

Cleaner Production Assessment in Meat Processing

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for



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PREFACE

The purpose of the Industrial Sector Guides for Cleaner Production Assessment is to raise awareness of the environmental impacts associated with industrial and manufacturing processes, and to highlight the approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

This guide is designed for two principal audiences:

- People responsible for environmental issues at meat processing plants (environmental managers or technicians) who seek information on how to improve production processes and products. In many countries, managers are ultimately responsible for any environmental harm caused by their organisation's activities, irrespective of whether it is caused intentionally or unintentionally.
- Environmental consultants, Cleaner Production practitioners, employees of industry bodies, government officers or private consultants that provide advice to the meat processing industry on environmental issues.

This guide describes Cleaner Production opportunities for improving resource efficiency and preventing the release of contaminants to air, water and land. The Cleaner Production opportunities described in this guide will help improve production as well as environmental performance.

Chapter 1 provides a brief introduction to the concept of Cleaner Production and the benefits that it can provide.

Chapter 2 provides an overview of the meat processing industry including process descriptions, environmental impacts and key environmental indicators for the industry.

Chapter 3 describes Cleaner Production opportunities for each of the unit operations within the process and provides examples of their successful application. The processes discussed in most detail are the slaughtering of pigs and cattle, carcass dressing, casings and offal processing and rendering, as well as cleaning and ancillary operations. Quantitative data for the inputs and outputs associated with each unit operation are provided as an indication of typical levels of resource consumption and waste generation.

Chapter 4 provides a case study demonstrating the application of Cleaner Production at a meat processing plant.

Chapter 5 describes the Cleaner Production assessment methodology in detail. It can be used as a reference guide for carrying out a Cleaner Production assessment within an organisation.

Annex 1 contains a reference and bibliography list.

Annex 2 contains a glossary and list of abbreviations.

Annex 3 contains a list of literature and contacts for obtaining further information about the environmental aspects of the industry.

Annex 4 contains background information about the UNEP Division of Technology, Industry and Economics (UNEP DTIE).

Monetary figures quoted in this guide are based on 1995–98 figures and are presented as US dollars for consistency. As prices vary from country to country and from year to year, these figures should be used with care. They are provided as a guide to capital expenditure and savings only.

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EXECUTIVE SUMMARY

This document is one in a series of Industrial Sector Guides published by the United Nations Environment Programme UNEP Division of Technology, Industry and Economics (UNEP DTIE) and the Danish Environmental Protection Agency. The documents in this series include:

- *Cleaner Production Assessment in Dairy Processing;*
- *Cleaner Production Assessment in Meat Processing;* and
- *Cleaner Production Assessment in Fish Processing.*

This document is a guide to the application of Cleaner Production to the meat processing industry, with a focus on the slaughtering of cattle and pigs at abattoirs. Its purpose is to raise awareness of the environmental impacts of meat processing, and to highlight approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

The life cycle of meat products commences with the production of livestock. Beef cattle are raised on grazing properties or in intensive feedlots. Pigs are generally raised intensively at piggeries. At abattoirs, livestock are slaughtered and the carcasses dressed to produce sides of meat. The basic steps in this process are stunning and bleeding, hide removal or hide treatment, evisceration and carcass dressing. It is common for abattoirs to also undertake the boning of carcasses to produce smaller retail cuts of meat.

Even though meat is the most significant product from the abattoir, by-products such as hides, blood, fat, bone and offal are also produced. The profitability of an abattoir can often depend on the extent to which these materials are utilised. Edible by-products are further processed into saleable products and inedible by-products are converted into animal feed supplements by rendering.

From the abattoir, carcasses, boned meat and edible by-products are distributed on a wholesale basis to butchers or to other meat processing plants for further processing into specialty products and processed meats. Retail cuts of meat are packaged and then further distributed to retail outlets. Fresh meat products are highly perishable and refrigerated storage is required throughout their life to maintain eating appeal and prevent microbiological spoilage. The life cycle ends with consumption by the consumer and disposal or recycling of the packaging.

In this guide, the upstream process of livestock production, and the downstream processes of distribution and post-consumer packaging management are not covered. The manufacture of specialty meat products and processed meats is also not covered. The guide focuses on activities, which occur at abattoirs, namely, slaughter and its associated processes. The slaughtering of livestock is a significant contributor to the overall environmental load produced over the life cycle of meat production and consumption. Therefore, the application of Cleaner Production in this phase of the life cycle is important.

As with many food processing industries, the key environmental issues associated with abattoir operations are the high consumption of water, the generation of high-strength effluent streams, the consumption of energy and the generation of by-products. For some sites, noise and odour may also be concerns.

This guide contains background information about the industry and its environmental issues, including quantitative data on rates of resource consumption and waste generation, where available. It also describes examples of ways to improve the environmental performance of abattoir operations through the application of Cleaner Production. Case studies of successful Cleaner Production projects are also presented.

Cleaner Production

Cleaner Production is defined as *the continuous application of an integrated, preventive, environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment*. It is different to the traditional 'pollution control' approach to environmental management. Where pollution control is an after-the-event, 'react and treat' approach, Cleaner Production is a proactive, 'anticipate and prevent' philosophy.

Cleaner Production has most commonly been applied to production processes, by bringing about the conservation of resources, the elimination of toxic raw materials, and the reduction of wastes and emissions. However it can also be applied throughout the life cycle of a product, from the initial design phase, through to the consumption and disposal phase. Techniques for implementing Cleaner Production include improved housekeeping practices, process optimisation, raw material substitution, new technology or new product design.

The other important feature of Cleaner Production is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, an organisation can benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability. Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than relying on increasingly expensive 'end-of-pipe' solutions. There have been many examples that demonstrate the financial benefits of the Cleaner Production approach as well as the environmental benefits.

Water consumption

Water is used for the watering and washing of livestock, the washing of trucks, washing of carcasses and by-products, and for cleaning and sterilising equipment and process areas.

Rates of water consumption can vary considerably depending on the scale of the plant, the age and type of processing, the level of automation, and cleaning practices. Typical figures for fresh water consumption are 2–15 m³ per tonne of live carcass weight.

In most parts of the world, the cost of water is increasing as supplies of fresh water become scarcer and as the true environmental costs of its supply are taken into consideration. Water is therefore becoming an increasingly valuable commodity and its efficient use is becoming more important.

Strategies for reducing water consumption can involve technological solutions or equipment upgrade. However reviewing cleaning procedures and operator practices can make some of the most significant gains.

Some key strategies for reducing water consumption are listed below, and the use of these techniques would represent best practice for the industry:

- undertaking dry cleaning of trucks prior to washing with water;
- using automatically operated scalding chambers rather than scalding tanks for the de-hairing of pigs;
- using offal transport systems that avoid or minimise the use of water;
- using dry dumping techniques for the processing of cattle paunches and pig stomachs that avoid or minimise the use of water, instead of wet dumping techniques;
- reusing relatively clean wastewaters from cooling systems, vacuum pumps etc. for washing livestock if possible;
- reusing final rinse waters from paunch and casings washing for other non-critical cleaning steps in the casings department;
- reusing wastewaters from the slaughter floor, carcass washing, viscera tables and hand-wash basins for the washing of inedible products if possible;
- reusing cooling water from the singeing process for other application in the pig de-hairing area;
- reusing the final rinse from cleaning operations for the initial rinse on the following day;
- using dry cleaning techniques to pre-clean process areas and floors before washing with water;
- using high pressure rather than high volume for cleaning surfaces;
- using automatic control systems to operate the flow of water in hand-wash stations and knife sterilisers.

Effluent discharge

Most water consumed at abattoirs ultimately becomes effluent. Abattoir effluent contains high levels of organic matter due to the presence of manure, blood and fat. It can also contain high levels of salt, phosphates and nitrates. The most significant contributor to the organic load is blood, followed by fat. Blood is also the major contributor to the nitrogen content of the effluent stream. Salt and phosphorus originate from the presence of manure and stomach contents in the effluent. At those plants where rendering occurs, the effluent from rendering typically represents the single most significant source of pollutant load in abattoir effluent.

It follows therefore that effluent quality depends on the extent to which blood, fat, manure and stomach contents are excluded from the effluent stream, and whether or not rendering occurs at the site. Typical values for the organic loads discharged in abattoir effluent are 4–18 kg COD per tonne of live carcass weight.

Strategies for reducing the pollutant load of abattoir effluent principally focus on excluding blood, fat, manure and scraps of meat from the effluent stream. This means capturing materials before they enter drains and using dry cleaning methods.

Some key strategies are listed below:

- maximising the segregation of blood by designing suitable blood collection facilities and allowing sufficient time for bleeding, typically seven minutes;
- sweeping up solid materials for use as by-products, instead of washing them down the drain;
- fitting drains with screens and/or traps to prevent solid materials from entering the effluent system;
- using offal transport systems that avoid or minimise the use of water;
- using water sprays with a pressure of less than 10 bar for carcass washing to avoid removing fat from the surface;
- using dry cleaning techniques to pre-clean process areas and floors before washing with water;
- segregating high-strength effluent streams, such as rendering effluent and wastewaters from paunch washing, and treating them separately.

Energy consumption

Approximately 80–85% of total energy consumed by abattoirs is provided by thermal energy from the combustion of fuels in on-site boilers. Thermal energy is used to heat water for cleaning, pig scalding, rendering, blood coagulation and blood drying. The remaining 15–20% of energy is provided by electricity, which is used for operating equipment in the slaughter and boning areas, for by-product processing, and for refrigeration and compressed air. Typical ranges for the energy consumption are 1200–4800 MJ per tonne of hot standard carcass weight.

Energy is an area where substantial savings can be made almost immediately with no capital investment, through simple housekeeping efforts. Additional savings can be made through the use of more energy-efficient equipment and heat recovery systems. Some key strategies are listed below:

- implementing switch-off programs and installing sensors to turn-off or power-down lights and equipment when not in use;
- improving insulation on heating or cooling systems and pipework etc.;
- insulating and covering scald tanks to prevent heat loss;
- recovering waste heat from effluent streams, vents, exhausts and compressors;
- recovering evaporative energy in the rendering process using multi-effect evaporators;
- maintaining a leak-free compressed air system;
- favouring more efficient equipment;
- improving maintenance to maximise energy efficiency of equipment;
- maintaining optimal combustion efficiencies on boilers;
- eliminating steam leaks;

In addition to reducing a plant's demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas,

purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

Implementing a Cleaner Production assessment

This guide contains information to help the reader undertake a Cleaner Production assessment at an abattoir. A Cleaner Production assessment is a systematic procedure for identifying areas of inefficient resource consumption and poor waste management, and for developing Cleaner Production options. The methodology described in this guide is based on that developed by UNEP and UNIDO, and consists of the following basic steps:

- planning and organising the Cleaner Production assessment;
- pre-assessment (gathering qualitative information about the organisation and its activities);
- assessment (gathering quantitative information about resource consumption and waste generation and generating Cleaner Production opportunities);
- evaluation and feasibility assessment of Cleaner Production opportunities;
- implementation of viable Cleaner Production opportunities and developing a plan for the continuation of Cleaner Production efforts.

It is hoped that by providing technical information on known Cleaner Production opportunities and a methodology for undertaking a Cleaner Production assessment, individuals and organisations within the meat processing industry will be able to take advantage of the benefits that Cleaner Production has to offer.

1 CLEANER PRODUCTION

1.1 What is Cleaner Production?¹

Over the years, industrialised nations have progressively taken different approaches to dealing with environmental degradation and pollution problems, by:

- ignoring the problem;
- diluting or dispersing the pollution so that its effects are less harmful or apparent;
- controlling pollution using 'end-of-pipe' treatment;
- preventing pollution and waste at the source through a 'Cleaner Production' approach.

The gradual progression from 'ignore' through to 'prevent' has culminated in the realisation that it is possible to achieve economic savings for industry as well as an improved environment for society. This, essentially, is the goal of Cleaner Production.

Definition of Cleaner Production

Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment.

- For production processes, Cleaner Production involves the conservation of raw materials and energy, the elimination of toxic raw materials, and the reduction in the quantities and toxicity of wastes and emissions.
- For product development and design, Cleaner Production involves the reduction of negative impacts throughout the life cycle of the product: from raw material extraction to ultimate disposal.
- For service industries, Cleaner Production involves the incorporation of environmental considerations into the design and delivery of services.

Difference between Cleaner Production and pollution control

The key difference between pollution control and Cleaner Production is one of timing. Pollution control is an after-the-event, 'react and treat' approach, whereas Cleaner Production reflects a proactive, 'anticipate and prevent' philosophy. Prevention is always better than cure.

This does not mean, however, that 'end-of-pipe' technologies will never be required. By using a Cleaner Production philosophy to tackle pollution and waste problems, the dependence on 'end-of-pipe' solutions may be reduced or in some cases, eliminated altogether.

Cleaner Production can be and has already been applied to raw material extraction, manufacturing, agriculture, fisheries, transportation, tourism, hospitals, energy generation and information systems.

Changing attitudes

It is important to stress that Cleaner Production is about attitudinal as well as technological change. In many cases, the most significant Cleaner Production benefits can be gained through lateral thinking,

¹ This chapter has been adapted from a UNEP publication, *Government Strategies and Policies for Cleaner Production*, 1994.

without adopting technological solutions. A change in attitude on the part of company directors, managers and employees is crucial to gaining the most from Cleaner Production.

Applying know-how

Applying know-how means improving efficiency, adopting better management techniques, improving housekeeping practices, and refining company policies and procedures. Typically, the application of technical know-how results in the optimisation of existing processes.

Improving technology

Technological improvements can occur in a number of ways:

- changing manufacturing processes and technology;
- changing the nature of process inputs (ingredients, energy sources, recycled water etc.);
- changing the final product or developing alternative products; and
- on-site reuse of wastes and by-products.

Types of Cleaner Production options

Housekeeping	Improvements to work practices and proper maintenance can produce significant benefits. These options are typically low cost.
Process optimisation	Optimising existing processes can reduce resource consumption. These options are typically low to medium cost.
Raw material substitution	Environmental problems can be avoided by replacing hazardous materials with more environmentally benign materials. These options may require changes to process equipment.
New technology	Adopting new technologies can reduce resource consumption and minimise waste generation through improved operating efficiencies. These options are often highly capital intensive, but payback periods can be quite short.
New product design	Changing product design can result in benefits throughout the life cycle of the product, including reduced use of hazardous substances, reduced waste disposal, reduced energy consumption and more efficient production processes. New product design is a long-term strategy and may require new production equipment and marketing efforts, but paybacks can ultimately be very rewarding.

1.2 Why invest in Cleaner Production?

Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions.

Cleaner Production versus pollution control

When Cleaner Production and pollution control options are carefully evaluated and compared, the Cleaner Production options are often more cost effective overall. The initial investment for Cleaner Production options and for installing pollution control technologies may be similar, but the ongoing costs of pollution control will generally be greater than for Cleaner Production. Furthermore, the Cleaner Production option will generate savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance.

Greener products

The environmental benefits of Cleaner Production can be translated into market opportunities for 'greener' products. Companies that factor environmental considerations into the design stage of a product will be well placed to benefit from the marketing advantages of any future eco-labelling schemes.

Some reasons to invest in Cleaner Production

- improvements to product and processes;
- savings on raw materials and energy, thus reducing production costs;
- increased competitiveness through the use of new and improved technologies;
- reduced concerns over environmental legislation;
- reduced liability associated with the treatment, storage and disposal of hazardous wastes;
- improved health, safety and morale of employees;
- improved company image; and
- reduced costs of end-of-pipe solutions.

1.3 Cleaner Production can be practiced now

It is often claimed that Cleaner Production techniques do not yet exist or that, if they do, they are already patented and can be obtained only through expensive licences. Neither statement is true, and this belief wrongly associates Cleaner Production with 'clean technology'.

Cleaner Production also covers changing attitudes and management

Firstly, Cleaner Production depends only partly on new or alternative technologies. It can also be achieved through improved management techniques, different work practices and many other 'soft' approaches. Cleaner Production is as much about attitudes, approaches and management as it is about technology.

Cleaner Production techniques already exist

Secondly, Cleaner Production approaches are widely and readily available, and methodologies exist for its application. While it is true that Cleaner Production technologies do not yet exist for all industrial processes and products, it is estimated that 70% of all current wastes and emissions from industrial processes can be prevented at source by the use of technically sound and economically profitable procedures (Baas et al., 1992).

1.4 Cleaner Production and sustainable development

In the past, companies have often introduced processes without considering their environmental impact. They have argued that a trade-off is required between economic growth and the environment, and that some level of pollution must be accepted if reasonable rates of economic growth are to be achieved. This argument is no longer valid, and the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992, established new goals for the world community that advocate environmentally sustainable development.

Economy and environment go hand in hand

Cleaner Production can contribute to sustainable development, as endorsed by Agenda 21. Cleaner Production can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets. Setting goals across a range of sustainability issues leads to 'win-win' situations that benefit everyone. Cleaner Production is such a 'win-win' strategy: it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness.

Cleaner Production can provide advantages for all countries

Cleaner Production can be especially beneficial to developing countries and those undergoing economic transition. It provides industries in these countries with an opportunity to 'leapfrog' those more established industries elsewhere that are saddled with costly pollution control.

1.5 Cleaner Production and quality and safety

Safety and quality are very important issues for the food industry. While food safety has always been an important concern for the industry, it has received even greater attention over the past decade due to larger scales of production, more automated production processes and more stringent consumer expectations. A stronger emphasis is also being placed on quality due to the need for companies to be more efficient in an increasingly competitive industry.

In relation to food safety, Hazard Analysis Critical Control Point (HACCP) has become a widely used tool for managing food safety throughout the world. It is an approach based on preventing microbiological, chemical and physical hazards within food production processes by anticipating and preventing problems, rather than relying on inspection of the finished product.

Similarly, quality systems such as Total Quality Management (TQM) are based on a systematic and holistic approach to production processes and aim to improve product quality while lowering costs.

Cleaner Production should operate in partnership with quality and safety systems and should never be allowed to compromise them. As well, quality, safety and Cleaner Production systems can work synergistically to identify areas for improvement in all three areas.

1.6 Cleaner Production and environmental management systems

Environmental issues are complex, numerous and continually evolving, and an *ad hoc* approach to solving environmental problems is no longer appropriate. Companies are therefore adopting a more systematic approach to environmental management, sometimes through a formalised environmental management system (EMS).

An EMS provides a company with a decision-making structure and action programme to bring Cleaner Production into the company's strategy, management and day-to-day operations.

ISO 14001

As EMSs have evolved, a need has arisen to standardise their application. An evolving series of generic standards has been initiated by the International Organization for Standardization (ISO), to provide company management with the structure for managing environmental impacts. The UNEP/ICC/FIDIC *Environmental Management System Training Resource Kit*, mentioned above, is compatible with the ISO 14001 standard.

EMS training resources

UNEP DTIE, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*, which functions as a training manual to help industry adopt EMSs.

2 OVERVIEW OF MEAT PROCESSING

Meat and meat products are an important component of diet in many parts of the world, particularly in developed nations, where the consumption of animal protein per head of population is the highest. For developing nations, the production and consumption of meat is increasing as levels of affluence increase.

Table 2—1 provides an overview of world meat production, showing the contributions of different meat species to overall meat-production and the relative scales of production for the major meat producing countries. Of the red meats, pork and beef are produced in the greatest quantities. Poultry meat is also a major source of world meat production. China and the United States of America are the world's largest producers of beef and pork. Brazil, Mexico, the Russian Federation and a number of western European countries are also large producers.

The slaughter of livestock to produce meat and meat products is a widespread activity and can be an important industry in many countries.

Table 2—1 Overview of world meat production ¹

	Beef (includes veal)	Pork	Mutton, lamb and goat meat	Poultry
Total world production (1000 tonnes/yr)	45,293	69,696	6,435	53,282
Percentage of world production	26%	40%	4%	30%
Major producing countries (1000 tonnes/yr)				
Argentina	2,600	-	82	675
Australia	1,839	344	580	498
Brazil	4,475	1,300	-	3,491
China	3,300	32,048	1,609	7,550
Denmark	190	1,537	2	172
France	1,592	2,126	154	1,961
Germany	1,447	3,030	41	641
India	1,050	-	615	-
Italy	1,170	1,369	79	1,084
Japan	602	1,390	-	1,302
Mexico	1,810	900	140	1,240
Netherlands	603	1,673	18	594
New Zealand	572	45	513	-
Philippines	135	715	-	-
Russian Federation	3,100	2,260	310	1,170
Spain	478	2,107	240	880
Taiwan	5	1,204	-	604
United Kingdom	918	1,053	352	1,2789
United States of America	11,194	8,027	140	13,206

¹ Derived from data presented in Ockerman and Hansen, 2000

Terminology

Meat processing is the generic term used to describe the industry. However a number of terms are used to describe the facilities at which meat processing occurs, including abattoirs, slaughterhouses and meat packing plants.

The terms *abattoir* and *slaughterhouse* are synonymous and refer to plants which slaughter livestock and dress carcasses only, often with limited or no processing of by-products. The products from these plants are usually dressed carcasses, which are sold on a wholesale basis to butchers and other meat processing plants. However, it is common for abattoirs or slaughterhouses to also undertake the boning of carcasses to produce retail cuts.

Meat packing plants undertake slaughter and carcass dressing, but also undertake the further processing of meat products and by-products. A meat packing plant will often undertake the cooking, curing, smoking and pickling of meat and the manufacture of sausage.

Focus of this guide

Since livestock slaughter along with its associated activities contributes the most to pollution loads from the meat processing industry as a whole, this guide focuses on abattoir (or slaughterhouse) operations. There is no discussion on the further processing of meat. For simplicity the term *abattoir* will be used throughout this document.

Slaughtering can take place either on farms, at butchers' premises or at abattoirs. Consequently, the scale on which slaughtering takes place can vary enormously, from slaughtering only a few animals through to thousands each day. Methods and equipment for slaughtering may vary, but the basic principles are independent of plant capacity.

Large, highly automated abattoirs may specialise in the slaughter of one species of livestock. However it is also common for abattoirs to kill a number of species at a single premises. Species slaughtered include beef cattle, pigs, sheep, goats, horses and deer. This guide covers the slaughter of beef cattle and pigs only and does not discuss the other species specifically. However, many of the Cleaner Production principles will apply also to them.

For small-scale operations taking place on farms or at butchers' premises, mechanisation is limited and extensive use is made of all by-products, meaning that very little waste and pollution are created. This guide does not deal with such small-scale operations, since the Cleaner Production opportunities described in this guide are generally not applicable or viable in these situations. Instead, the guide describes the application of Cleaner Production to medium and large-scale abattoirs.

An increasing trend in many countries is for abattoirs to incorporate rendering facilities to process solid by-product materials into meat meal and tallow. For abattoirs without rendering facilities, by-products are sent to independent rendering plants. German abattoirs, for example, do not undertake rendering since by law it must be performed in a separate off-site facility.

Units of production

There are a number of units used to describe the scale of production in abattoirs. Commonly used units are per head of livestock slaughtered, tonne of live carcass weight (LCW), tonne of dressed weight (DW) or tonne of hot standard carcass weight (HSCW). Units based on carcass weight are often most useful because they allow for comparison between abattoirs slaughtering livestock with different unit weights. Data presented in this document are reported according to the units used in the original source, therefore the units may vary.

2.1 Process overview

The generic processes that take place at abattoirs are stunning and bleeding, hide removal or treatment, evisceration, carcass dressing and washing. Many abattoirs also have a boning process in which finished carcasses are cut into retail portions. Most abattoirs also have casings and offal processing departments, which produce value-added products from the casings (intestinal tract) and edible offal. The sections that follow provide a brief description of these processes.

2.1.1 Slaughtering and processing of pigs

The basic process for slaughtering and processing pigs is shown in Figure 2—1.

<i>Pre-handling of pigs</i>	Pigs are delivered to the abattoir in trucks, and held for one to two days in holding yards. They are generally fasted for a day to reduce the amount of intestinal contents.
<i>Stunning and bleeding</i>	Pigs are stunned using an electric shock or by anaesthetising in carbon dioxide, after which they are bled. Bleeding, also referred to as sticking, is carried out using a hollow knife, which directs the blood to a collection trough, from where it is pumped to an agitated tank for further processing.
<i>Dehairing and finishing</i>	Before being processed further, hair is removed from the pig carcasses, by scalding in hot water followed by scraping. Carcasses are then singed to remove any remaining hair. This process leaves the hide almost white in colour, clean and smooth without any trace of hair.
<i>Evisceration and splitting</i>	After dehairing and hide finishing, the carcasses pass to the evisceration area, where the stomachs are opened and the viscera removed. The breastbone is split and the plucks (heart, liver and lungs) are loosened and removed. The carcasses are then de-headed and split along the backbone. Finally, the carcasses are chilled rapidly overnight before the subsequent processes of cutting and boning can take place.
<i>By-product processing</i>	Edible offal components and casings (intestinal tract) are separated from the viscera and sent on for cleaning and further processing, generally in other parts of the plant.
<i>Rendering</i>	At various stages in the process, inedible by-products such as bone, fat, heads, hair and condemned offal are generated. These materials are sent to a rendering plant either on site or off site for rendering into feed materials and tallow.

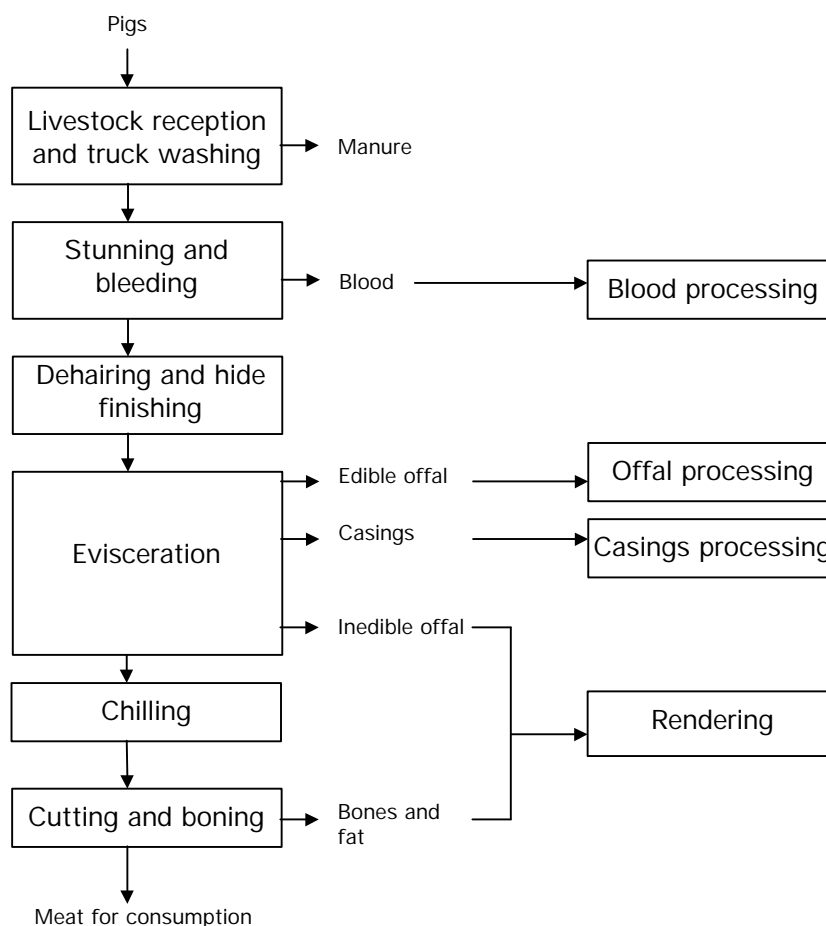


Figure 2—1 Flow diagram for slaughtering of pigs

Table 2—2 is a summary of the major products and by-products from the slaughter of a 90 kg pig, including an indication of the relative proportions.

Table 2—2 Products and by-products from the slaughter of a 90 kg pig

	Weight (kg)	Percentage of LCW
Live carcass weight (LCW)	90.0	100%
Boned meat	57.6	64%
Inedible material for rendering (bones, fat, head, hair, condemned offal etc.)	18.0	20%
Edible material (tongue, liver, heart, kidneys, trotters)	9.0	10%
Blood	2.7	3%
Miscellaneous (stomach contents, shrinkage, blood loss etc.)	2.7	3%

A pig carcass can be utilised to a much greater extent than any other farm animal species (up to 70% utilisation. This is because pigs have one stomach instead of four and are dressed with the feet and skin left on instead of removed. In addition, the proportion of edible components is higher than for cattle.

2.1.2 Slaughtering and processing of cattle

The live weight of cattle slaughtered for meat production can vary from 250 kg to 600 kg, depending on the age and breed of the animal. As a guide, heifers weigh 250–300 kg, cows 350–400 kg, and steers 400–600 kg.

The basic slaughtering procedure for beef cattle has become more automated and efficient over the past few decades. Most improvements have occurred in stunning, hide removal, evisceration and splitting techniques. As an example, processing rates in the United States now average around 350 head per hour (Savell and Smith, 1998).

The basic process for the slaughtering and processing of cattle is shown in Figure 2—2.

<i>Pre-handling of cattle</i>	Cattle are delivered to the abattoir in trucks and unloaded into holding pens, where they are rested for one or two days before slaughter. Any cattle classed as 'dirty' are washed.
<i>Stunning and bleeding</i>	The cattle are led to the slaughter area where they are stunned using a bolt pistol or electric shock. They are then shackled by a hind leg and hoisted onto an overhead rail or dressing trolley. Bleeding, or sticking, then takes place, with the blood collected in a trough for disposal or for further processing.
<i>Dressing and hide removal</i>	The bled carcasses are conveyed to the slaughter hall where dressing and evisceration take place. The first stage of this process, dressing, can be performed as the carcass hangs from the overhead rail, or the animal can be unshackled and laid in a cradle. The head and hoofs are removed, the head is cleaned with water, and the tongue and brain are recovered. Hides are then removed and conveyed to the hide processing area, where they are preserved by salting or chilled on ice.
<i>Evisceration</i>	The carcasses are then opened to remove the viscera. The stomach (paunch) and intestines are emptied of manure and cleaned in preparation for further processing. Edible offal (tongue, lungs, heart and liver) is separated, washed and chilled. The carcasses are then split, rinsed and then conveyed to a cold storage area for rapid chilling.
<i>Cutting and boning</i>	Carcass cutting and boning often take place after chilling, since a carcass is easier to handle and cut when it is chilled. Boning is the term used to describe the process of cutting meat away from the bone. Recent developments in processing technology have made it possible to undertake boning while the carcass is still warm, eliminating the need to chill the carcass at this stage in the process. This is referred to as 'hot boning'.
<i>Inspection</i>	Carcasses and viscera are inspected to determine if they are suitable for human consumption. Each carcass and its components are identified and kept together wherever possible until inspection is complete.
<i>By-products</i>	At various stages in the process, inedible by-products such as bone, fat, heads, hair and condemned offal are generated. These materials are sent to a rendering plant either on site or off site for rendering into feed materials.

Table 2—3 is a summary of the major products and by-products from the slaughter of a 400 kg animal, including an indication of the proportions of each.

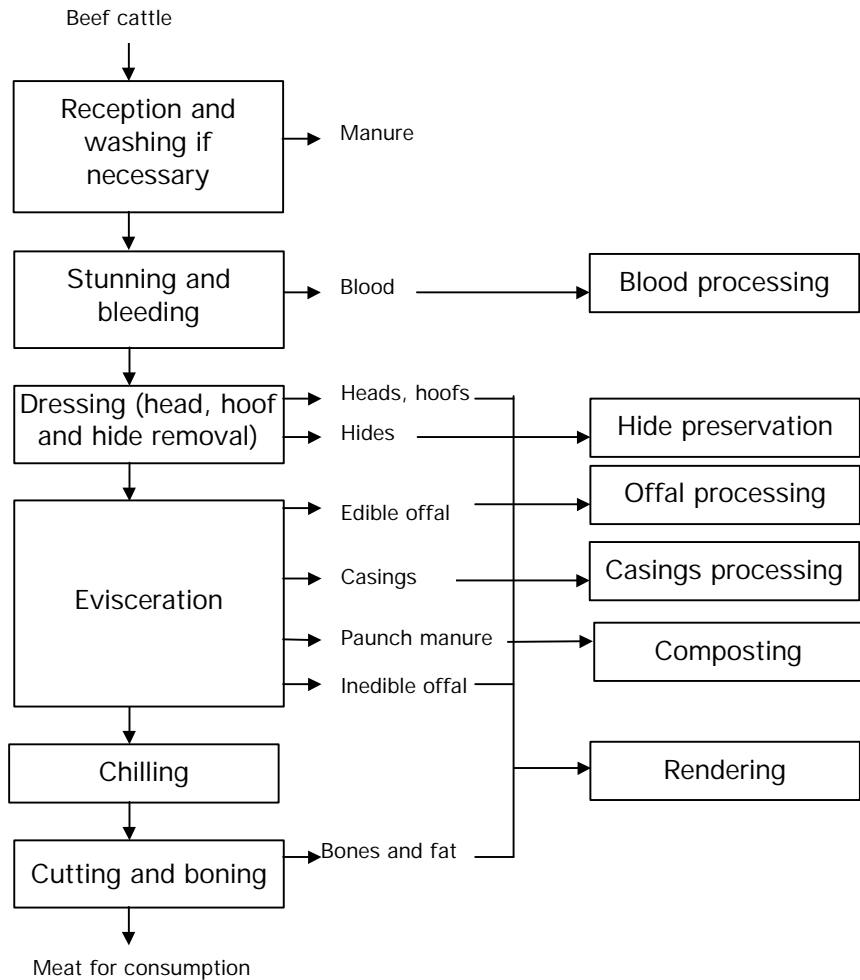


Figure 2—2 Flow diagram for slaughtering of cattle

Table 2—3 Products and by-products from the slaughter of 400 kg beef cattle

	Weight (kg)	Percentage of LCW
Live carcass weight (LCW)	400	100%
Boned meat	152	40%
Inedible material for rendering (bones, fat, head, condemned offal etc.)	155	39%
Hide	36	7%
Edible offal (tongue, liver, heart, kidneys, plucks etc.)	19	5%
Blood	12	3%
Miscellaneous (paunch manure, shrinkage, blood loss etc.)	26	6%

2.1.3 By-product processing

Meat is the most significant product from the abattoir, by weight and also in monetary terms. However, by-products can contribute significantly to the profitability of an abattoir operation since they generally have a commercial value.

If animal by-products are not used effectively a valuable source of revenue is lost, and the added and increasing cost of disposal of these products is incurred by the company. Also, from an environmental perspective, utilisation of by-products reduces the overall environmental load of the process.

The modern livestock industry is an effective user of by-products. However more than 2% of the carcass weight is often unaccounted for and is usually lost to effluent. Therefore, there is potentially more that can be done.

By-products from livestock slaughter include, but are not limited to (Ockerman and Hansen, 2000):

- edible offal for human consumption;
- edible fats for shortening, margarine, sweets and chewing gum;
- bone utilised in soup for human consumption, mixed with potter's clay, or the manufacture of buttons, knife handles and bone meal;
- blood for human consumption and for animal feed, pharmaceuticals and food additives;
- glycerin for numerous industrial uses, such as nitroglycerin, ointment bases, solvents, food preservatives and plasticisers;
- intestines for sausage casings, the strings of musical instruments and surgical ligatures;
- gelatin for confectionery items, ice cream and jellied food products;
- rennin for cheese making;
- numerous pharmaceutical products;
- livestock feed (usually high in protein, fat and minerals);
- pet food and feed for fish farming;
- hides and skins for use as fur, leather or leather goods;
- inedible fats for use in industrial products such as tyres, lubricants, insecticides and germicides;
- hair for brushes, felt, rugs, upholstery, plaster binding and insulation; and
- glue.

Edible offal for human consumption, such as liver, heart, kidney, tongue, sweetbread, brain and tripe is often processed at abattoirs. Processing of these materials is generally limited to trimming and rinsing. The preparation of animal intestines for use as sausage casings is a more involved process, requiring emptying, de-sliming and cleaning.

Other edible by-products include cheeks, head trimmings, lungs, spinal cord, breast fat and stomachs and cattle paunches. These are commonly sent to other facilities for the manufacture of animal feed, including pet

food. The processing of these materials at abattoirs is generally limited to cleaning in preparation for being sent off site.

Inedible by-products, such as fat, bones, hoofs, condemned offal and dead carcasses are rendered into tallow (derived from both cattle and sheep fat) or lard (derived from pig fat), and meat and bone meal. Tallow and lard have numerous applications and meat and bone meal are used predominantly as animal feed supplements. Rendering can take place either on site or at independent rendering plants.

In some regions, in particular the European Union, restrictions have been placed on the use of some animal by-products for human or animal consumption. This has been due to outbreaks of Bovine Spongiform Encephalopathy (BSE), which is a fatal neurological disorder of adult cattle. In those areas where BSE is a concern, the use of dead carcasses for the production of animal feed is prohibited, as is the use of the brain and spinal cord for human consumption.

Blood collected at abattoirs is a potentially valuable by-product. Blood is used in the formulation of food additives (emulsifiers, stabilisers, clarifiers, nutritional additives, egg albumin substitute), pharmaceuticals, fertilisers, animal feeds as well as in numerous industrial applications. At abattoirs, blood is usually collected and stored in tanks and then transported to specialised blood processing facilities.

Animal hide is one of the most valuable by-products from meat processing, since there are well-established markets for its use in most parts of the world. Hides are converted into a variety of consumer goods, in particular shoes, bags and clothing. However other parts of the original hide can be recovered for use in the manufacture of cosmetic ingredients and medical prosthetics. At abattoirs, hides may be chilled or salted and sent directly to the tannery. Alternatively, fleshing may take place at abattoirs to recover the meat trimmings and fat from the hides before they are sent to the tannery.

2.2 Environmental impacts

As for many other food processing operations, the main environmental issues associated with meat processing are the high consumption of water, the discharge of high-strength effluent and the consumption of energy. Noise, odour and solid wastes may also be issues for some plants. Common environmental issues are summarised in Table 2—4.

Water consumption

Hygiene standards necessitate the use of large quantities of fresh water. Water is used for watering and washing livestock, cleaning process equipment and work areas and washing carcasses. Cleaning, in particular, is a major area of water use.

Effluent discharge

One of the most obvious environmental issues common to all abattoirs is the discharge of large quantities of effluent. Abattoir effluent contains blood, fat, manure, undigested stomach contents and cleaning agents. It is typically characterised as having a high level of organic matter, fat, nitrogen, phosphorus and salt (sodium).

For plants located near urban areas, effluent may be discharged to municipal sewage treatment systems. This is the case in much of Europe. However, in rural areas effluent is often treated on site and irrigated to land.

If irrigation is not managed correctly, dissolved salts contained in the effluent can adversely affect soil structure and cause salinity problems. Nitrogen and phosphorus can also leach into underlying groundwater and affect its quality.

In some locations effluent may be discharged directly into water bodies. However this is generally discouraged as the high levels of organic matter can deplete oxygen levels and thus degrade water quality.

Table 2—4 Environmental issues at abattoirs

Process	Environmental issue
Reception of livestock	Effluent containing manure wastes
Truck washing	High water consumption
Cattle washing	Noise
Stunning and bleeding	Effluent with high organic load, especially if blood is discharged
Hide treatment (pigs)	Energy consumption for hot water used in scalding Generation of putrescible by-products Effluent with a high content of organic matter
Splitting and evisceration	Energy consumption for equipment sterilisation Generation of putrescible by-products Effluent with high organic load
Refrigeration	High energy consumption Fugitive losses of refrigerants, e.g. CFCs or ammonia
Cutting and boning	Electricity consumption Generation of putrescible by-products Energy consumption for equipment sterilisation
Casing and offal processing	Effluent with very high organic load Very high water consumption
Rendering	Effluent with very high organic load Potential for odour generation High energy consumption
Cleaning	High water consumption Consumption of chemicals Large volumes of effluent with high organic load

<i>Energy consumption</i>	<p>Thermal energy, in the form of steam and hot water, is used for cleaning and sterilising and for rendering. Electricity is used for the operation of machinery and for refrigeration, ventilation, lighting and the production of compressed air.</p> <p>Like water consumption, the use of energy for refrigeration and sterilisation is important for ensuring good keeping quality of meat products. Storage temperatures are often specified by regulation. As well as depleting fossil fuel resources, the consumption of energy causes air pollution and greenhouse gas emissions, which have been linked to global warming.</p>
<i>By-products</i>	<p>By-products from the slaughter of livestock can cause environmental problems if not managed correctly. They are highly putrescible and can cause odour if not heat treated in a rendering process or removed from site within a day of being generated.</p> <p>Dead stock and condemned carcasses must be disposed of in a way that ensures the destruction of all pathogenic organisms. All materials that may contain condemned parts are considered high-risk materials, and have to enter an authorised rendering plant where proper sterilisation can take place.</p> <p>For small plants, the handling of animal by-products can be an important waste management issue. Smaller plants are often too small to economically undertake on-site rendering and may have difficulty in securing access to rendering companies.</p>
<i>Air emissions</i>	<p>Air emissions from meat processing plants are mostly attributed to energy consumption. Steam, which is used for rendering and cleaning operations, is generally produced in on-site boilers. Air pollutants generated from combustion include oxides of nitrogen and sulphur and suspended particulate matter.</p>
<i>Odour</i>	<p>Odour can be a serious problem for meat processing plants if by-products and effluent streams are not managed correctly, or if rendering takes place on site. Biological treatment systems, commonly used to treat abattoir effluent, are another common source of odours. Insufficient capacity of treatment systems or shock-loadings to the system can upset the microbiological balance of the system, resulting in the release of hydrogen sulphide and other odorous compounds.</p>
<i>Refrigerants</i>	<p>For operations that use refrigeration systems based on chlorofluorocarbons (CFCs), the fugitive loss of CFCs to the atmosphere is an important environmental consideration, since these gases are recognised to be a cause of ozone depletion in the atmosphere. For such operations, the replacement of CFC-based systems with non- or reduced-CFC systems, such as ammonia, is important.</p>
<i>Noise</i>	<p>If an abattoir is located close to residential areas or other noise-sensitive receptors, the noise generated from various items of equipment and the manoeuvring of trucks delivering livestock and removing by-products, can cause a nuisance. These potential problems should be taken into consideration when determining plant location.</p>

2.3 Environmental indicators

Environmental indicators are important for assessing Cleaner Production opportunities and for comparing the environmental performance of one meat processing operation against another. They provide an indication of resource consumption and waste generation per unit of production.

Environmental indicators for abattoir operations will vary according to the size of plant, degree of utilisation of by-products, implementation of Cleaner Production, climate and many other factors. Large variations are typical, particularly for water, effluent and energy figures.

2.3.1 Water consumption

In abattoirs, water is used for numerous purposes, including:

- livestock watering and washing;
- truck washing;
- scalding and hide finishing of pigs;
- washing of casings, offal and carcasses;
- transport of certain by-products and wastes;
- cleaning and sterilising of knives and equipment;
- cleaning floors, work surfaces, equipment etc.;
- make-up water for boilers;
- cooling of machinery (compressors, condensers etc.).

Surveys of water consumption per unit of production consistently show considerable variation within the industry. A factor that affects water consumption is cleaning practices. Plants which produce meat for export often have stricter hygiene requirements and therefore may consume more water for cleaning and sanitising.

Table 2—5 provides indicative figures for the breakdown of water consumption in abattoirs, based on Australian and Danish survey data. Slaughter, evisceration and casings and offal processing tend to account for a large proportion of total water use, where it is used principally for cleaning.

Table 2—6 provides a summary of data from industry surveys describing water consumption figures per unit of production. These figures are based on a variety of production units, depending on the source literature.

Table 2—5 Breakdown of water consumption

Australian survey data ¹		Danish survey data ²		
Purpose	General	Purpose	Pig	Cattle
Stockyard washdowns and stock watering	7–22%	Livestock receipt and holding	8%	22%
Slaughter, evisceration and boning	44–60%	Slaughter	32%	28%
Casings processing	9–20%	Casings processing	24%	21%
Inedible and edible offal processing	7–38%	Scalding (pigs)	3%	NA
Rendering	2–8%	Hair removal (pigs)	8%	NA
Domestic-type uses	2–5%	Dressing (cattle)	NA	22%
Chillers	2%	Cleaning	25%	7%
Boiler losses	1–4%			

¹ MRC, 1995 (based on a survey of Australian abattoirs)

² Hansen and Mortesen, 1992 (based on a survey of Danish abattoirs)

Table 2—6 Water consumption per unit of production

Country	m ³ /t LCW	m ³ /t HSCW	m ³ /t meat	L/head
US (1984) ¹	4.2–16.7			
UK (1990) ¹	5–15			
Europe (1979) ¹	5–10			
Hungary (1984) ¹	2–3.8			
Germany (1992) ¹	0.8–6.2			
Australia (1995) ²		4–12		
Australia (1998) ³		6–15		
Denmark (pigs)			5–20 ⁴	225 ⁵
Denmark (cattle)			4–17 ⁴	860 ⁵

¹ Johns, 1993 (based on a literature review 1979–1993)

² MRC, 1995

³ MLA, 1998

⁴ Hansen and Mortensen, 1992

⁵ Hansen, 1997

2.3.2 Effluent discharge

The volume of effluent generated is a reflection of the volumes of water used, since 80–95% of water used in abattoirs is discharged as effluent (MRC, 1995). The remainder is held up with by-products and wastes or lost through evaporation.

Meat processing effluents generally exhibit the following properties:

- high organic loads due to the presence of blood, fat, manure and undigested stomach contents;
- high levels of fat;
- fluctuations in pH due to the presence of caustic and acidic cleaning agents;
- high levels of nitrogen, phosphorus and salt;
- high temperature.

The concentration of organic matter is a key indicator of effluent quality, and is commonly expressed as chemical oxygen demand (COD) or 5-day biochemical oxygen (BOD₅). Both of these indicators are widely used and this document uses both, depending on the literature source.

Animal fats contained in abattoir effluent are long-chain fatty acids and glycerol, collectively referred to as fats, oils and greases. For simplicity, this document will refer to them as fats. Fats from animal sources are generally biodegradable and exhibit extremely high specific BOD₅, more than 2 g BOD₅ per gram of lipid (Hrudey, 1984).

Nitrogen in abattoir effluent occurs mainly in the form of ammonia, due to the breakdown of proteinaceous materials into amino acids and then, ammonia. However the nature of the ammonia species present depends on the pH. Therefore, nitrogen levels in abattoir effluent are commonly expressed as total nitrogen.

Pollutant concentrations in abattoir effluent can vary significantly from one plant to the next, depending on the extent to which wastes are excluded from the effluent stream. Table 2—7 provides indicative figures for the concentration of pollutants in effluent from pig, cattle and mixed species abattoirs.

Table 2—7 Average concentrations of pollutants in abattoir effluent ¹

Parameter (unit)	Pig slaughtering ¹	Cattle slaughtering ¹	Mixed species abattoirs ²
BOD ₅ (mg/L)	1250	2000	-
COD (mg/L)	2500	4000	1000-3000
Suspended solids (mg/L)	700	1600	400–800
Total nitrogen (mg/L)	150	180	< 300
Total phosphorus (mg/L)	25	27	< 10
Oil and grease (fat) (mg/L)	150	270	< 350
pH	7.2	7.2	7–8.5

¹ Hansen and Mortensen, 1992

² MRC, 1995 (based on a survey of Australian abattoirs)

Organic matter contained in abattoir effluent originates from all areas of the plant where water comes into contact with carcasses, manure, offal and blood etc. Of all the components of the abattoir effluent stream, blood constitutes the highest pollution load, followed by fat.

Blood is also the single most significant source of nitrogen in abattoir effluent. Therefore slaughter and evisceration areas as well as rendering plants, where blood processing takes place, contribute the most to nitrogen levels.

Phosphorus originates from manure and undigested stomach contents. Blood processing within the rendering plant can also be a source of phosphorus, if this process is practiced.

Salt (sodium) originates from manure and undigested stomach contents, and also from rendering and pickling processes. In some areas, the raw water used in the plant can contribute towards high salt levels in the effluent.

Fat in the effluent stream originates from trimmings that are allowed to fall to the floor, some of which will inevitably find its way into the effluent stream. Fat can also originate from carcass washing.

It follows therefore that effluent quality depends on the extent to which blood, fat, manure and undigested stomach contents are excluded from the effluent stream. In the case of blood and fat, allowing these materials to enter the effluent stream increases the cost of effluent treatment and represents the loss of valuable products.

Another factor with an important bearing on effluent quality is whether rendering occurs as part of a plant's operations. At those plants where rendering occurs, the rendering plant is generally the largest single source of effluent contamination. Rendering typically contributes about 60% of a plant's total organic load but only 5–10% of the total volume (MRC, 1995).

Table 2—8 provides a typical breakdown of effluent loads generated from different processing areas within abattoir operations in terms of the key effluent contaminants.

Table 2—8 Breakdown of effluent loads for key contaminants in abattoir effluent ¹

	Organic load (COD)	Total nitrogen	Total phosphorus	Sodium
Fresh water	0%	1%	0%	10%
Recycled water	0%	5%	10%	7%
Stockyards	2%	6%	8%	6%
Slaughter and evisceration	7%	19%	4%	8%
Offal processing	7%	7%	7%	3%
Casings processing	1%	7%	6%	9%
Boning	1%	3%	0%	2%
Manure and paunch handling	13%	12%	37%	22%
Rendering	63%	33%	26%	15%
Pickling	5%	8%	2%	16%

¹ MRC, 1995 (based on a survey of Australian abattoirs)

In order to be a useful indicator of plant performance, effluent discharge is expressed as pollutant load per unit of production. Table 2—9 provides indicative figures for effluent pollutant loads generated per head of animal slaughtered (pig and cattle) and Table 2—10 provides figures based on tonne LCW and tonne HSCW.

Table 2—9 Pollution loads in abattoir effluent per head¹

Parameter (unit)	Pig slaughtering (average 90 kg)	Cattle slaughtering (average 250 kg)
BOD ₅ (kg/head)	0.5–2.0	1–5
Total nitrogen (kg/head)	0.075–0.25	0.25–1.0
Total phosphorus (kg/head)	0.015–0.03	0.030–0.1

¹ COWI, 1999

Table 2—10 Pollution load in abattoir effluent per unit of production

Parameter	Pollutant load (kg per tonne LCW)		Pollutant load (kg per tonne HSCW)	
	(1)	(2)	(3)	(4)
COD	-	-	12–66	-
BOD ₅	12–15	6–16	-	8–66
Suspended solids	9–12	4–18	4–14	-
Total nitrogen	1–1.7	-	1–3	0.9–3.4
Ammonia nitrogen	-	0.08–0.25	-	-
Organic nitrogen	-	0.3–0.8	-	-
Total phosphorus	-	-	0.1–0.5	0.1–0.5
Soluble phosphorus	-	0.06–0.21	-	-
Sodium	-	-	0.6–4.0	-
Oil and grease (fat)	1.5–8	1.5–23	2–12	-

¹ Ockerman and Hansen, 2000 (summary of survey data from US abattoirs)

² Hansen and Mortensen, 1992

³ MRC, 1995 (survey of Australian abattoirs)

⁴ MLA, 1998 (survey of Australian abattoirs)

2.3.3 Energy consumption

Overall energy consumption will depend on the types of activities occurring at an abattoir. For example rendering, if it occurs on site, will add substantially to overall energy consumption. Pig scalding is an energy-consuming process specific to pig abattoirs.

Approximately 80–85% of an abattoir's total energy need is for thermal energy, in the form of steam or hot water, produced from the combustion of fuels in on-site boilers.

Table 2—11 provides an indicative breakdown of thermal energy use in an abattoir. The figures assume that rendering and pig scalding take place as part of the operation.

Table 2—11 Breakdown of thermal energy consumption ¹

Purpose	Percentage of total
Rendering	42%
Boiler losses	25%
Hot water	14%
Pig scalding	3%
Blood coagulation	3%
Blood drying	3%
Others	10%

¹ Energy Authority of NSW, 1985

Fuel used for steam production in boilers is typically coal or fuel oil. However the use of natural gas and liquid petroleum gas is increasing due to environmental pressures to burn cleaner fuels. Fuel sources with a low sulphur content should be chosen in order to minimise sulphur dioxide emissions.

In some areas, abattoirs may be able to obtain heat energy from district heating or steam from outside sources. It is also possible to recover waste heat from high-temperature rendering processes to heat water.

The remaining 15–20% of an abattoir's energy consumption is provided by electricity. Table 2—12 provides an indicative breakdown of electricity use in an abattoir. As can be seen, refrigeration accounts for a significant proportion of electricity use.

Table 2—12 Breakdown of electricity consumption ¹

Purpose	Percentage of total
Refrigeration	59%
Boiler room	10%
By-products processing	9%
Slaughter area	6%
Compressed air	5%
Boning room	3%
Others	8%

¹ Energy Authority of NSW, 1985

To serve as a useful indicator of plant performance, energy use is expressed per unit of production. Table 2—13 provides a summary of data from literature describing typical energy consumption in those terms.

Table 2—13 Energy consumption per unit of production

	Electrical energy	Thermal energy	Total energy
Australia ¹			1200–4800 MJ/tonne HSCW
Denmark (pig) ²			27 kW.h/head
Denmark (cattle) ²			61 kW.h/head
Canada (pig) ³	70–300 kW.h/tonne DW	500–900 MJ/tonne DW	
Canada (cattle) ³	70–250 kW.h/tonne DW	200–500 MJ/tonne DW	

¹ Meat and Livestock Australia, 1998

² Hansen, 1997

³ Ontario Ministry of the Environment, 1999

2.4 Benchmarks

A benchmark is a number that acts as a guide to the level of best practice that is achievable in a specific area, for example environmental performance. Often, suitable benchmarks are difficult to obtain and difficult to use. However, when they are available they can be useful in assessing the relative performance of a process or organisation.

Environmental indicators sometimes used by abattoirs to benchmark performance are water consumption, energy consumption and the organic load in effluent (COD or BOD₅), expressed as figures per unit of production. However, other indicators such as nitrogen and phosphorus loads in effluent have also been used.

In some industries, environmental benchmarks are used extensively to gauge the performance and competitiveness of a manufacturing process. For the meat processing industry however, benchmarking of environmental performance is not common and it is difficult to find examples. The lack of environmental benchmarking is thought to be due to the considerable variation in production processes and scales of operation within the industry. The issue is further complicated by the fact that there is no widely recognised standard unit of production. Units used to describe production at abattoirs vary from country to country and even within a country.

An additional problem is that existing benchmarks do not necessarily relate to specific types of processes. For example, in order to compare one process with another, or to compare a process with a specified benchmark, the scale, age, efficiency and type of process should be similar to enable sensible comparison.

It is recommended that companies should first establish environmental benchmarks internally. It may then be possible to compare performance with other similar organisations within the same state or country. From there, the next step may be to compare performance with industries in other countries as long as the factors contributing to those countries' level of performance are understood.

A selection of environmental benchmarks that have been established in a number of countries is provided in Table 2—14. These figures should be used as a rough guide only.

Table 2—14 Examples of environmental benchmarks for abattoirs

	Water consumption	Energy consumption	Organic load in effluent
Denmark ¹			
pigs	300 L/head	30 kW.h/head	0.5 kg BOD ₅ /head
cattle	1000 L/head	70 kW.h/head	1.2 kg BOD ₅ /head
Canada ²			
pigs	180–230 L/head	500–900 MJ/ t DW	-
cattle	800–1700 L/head	200–500 MJ/t DW	-
Australia ³			
mixed	12 kL/tHSCW	1700 MJ/tHSCW	15 kg BOD ₅ /tHSCW

¹ COWI, 1999 (based on best available technology)

² Ontario Ministry of the Environment, 1999

³ Meat and Livestock Australia, 1998

Tables 2—15 and 2—16 provide examples of Denmark benchmarks that relate to the level of technology utilised. The levels of technology are described as follows:

- *Traditional technology*: medium to large abattoirs with low utilisation of installed capacity and no Cleaner Production (typically in developing countries and countries in transition);
- *Average technology*: large abattoirs using minimal Cleaner Production methods (many Western countries);
- *Best available technology*: industrial abattoirs with good utilisation of installed capacity, high throughput and good housekeeping.

Table 2—15 Benchmarks for pig abattoirs (90 kg pigs)¹

	Unit	Traditional technology	Average technology	Best available technology
Water	L/animal	1400	700	300
Heat and electricity	kW.h/ animal	125	50	30
BOD ₅	g/ animal	2500	1000	500

¹ COWI, 1999

Table 2—16 Benchmarks for cattle abattoirs (250 kg cattle)¹

	Unit	Traditional technology	Average technology	Best available technology
Water	L/ animal	5000	2500	1000
Heat and electricity	kW.h/ animal	300	125	70
BOD ₅	g/ animal	5500	2500	1200

¹ COWI, 1999

3 CLEANER PRODUCTION OPPORTUNITIES

Meat processing typically consumes large quantities of water and energy, discharges significant quantities of effluent and generates by-products. For this reason, Cleaner Production opportunities described in this guide focus on reducing the consumption of resources (water and energy), increasing product yields and reducing the volume and pollutant load of effluent discharges.

Although many processes in the food sector can be automated, it is difficult to automate many of the processes within an abattoir because of the irregular shape and weight of the animal carcasses. This means that individual operators' practices have a significant impact on the overall performance. Therefore, many of the Cleaner Production opportunities described in this guide relate to housekeeping practices, work procedures, maintenance regimes and resource handling, as opposed to technological changes.

Section 3.1 provides examples of general Cleaner Production opportunities that apply across the entire process, whereas Sections 3.2 to 3.11 present opportunities that relate specifically to individual unit operations within the process. For each unit operation, a detailed process description is provided along with Cleaner Production opportunities specific to that process. Where available, quantitative data for the environmental indicators applicable to each unit operation are provided.

3.1 General

Many food processors that undertake Cleaner Production projects find that significant environmental improvements and cost savings can be derived from simple modification to housekeeping practices and maintenance regimes. Table 3—1 contains generic housekeeping ideas that apply to the process as a whole.

Table 3—1 Checklist of general housekeeping ideas ¹

- | |
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| <ul style="list-style-type: none"> • Keep work areas tidy and uncluttered to avoid accidents. • Maintain good inventory control of consumables, such as cleaning chemicals, packaging materials, food additives etc., to avoid waste. • Ensure that employees are aware of the environmental aspects of the company's operations and their personal responsibilities. • Train staff in good cleaning practices. • Schedule regular maintenance activities to avoid inefficiencies and breakdowns. |
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¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.1 Water consumption

Water is used extensively in meat processing, so water saving measures are common Cleaner Production opportunities in this industry. The first step is to analyse water use patterns carefully, by installing water meters and regularly recording water consumption. Water consumption data should be collected during production hours, especially during

periods of cleaning. Some data should also be collected outside normal working hours to identify leaks and other areas of unnecessary waste. Water consumption data should be presented and discussed at management meetings to formulate strategies for improved water efficiency.

The next step is to undertake a survey of all process area and ancillary operations to identify wasteful practices. Examples might be hoses left running when not in use, excessive flowrates, and so on. Installing automatic shut-off equipment and flow restrictors, for example, could prevent such wasteful practices. Automatic control of water use is preferable to relying on operators to manually turn water off.

Once wasteful practices have been addressed, water use for essential process functions can be investigated. It can be difficult to establish the minimum consumption rate necessary to maintain process operations and food hygiene standards. The optimum rate can be determined only by investigating each process in detail and undertaking trials. Such investigations should be carried out collaboratively by production managers, food quality and safety representatives and operations staff. When an optimum usage rate has been agreed upon, measures should be taken to set the supply at the specified rate and avoid manual control.

Once water use for essential operations has been optimised, water reuse can be considered. Wastewaters that are only slightly contaminated could be used in other areas. For example, defrost water from refrigeration systems and vacuum pump water is usually clean, and could be reused for non-critical applications. Water used for carcass washing could be recirculated. Wastewaters from the slaughter floor, washbasins, knife and implement sterilisers and carcass washing could be reused for gut cutting and washing. Treated effluent from on-site effluent treatment systems may be reused for stockyard washing, hide cleaning and livestock washing, as long as fresh water is used for the final livestock rinse. Some of these options may require screening, filtering or in-line bacterial control. It should also be noted that some water reuse and recycle opportunities may be prohibited by some authorities.

Wastewater reuse should not compromise product quality and hygiene, and reuse systems should be carefully installed so that reused wastewater lines cannot be mistaken for fresh water lines, and any reuse plans should be approved by all food safety officers.

The option to fully recycle treated effluent for use within the process may become viable in the future, as effluent discharge quality standards become tighter. As quality standards approach those of potable water, there will be a powerful incentive to take advantage of the investment that goes into effluent treatment. For this to occur however, treatment processes would probably have to incorporate techniques such as membrane filtration to remove dissolved solids. This would be necessary to avoid progressive concentration of salts in the recycled water.

Table 3—2 is a checklist of common ideas for reducing water consumption. Many of these opportunities are discussed in more detail later in this chapter.

Table 3—2 Checklist of water saving ideas ¹

- Undertake dry cleaning of trucks prior to washing with water.
- Install high-pressure, low-volume spray nozzles.
- Use high pressure rather than high volume for cleaning surfaces.
- Use automatically operated scalding chambers rather than scalding tanks for the de-hairing of pigs.
- Use offal transport systems that avoid or minimise the use of water.
- Use dry dumping techniques that avoid or minimise the use of water for the processing of cattle paunches and pig stomachs, instead of wet dumping techniques.
- Reuse relatively clean wastewaters from cooling systems, vacuum pumps etc., for washing livestock.
- Reuse final rinse waters from paunch and casings washing for other non-critical cleaning steps in the casings department.
- Reuse wastewaters from the slaughter floor, carcass washing, viscera tables and hand wash basins for the washing of inedible products.
- Reuse cooling water from the singeing process for other application in the pig de-hairing area.
- Reuse the final rinse from cleaning operations for the initial rinse on the following day.
- Use dry cleaning techniques to pre-clean process areas and floors before washing with water.
- Use automatic control systems to operate the flow of water in hand wash stations and knife sterilisers.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.2 Effluent

Cleaner Production efforts in relation to effluent generation should focus on reducing the pollutant load in effluents. The volume of effluent generated is also an important issue. However this aspect is linked closely to water consumption, so efforts to reduce water consumption will also result in reduced effluent volumes. Opportunities for reducing water consumption are discussed in the previous section.

Opportunities for reducing the pollutant load of abattoir effluent principally focus on avoiding the discharge of polluting substances, such as blood, undigested stomach contents, fat and scraps of meat, to the effluent stream. This means capturing materials before they enter drains and utilising dry cleaning methods wherever possible. Improvements to cleaning practices are therefore where the most gains can be made. Table 3—3 is a checklist of common ideas for reducing pollutant loads in effluent.

Since blood is one of the major sources of organic pollution for abattoirs, its recovery is an important Cleaner Production initiative. Blood recovery can decrease organic loads by approximately 40% (Jones, 1974).

Table 3—3 Checklist of ideas for reducing effluent loads ¹

- Maximise the segregation of blood by designing suitable blood collection facilities and allowing sufficient time for bleeding, typically seven minutes.
- Sweep up solid materials for use as by-products, instead of washing them down the drain.
- Fit drains with screens and/or traps to prevent solid materials from entering the effluent system.
- Use offal transport systems that avoid or minimise the use of water.
- Use water sprays with a pressure of less than 10 bar for carcass washing to avoid removing fat from the surface.
- Use dry cleaning techniques to pre-clean process areas and floors before washing with water.
- Segregate high-strength effluent streams, such as rendering effluent and wastewaters from casings and paunch washing and treat them separately.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.3 Energy

Energy is often an area where simple plant optimisation efforts can provide substantial savings almost immediately with no capital investment. Significant reductions can be made through simple housekeeping and optimisation of existing processes. Additional savings can be made through the use of more energy-efficient equipment and heat recovery systems. Table 3—4 is a checklist of common ideas for reducing energy consumption.

Table 3—4 Checklist of energy saving ideas ¹

- Implement switch-off programs and install sensors to turn off or power down lights and equipment when not in use.
- Improve insulation on heating and cooling systems and pipework.
- Insulate and cover scald tanks.
- Recover waste heat from effluent streams, vents, exhausts and compressors.
- Recover evaporative energy in the rendering process, using multi-effect evaporators.
- Maintain a leak-free compressed air system.
- Favour more efficient equipment.
- Improve maintenance to maximise energy efficiency of equipment.
- Maintain optimal combustion efficiencies on boilers.
- Eliminate steam leaks.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

In addition to reducing a plant's demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, possibly purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

3.1.4 By-products

Almost all animal by-products can potentially be used to produce a useful commodity. It may not always be possible, however, to find economic markets for all by-products. This will depend on the scale of the operation, the cultural and culinary characteristics of the region and the distance to suitable markets.

The ability to use all animal by-products to their full extent will often depend on whether rendering facilities are available to convert inedible components into useful products such as bone meal and tallow. Large plants typically incorporate integrated on-site rendering and blood processing facilities or generate sufficient material to be attractive for off-site renderers.

Table 3—5 Checklist of ideas for maximising utilisation of by-products¹

- Segregate all by-products.
- Ensure that by-products are not contaminated with water or materials that would limit or prevent their reuse.
- Store by-products correctly to maintain quality and maximise the viability of reuse opportunities.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.2 Livestock reception

Process description

Animals are delivered to the abattoir in trucks, which are unloaded at the reception area. Trucks are generally washed and sometimes disinfected before leaving the site.

Most abattoirs hold livestock on site for a period, typically 1 to 2 days, prior to slaughter. During this period animals are usually fasted to reduce the quantity of stomach contents, thereby making cleaning of the intestines easier. Livestock for the following day's kill are held in stockyards adjacent to the plant, whereas livestock being held for longer periods may be grazed in paddocks around the plant.

Some plants may use holding periods to de-stress cattle, which helps to improve final meat quality. Pigs are susceptible to heat stress and therefore it is common for pig holding facilities to incorporate sprinkler systems, which spray water on the pigs to keep them cool, especially in summer. The water sprays can also assist in suppressing dust.

In some regions, bedding may be used in trucks and in holding yards for animal welfare reasons and also to facilitate the collection of manure.

Prior to being slaughtered, livestock are also washed with water to minimise the amount of dirt and manure introduced to the plant.

Inputs and outputs

Figure 3—1 is a flow diagram showing the inputs and outputs associated with livestock reception, and Tables 3—6 and 3—7 provide data on the key inputs and outputs for pig and cattle reception respectively.

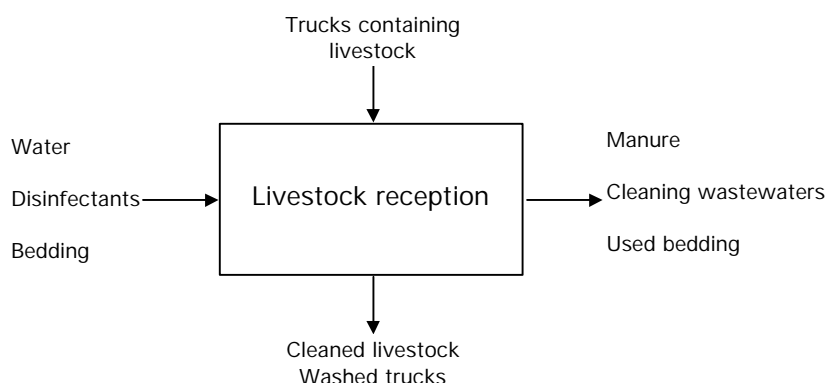


Figure 3—1 Inputs and outputs for livestock reception

Table 3—6 Input and output data for the reception of a 100 kg pig

Inputs		Outputs	
Live pig	100 kg	Live pig	100 kg
Water for cleaning	15 L	Wastewater	15 L
Bedding (if used)	2.5 kg	BOD ₅	0.02 kg
		Solid waste	1.5 kg

Table 3—7 Input and output data for reception of 250 kg beef cattle

Inputs		Outputs	
Live cattle	250 kg	Live cattle	250 kg
Water for cleaning	75 L	Wastewater	75 L
Bedding (if used)	7.5 kg	BOD ₅	0.1 kg
		Solid waste	5 kg

Environmental issues

Water is used for truck washing, cattle watering and washing and hosing out holding yards. Waste of water can occur due to overflowing drinking troughs, leaking hoses and poor washing practices. Excessive use of water or poor containment of water can also lead to ponding of water in holding yards or paddocks. This can result in the need for extra washing to remove accumulated mud from livestock.

The wastewaters generated from these activities contain manure and urine and therefore have a high organic load and solids content. They also are a significant contributor to phosphorus loads.

Cleaner Production opportunities

Manure along with bedding can be a valuable source of nutrients and organic carbon, but can also cause pollution problems if not used or disposed of correctly.

Dirty livestock should be segregated on arrival and given a preliminary wash before joining the rest of the herd. This will reduce the amount of washing required for the herd as a whole.

Water troughs should be designed and located to avoid overflowing and production of muddy areas. They should be set on a concrete base and protected from damage by livestock.

For truck washing, water should be used only after dry cleaning has been undertaken. Using a high-pressure water supply and hoses fitted with trigger nozzles will help reduce water consumption.

Manual cleaning of livestock should be restricted to those that need it. A 20–35 mm diameter hose fitted with a 9–10 mm nozzle will maximise efficiency. Large diameter hoses should be avoided as they are cumbersome and inefficient and nozzles are easily damaged (McNeil and Husband, 1995).

Recycled water from other areas of the plant, such as cooling systems and vacuum pumps, can be used for washing trucks. Recycled water could also be used for washing livestock. However for some markets, such as the European Union, the use of recycled water for stock washing may be prohibited.

Wastewaters from truck and livestock washing should be screened before being discharged to the effluent system. This will help reduce the loads of organic matter, suspended solids and also phosphorous entering the wastewater treatment system. Screening can best be achieved using rotating screens or static run-down screens.

3.3 Stunning and bleeding

Process description

For pigs, stunning can be carried out by electric shock or by anaesthetisation with carbon dioxide. Mechanical stunning with a bolt pistol is not often undertaken because of problems with skull penetration. Electric stunning is carried out using a pair of tongs with two electrodes positioned behind the animal's ears. Carbon dioxide anaesthetisation is undertaken by passing pigs through an atmosphere containing about 60–70% carbon dioxide. For cattle, concussion devices or bolt pistols are the most commonly used stunning techniques.

After stunning, carcasses are shackled by the hind legs to a conveyor. Bleeding, also referred to as sticking, takes place by cutting the cervical vein and one of the arteries.

Bleeding is commonly undertaken using a hollow, sterilised knife, which feeds the blood to a collection facility. Blood accounts for about 5% of the live weight of beef cattle and pigs. However only about 70–80% of this is collected during bleeding, the remainder typically being lost to the effluent stream.

The proportion collected will depend on the bleeding time. Time required for effective bleeding is generally not less than seven minutes. Some blood loss continues during subsequent dressing operations—up to the point of hide removal, in the case of cattle.

Inputs and outputs

Figure 3—2 is a flow diagram showing the inputs and outputs associated with the stunning and bleeding process, and Tables 3—8 and 3—9 provide data for the key inputs and outputs for pigs and cattle respectively.

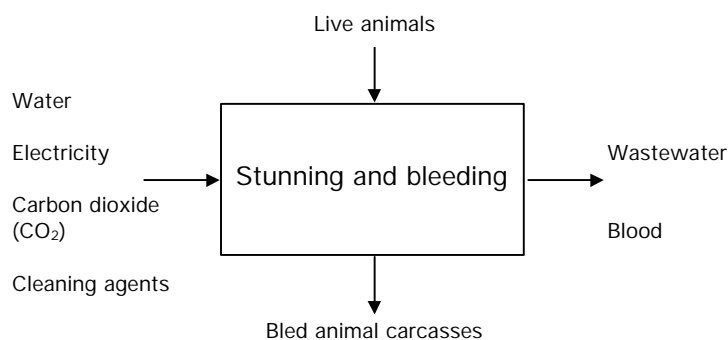


Figure 3—2 Inputs and outputs for stunning and bleeding

Table 3—8 Input and output data for the stunning and bleeding of a 100 kg pig

Inputs		Outputs	
Live pig	100 kg	Bled pig	95 kg
Water	5 L	Blood (assuming 80% recovery)	4 kg
Carbon dioxide	0.16 kg	Wastewater	6 L
		BOD ₅ (blood loss)	0.2 kg

Table 3—9 Input and output data for the stunning and bleeding of 250 kg beef cattle

Inputs		Outputs	
Live cattle	250 kg	Bled cattle carcass	238 kg
Water	5 L	Blood (assuming 80% recovery)	10 kg
		Wastewater	7 L
		BOD ₅ (blood loss)	0.4 kg

Environmental issues

Of all the components present in abattoir effluent, blood constitutes the highest pollution load. The bleeding area of the slaughter floor is the main source of blood contamination. Blood has a very high organic content, with its organic load equivalent estimated to be 0.14—0.18 kg BOD₅ per kg. If it is discharged to the effluent stream, the effectiveness of any downstream effluent treatment system will be greatly affected due to the increased organic loads.

Blood is also the main contributor to nitrogen loads in effluent. This can have serious implications for the disposal of the treated effluent, since nitrogen is not readily removed in standard effluent treatment systems. The release of treated effluents containing high levels of nitrogen can cause eutrophication problems downstream.

If collected blood is allowed to become contaminated with water, the effectiveness of its subsequent processes is reduced. The presence of water reduces the efficiency of coagulation processes, and if the blood is to be dried, increases the energy required to evaporate the water content.

After blood, fat is the next most important contaminant in effluent generated from the slaughter area. Fat blinds screens in the effluent treatment system, resulting in the need for greater use of hot water to clean them.

Cleaner Production opportunities

Every effort should be made to maximise raw blood collection and its subsequent processing into blood meal or other value-added by-products. Blood recovery yields should be routinely assessed to check the effectiveness of the blood collection system.

Design of the bleeding area should ensure that all blood is directed to the blood collection facility. Animals should not be bled until they are located over the blood collection facility and they should be allowed to bleed in this location for a minimum period of time, generally no less than about seven minutes (McNeil and Husband, 1995).

A shallow, inclined, stainless steel trough under the bleeding area, extending through to the hide removal area, is a suitable mechanism for collecting blood. The trough should be elevated some distance above floor level to exclude cleaning water (McNeil and Husband, 1995). Coagulated blood collecting in the trough will need to be scraped away at regular intervals.

The most effective method of continuously recovering blood is a belt conveyor under the bleeding area. The belt should be troughed or have side skirts to contain the blood and be fitted with scrapers to recover blood from the conveyor. This type of system comes at the expense of some water consumption due to the requirement to clean the belt itself. However fixed spray nozzles can provide efficient cleaning (McNeil and Husband, 1995).

To avoid cross contamination of blood and wastewater, two-way drain diversion systems can be used in the bleeding area. Two drain outlets are provided in the blood collection area, one to the blood tank and the other to the effluent system. During slaughtering, the outlet to the effluent system is closed off so that all blood drains to the blood tank. When slaughtering is finished, the outlet to the blood tank is closed and the outlet to the effluent system is opened so that cleaning wastewaters are directed to the effluent system.

Removable plugs or valves can be used to close off the outlets to these drains. Full-flow ball valves are preferred as they can be mechanically interlocked so that as one valve opens, the other valve shuts. Control of the changeover of plugs or valves should be the responsibility of a designated operator who also gives the go-ahead to start cleaning the area.

Blood is highly perishable, therefore it should be chilled quickly and promptly processed into value-added products. The investment required for installation of a well-cooled storage tank and processing equipment is high, but necessary if the blood is to be sold as a by-product.

3.4 Hide treatment of pigs

Process description

The objective of surface treatment is to remove dirt and hair from pig carcasses, prior to further processing. In some processes, skins may be removed and sold for tanning. However skinning is usually restricted to the slaughter of large sows for sausage manufacture or to small-scale plants where the costs of scalding and dehairing equipment makes it prohibitive.

Carcasses are scalded with water at 60°C in a scald tank or in scalding cabinets, to soften the skin in preparation for hair removal. Alkaline reagents may be added to the scald water to help remove the layer of accumulated oil, dirt and epidermal cells from the skin surface, making the skin whiter.

After scalding, hair is partly removed by manual shaving or for larger operations, in de-hairing machines. Any remaining hair is singed with a gas-fired hand-held torch or, for larger plants, by passing the carcasses through a singeing oven. The singeing operation may be followed by flushing with cold water. Any skin discolouration is then removed by scraping, either manually or in a scraping machine.

If the hide is to be removed, the surface is first cleaned by showering and brushing, then the skin is loosened and pulled off. Fat is removed and the skins are salted or iced immediately and before being sold for tanning.

Inputs and outputs

Figures 3—3 and 3—4 are flow diagrams showing the inputs and outputs for the dehairing and hide removal processes respectively. Table 3—10 provides input and output data for the more common dehairing process.

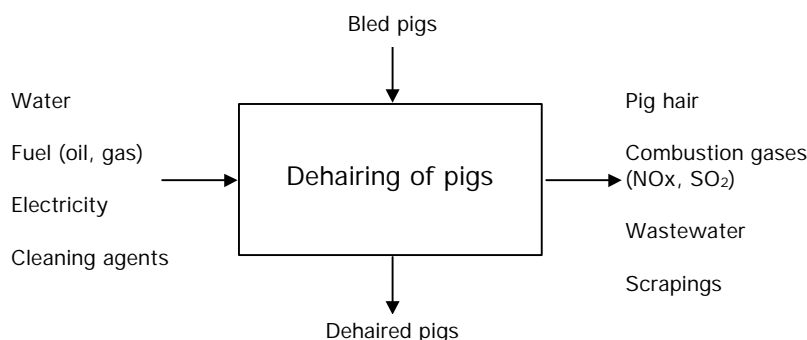


Figure 3—3 Inputs and outputs for dehairing of pigs

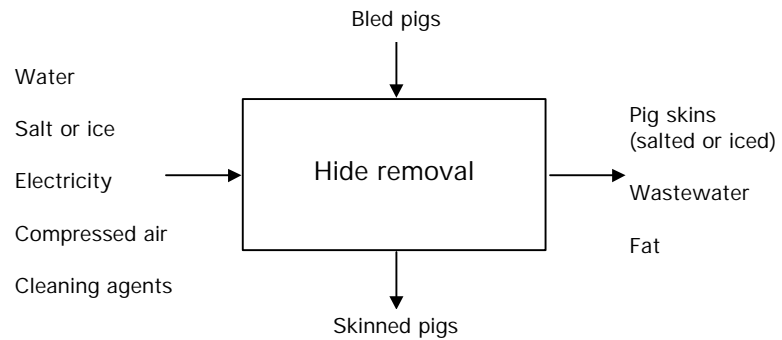


Figure 3—4 Inputs and outputs for skinning pigs

Table 3—10 Input and output data for the dehairing of a 100 kg pig

Inputs		Outputs	
Bled pig carcass	95 kg	De-haired pig carcass	93 kg
Water	60 L	Wastewater	60 L
Oil	0.6 L	BOD ₅	0.3 kg
Gas (if used instead of oil)	0.5 m ³	Pig hair	1 kg
		Scrapings	1 kg

Environmental issues

Water consumption can be high, especially for the de-hairing process and for cooling after singeing.

Wastewaters from this process contain high levels of organic matter, fat and dirt. In particular, wastewaters from scald tanks or from in-line scalding cabinets can have temperatures of up to 75°C. If they are discharged while hot they will melt fat and allow it to pass through the primary effluent screening system. This increased loading of fat will cause problems for downstream effluent treatment systems.

The process consumes a lot of energy, particularly for heating water and for operating singeing ovens.

Cleaner Production opportunities

If scalding tanks are used, they should be insulated and covered by a lid to avoid heat and evaporation losses. This will save both energy and water. The payback period depends on the existing heat losses, but should be 1–2 years.

To reduce water consumption for cleaning of the scalding tank, the tank bottom should have a steep gradient towards the outlets. The wastewater should pass through a sedimentation tank, interceptor trap or sand trap before discharge. The investment required is high, but these measures should be considered when replacing an existing scalding tank.

Water consumption for de-hairing can be minimised by applying water only as required and ensuring that water pressure and the number, placement and size of water nozzles are optimal.

There are also a number of opportunities for water reuse in this area. Cooling water can be collected in a tank and reused for other purposes, such as water sprays in the de-hairing machines. Boiler condensate can also be used as make-up water for the scalding tank.

Automatically operated scalding chambers use less water than scalding tanks. Using such systems, water consumption can be reduced by 50–70%. The investment required is high, and the payback period may be more than 5 years.

The de-hairing process results in substantial quantities of hair collecting on the floor where it can enter the drainage system. Strainers should be fitted to floor drain outlets to collect the hair and avoid blockages.

The singeing oven must be insulated and provided with automatic doors that close during singeing. If not, significant energy is lost. Payback on investment for insulation and automatic doors will be at most one year.

Gas consumption in singeing ovens can be reduced by using solenoid switches to initiate the singeing flame only when carcasses are passing through and to regulate flame intensity in line with line speed.

Overhead rails in singeing ovens are sometimes cooled using cold water. In these situations, the consumption of cooling water can often be much greater than necessary. Installing thermometers to measure the temperature of cooling water can allow flow to be regulated to the minimum required.

Case study 3—1: Reducing water consumption for pig de-hairing

At a pig abattoir, water consumption for dehairing, singeing, scraping and brushing amounted to 141 L/pig before the water-saving campaign began. By reducing the water pressure and installing on–off regulation controlled by the carcass conveyor, consumption was reduced to 96 L/pig, a 32% reduction. The next step was to collect all cooling water from the singeing oven and use it in the other machines instead of disposing of it. In addition, the trickling system in the hide treatment machines was replaced with nozzles which give a well-defined direction and angle of spray. This resulted in a further decrease in water consumption from 96 to 26 L/pig, a 73% reduction.

The investment for a slaughter line treating up to 400 pigs per hour was about US\$33,000, resulting in a saving of US\$0.2–0.3/pig, depending on water and wastewater charges.

(Hansen and Mortensen, 1992)

3.5 Hide removal and dressing of cattle

Process description

Prior to hide removal, the head, hoofs, feet and tail are removed. In some smaller operations, hides may be removed manually. However, in medium to large plants hide removal is generally performed mechanically. Most hide removal equipment is either pneumatically or hydraulically powered. Electrical stimulation is often applied to 'stiffen' the carcass during the hide-pulling operation.

Before hides can be processed further at a tannery, the flesh must be removed and the hides washed and immersed in brine. The fleshing process may take place at the abattoir, thereby recovering the fleshings for rendering, or at the tannery. If they are to be sent to the tannery without fleshing, hides are packed unwashed in salt. Fleshings are made up of fat and flesh and represent about 15% of the weight of the hide.

The cattle hide accounts for 5–9% (average 7%) of the live weight of beef cattle (Ockerman and Hansen, 2000). Consequently it is one of the most valuable by-products from beef cattle.

Inputs and outputs

Figure 3—5 is a flow diagram showing the inputs and outputs from this process, and Table 3—11 provides data for the key inputs and outputs.

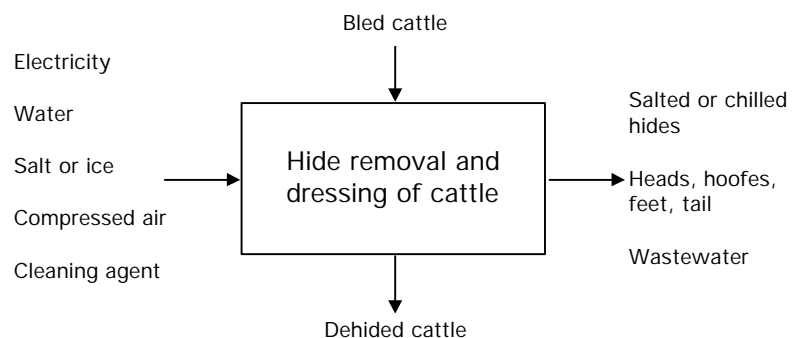


Figure 3—5 Inputs and outputs for hide removal and dressing of cattle

Table 3—11 Input and output data for hide removal and dressing of cattle

Inputs		Outputs	
Bled cattle carcass	238 kg	Dehided cattle carcass	207 kg
Water	5 L	Hide	15 kg
		Head, hooves, tail etc.	16 kg
		Fleshings	3 kg
		Wastewater	5 L

Environmental issues

When hides are preserved by salting, saturated brine or salt crystals are used. Up to 4 litres of saturated brine can be lost for each hide treated. These spent brine solutions can pose substantial disposal problems.

Cleaner Production opportunities

A typical consumption of salt for conserving hides is about 350 kg per tonne of hide. However, if hides are to be stored for 6 weeks or less, salt use can be reduced to 150 kg per tonne of hide. If a biocide is added, the consumption of salt can be further reduced to 50 kg per tonne.

Reduced salt consumption would also be advantageous for the receiving tannery, since many tanneries experience problems with too much salt in their wastewater.

Process description

3.6 Evisceration and splitting

The objective of evisceration is to remove the edible organs, the intestinal tract (casings) and the thoracic cavity (pluck). For pigs, the head is also removed as part of this process.

Edible organs consist of the liver and kidneys etc., and the intestinal tract consists of the stomach (or paunch in the case of cattle), intestines and spleen. The pluck materials consist of the heart, esophagus, lungs and trachea.

Offal, casings and pluck materials are collected in trolley bins (for small operations), or on a moving-top viscera table (for larger operations) and then transferred to other areas of the plant for further processing.

The carcasses are split into two using saws and knives, and then trimmed and graded. This is followed by washing, either manually using hoses or in automated carcass washing units.

Finally, the carcasses are sent for chilling or directly to the boning area for further processing. Carcasses are chilled to temperatures between 0.5°C and 1.5°C for at least 24 hours.

Inputs and outputs

Figure 3—6 is a flow diagram showing the inputs and outputs from this process, and Tables 3—12 and 3—13 provide data for the key inputs and outputs for pigs and beef cattle respectively.

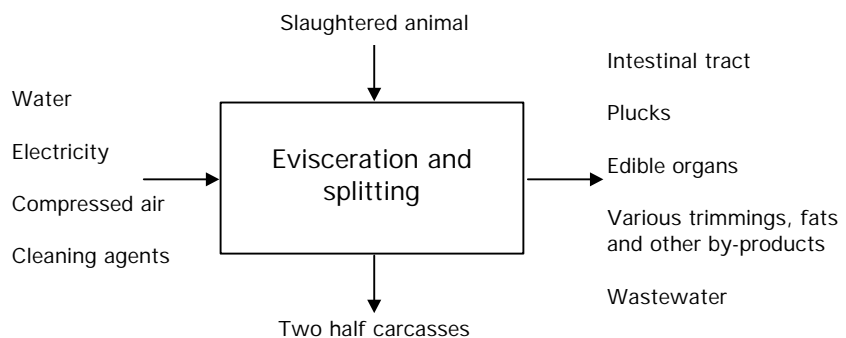


Figure 3—6 Inputs and outputs for evisceration and splitting

Table 3—12 Input and output data for the evisceration and splitting of a 100 kg pig

Inputs		Outputs	
Dehaired pig carcass	93 kg	Split pig carcass	74 kg
Water	40 L	Intestinal tract	10 kg
		Plucks and edible organs	3 kg
		By-products	5.5 kg
		Wastewater	40 L
		BOD ₅	0.05 kg

Table 3—13 Input and output data for the evisceration and splitting of 250 kg beef cattle

Inputs		Outputs	
Dehided cattle carcass	207 kg	Split cattle carcass	125 kg
Water	100 L	Intestinal tract	60 kg
		Plucks and edible organs	9 kg
		By-products	12 kg
		Wastewater	100 L
		BOD ₅	0.12 kg

Environmental issues

Evisceration and splitting are generally undertaken without water. However large amounts of hot water (82°C) are used for the cleaning and sterilisation of knives and equipment (saws, trays, gambrels, hooks, rails etc).

Carcass washing can be a significant source of water waste and effluent contamination. In manual operations there is a tendency for operators to use more water than is necessary. In contrast, in automated carcass washing units sprays are activated only when a side of meat is in the washing cabinet. The amount of water used can be set to the minimum required.

Water pressures greater than 10 bar for carcass washing can remove fat from the surface. This fat contributes to high oil and grease levels in the effluent stream. Water temperatures greater than 30°C can further exacerbate fat loss.

The use of water for cooling and transport of by-products results in high water consumption and high organic content in the effluent.

Cleaner Production opportunities

By-products should be transported dry on conveyors or in small containers with wheels. Container systems are a cheap and easy solution, whereas conveyors can be very expensive to install.

If water sprays are to be used on conveyor systems, variable-speed drives and flow-control valves should be used to regulate water flow as the conveyor speed alters.

The pressure of water sprays used for carcass washing should be less than 10 bar and cool water should be used to reduce the removal of fat from the surface of the carcass.

If carcasses are chilled in chill tanks, the rate of water discharge from the tanks should be reduced to the minimum level required to maintain acceptable bacterial counts. In addition, counter-current flow system should be used on chill tanks.

3.7 Casings processing

Process description

The term 'casings' refers to the intestinal tract of the animal or gut set. For pigs, it consists of the stomach, small and large intestines, middle cap, bladder and bung. For cattle the casings consist of the stomach (paunch, honeycomb, bible and rennet), bladder, small intestine, middle intestine and bung.

Certain parts of the casings can be processed into a number of value-added products, such as sausage skins, surgical sutures and strings for musical instruments and tennis rackets. Processing of casings involves de-sliming to remove the inner lining 'mucosa', and washing.

If casings are not processed into value-added products, they are generally sent for rendering with or without prior washing.

Inputs and outputs

Figure 3—7 is a flow diagram showing the inputs and outputs from this process and Tables 3—14 and 3—15 provide data for the key inputs and outputs for the processing of casings from pigs and cattle respectively.

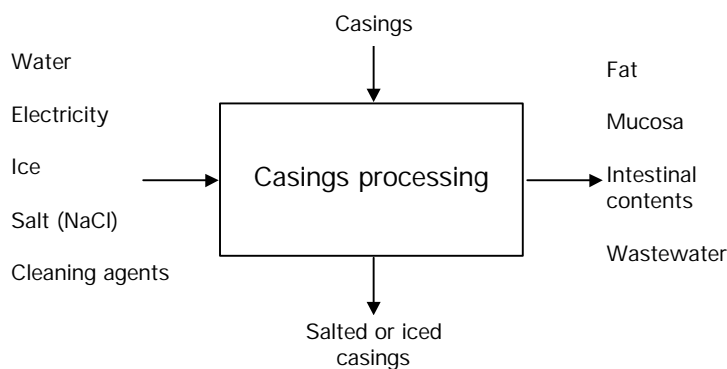


Figure 3—7 Inputs and outputs for casings processing

Table 3—14 Input and output data for the processing of one set of pig casings

Inputs		Outputs	
Pig casings	10 kg	Washed casings	~ 10 kg
Water	50–100 L	Wastewater	50–100 L
		BOD ₅	0.1–0.3 kg

Table 3—15 Input and output data for processing of one set of beef cattle casings

Inputs		Outputs	
Cattle casings	30 kg	Washed casings	~ 30 kg
Water	300–500 L	Wastewater	300–500 L
		BOD ₅	1–1.5 kg

Environmental issues

Water consumption for casings processing is very high, and can be up to 20% of total water consumption in plants where it is undertaken. Casings processing can also be a significant contributor to the organic and fat load in the effluent stream.

Cleaner Production opportunities

Fasting of animals for a period of 12 to 24 hours prior to slaughter reduces the quantity of undigested materials in the intestinal tract, making the evisceration process easier.

Since the water consumption and effluent loads generated by this process can be considerable, an assessment should be made of whether casings cleaning is a profitable choice. It may be better to send the empty intestines for inedible rendering, especially if water resources are scarce and the wastewater is poorly treated.

Water from the final rinse of the casings could be collected and recirculated or used for cleaning the large intestines and bungs. This would require a collection vessel and pipework.

If casings are to be washed for rendering only, recycled water from the slaughter floor, carcass washing, viscera tables and hand wash basins could be used, as it is still of high quality. To prevent blockages of nozzles or jets, the water should first be screened to remove gross solids (McNeil and Husband, 1995).

New techniques for emptying gut sets from pigs, without the use of water, have been developed in Denmark. Pig stomachs are conveyed over a rotating slitting blade and the stomach contents fall into a chute. Whether this option is feasible depends on the cost of water and the charges on wastewater.

3.8 Paunch washing (cattle)

Process description

In ruminants (cattle, sheep etc.), the paunch or first stomach contains a large amount of undigested material, referred to as paunch manure. For cattle, it is estimated that about 36–45 kg of wet paunch material is produced per head, but this depends on the size of the cattle being slaughtered and their history.

In some plants paunches are slashed, emptied and washed with water (wet dumping), so that edible products can be recovered from the paunch. Alternatively, paunches can be emptied and sent, without washing (dry dumping), to be rendered or used in pet food production.

Wet-dump systems generate 145–390 L effluent per paunch processed, whereas dry-dump systems generate 7–19 L effluent per paunch (MIRINZ, 1996). In the dry-dump system however, the paunch sack is not used as an edible by-product, due to the residual contamination with paunch manure.

Paunch manure is usually collected as a separate stream and screened to remove solids. Screened paunch solids are a good source of nutrients and are often applied to land or composted. The screened effluent is generally sent to the effluent treatment plant along with other effluent streams. At some plants the entire paunch manure stream is sent to the effluent treatment plant, but this practice is becoming less common as companies attempt to reduce the organic loads entering treatment plants.

Inputs and outputs

Figure 3—8 is a flow diagram showing the inputs and outputs from this process and Table 3—16 provides data for the key inputs and outputs.

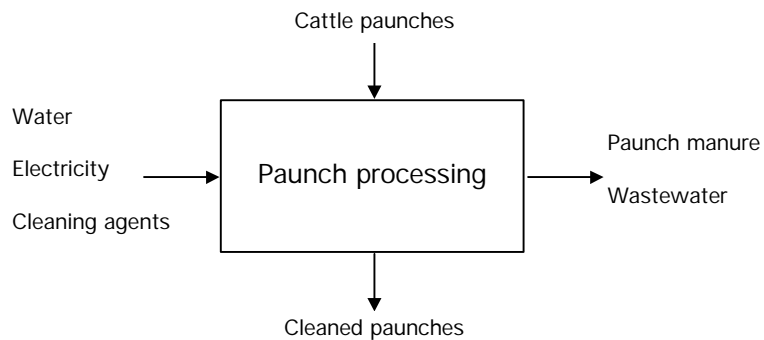


Figure 3—8 Inputs and outputs for paunch processing

Table 3—16 Input and output data for paunch processing

Inputs		Outputs	
Cattle paunch	50 kg	Washed cattle paunch	10 kg
Water	200 L ¹	Paunch manure	40 kg
		Wastewater	200 L ¹
		BOD ₅	0.5 kg

¹ This applies to wet-dump systems

Environmental issues

In plants where paunch washing takes place, water consumption in the casing process can be very high.

Paunch manure contains high concentrations of organic solids and other pollutants. BOD₅ concentrations have been estimated to be about 50,000 mg/L (Baumann, 1971). If paunch manure is discharged to an effluent treatment plant, problems can arise due to the resultant high total solids concentration. The undigested solids are not easily degraded in biological treatment systems and build up as sludge in the system, reducing its overall treatment capacity.

Cleaner Production opportunities

Fasting animals for a period of 12 to 24 hours prior to slaughtering reduces the quantity of paunch material, making the evisceration process easier.

Since the water consumption and effluent loads generated by this process are considerable, an assessment should be made of whether paunch washing is a profitable choice.

As with casings processing, use may be made of recycled water from other parts of the plant.

For cattle, a technique which allows for the recovery of the paunch sack, while reducing water consumption and effluent loading, is the two-step dry dump/spray wash system. The paunches are first emptied of their contents, without the use of water, and then rinsed using an efficient water spray system. See case study below.

Case study 3—2: Reduced effluent generation in paunch wash system

A survey was undertaken in New Zealand at five beef processing plants to evaluate different paunch handling operations and to trial a two-step dry dump/spray wash system.

It was found that the two-step system reduced water consumption and the pollutant load of the effluent stream, while allowing the paunch sack to be used as an edible by-product.

It was estimated that converting a wet-dump system to a two-step system could reduce the total effluent loading of a typical beef abattoir by 18–33% for total solids, 16–31% for COD, 9–18% for total nitrogen and 20–46% for total phosphorus. Potentially, the conversion could reduce a plant's effluent treatment or disposal costs by a similar proportion.

(MIRINZ, 1996)

Paunch manure from cattle is an ideal medium for composting or vermiculture (worm composting) along with other waste materials. After composting it can be used or marketed as a fertiliser and soil conditioner. Under some circumstances, paunch manure may be spread directly onto agricultural land; however prior composting is preferable.

3.9 Rendering*Process description*

Rendering is an essential part of the meat processing industry. Rendering converts highly perishable meat by-products that are unfit for human consumption into useful commodities such as meat meal, bone meal, tallow and also pet food. Materials that are commonly rendered include inedible offal and fat from the slaughtering process, dead animals and animal that have been classed as 'condemned' as a result of the post slaughter inspection.

The basic aims of rendering are:

- Sterilisation to make products safe;
- Recovery of fat to make the meal suitable for milling and stabilise it against oxidation; and
- Drying, to prevent bacterial growth and to facilitate transportation and storage.

Rendering is carried out using a number of different systems ranging from simple batch cooking systems in which fat is removed by hydraulic presses to highly sophisticated continuous systems. Pre-crushed raw materials are loaded into the rendering cooker. The material is heated to high temperatures, which evaporates the water and sterilises it. Fat is allowed to drain from the mixture in a percolator pan and the remainder of the fat is pressed out mechanically, either in a hydraulic press (batch process) or continuously in a screw press. The press cake is milled to produce meat meal and bone meal and the fat is further refined to remove impurities, by precipitation, centrifugation etc.

Inputs and outputs

Figure 3—9 is a flow diagram showing the inputs and outputs from a typical small rendering process. Table 3—17 provides data for the key inputs and outputs.

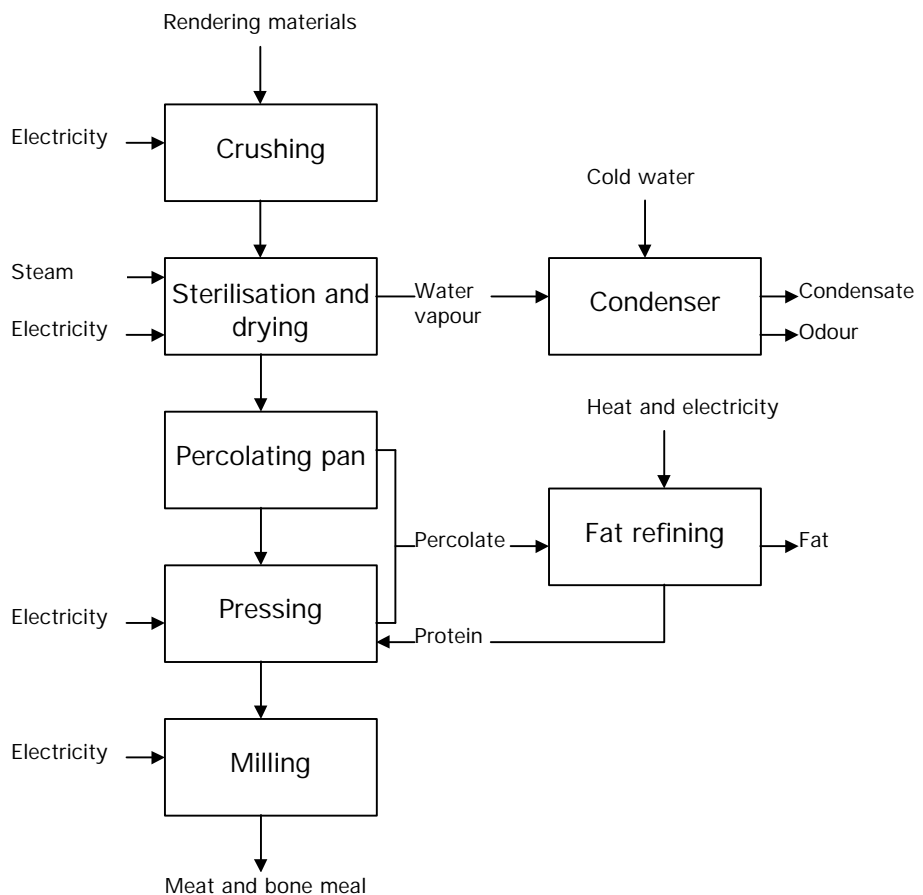


Figure 3—9 Inputs and outputs for rendering

Table 3—17 Input and output data for rendering

Inputs		Outputs	
Raw materials (offal, dead animals, etc.)	1000 kg ¹	Bone meal	280 kg
Fuel oil for steam generation	60 kg	Fat	110 kg
Electricity	70 kW.h	Wastewater	1000–1600 L ¹
Water for boiler	150–200 L	COD	5 kg
Water for condenser	200–500 L	Total nitrogen	0.6 kg
Water for cleaning	200–300 L		

¹ Approximately 60% of the weight of the raw materials is water, which ends up as condensate wastewater as a result of the rendering process.

Environmental issues

Water consumption for rendering is relatively low with a usage rate of about 1m³/tonne raw material and typically represents less than 10% of total water use at an abattoir.

Effluent from the rendering plant contains very high loads of organic matter, and at those plants where it is undertaken rendering is the largest single source of effluent contamination. Rendering effluent comprises condensate from dry rendering, stickwaters from wet rendering, decanters and blood coagulation and from polisher centrifuges.

The energy consumption for rendering is very high, especially for the drying step. However modern systems can be quite energy efficient, especially when multiple effect evaporators are used.

Rendering materials are highly putrescible, and if not handled and treated correctly can cause extremely bad odours. The exhaust fumes from the rendering process are also extremely odourous. It is often necessary to install odour control systems to reduce odour emissions to within required limits.

Cleaner Production opportunities

Since the rendering process converts 'waste' materials into useful, value-added products, rendering in itself is a Cleaner Production option.

Raw materials for rendering should be received at the rendering plant as soon as possible, and processed promptly to avoid odour. Delays in processing result in poor quality raw materials which lead to lower yields, lower quality products, and difficulties in processing the raw materials. Rendering materials should also be kept cool on ice, at about 10–15°C or preferably lower.

The heat contained in the vapour from the cookers can also be recovered in multiple effect evaporators etc. and used to pre-heat raw materials. This can reduce energy consumption from about 60 kg to 35–40 kg oil per tonne of raw material.

The effluent stream from rendering along with other high-strength streams, such as that from paunch and stomach dumping, could be collected and treated separately. By treating these streams separately from the low-strength streams from the rest of the plant, overall treatment performance is improved. Segregated, high-strength effluent

streams could be anaerobically digested to produce methane-rich biogas. The biogas could be used to supplement energy supplies on site.

3.10 Cleaning

Process description

All work areas and equipment are cleaned daily, usually at the end of each production shift. A common cleaning regime is as follows. First, equipment and floors are roughly hosed down. Then detergents and foam are applied, followed by washing and scrubbing. The detergents normally used are alkaline to remove fat and protein. The detergents and dirt are removed by hosing and/or scraping. Finally, there is a rinse with clean water to remove all detergent or disinfectant.

Areas that have high levels of fat residues such as boning and cutting rooms require high-pressure, low-volume water at approximately 60°C to give the most economical water usage. Higher water temperature will increase the amount of steam vapour and associated condensation problems, without any increase in cleaning efficiency (McNeil and Husband, 1995).

As well as the major cleaning that occurs at the end of each shift, knives and some items of equipment are washed and sterilised frequently throughout production. Hygiene regulations usually require that knives be sterilised in hot water and that the water in the sterilisers be replaced at set frequencies. Operators also regularly wash their hands. Knife sterilisers and hand wash stations are located at work-stations on slaughter floors and in processing areas for this purpose.

Hand basins provide a flow of hot water (35–43°C) at about 15 L/min (McNeil and Husband, 1995). The flow is controlled by thigh or pedal operated mechanisms; however microprocessor controlled units are also used. Knife sterilisers can be bowl-type or spray-type systems. Bowl-type sterilisers contain hot water that is continuously replenished to maintain the required temperature of about 82°C.

Inputs and outputs

Figure 3—10 is a flow diagram showing the inputs and outputs from this process.

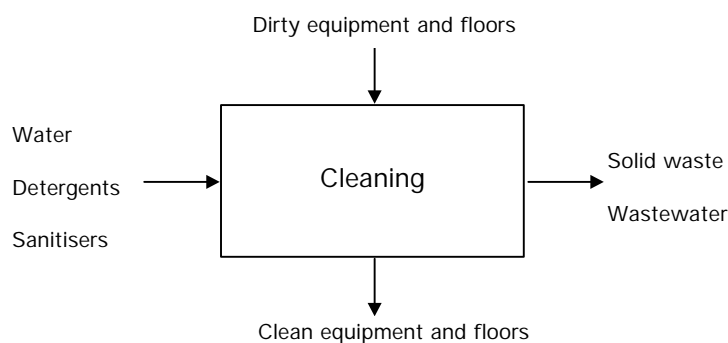


Figure 3—10 *Inputs and outputs for cleaning*

Environmental issues

Cleaning is one of the most water-intensive operations at abattoirs, typically accounting for 20–25% of total water consumption. Wastewater from cleaning contains a high organic load, as well as detergents and disinfectants.

Cleaner Production opportunities

The best way to reduce water consumption in cleaning is to undertake dry cleaning before washing with water. Solid materials should first be scraped and swept from all surfaces, including boning, slicing and packing tables, cutting boards, work platforms and floors.

Case study 3—3: Proper work procedures and control of water consumption in cleaning

Changes in cleaning practices at a pig abattoir resulted in a 31% reduction in water consumption and a 67% reduction in the use of detergents, without impairing hygiene. Undertaking dry cleaning to remove solid materials from floors and equipment prior to washing also resulted in a 30% decrease in overall man-hours used for the cleaning operations. The investment was low and water saving amounted to 10 litres per pig. This is a saving of US\$0.02–0.03 per pig. Labour costs and costs for cleaning agents were also substantially reduced.

Industrial vacuum cleaners have been used successfully in boning rooms for dry cleaning operations at abattoirs. Solids may have to be loosened and scraped free from surfaces, before the vacuum cleaner can be used to collect the solids for transfer to a rendering plant (McNeil and Husband, 1995).

Case study 3—4: Collection of waste from floors with a vacuum cleaner

Experiments have shown that collection of waste materials from floors in the slaughter, bleeding and evisceration areas using a vacuum cleaner can reduce wastewater loads by 50 g BOD₅ per pig. The investment required is approximately US\$25,000. The annual savings depend largely on costs for discharge of wastewater and surcharges for pollution load, but can amount to US\$4000–37,000 per year.

After thorough dry cleaning, work surfaces, walls and floors can be washed down in preparation for cleaning with detergents. The following measures will help reduce water consumption for this step:

- Hoses should be fitted with spray nozzles, since a pressurised spray is far more effective for cleaning surfaces and therefore uses less water. A pressure of 25–30 bar is advisable.
- Flat-jet nozzles should be used to provide maximum impact and velocity. Spray angles of up to 60° provide wide coverage and a sweeping effect to propel solids towards floor drains.
- The first rinse should be with cold water, because warm water will make protein materials stick to the surfaces. The temperature of the water for the subsequent cleaning depends on the kind of contamination. Cold water is often sufficient.
- The wastewater from the final rinse can be collected and used for the initial rinse on the following day.

Detergents and disinfectants can be a significant source of pollution if the amounts used are too great. It is very important, therefore, to monitor their consumption.

The following measures will help reduce detergent consumption:

- Determine the required amount or concentration for effective cleaning;
- Use a set concentration of detergents so that detergent use reduces as water consumption reduces;
- Use new detergents, some of which are more effective and more environmentally friendly than older ones. Alternative detergents should be evaluated on the basis of their cleaning performance as well as their cost and environmental attributes.

Sanitisers should be applied as a fine spray to cleaned surfaces, rather than as a final rinse with hot water. Chemical sanitisers can be more effective in bacteriological control, less damaging to the building and safer for personnel than large quantities of hot water (McNeil and Husband, 1995).

Spray nozzles, commonly used for cleaning operations, are subject to wear that causes deterioration of the orifice and distortion to the spray pattern. This results in an increased flowrate of water and reduced effectiveness. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995). Nozzles made from different materials have varying abrasion resistance, as shown in Table 3—18.

Regular monitoring of spray nozzle wear should be incorporated into maintenance programs. Nozzles in service can be compared with new nozzles to determine the extent of wear. The flowrate of a nozzle can be determined by measuring the time taken to fill a container of known volume.

Table 3—18 Abrasion wear index for nozzle materials¹

Material	Abrasion wear index
Brass	1 (poor)
Stainless steel	4–6 (good)
Hard plastic	4–6 (good)
Ceramic	90–200 (excellent)

¹ McNeil and Husband, 1995

Microprocessor-controlled hand wash stations, which use an infrared beam to initiate the flow of water for a pre-set period help overcome the problem of water wastage that can sometimes occur when operators tie down the controls of manually operated units.

Double-skin insulated knife steriliser bowls use less water than conventional bowl-type sterilisers, since they minimise heat loss and therefore reduce the rate of overflow required to maintain the required temperature. For a 3-litre bowl, this can mean an overflow rate of 15 L/hr compared with 36 L/hr for conventional bowl sterilisers. (McNeil and Husband, 1995).

For spray-type knife sterilisers, continually running sprays should be avoided and the flow should be initiated only when the implement is introduced into the unit and the sprays should run for a pre-set period of time. Control of steriliser flow rates should be the responsibility of a designated person and flow rates should be checked regularly.

3.11 Ancillary operations

3.11.1 Compressed air supply

Process description

Air is compressed in an air compressor and distributed throughout the plant in pressurised pipes. Usually, compressors are electrically powered and cooled with water or air.

Figure 3—11 is a flow diagram showing the inputs and outputs from this process.

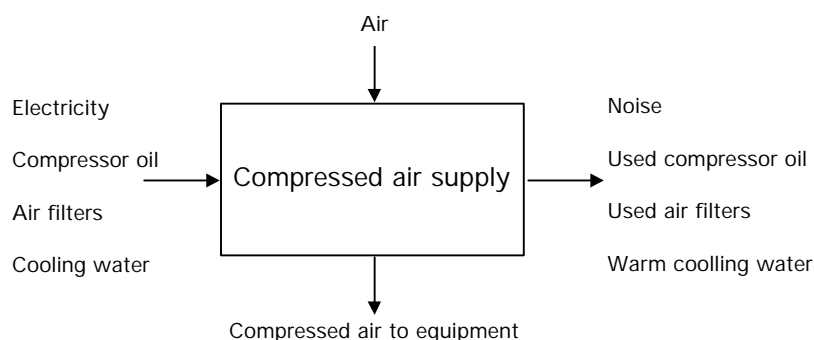


Figure 3—11 Inputs and outputs for production of compressed air

Environmental issues

Even a few small holes in the compressed air system (pipes, valves etc.), result in the loss of a large amount of compressed air continuously. This results in a waste of electricity because the compressor has to run more than is necessary. Table 3—19 lists unnecessary electricity consumption that can be caused by leaks in a compressed air system.

Table 3—19 Electricity losses from compressed air system leaks (6 bar)¹

Hole size (mm)	Air losses (L/s)	kW.h/day	MW.h/year
1	1	6	3
3	19	74	27
5	27	199	73

¹ UNEP 1996

Air compressors are often very noisy, and can be a nuisance for noise-sensitive receptors in some circumstances. If the air compressor is water cooled, water consumption can be quite high.

Cleaner Production opportunities

It is very important to check the compressed air system frequently. The best method is to listen for leaks during periods when there is no production. Maintenance (e.g. change of compressor oil) and the keeping of accurate logbooks will often help identify the onset of system leaks.

Shutting the system off when not in use and reducing the operating pressure of the system can also reduce the use of compressed air.

A temperature-sensitive valve, ensuring the optimum cooling temperature and minimum use of water should regulate the consumption of cooling water. Furthermore, cooling water can be recirculated via a

cooling tower. Alternatively, the cooling water can be reused for other purposes such as cleaning, where hygiene requirements are low.

Case study 3—5: Reuse of air compressor cooling water

An air-cooling system for an air compressor was replaced with a water-cooled one. The water absorbs the heat from the compressor and is then reused in the boilers. Energy is saved in the boilers because the water is preheated.

The installation of the water cooling system cost US\$18,000 and provided a payback period of less than two years.

3.11.2 Steam production

Process description

Steam is produced in a boiler and distributed throughout the plant through insulated pipes. Condensate is returned to a condensate tank, from where it is recirculated as boiler feed water, unless it is used for heating in the production process.

The amount and pressure of the steam produced depends on the size of the boiler and how the fuel is injected into the combustion chamber. Other parameters include pressure, fuel type, maintenance and operation of the boiler.

Inputs and outputs

Figure 3—12 is a flow diagram showing the inputs and outputs from this process.

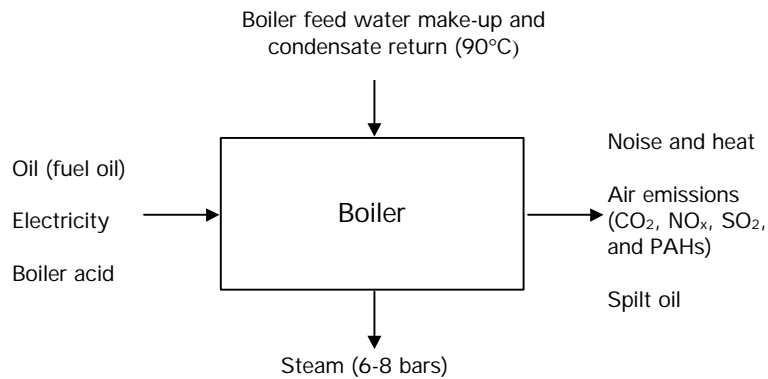


Figure 3—12 Inputs and outputs for supply of steam

Environmental issues

Inefficiencies in boiler operation and steam leaks lead to the waste of valuable fuel resources as well as additional operating costs.

Combustion of fuel oil results in emissions of carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxides (NO_x) and polycyclic aromatic hydrocarbons (PAHs). Some fuel oils contain 3–5% sulphur and result in sulphur dioxide emissions of 50–85kg per 1000 litres of fuel oil.

Sulphur dioxide converts to sulphuric acid in the atmosphere, resulting in the formation of acid rain. Nitrogen oxides contribute to smog and can cause lung irritation.

If the combustion is not adjusted properly, and if the air: oil ratio is too low, high emissions of soot can result. Soot contains PAHs that are carcinogenic.

Table 3—20 shows the emissions produced from the combustion of various fuels to produce steam.

Table 3—20 Emissions from the combustion of fuel oil

Inputs		Outputs	
Fuel oil (1% sulphur)	1 kg	Energy content	11.5 kW.h
		Carbon dioxide	3.5 kg
		Nitrogen oxides	0.01 kg
		Sulphur dioxide	0.02 kg

1 kg of oil = 1.16 litre of oil (0.86 kg/L)

1 kW.h = 3.6 MJ

Oil is often spilt at the oil storage area and at the boiler. If the spilt oil is not collected and reused or sold, it can cause serious pollution of soil and water.

Although most condensate from steam systems is returned to the boiler, some fresh water make-up is required. For inefficiently operated boilers, the amount of feed water required can be excessive. As well as higher water consumption, this results in the need to add additional boiler chemicals and increased fuel consumption to preheat the feed water.

Cleaner Production opportunities

Instead of using fuel oil with high sulphur content, it is advantageous to change to a fuel oil with a low sulphur content—less than 1%. This will increase the efficiency of the boiler and reduce the emission of sulphur dioxide. There are no investment costs related to this option, but the running costs will be higher because the fuel oil with a lower sulphur content is more expensive.

It is essential to avoid oil spills and, if they do occur, to clean them up properly and either reuse or sell the oil. A procedure for handling oil and oil spills should be prepared and followed.

If the boiler is old, the installation of a new one should be considered. Changing from coal to oil, or from oil to natural gas, should also be considered. In some burners it is possible to install an oil atomiser and thereby increase efficiency. When purchasing a new boiler, emphasis should be placed on purchasing the minimum sized boiler that is sufficient to meet the steam demand of the plant. Purchasing an over-sized boiler for the sake of contingency may not really be necessary.

Insulation of hot surfaces is a cheap and very effective way of reducing energy consumption. Equipment such as valves, flanges, autoclaves, heated vessels and pipe connections to machinery should be insulated: Proper insulation of these surfaces can reduce heat loss by 90%. The payback period for insulation is often less than 3 years.

The way in which a boiler is operated will affect its efficiency. If the air:fuel ratio is wrongly adjusted burning will be poor, causing more pollution and less efficient utilisation of the fuel. Proper operation of the boiler requires appropriate training of employees and, if the expertise is not available within the company, and possibly frequent visits of specialists.

Condensate return to the boiler should be maximised to minimise water consumption and improve boiler efficiency. If condensate from some areas is not returned to the boiler, piping systems to return it should be installed. Steam trap performance should be monitored regularly to ensure efficient return of condensate and to ensure they are not leaking.

Case study 3—6: Poorly operated coal-fired boiler

Samples of coal and waste ash were taken from coal-fired boilers and were measured for specific energy (kJ/kg), ash percentage and moisture percentage. Results showed that up to 29% of the total fuel supply was not being combusted in the boilers, with the least efficient boiler generating an additional 230 kg of unburnt material per tonne of coal. This unburnt material was retained in the ash and disposed of in landfill.

To improve performance, the company trained employees in efficient boiler operation, so that boilers could be run on automatic control. After this training, boiler efficiency increased by 25%, and the specific energy of the ash reduced to 6 kJ/kg.

Coal use was reduced by 1500 tons, making an annual saving of US\$45,000. Improved boiler operation also reduced annual landfill disposal by 275 tonnes. The company hired a specialist company to monitor boiler efficiency on an ongoing basis. The cost of this service is US\$2100 per month.

3.11.3 Water supply

Process description

High-quality domestic water supplies may not need any treatment before use in the plant, however if the available water is of poor quality it may be necessary to treat it to meet hygiene requirements. Treatment normally consists of aeration and filtration through gravel or sand, and chlorination may also be necessary.

Inputs and outputs

Figure 3—13 is a flow diagram showing the inputs and outputs from this process.

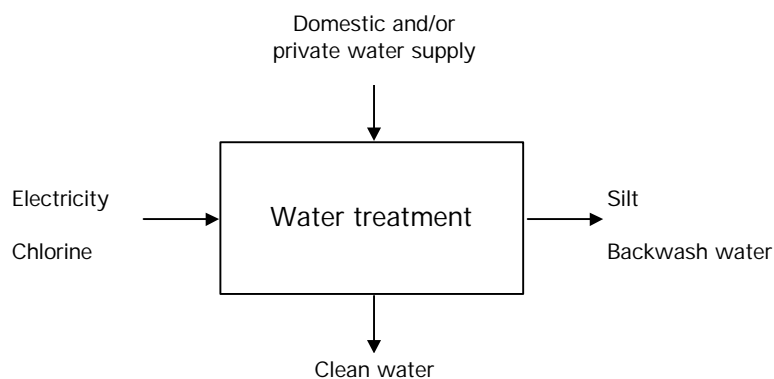


Figure 3—13 Inputs and outputs for supply of water

Environmental issues

Water is a valuable resource so its use should be minimised wherever possible. Since electricity is needed for pumping water, energy consumption also increases with increasing water consumption.

The losses that occur due to holes in water pipes and running taps can be considerable. Table 3—21 shows the relationship between size of leaks and water loss.

Table 3—21 Water loss from leaks at 4.5 bar pressure ¹

Hole size (mm)	Water loss (m ³ /day)	Water loss (m ³ /year)
0.5	0.4	140
1	1.2	430
2	3.7	1,300
4	18	6,400
6	47	17,000

¹ UNEP, 1996

Cleaner Production opportunities

To ensure that water consumption is optimised, usage rates should be monitored on a regular basis. It is helpful to install water meters for separate departments and even for individual processes or pieces of equipment. Whether this is feasible depends on the level of water consumption and the expected savings in each instance. Water consumption can be reduced by 10–50% simply by increasing employees' awareness and by educating them on how to reduce unnecessary consumption.

Energy-efficient pumps should be installed to reduce the energy consumed for pumping of water. New and efficient pumps can reduce energy consumption by up to 50% compared with standard pumps. It is very important to select a pump with optimum pumping capacity and position it close to the required work area.

3.11.4 Refrigeration and cooling

Process description

In refrigeration and cooling systems a refrigerant, typically ammonia or a chlorofluorocarbon (CFC)-based substance, is compressed, and its subsequent expansion is used to chill a closed circuit cooling system. The refrigerant itself can act as a primary coolant, recirculated directly through the cooling system, or alternatively, it can be used to chill a secondary coolant, typically brine or glycol.

CFCs were once extensively used in refrigeration systems, but they are now prohibited in many countries, and their use is being phased out as a result of the Montreal Protocol on ozone-depleting substances. All cooling systems should be closed circuit systems and free of leaks. However, due to wear and tear and inadequate maintenance, leaks may occur.

Inputs and outputs

Figure 3—14 is a flow diagram showing the inputs and outputs from this process.

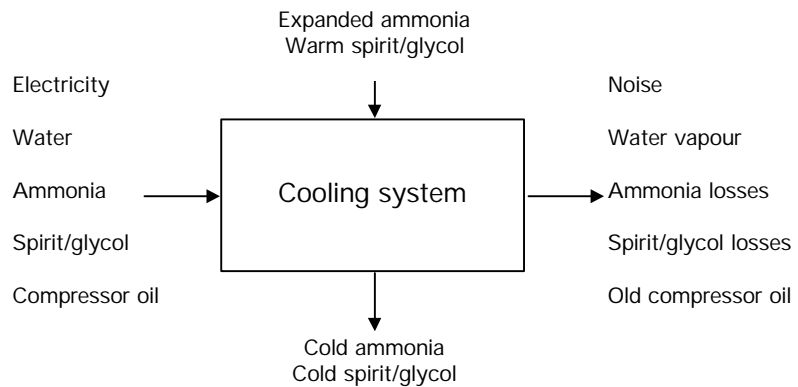


Figure 3—14 Inputs and outputs for cooling system

Environmental issues

The consumption of electricity and of water can be quite high.

If CFC-based refrigerants are used there is a risk that refrigerant gases will be emitted to the atmosphere, contributing to the depletion of the ozone layer. There is also a risk of ammonia and glycol leaks, which can be an occupational, health and safety problem for workers, and can also result in environmental problems.

Cleaner Production opportunities

CFC-based refrigerants should be replaced by the less hazardous hydrochlorofluorocarbons (HCFCs) or, preferably, by ammonia. In the long run both CFCs and HCFCs should be replaced by other refrigerants according to the Montreal Protocol. Replacing CFCs can be expensive, as it may require the installation of new cooling equipment.

Minimising the ingress of heat into refrigerated areas can reduce energy consumption. This can be accomplished by insulating cold rooms and pipes that contain refrigerant, by closing doors and windows to cold areas, and by installing self-closing doors.

If water and electricity consumption in the cooling towers seems high, it could be due to algal growth on the evaporator pipes. Another reason could be that the fans are running at too high a speed, blowing the water off the cooling tower.

4 CLEANER PRODUCTION CASE STUDY

This case originates from a Cleaner Production assessment carried out at a Danish pig abattoir. It describes what the company did and what the assessment achieved. The description below follows the Cleaner Production assessment procedure as described in Chapter 5.

4.1 Phase I: Planning and organisation

Obtain management commitment

The company wanted to reduce water consumption, because the costs of water and disposing of wastewater were too high.

Set up a project team

The management formed a project team, which comprised a foreman, a technical engineer and an external consultant.

Develop environmental policy

The company did not have a formal environmental policy; however, its strategy was to reduce water consumption and pollution without impairing product quality.

Plan the Cleaner Production assessment

The project team decided to focus the Cleaner Production assessment on the pig reception and holding areas. An assessment of the slaughter line had been undertaken previously. The following steps were decided upon:

- inspection of the area;
- measurement of water consumption;
- assessment of the work procedure;
- development of a list of possible improvements.

4.2 Phase II: Pre-assessment

Describe the process

The project team first described the processes that take place in the reception and holding areas. The abattoir processes about 1.1 million pigs per year. The pigs are delivered in trucks, each containing 50–60 pigs. Each truck must be cleaned and disinfected after unloading, according to regulations. The cleaning procedure takes place in a segregated cleaning area. Approximately 75 trucks are cleaned every working day.

Undertake walk-through site inspection

During the site inspection the following points were noted regarding the cleaning of trucks:

- Sawdust is used as bedding in the trucks.
- The driver removes the bedding and manure using water hoses with 10 mm nozzles.
- The waste is washed to drains and very little is collected.
- Afterwards the driver cleans the truck carefully, using cold water.

The site inspection revealed the following problems:

- High consumption of water.
- Running hoses.
- Discharge of manure and sawdust bedding to the sewer, causing high organic loading in the effluent.

Plan assessment phase

The project team decided to continue with the assessment of the reception area, since the pre-assessment had shown a considerable

number of opportunities for Cleaner Production improvements. In reality, the project team did not distinguish between work in the pre-assessment phase and in the assessment phase.

4.3 Phase III: Assessment

Collect data

The team measured water consumption by measuring the time it took to fill a container of known volume. Readings from a water meter supplying water to a larger area were taken to verify the data collected manually.

The following data were collected:

- Water consumption was approximately 17 L per pig or 950 L per truck.
- The water pressure was approximately 12 bar.
- The quantity of solid organic waste generated was not measured, neither was the organic pollution load of the effluent.

Identify Cleaner Production options

The project team discussed ways of reducing water consumption and minimising the organic load of the wastewater. The following options were identified:

- Using water at a pressure higher than 12 bar and using smaller nozzles;
- Removing the bedding with a scraper before washing with water;
- Reducing the amount of sawdust bedding in the trucks;
- Training employees to reduce the losses.

These options were discussed further in the evaluation phase.

4.4 Phase IV: Evaluation and feasibility study

Undertake preliminary evaluation

As the number of options was limited, the project team could quickly assess them. Reducing the amount of bedding would not give significant reductions in water consumption and pollution. It was therefore decided to focus on the other options.

Undertake technical evaluation

During the technical evaluation it was found that it was desirable and feasible to increase the water pressure from 12–18 bar, and at the same time change from the 10 mm nozzles to a trigger-controlled, jet spray gun.

The technical evaluation also showed that the dry collection of bedding and manure (i.e. before washing) would require the construction of a new area where the trucks could park, so that the bedding could be scraped directly into an automatic solid waste removal system. The project team inspected an existing area that was not in use, and found that it would be suitable for this purpose.

Undertake economic evaluation

The team estimated the costs of changing to high-pressure jet sprays and found that it would be feasible since only a minor investment was required. No large investments were required for the dry collection of bedding and manure, so the most important issue was whether it would require more labour to carry out the dry cleaning as well as wet cleaning. A trial showed that the dry cleaning and wet cleaning could be done as quickly as the previous method. The total investment in equipment and installation was estimated to be US\$5000.

Undertake environmental evaluation The project team expected that implementing the options would bring about a 50% reduction in water consumption and a similar reduction in organic load of the effluent.

Select options The project team presented the four options to the manager. It was decided to implement them all and to train the employees and truck drivers in the new procedures.

4.5 Phase V: Implementation and continuation

Prepare an action plan After the meeting with the manager, an implementation plan was drawn up. The plan took into account the time required for training the employees and drivers, without disrupting normal production. Staff responsible for the various options were appointed.

The following options were implemented:

- Bedding and manure were collected dry in a separate area by scraping them into a solid waste storage container. The waste was composted and later applied to land as fertiliser.
- Hoses were equipped with trigger-controlled spray guns and the water pressure was increased to 18 bar. Each gun delivered approximately 60 L of water per minute.
- The drivers were instructed in the proper use of the equipment and made aware of the importance of saving water and reducing pollution.

Monitor performance As part of the implementation process, a monitoring program was established to document improvements. The new cleaning operation was evaluated and figures for water consumption and pollution were recorded. The results were as follows:

- Water consumption was reduced to 5.6 L per pig (67% reduction).
- BOD was reduced to 13 g per pig.
- Solid organic waste was reduced to 1.4 kg per pig.
- Man-hours required for the cleaning of trucks remained unchanged.

The savings for the abattoir were nearly 12 L of potable water per pig. Based on a cost of US\$2 per KL, which includes the cost of water and charges for disposal of the wastewater, the annual savings are approximately US\$24,000. The extra costs for pressurising water and transporting the manure and bedding have not been included in this calculation.

4.6 Contacts

For more information on this case please contact:

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5 CLEANER PRODUCTION ASSESSMENT

A Cleaner Production assessment is a methodology for identifying areas of inefficient use of resources and poor management of wastes, by focusing on the environmental aspects and thus the impacts of industrial processes.

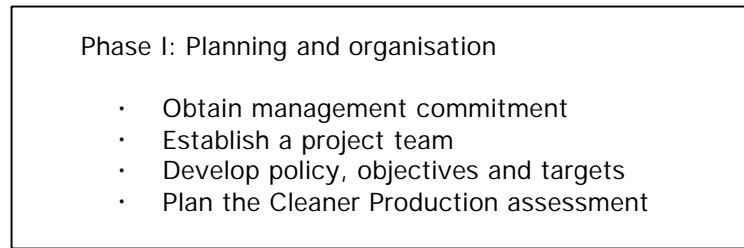
Many organisations have produced manuals describing Cleaner Production assessment methodologies at varying levels of detail. However, the underlying strategies are much the same. The basic concept centres around a review of a company and its production processes in order to identify areas where resource consumption, hazardous materials and waste generation can be reduced. Table 5-1 lists some of the steps described in the more well-known methodologies.

Table 5-1 Methodologies for undertaking a Cleaner Production assessment

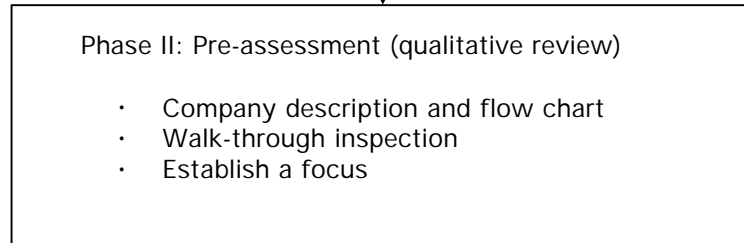
Organisation	Document	Methodology
UNEP, 1996	<i>Guidance Materials for the UNIDO/UNEP National Cleaner Production Centres</i>	<ol style="list-style-type: none"> 1. Planning and organisation 2. Pre-assessment 3. Assessment 4. Evaluation and feasibility study 5. Implementation and continuation
UNEP, 1991	<i>Audit and Reduction Manual for Industrial Emissions and Wastes. Technical Report Series No. 7</i>	<ol style="list-style-type: none"> 1. Pre-assessment 2. Material balance 3. Synthesis
Dutch Ministry of Economic Affairs, 1991	<i>PREPARE Manual for the Prevention of Waste and Emissions</i>	<ol style="list-style-type: none"> 1. Planning and organisation 2. Assessment 3. Feasibility 4. Implementation
USEPA, 1992	<i>Facility Pollution Prevention Guide</i>	<ol style="list-style-type: none"> 1. Development of pollution prevention programme 2. Preliminary assessment

The rest of this chapter describes the steps within a Cleaner Production assessment as outlined in the UNEP/UNIDO document, *Guidance Materials for UNIDO/UNEP National Cleaner Production Centres*. (UNEP, 1995). The steps from this methodology are detailed further in Figure 5—1.

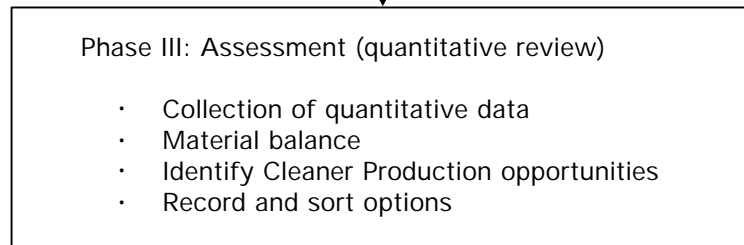
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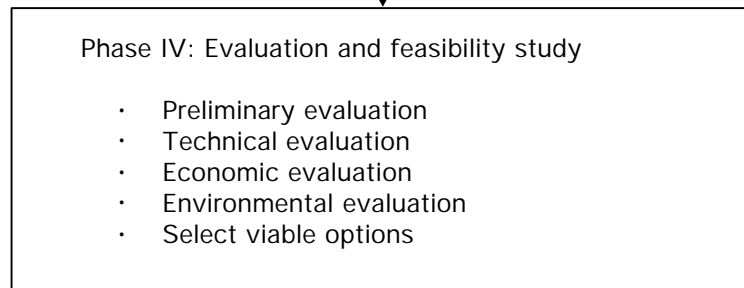
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See section 5.3



See section 5.4



See section 5.5

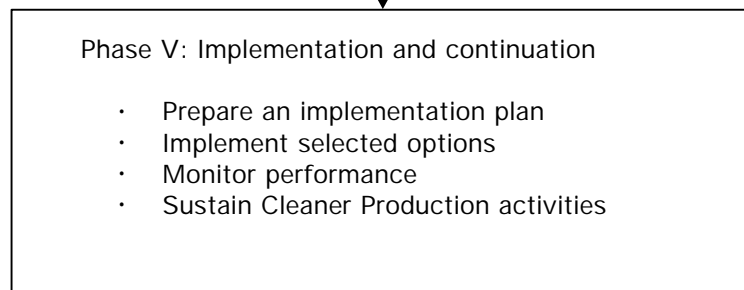


Figure 5—1 Overview of the Cleaner Production assessment methodology (UNEP, 1996)

5.1 Planning and organisation

The objective of this phase is to obtain commitment to the project, initiate systems, allocate resources and plan the details of the work to come. A project has more chance of success if this groundwork is done well.

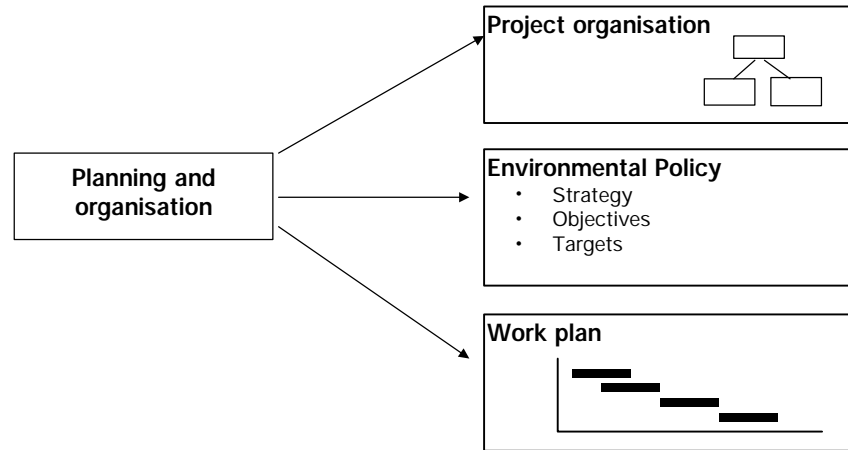


Figure 5—2 Planning and organisation phase

5.1.1 Obtain management commitment

Experience from companies throughout the world shows that Cleaner Production results in both environmental improvements and better economic performance. However, this message has to reach the management of the company. Without management commitment the Cleaner Production assessment may be only a short-term environmental management tool.

5.1.2 Establish a project team

It is best to establish a project team as early in the process as possible. The project team is responsible for progressing the assessment and will normally undertake the following tasks:

- analysis and review of present practices (knowledge);
- development and evaluation of proposed Cleaner Production initiatives (creativity);
- implementation and maintenance of agreed changes (authority).

5.1.3 Develop environmental policy, objectives and targets

The environmental policy outlines the guiding principles for the assessment. It acts to focus efforts in a way considered most important by management. The environmental policy can be refined as the project team gains more insight into the Cleaner Production possibilities within the company.

The policy contains the company's mission and vision for continuous environmental improvement and compliance with legislation. Objectives describe how the company will do this. For example, objectives could include reducing consumption of materials and minimising the generation of waste. Targets are measurable and scheduled, and are used to

monitor if the company is proceeding as planned. An example of a target might be a 20% reduction in electricity consumption within 2 years.

In general, objectives and targets should be:

- acceptable to those who work to achieve them;
- flexible and adaptable to changing requirements;
- measurable over time (targets only);
- motivational;
- in line with the overall policy statement.

5.1.4 Plan the Cleaner Production assessment

The project team should draw up a detailed work plan and a time schedule for activities within the Cleaner Production assessment. Responsibilities should be allocated for each task so that staff involved in the project understand clearly what they have to do. It is also wise to anticipate any problems or delays that may arise and plan for them accordingly. Lengthy delays and problems arising out of poor planning erode motivation at both the worker and management level.

5.2 Pre-assessment

The objective of the pre-assessment is to obtain an overview of the company's production and environmental aspects. Production processes are best represented by a flow chart showing inputs, outputs and environmental problem areas.

5.2.1 Company description and flow chart

A description of the company's processes should answer the following questions:

- What does the company produce?
- What is the history of the company?
- How is the company organised?
- What are the main processes?
- What are the most important inputs and outputs?

Processes which take place as part of the company's activities can be represented using a detailed process flow chart. Flow chart production is a key step in the assessment and forms the basis for material and energy balances which occur later in the assessment. Process flow charts should pay particular attention to activities which are often neglected in traditional process flow charts, such as:

- cleaning;
- materials storage and handling;
- ancillary operations (cooling, steam and compressed air production);
- equipment maintenance and repair;
- materials that are not easily recognisable in output streams (catalysts, lubricants etc.);
- by-products released to the environment as fugitive emissions.

The process flow chart is meant of providing an overview and should thus be accompanied by individual input/output sheets for each unit operation or department. Figure 5—3 provides an example of an input/output worksheet, however it may be arranged in various ways.

Inputs	Process	Outputs
Raw materials: _____ _____	Department: _____ _____ Process: _____ _____ Short description: _____ _____ _____ _____ Occupational health and safety: _____ _____	Product: _____
Ancillary materials: _____ _____		By-products: _____
Hazardous materials: _____ _____		Air emissions: _____ _____
Water: _____ _____		Solid waste: _____ _____
Energy: _____		Hazardous waste: _____
		Wastewater discharge: _____

Figure 5—3 Example of an input/output worksheet

5.2.2 Walk-through inspection

Much of the information needed to fill out the input/output sheets, described above, may be obtained during a walk-through inspection of the company.

The walk-through inspection should, if possible, follow the process from the start to the finish, focusing on areas where products, wastes and emissions are generated. During the walk-through, it is important to talk to the operators, since they often have ideas or information that can be useful in identifying sources of waste and Cleaner Production opportunities. The text box over page provides examples of the types of questions that may be asked to prompt the investigation.

During the walk-through problems encountered along the way should be listed, and if there are obvious solutions to these they should also be noted. Special attention should be paid to no-cost and low-cost solutions. These should be implemented immediately, without waiting for a detailed feasibility analysis.

5.2.3 Establish a focus

The last step of the pre-assessment phase is to establish a focus for further work. In an ideal world, all processes and unit operations should be assessed. However time and resource constraints may make it necessary to select the most important aspect or process area. It is common for Cleaner Production assessments to focus on those processes that:

- generate a large quantity of waste and emissions;
- use or produce hazardous chemicals and materials;
- entail a high financial loss;
- have numerous obvious Cleaner Production benefits;
- are considered to be a problem by everyone involved.

All the information collected during the pre-assessment phase should be well organised so that it is easily accessed and updated.

Questions to be answered during a walk-through inspection

Are there signs of poor housekeeping (untidy or obstructed work areas etc.)?

Are there noticeable spills or leaks? Is there any evidence of past spills, such as discoloration or corrosion on walls, work surfaces, ceilings and walls, or pipes?

Are water taps dripping or left running?

Are there any signs of smoke, dirt or fumes to indicate material losses?

Are there any strange odours or emissions that cause irritation to eyes, nose or throat?

Is the noise level high?

Are there open containers, stacked drums, or other indicators of poor storage procedures?

Are all containers labelled with their contents and hazards?

Have you noticed any waste and emissions being generated from process equipment (dripping water, steam, evaporation)?

Do employees have any comments about the sources of waste and emissions in the company?

Is emergency equipment (fire extinguishers etc.) available and visible to ensure rapid response to a fire, spill or other incident?

5.3 Assessment

The aim of the assessment phase is to collect data and evaluate the environmental performance and production efficiency of the company. Data collected about management activities can be used to monitor and control overall process efficiency, set targets and calculate monthly or yearly indicators. Data collected about operational activities can be used to evaluate the performance of a specific process.

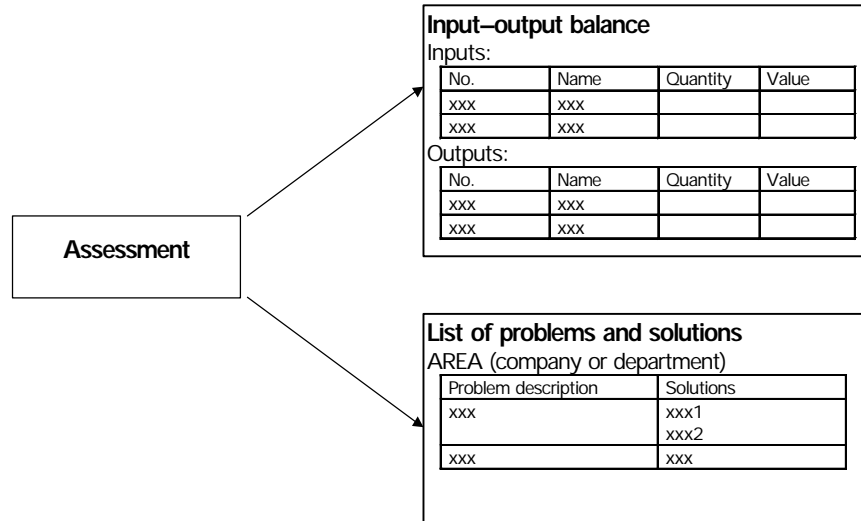


Figure 5—4 Assessment phase

5.3.1 Collection of quantitative data

It is important to collect data on the quantities of resources consumed and wastes and emissions generated. Data should be represented based on the scale of production: for example: water consumption per tonne of live carcass weight (LCW) processed or mass of organic matter (COD) generated per tonne of live carcass weight (LCW) processed. Collection and evaluation of data will most likely reveal losses. For instance, high electricity consumption outside production time may indicate leaking compressors or malfunctioning cooling systems.

In determining what data to collect, use the input/output worksheets, described previously, as a guide. Most data will already be available within the company recording systems, e.g. stock records, accounts, purchase receipts, waste disposal receipts and the production data. Where information is not available, estimates or direct measurements will be required.

5.3.2 Material balance

The purpose of undertaking a material balance is to account for the consumption of raw materials and services that are consumed by the process, and the losses, wastes and emissions resulting from the process. A material balance is based on the principle of 'what comes into a plant or process must equal what comes out'. Ideally inputs should equal outputs, but in practice this is rarely the case, and some judgment is required to determine what level of accuracy is acceptable.

A material balance makes it possible to identify and quantify previously unknown losses, wastes or emissions, and provide an indication of their sources and causes. Material balances are easier, more meaningful and more accurate when they are undertaken for individual unit operation. An overall company-wide material balance can then be constructed with these.

The material balance can also be used to identify the costs associated with inputs, outputs and identified losses. It is often found that

presenting these costs to management can result in a speedy implementation of Cleaner Production options.

While it is not possible to lay down a precise and complete methodology for undertaking a material balance, the following guidelines may be useful:

- Prepare a process flow chart for the entire process, showing as many inputs and outputs as possible.
- Sub-divide the total process into unit operations. (Sub-division of unit operations should occur in such a way that there is the smallest possible number of streams entering and leaving the process).
- Do not spend a lot of time and resources trying to achieve a perfect material balance; even a preliminary material balance can reveal plenty of Cleaner Production opportunities.

Environmental performance indicators for the process can be developed from the material balance data. This is achieved by dividing the quantity of a material input or waste stream by the production over the same period. Performance indicators may be used to identify over-consumption of resources or excessive waste generation by comparing them with those of other companies or figures quoted in the literature. They also help the company track its performance towards its environmental targets.

5.3.3 Identify Cleaner Production opportunities

Identifying Cleaner Production opportunities depends on the knowledge and creativity of the project team members and company staff, much of which comes from their experience. Many Cleaner Production solutions are arrived at by carefully analysing the cause of a problem.

Another way of identifying Cleaner Production opportunities is to hold a 'brainstorming' session, where people from different parts of the organisation meet to discuss solutions to specific problems in an open and non-threatening environment.

Some other sources of help from outside the organisation could be:

- this guide;
- external industry personnel or consultants;
- trade associations;
- universities, innovation centres, research institutions, government agencies;
- equipment suppliers;
- information centres, such as UNEP or UNIDO;
- literature and electronic databases.

5.3.4 Record and sort options

Once a number of Cleaner Production opportunities have been suggested and recorded, they should be sorted into those that can be implemented directly and those that require further investigation.

It is helpful to follow the following steps:

- Organise the options according to unit operations or process areas, or according to inputs/outputs categories (e.g. problems that cause high water consumption).
- Identify any mutually interfering options, since implementation of one option may affect the other.
- Opportunities that are cost free or low cost, that do not require an extensive feasibility study, or that are relatively easy to implement, should be implemented immediately.
- Opportunities that are obviously unfeasible, or cannot be implemented should be eliminated from the list of options for further study.

Table 5—2 Example of information recorded for identified options

Problem type	Problem description	Cleaner Production options
<p>Examples:</p> <ul style="list-style-type: none"> • resource consumption • energy consumption • air pollution • solid waste • wastewater • hazardous waste • occupational health and safety 	<p>Examples:</p> <ul style="list-style-type: none"> • name of process and department • short background of problem • amount of materials lost or concentration of pollutants • money lost due to lost resources 	<p>Examples:</p> <ul style="list-style-type: none"> • how the problem can be solved • short-term solution • long-term solution • estimated reductions in resource consumption and waste generation

5.4 Evaluation and feasibility study

The objective of the evaluation and feasibility study phase is to evaluate the proposed Cleaner Production opportunities and to select those suitable for implementation.

The opportunities selected during the assessment phase should all be evaluated according to their technical, economic and environmental merit. However, the depth of the study depends on the type of project. Complex projects naturally require more thought than simple projects. For some options, it may be necessary to collect considerably more information. An important source of this information may be employees affected by the implementation.

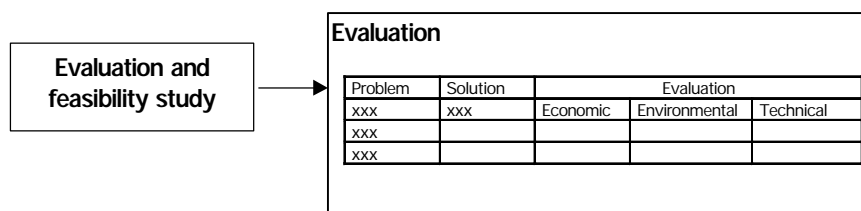


Figure 5—5 Evaluation and feasibility study phase

5.4.1 Preliminary evaluation

The quickest and easiest method of evaluating the different options is to form a group, consisting of the project team and management personnel, and discuss the possible solutions one by one. This process should give a good indication of which projects are feasible and what further information is required.

5.4.2 Technical evaluation

The potential impacts on products, production processes and safety from the proposed changes need to be evaluated before complex and costly projects can be decided upon. In addition, laboratory testing or trial runs may be required when options significantly change existing practices. A technical evaluation will determine whether the opportunity requires staff changes or additional training or maintenance.

5.4.3 Economic evaluation

The objective of this step is to evaluate the cost effectiveness of the Cleaner Production opportunities. Economic viability is often the key parameter that determines whether or not an opportunity will be implemented.

When performing the economic evaluation, costs of the change are weighed against the savings that may result. Costs can be broken into capital investments and operating costs. Standard measures used to evaluate the economic feasibility of a project are payback period, net present value (NPV), or internal rate of return (IRR).

Capital investment is the sum of the fixed capital costs of design, equipment purchase, installation and commissioning, costs of working capital, licenses, training, and financing. Operating costs, if different to existing conditions will need to be calculated. It may be that operating costs reduce as a result of the change, in which case, these should be accounted for in the evaluation as an ongoing saving.

5.4.4 Environmental evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the option. In many cases the environmental advantages are obvious: a net reduction in toxicity and/or quantity of wastes or emissions. In other cases it may be necessary to evaluate whether, for example, an increase in electricity consumption would outweigh the environmental advantages of reducing the consumption of materials.

For a good environmental evaluation, the following information is needed:

- changes in amount and toxicity of wastes or emissions;
- changes in energy consumption;
- changes in material consumption;
- changes in degradability of the wastes or emissions;
- changes in the extent to which renewable raw materials are used;
- changes in the reusability of waste streams and emissions;
- changes in the environmental impacts of the product.

In many cases it will be impossible to collect all the data necessary for a good environmental evaluation. In such cases a qualified assessment will have to be made, on the basis of the existing information.

Given the wide range of environmental issues, it will probably be necessary to prioritise those issues of greatest concern. In line with the national environmental policy of the country, some issues may have a higher priority than others.

Aspects to be considered in the evaluation

Preliminary evaluation

- Is the Cleaner Production option available?
- Can a supplier be found to provide the necessary equipment or input material?
- Are consultants available to help develop an alternative?
- Has this Cleaner Production opportunity been applied elsewhere? If so, what have been the results and experience?
- Does the option fit in with the way the company is run?

Technical evaluation

- Will the option compromise the company's product?
- What are the consequences for internal logistics, processing time and production planning?
- Will adjustments need to be made in other parts of the company?
- Does the change require additional training of staff and employees?

Economic evaluation

- What are the expected costs and benefits?
- Can an estimate of required capital investment be made?
- Can an estimate of the financial savings be made, such as reductions in environmental costs, waste treatment costs, material costs or improvements to the quality of the product?

Environmental evaluation

- What is the expected environmental effect of the option?
- How significant is the estimated reduction in wastes or emissions?
- Will the option affect public or operator health (positive or negative)? If so, what is the magnitude of these effects in terms of toxicity and exposure?

5.4.5 Select options

The most promising options must be selected in close collaboration with management. A comparative ranking analysis may be used to prioritise opportunities for implementation. The concept of such a method is shown below in Table 5-3. An option can be assigned scores, say from 1 to 10, based on its performance against a set of evaluation criteria. By multiplying each score by a relative weight assigned to each criterion, a final score can be arrived at. The options with the highest scores will probably be best suited for implementation. However, the results of this analysis should not be blindly accepted. Instead, they should form a starting point for discussion.

All simple, cost-free and low-cost opportunities should of course be implemented as soon as possible.

Table 5-3 Example of a weighted sum method for evaluating alternative options

Evaluation criterion	Weight	Score*					
		Option A		Option B		Option C	
		score	weighed score	score	weighed score	score	weighed score
Reduced hazardous waste treatment	3	+ 3	9	+ 2	6	+ 3	9
Reduced wastewater treatment costs	3	+ 1	3	0	0	+ 2	6
Reduced amount of solid waste	3	+ 3	9	+ 2	6	+ 3	9
Reduced exposure to chemicals	2	+ 3	6	0	0	-1	-2
Reduced amount of water consumption	1	+ 1	1	0	0	+ 2	2
Reduced odour problems	1	0	0	-1	-1	0	0
Reduced noise problems	1	-2	-2	0	0	0	0
Easy to install and maintain	3	-1	-3	-1	-3	+ 1	3
Weighted sum			23		8		27

* -3 = lowest rank, 0 = no change, + 3 = highest rank (preferred)

5.5 Implementation and continuation

The objective of the last phase of the assessment is to ensure that the selected options are implemented, and that the resulting reductions in resource consumption and waste generation are monitored continuously.

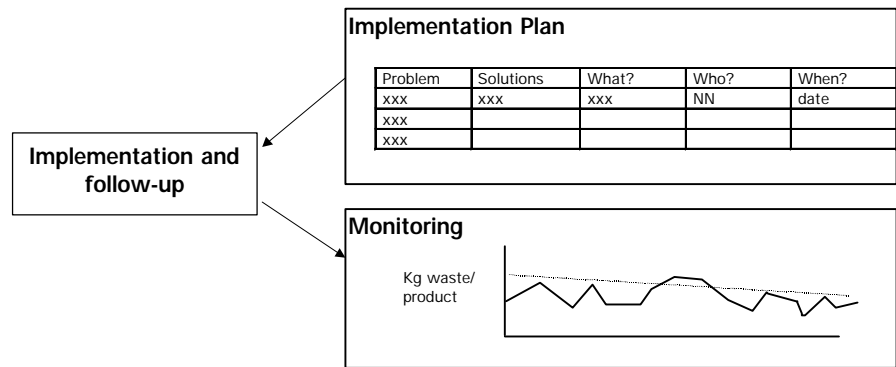


Figure 5—6 Implementation and continuation phase

5.5.1 Prepare an implementation plan

To ensure implementation of the selected options, an action plan should be developed, detailing:

- activities to be carried out;
- the way in which the activities are to be carried out;
- resource requirements (finance and manpower);
- the persons responsible for undertaking those activities;
- a time frame for completion with intermediate milestones.

5.5.2 Implement selected options

As for other investment projects, the implementation of Cleaner Production options involves modifications to operating procedures and/or processes and may require new equipment. The company should, therefore, follow the same procedures as it uses for implementation of any other company projects.

However, special attention should be paid to the need for training staff. The project could be a failure if not backed up by adequately trained employees. Training needs should have been identified during the technical evaluation.

5.5.3 Monitor performance

It is very important to evaluate the effectiveness of the implemented Cleaner Production options. Typical indicators for improved performance are:

- reductions in wastes and emissions per unit of production;
- reductions in resource consumption (including energy) per unit of production;
- improved profitability.

There should be periodic monitoring to determine whether positive changes are occurring and whether the company is progressing toward its targets. Examples of the types of aspects that could be checked to evaluate improvements are shown in Table 5-4.

5.5.4 Sustain Cleaner Production activities

If Cleaner Production is to take root and progress in an organisation, it is imperative that the project team does not lose momentum after it has implemented a few Cleaner Production options. Sustained Cleaner Production is best achieved when it becomes part of the management culture through a formal company environmental management system or a total environmental quality management approach.

An environmental management system provides a decision-making structure and action plan to support continuous environmental improvements, such as the implementation of Cleaner Production.

If a company has already established an environmental management system, the Cleaner Production assessment can be an effective tool for focusing attention on specific environmental problems. If, on the other hand, the company establishes a Cleaner Production assessment first, this can provide the foundations of an environmental management system.

Regardless of which approach is undertaken, Cleaner Production assessment and environmental management systems are compatible. While Cleaner Production projects have a technical orientation, an environmental management system focuses on setting a management framework, but it needs a technical focus as well.

To assist industry in understanding and implementing environmental management systems, UNEP, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*. This kit is compatible with the ISO 14001 standard.

Like the Cleaner Production assessment, an environmental management system should be assessed and evaluated on an ongoing basis and improvements made as required. While the specific needs and circumstances of individual companies and countries will influence the nature of the system, every environmental management system should be consistent with and complementary to a company's business plan.

Table 5—4 Evaluation checklist

Overall Cleaner Production assessment check	YES	NO
• Are the opportunities implemented according to the action plan?		
• Are new procedures being followed correctly by the employees?		
• Where do problems occur and why?		
• Do licenses or permits require amendments? Which ones?		
• Has compliance with legislation been maintained as a result of the changes?		
Environmental performance check		
• Are the opportunities cost effective? Is the cost effectiveness as expected?		
• Has the number of waste and emission sources decreased? By how many?		
• Has the total amount of waste and emissions decreased? By how much?		
• Has the toxicity of the waste and emissions decreased? By how much?		
• Has the energy consumption decreased? By how much?		
• Have the Cleaner Production goals been achieved? Which have and which have not?		
• Have there been any technical ramifications? Which and why?		
Documentation check (The following items should be included in the files.)		
• Statements of the company's objectives and targets and the environmental policy		
• Company description and flow diagram with input and outputs		
• Worksheets completed during the Cleaner Production assessment		
• Material balances		
• List of Cleaner Production opportunities generated during brainstorming sessions		
• Lists of opportunities that are technically, economically and environmentally feasible		
• Implementation action plan		
• Monitoring data		
• 'Before-and-after' comparisons		
• Post-implementation evaluation reports		

Evaluation Questionnaire

CLEANER PRODUCTION ASSESSMENT IN MEAT PROCESSING

As part of its continuing review of the quality and impact of publications it supports, the United Nations Environment Programme's Division of Technology, Industry and Economics would appreciate your co-operation in completing the following questionnaire.

1. Quality

Please rate the following quality aspects of the publication by ticking the appropriate box:

	<i>Very good</i>	<i>Adequate</i>	<i>Poor</i>
Presentation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Structure of content	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Subject coverage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ease of reading	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Level of detail	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rigour of analysis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Up-to-date	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Usefulness

In general, how much of the publication is:

	<i>Most</i>	<i>About half</i>	<i>Little</i>
Of technical/substantive value to you?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Relevant to you?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
New to you?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Will be used by you?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What would make the manual more useful for you?

3. Effectiveness in achieving the objective

The objective of this publication is to provide the reader with an appreciation of how Cleaner Production can be applied to the meat processing industry as well as providing resources to help undertake a Cleaner Production assessment at a meat processing facility. In your opinion, to what extent does this document fulfil this objective?

Please tick one box Fully Adequately Inadequately

Please state reasons for your rating:

4. Uses

a. Please state how the publication will affect or contribute to your work, illustrating your answer with examples.

b. Please indicate, in order of importance (first, second or third), the usefulness of the publication to you:

	<i>First</i>	<i>Second</i>	<i>Third</i>
For your own information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
As reference material	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
As guidelines for on-the-job application	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Distribution

Will others read your copy of this publication? Yes No Unknown

If 'yes', how many?

Did you receive this publication directly from UNEP? Yes No Unknown

If 'no', who forwarded it to you?

6. General Observations

a. Please indicate any changes in the publication that would increase its value to you.

b. Please indicate, in order of importance (first, second or third), which of the following items might increase the value of the publication to you.

	<i>First</i>	<i>Second</i>	<i>Third</i>
Translation into your own language	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Specific regional information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Additional technical information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7. The following data would be useful for statistical analysis

Your name (optional)

Professional background

Position/function/occupation

Organisation

Country

Date

UNEP would like to thank you for completing this questionnaire. Please return to:

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ANNEX 1 REFERENCES AND BIBLIOGRAPHY

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ANNEX 2 GLOSSARY

BAT	Best available technology and best available techniques (from an environmental viewpoint). BAT covers both equipment and operation practice.
BOD ₅	Biochemical oxygen demand: a measure of the quantity of dissolved oxygen consumed by microorganisms due to the breakdown of biodegradable constituents in wastewater over 5 days.
CFC	Chlorofluorocarbon: CFCs have very good technical properties as coolants, but are causing depletion of the ozone layer, which protect humans, animals and crops against ultraviolet radiation. CFCs and HCFCs (hydrogenated chlorofluorocarbon) are being phased out according to the Montreal Protocol. CFC-11 is commonly known as freon.
CIP	Cleaning in place: circulation of a cleaning solution through or over the surface of production equipment.
CO ₂	Carbon dioxide
COD	Chemical oxygen demand: a measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater.
CP	Cleaner Production
CPA	Cleaner Production assessment
DW	Dressed weight
EMS	Environmental management system
Eutrophication	Excessive growth of algae, reducing penetration of light through water and consuming large amounts of oxygen, resulting in a high risk of fish death due to lack of oxygen.
HCFC	Hydrogenated chlorofluorocarbon; see CFC.
HSCW	Hot standard carcass weight
ISO 14001	International Standard ISO 14001 Environmental Management Systems—specification with guidance for use. International Organization for Standardization
LCW	Live carcass weight
N	Nitrogen
NO _x	Nitrogen oxides. Notation covers both NO ₂ and NO (nitrogen monoxide).
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbons: occur in flue gases from combustion of fuel. Some PAHs are carcinogenic.
SS	Suspended solids

TS	Total solids
UN	United Nations
UNEP DTIE	United Nations Environment Program Division of Technology, Industry and Economics
UNIDO	United Nations Industrial Development Organization
US\$	US dollars
VOC	Volatile organic compounds; e.g. solvents with a low boiling point.

Units

bar	unit for measuring pressure (1 bar = 0.987 atmosphere)
°C	degrees Celsius
J	joule (1 W = 1 J/s)
kg	kilogram
kW.h	kilowatt hour (1 kW.h = 3.6 MJ)
L	litre
m	metre
m ²	square metre
m ³	cubic metre (= 1000 L)
MJ	1 million joules (1 MJ = 0.278 kW.h)
MW.h	megawatt hour (1 MW.h equals 1000 kW.h)
Nm ³	normal cubic meter
S	second
t / tonne	tonne (= 1000 kg)

ANNEX 3 FURTHER INFORMATION

Journals

In English

Meat International

Elsevier International Business Information
 PO Box 4, 7000 BA Doetinchem
 The Netherlands
 Phone: + 31 31 43 49 249
 Fax: + 31 31 43 40 515
 Email: int@misset.nl

Food Technology

Institute of Food Technologists
 221 N. La Salle St. Ste. 300, Chicago, Il. 60601
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In German

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Organisations

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 Website: <http://www.uneptie.org>

This organisation publishes a number of useful resources, including the UNEP Technical Report Series, Cleaner Production and environmental management training packages and UNEP periodicals such as *UNEP Industry and Environment Review*. It also maintains the International Cleaner Production Information Clearinghouse (ICPIC) database which contains Cleaner Production case studies (see Cleaner Production on the Web section).

UNEP Cleaner Production Working Group for the Food Industry

Environmental Management Centre

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Fax: + 61 7 33 65 60 83

Email: R.Pagan@mailbox.uq.edu.au

Website: <http://www.geosp.uq.edu.au/emc/CP/default.HTM>

The aim of the group is to promote Cleaner Production in the food industry. The group's activities include maintaining a network of food industry and Cleaner Production experts, maintaining a library and database of information related to Cleaner Production in the food industry, delivering workshops and seminars and producing a newsletter.

United Nations Industrial Development Organization (UNIDO)

Vienna International Centre

P.O. Box 300

A-1400 Vienna

Austria

Phone: + 43 1 21 13 10

Fax: + 43 1 23 21 56

Email: zcsizer@unido.org

Website: <http://www.unido.org/doc/f50135.htmls>

UNIDO provides seminars, conferences, workshops, media coverage, demonstration projects, training and information dissemination. It also offers support in establishing National Cleaner Production Centres. Fifteen such centres had been set up by October 1998, with several more on the way.

Information manuals available from UNIDO include the *UNEP/UNIDO Audit and Reduction Manual for Industrial Emissions and Wastes* and UNIDO's DESIRE kit (Demonstration in Small Industries for Reducing Wastes). In addition, nine of the National Cleaner Production Centres have their own country-specific manuals. UNIDO has also prepared seven manuals specific to particular industry sub-sectors and has contributed to 26 UNEP Technical Reports on specific Cleaner Production options. All these publications can be obtained through UNIDO.

Food and Agriculture Organization of the UN (FAO)

Via delle Terme di Caracalla

00100 Rome

Italy

Phone: + 39.0657051

Fax: + 39.0657053152

Website: <http://www.fao.org/>

FAO's aim is to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations. It is active in the areas of land and water development, plant and animal production, forestry, fisheries, economic and social policy, investment, nutrition, food standards and commodities and trade.

It provides regular and comprehensive statistics on world food production and also commissions projects and publication related to the environmental sustainability of food production.

Cleaner Production on the web

UNEP International Cleaner Production Information Clearinghouse (ICPIC)

ICPIC is a Cleaner Production database containing case studies, publication abstracts, lists of expert organisations, and information on the resources available from UNEP DTIE. It is an electronic reference tool that is searchable by key word.

The database can be accessed via the internet at the site indicated below. A CD-ROM version of the database can also be ordered through the same website.

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Website: http://www.unepie.org/Cp2/info_sources/icpic_data.html

US EPA Enviro\$en\$e

States Environmental Protection Agency's website. It provides information on pollution prevention, compliance and enforcement. The information available includes pollution prevention case studies, pollution control technologies, environmental statutes and regulations, compliance and enforcement policies and environmental guidelines.

Website: <http://es.epa.gov/>

National Technology Transfer Centre, USA

At the National Technology Transfer Centre website you can search the internet for Cleaner Production cases.

Wheeling Jesuit University

316 Washington Avenue

Wheeling, WV 26003

United States of America

Phone: + 1 80 06 78 68 82

Website: <http://endeavor.nttc.edu/>

EnviroNET Australia

The EnviroNET Australia website contains a wide range of Cleaner Production case studies from Australia.

Environment Australia

Environment Protection Group

40 Blackall Street

Barton ACT 2600

Australia

Phone: + 61 2 62 74 17 81

Fax: + 61 2 62 74 16 40

Email: environet@ea.gov.au

Website: <http://www.erin.gov.au/net/environet.html>

ANNEX 4 ABOUT UNEP DTIE

The mission of United Nations Environment Programme is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

The activities of UNEP DTIE, located in Paris, focus on raising awareness, improving the transfer of information, building capacity, fostering technology transfer, improving understanding of the environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and promoting global chemical safety. The division is composed of one centre and four units, as described below.

The **International Environmental Technology Centre** (Osaka) promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins in developing countries and countries with economies in transition.

The **Production and Consumption Unit** (Paris) fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

The **Chemicals Unit** (Geneva) promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety worldwide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

The **Energy and OzonAction Unit** (Paris) supports the phase-out of ozone-depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of this unit.

The **Economics and Trade Unit** (Geneva) promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

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