends in Food Science and Technology,* 13(4), pp. 136-145.

Susmilk, 2016. *Redesign of the dairy industry for sustainable milk processing - absorption chillers.* [Online]
Available at: www.susmilk.com/index.php/en-home/en-the-industrial-application/en-absorption-chillers
[Accessed 10th November 2018].

Sustainability Victoria, 2006. *Energy Efficiency Best Practise Guide - Compressed Air Systems,* s.l.: Energy Efficiency Exchange.

Sustainability Victoria, 2009. *Best Practice Guide: Industrial Refrigeration,* s.l.: s.n.

Sustainability Victoria, est 2010. *Case study Energy Efficiency Best Practices Pumping Systems Murray Goulburn Koroit,* s.l.: s.n.

Teco Australia, 2003. *Premium efficiency motors Max-E2, information brochure.* [Online]
Available at: www.teco.com.au

Tetra Pak, 1995. *Dairy Processing Handbook.,* Lund, Sweden: Tetra Pak Processing Systems AB, .

Tetrapak, 2015. *Dairy Processing Handbook. Revision 1.* s.l.:Tetrapak International S.A..

Tetrapak, 2015. *Partial homogenization,* s.l.: https://dairyprocessinghandbook.com/chapter/homogenizers.

Thomson, N., 2016. *Making the best of energy in your dairy.* [Online]
Available at: www.dairyreporter.com/Article/2016/05/10/Making-the-best-of-energy-in-your-dairy

UK Environment Agency, 2009. *How to comply with your environmental permit. Additional guidance for Dairy and Milk Processing Sector (EPR 6.13),* s.l.: UK Environment Agency.

UNEP Working Group for Cleaner Production, 1999. *The potential for generating energy from wet waste streams in NSW,* s.l.: NSW Sustainable Energy Development Authority.

UNEPTIE, 2003. *Environmental Management Tools - cleaner production, viewed 4th May 2004,* s.l.: United Nations Environment Program.

UNFCC, 2015. *Paris Agreement,* s.l.: United Nations Framework Climate Change.

University of Minnesota, 2003. *Schroder milk saves $400 000 through product savings and water conservation.* [Online]
Available at: mntap.umn.edu/food/cs80.html
[Accessed August 2003].

USDOE, 2002. *Energy tips: Insulate steam distribution and condensate return lines,* Washington: US Department of Energy. Office of Industrial Technologies, Energy.

USDOE, 2004. *Energy efficiency and renewable energy website: Motor selector software,.* [Online]
Available at: www.oit.doe.gov/bestpractices/compressed_air/
[Accessed July 2004].

USDOE, 2011. *Cooling Towers: Understandng key components and how to improve water efficiency,* s.l.: US Department of Energy. Federal Energy Management Program.

USDOE, 2014. *Determining electric motor load and efficiency. Factsheet,* s.l.: US Department of Energy Motor Challenge.

USEPA, 2011. *Energy Star Guide - Energy Efficiency Improvement and Cost Saving Opportunities for the Dairy Processing Industry,* s.l.: Ernest Orlando Lawrence Berkeley National Laboratory. Funded by US Environmental Protection Agency.

Varga, L. & Szigeti, J., 2016. Use of ozone in the dairy industry: A review. *Journal of Dairy Technology,* May, Volume 69, pp. 157-168.

Visy, 2015. *There is 'A Better Way'.* [Online]
Available at: www.visy.com.au/there-is-a-better-way/
[Accessed 24 November 2018].

Walmsley, M., Walmsley, T., Atkins, M. & Neale, J., 2016. Sustainable Milk Powder Production using Enhanced Process Integration and 100 % Renewable Energy. *Chemical Engineering Transactions. Vol 52,* p. Pg 559.

Walmsley, T. et al., 2016. Total site utility systems optimisation for milk powder production. *Chemical Engineering Transactions,* Volume 52, pp. 235-240.

Walmsley, T. G., Walmsley, M. R., Neale, J. R. & Atkins, M. J., 2015. *Pinch Analysis of an Industrial Milk Evaporator with Vapour Recompression Technologies.* s.l., The University of Waikato.

Walmsley, T. et al., 2015. Thermo-economic optimisation of industrial milk spray dryer exhaust to inlet air heat recovery. *Energy,* pp. 1-10.

WBCSD, n.d.. *Ecoefficiency Learning Module,* s.l.: World Business Council for Sustainable Development.

WCBF, 2018. *Warrnambool Cheese and Butter - Environment.* [Online]
Available at: www.wcbf.com.au/en/our-promise/environment
[Accessed 21 11 2018].

WCBF, est 2012. *Sustainable Productivity - the challenge - making more with less. Powerpoint presentation by David Lord CEO and Managing Director. Downloaded from www.hotcopper.com.au.* s.l., Warrnambool Cheese and Butter.

Weeks, M. et al., 2007a. *Closing the Loop: Investigation of alternative CIP chemicals and practices for reduction in sodium in dairy processor waste streams: Stage 3 Factory evaluation of low sodium cleaners,* Melbourne: DISC, Victoria DPI, RMIT, Food Science Austrlaia, Deakin Universtity.

Weeks, M. et al., 2007. *Closing the loop [electronic resource] : an holistic approach to the management of dairy processor waste streams : investigation of alternative CIP chemicals and practices for reduction in sodium in dairy processor waste streams : stage 4 - bringing it al,* s.l.: Dairy Industries Sustainability Consortium.

Wilbey, R., 2011. Homogenization of Milk: Principles and Mechanism of Homogenization, Effects and Assessment of Efficiency: Valve Homogenizers. *Encyclopedia of Dairy Sciences,* pp. 750-754.

Wood, T., Blowers, D. & Griffiths, K., 2017. *Powering through: how to restore confidence in the National Electricity Market,* Melbourne: The Grattan Institute.

WRAP, 2012. *Clean-in-Place,* s.l.: Waste and Resources Action Programme.

WRAP, 2013. *Water Minimisation in the Food and Drink Industry,* s.l.: Waste and Resources Action Program.

Wright, W., 1990. Chapter 3 The Chemistry of detergents. In: A. Romney, ed. *CIP. cleaning in place.* Cambridgeshire: Society of Dairy Technology.

WS_Atkins_Consultants_Ltd, 1997. *Cost effective membrane technologies for minimising waste and effluents,* s.l.: Environmental Technology Best Practice Programme, Good Practice Guide No. 5.

WWF, 2010. *The WWF Guide to Buying Paper,* s.l.: WWF World Wide Fund Pulp and Paper Programme.

Yoo, J. Y., Kim, H. J., Woo, E. J. & Park, C. J., 2017. On Solar Energy Utilization for Drying Technology. *International Journal of Environmental Science and Development,* 8(4), pp. 305-311.

Yoon, S.-H., 2016. Classification of membranes according to pore size.. In: *Excerpt from Membrane Bioreactor Processes Principles and Applications.* s.l.:s.n.

Zhang, Y. et al., 2018. Modelling of a milk powder falling film evaporator for predicting process trends and comparison of energy consumption. *Journal of Food Engineering,* Volume Edition 225, pp. 25-33.

Dairy Australia Limited ABN 60 105 227 987
Level 3, HWT Tower
40 City Road, Southbank Vic 3006 Australia
T +61 3 9694 3777 F +61 3 9694 3701
E enquiries@dairyaustralia.com.au
dairyaustralia.com.au

1881 | June 2019