European Commission

FINAL DRAFT

Best Environmental Management Practice for the Food and Beverage Manufacturing Sector

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June 2015

Joint Research Centre

Abstract

This report describes information pertinent to the development of Best Environmental Management Practice (BEMP) techniques for the Sectoral Reference Document on the food and beverage manufacturing sector, to be produced by the European Commission according to Article 46 of Regulation (EC) No 1221/2009 (EMAS Regulation). The report firstly outlines scientific information on the contribution of food and beverage manufacturing to key environmental burdens in the EU, alongside data on the economic relevance of the sector. Afterwards it presents best environmental management practices which are broadly applicable to all food and beverage manufacturers. The carrying out of an environmental assessment, sustainable supply chain management, cleaning operations, improvement of energy efficiency, use of renewable energies, optimisation of transport and distribution, refrigeration and freezing operations and avoidance of food waste are the topics covered. Subsequently, specific information for nine individual subsectors are presented, namely the processing of coffee, manufacture of olive oil, manufacture of soft drinks, manufacture of beer, production of meat and poultry meat products, manufacture of fruit juice, cheese making operations, manufacture of bread, biscuits and cakes and manufacture of wine. A range of best environmental management practices that can be applied in each of them are described.

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Acknowledgements

This report was prepared by the European Commission's Joint Research Centre in the framework of supporting the development of an EMAS Sectoral Reference Document for the food and beverage manufacturing sector[1]. This document is based on different preparatory studies carried out by the Instituto Andaluz de Tecnologia (IAT, Spain), Asociacion de Investigacion de la Industria Agroalimentaria (AINIA, Spain) and Oakdene Hollins (UK).

Moreover, a technical working group, comprising a broad spectrum of experts in the manufacture of food and beverages, supported the development of the document by providing input and feedback.

[1] Further information on the development of the EMAS Sectoral Reference Documents is available at: http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf

PREFACE

Context and overview

This **Best Practice Report**[2] provides an overview of techniques that are **Best Environmental Management Practices** (BEMPs) in the food and beverage manufacturing sector. The document was developed by the European Commission's Joint Research Centre (JRC) on the basis of desk research, interviews with experts, site visits and in close cooperation with a Technical Working Group (TWG) comprising experts from the sector. This Best Practice Report provides the basis for the development of the EMAS Sectoral Reference Document (SRD) for the food and beverage manufacturing sector. The structured process for the development of this best practice report is outlined in the guidelines on the ***"Development of the EMAS Sectoral Reference Documents on Best Environmental Management Practice"*** (European Commission, 2014), which are available online[3].

EMAS (the EU Eco-Management and Audit Scheme) is a management tool for companies and other organisations to evaluate, report and improve their environmental performance. To support this aim and according to the provisions of Art. 46 of the EMAS Regulation (EC No. 1221/2009), the European Commission produces SRDs to provide information and guidance on BEMPs in several priority sectors, including the food and beverage manufacturing sector.

Nevertheless, it is important to note that the guidance on BEMP is not only for EMAS participants, but rather, it is intended to be a useful reference document for any relevant company that wishes to improve its environmental performance or any actor involved in promoting best environmental performance.

BEMPs encompass techniques, measures or actions that can be taken to minimise environmental impacts. These can include technologies (such as more efficient machinery) and organisational practices (such as staff training).
An important aspect of the BEMPs proposed in this document is that they are proven and practical, i.e.:

- they have been implemented at full scale by several companies (or by at least one company if replicable/applicable for others);
- they are technically feasible and economically viable.

In other words, BEMPs are demonstrated practices that have the potential to be adopted on a wide scale in the food and beverage manufacturing sector, yet which at the same time are expected to result in an exceptional environmental performance compared to current mainstream practices.

[2] This report is part of a series of 'best practice reports' published by the European Commission's Joint Research Centre covering a number of sectors for which the Commission is developing SRDs on Best Environmental Management Practice. More information on the overall work and copies of the 'best practice reports' available so far can be found at: http://susproc.jrc.ec.europa.eu/activities/emas/

[3] http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf

A standard structure is used to outline the information concerning each BEMP, as shown in Table a.

Table a: Information gathered for each BEMP

Category	Type of information included
Description	Brief technical description of the BEMP including some background and details on how it is implemented.
Achieved environmental benefits	Main potential environmental *benefits* to be gained by implementing the BEMP.
Appropriate environmental indicators	Indicators and/or metrics used to monitor the implementation of the BEMP and its environmental benefits.
Cross-media effects	Potential *negative* impacts on other environmental pressures arising as side effects of implementing the BEMP.
Operational data	Operational data that can help understand the implementation of a BEMP, including any issues experienced. This includes actual and plant-specific performance data where possible.
Applicability	Indication of the type of plants or processes in which the technique may or may not be applied, as well as constraints to implementation in certain cases.
Economics	Information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, etc.).
Driving force for implementation	Factors that have driven or stimulated the implementation of the technique to date.
Reference organisations	Examples of companies that have successfully implemented the BEMP.
Reference literature	Literature or other reference material cited in the information for each BEMP.

Sector-specific Environmental Performance Indicators and Benchmarks of Excellence are also derived from the BEMPs. These aim to provide organisations with guidance on appropriate metrics and levels of ambition when implementing the BEMPs described.

- **Environmental Performance Indicators** represent the metrics that are employed by organisations in the sector to monitor either the implementation of the BEMPs described or, when possible, their environmental performance directly.
- **Benchmarks of Excellence** represent the highest environmental standards that have been achieved by companies implementing each related BEMP. These aim to allow all actors in the sector to understand the potential for environmental improvement at the process level. Benchmarks of excellence are not targets for all organisations to reach but rather a measure of what can be achieved (under stated conditions) that companies can use to set priorities for action in the framework of continuous improvement of environmental performance.

The sector-specific Environmental Performance Indicators and Benchmarks of Excellence presented in this report were agreed by the TWG at the end of its interaction with the JRC.

Role and purpose of this document

This document is intended to support the environmental improvement efforts of all companies in the food and beverage manufacturing sector by providing guidance on best practices.

Companies from the food and beverage manufacturing sector can use this document to identify the most relevant areas for action, find detailed information on best practices to address the main environmental aspects, as well as company-level environmental performance indicators and related benchmarks of excellence to track sustainability improvements.

This Best Practice Report provides the technical basis for the development of the EMAS Sectoral Reference Document (SRD) for the Food and Beverage Manufacturing Sector according to Article 46 of the EMAS Regulation.

How to use this document

This document is not conceived to be read from beginning to end, but as a working tool for professionals willing to improve the environmental performance of their organisation and who seek reliable and proven information in order to do so.

Different parts of the document will be of interest and will apply to different professionals and at different stages.

The best way to start using this document is by reading the short section about its structure to understand the content of the different chapters and, in particular, the areas for which BEMPs have been described and how these BEMPs have been grouped.

Then, Chapter 1 would be a good starting point for readers looking for a general understanding of the sector and its environmental aspects.

Those looking for an overview of the BEMPs described in the document could start from Chapter 13 (Conclusions) and in particular with Table 13.1 outlining all BEMPs together with the related environmental performance indicators and benchmarks of excellence, i.e. the exemplary performance level that can be reached in each area.

For readers looking for information on how to improve their environmental performance in a specific area, it is recommended to start directly at the concrete description of the BEMPs on that topic, which can be easily found through the table of contents (at the very beginning of the document).

STRUCTURE

After the Preface section, which gives an overview of the framework under which this document was developed, Chapter 1 presents some general facts and figures of the food and beverage manufacturing sector in the EU context. Chapter 2 defines the scope of the report and the main environmental aspects and pressures for food and beverage manufacturers while Chapter 3 presents in detail the Best Environmental Management Practices for the Food and Beverage Manufacturing Sector as a whole. The following chapters, from 4 to 12, present some sector specific best environmental management practices for a number of sectors (i.e. processing of coffee, manufacture of olive oil, manufacture of soft drinks, manufacture of beer, production of meat and poultry meat products, manufacture of fruit juice, cheese making operations, manufacture of bread, biscuits and cakes and manufacture of wine).

Finally, Chapter 13 summarises the BEMPs presented, highlighting their applicability and the suitable environmental performance indicators. Moreover, the benchmarks of excellence agreed with the TWG are also reported in the final chapter.

Table b: Summary of the structure of the document

	Topics and BEMPs
Chapter 1	General facts and figures of the food and beverage manufacturing sector
Chapter 2	Scope of the Best Practice Report and environmental aspects and pressures
Chapter 3	Best environmental management practices for the food and beverage manufacturing sector as a whole: - Performing an environmental sustainability assessment of products and/or operations - Sustainable supply chain management - Environmentally friendly cleaning operations - Improving transport and distribution operations - Improving freezing and refrigeration - Deploying energy management and energy efficiency throughout all operations - Integrating renewable energy in the manufacturing processes - Avoiding food waste in food and beverage manufacturing - Link to the reference document on best available techniques in the food, drink and milk industries (FDM BREF)
Chapter 4	Processing of coffee: - Reduction of energy consumption through the use of green coffee pre-heating in batch coffee roasting
Chapter 5	Manufacture of olive oil - Reduced washing of olives upon reception - Minimising water consumption in olive oil separation
Chapter 6	Manufacture of soft drinks: - Use of blowers in the drying stage of bottling/packaging

	Topics and BEMPs
Chapter 7	Manufacture of beer: - Cross-flow rough beer filtration - Reducing energy consumption in wort boiling - Moving from batch to continuous beer production systems - CO_2 recovery in beer production
Chapter 8	Production of meat and poultry meat products: - High pressure processing for decontamination of meat
Chapter 9	Manufacture of fruit juice: - Value-added use of fruit residues
Chapter 10	Cheesemaking operations: - Recovery of whey
Chapter 11	Manufacture of bread, biscuits and cakes: - Unsold bread and pastry waste reduction schemes - Minimising energy consumption for baking
Chapter 12	Manufacture of wine: - Reducing water use, organic waste generation and energy use in the winery
Chapter 13	Conclusions: BEMPs, environmental performance indicators and benchmarks of excellence

1. BASIC FACTS AND FIGURES OF THE EU FOOD AND BEVERAGE MANUFACTURING SECTOR

1.1. TURNOVER AND EMPLOYMENT

The food and drink industry represents the second largest manufacturing sector in the EU in terms of turnover, value added and employment. It accounts for 16.0 % of the total manufacturing turnover (EUR 956.2 billion for the EU 27), 14.6 % of employment and its value added was 13.8% of total EU manufacturing in 2009. In addition, it is the second manufacturing sector in the EU in terms of number of companies (FoodDrinkEurope, 2012a).

Food and drink manufacturers have been less affected by the economic downturn because of the output growth (1.8 %) registered during the period 2008 to 2011, while the output of the EU manufacturing industry decreased (4.2 %) in the same period (FoodDrinkEurope, 2011).

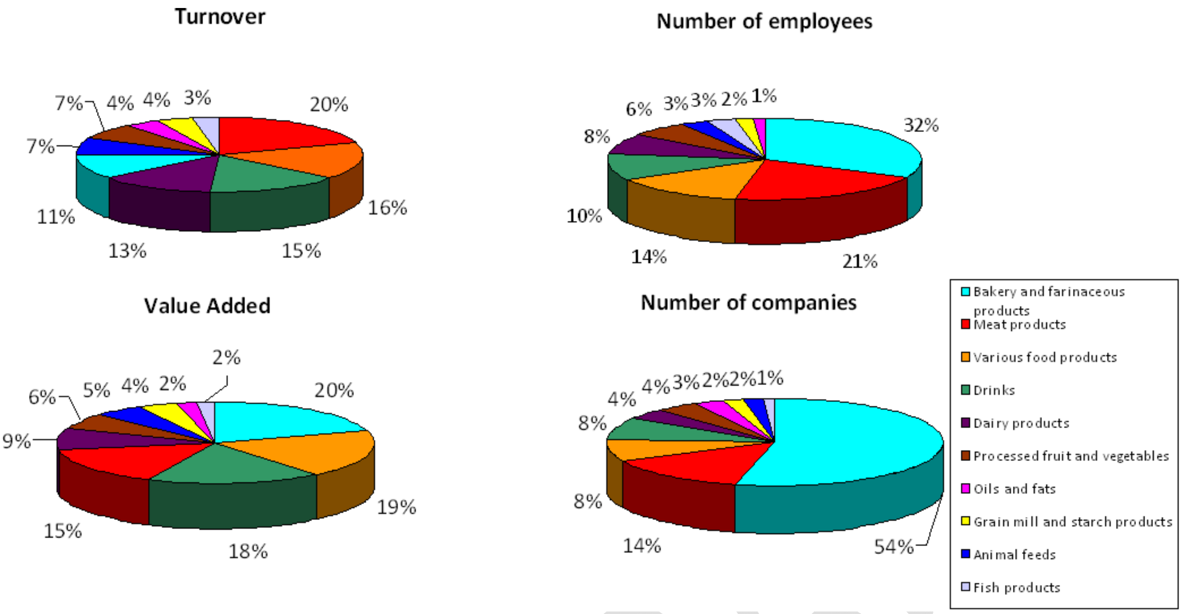
The EU food and beverage manufacturing sector (over 287,000 companies in 2010) provides jobs for more than 4 million people. It is very diverse in terms of products and company types, and is characterised by a very large number of small and medium-sized enterprises (SMEs): 99 % of the total number of companies. SMEs represent 48 % of the turnover, 48 % of the value added and 63 % of the employment of the food and drink sector (FoodDrinkEurope, 2011).

1.2. COMPOSITION OF THE FOOD AND DRINK SECTOR IN THE EU-27

The food and beverage manufacturing sector is characterised in general by high competition among companies of the sector and this supports the increasing level of product quality (European Commission, 2009).

As shown in Figure 1.1, the meat subsector is the largest one, representing 20% of total turnover. It has the largest number of companies, after the bakery and farinaceous products subsector. In addition, the bakery and farinaceous products category ranks first in terms of value added, employment and number of companies.

Figure 1.1: Distribution of turnover, value added, number of employees and number of companies in the subsectors of the food and drink industry 2010 (%)



Source: FoodDrinkEurope, 2011

1.3. EMAS in the food and drink sector

The Food and Beverage manufacturing sector (NACE 10 & 11) accounts for around 11% of all EMAS-registered organisations (148 out of 3,653 total EMAS-registered organisations) (European Commission, EMAS; 2013b). In addition, 63 of these organisations have published their corresponding Environmental Statements in the *Environmental Statements Library* (European Commission, EMAS 2013a).

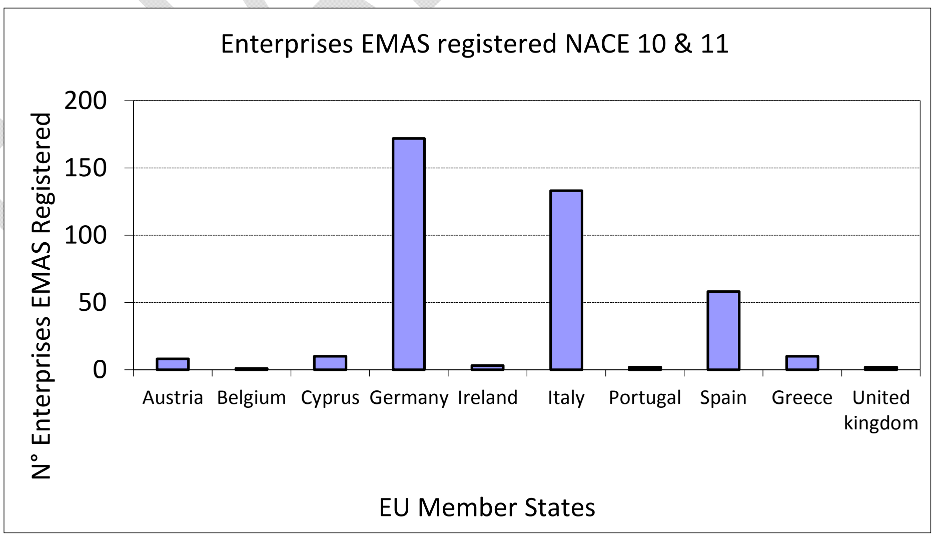
Food and drink EMAS-registered manufacturers come from 15 EU countries (Table 1.1 and Figure 1.2). The largest number of registrations belongs to Italy, followed by Germany and Spain.

Table 1.1: EMAS organisations in the food and drink sector, by NACE code (Rev. 2) and country, 2013

Country	Enterprises (NACE 10)	Enterprises (NACE 11)	Total
Austria	2	5	7
Belgium	1	0	1
Cyprus	3	2	5
Germany	25	19	44
Ireland	2	-	2
Italy	47	16	63
Portugal	1	1	2
Spain	14	7	21
Sweden	2	0	2
United Kingdom	-	1	1
TOTAL	**97**	**51**	**148**

Source: European Commission, EMAS 2013b[4]

Figure 1.2: Country repartition and size distribution of EMAS-registered organisations in the food and drink sector, in absolute numbers (2013).



Source: European Commission EMAS, 2013b

[4] At the time of writing, as some data in the EU EMAS register were out of date or have expired, a substantial update of the system was underway. Figures reported in the table may not reflect the true number of organisations and sites in EU Member States.

1.4. Initiatives for a sustainable food and drink manufacturing sector

At European level, there are several initiatives to address environmental aspects in the manufacturing of food and beverages and, more generally, the environmental sustainability of the whole food and drink value chain.

- European Food Sustainable Consumption and Production Round Table: this international initiative, gathering together actors from across the food and drink value chain, promotes sustainable consumption and production in the food and drink sector, considering different environmental aspects in the food chain and supporting EU policy objectives (European Food SCP Round Table, 2013).

  The Round Table aims to harmonise the environmental assessment of food and drink products, and it facilitates the voluntary communication of environmental information along the food chain to the consumer, through methods and tools used to promote good environmental performance (FoodDrinkEurope, 2012).

- The European Technology Platform (ETP): an industry cooperation, supported by the European Commission, with the aim of promoting innovation in the food and drink sector through a knowledge transfer among stakeholders in order to stimulate investment in R&D for national, regional and global markets.

  The ETP is developing a strategic agenda for research and innovation (2013-2020 and beyond), which includes:
    - Innovation and research areas.
    - Health.
    - Safe foods.
    - Sustainable and ethical production.
    - Food processing and packaging.
    - Food chain management.

The following table summarises the main opportunities and strategic priorities promoted by the food and drink manufacturing industry in seven key areas with the aim of improving the environmental sustainability throughout the value chain.

Table 1.2: Opportunities for the EU food and drink manufacturing sector, 2030.

SOURCE MATERIAL	ENERGY	WASTE	WATER	PACKAGING	TRANSPORT	CONSUMERS
Sustainable supply chain and responsible cultivation	Share and encourage best practices	R&D on the use of by-products and waste	Improve good management practices	R&D: lightweight, biodegradable, recyclability and bio-based	Optimising loading and back-haul	Avoiding food waste production
Investments in agricultural productivity	Increase R&D, investments and collaboration	Campaigns to avoid/reduce waste production	Incentives for water efficiency	Initiatives to prevent waste production	Use of alternative fuels	Optimisation of packaging
Communication about certification schemes	Improve competitiveness of alternative energy source	Resource efficiency	International standard for impact assessment	Data quality and reporting	Increase rail and water-based transport	Campaigns to promote sustainable consumption
Technical support to farmers on best practices	Incentives for energy efficiency	Identify options for centralisation of food waste utilisation	Increase availability of data on water consumption	Investment in recycling	Improve optimal route planning	Improve the management of surplus food

Source: FoodDrinkEurope, 2012.

Reference literature

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2. SCOPE OF THE DOCUMENT AND ENVIRONMENTAL ASPECTS AND PRESSURES

2.1. Scope of the document

This report addresses all companies producing food and beverages. The production activities are represented by NACE codes 10 (manufacture of food products) and 11 (manufacture of beverages).

Best practices presented for the overall food and beverage manufacturing sector (Chapter 3) are addressed to all companies belonging to NACE codes 10 and 11. In addition, for several subsectors, namely:

- Processing of coffee (NACE 10.83) in Chapter 4
- Manufacture of olive oil (NACE 10.41) in Chapter 5
- Manufacture of soft drinks (NACE 11.07) in Chapter 6
- Manufacture of beer (NACE 11.05) in Chapter 7
- Production of meat and poultry meat products (NACE 10.13) in Chapter 8
- Manufacture of fruit juice (NACE 10.32) in Chapter 9
- Cheese making operations (NACE 10.51) in Chapter 10
- Manufacture of bread (NACE 10.71) in Chapter 11
- Manufacture of wine (NACE 11.02) in Chapter 12

A range of sector-specific best practices are also presented.

2.2. Main environmental aspects and pressures of the food and drink manufacturing sector

The food and drink manufacturing industry is a very diverse sector because of the very large range of different products and manufacturing processes. Moreover, key environmental impacts are not only linked to the manufacturing itself, but also to upstream and downstream processes and, in particular, to the primary production of raw materials (mainly agriculture).

From a life cycle thinking perspective, Figure 2.1 shows the main actors involved in the value chain of food and beverage products, ranging from the purchase of raw and auxiliary materials (supply chain), through production, distribution, retail, catering and restaurants, to treatment, recycling or disposal of residues. For each phase, the main environmental pressures associated with the food and drink sector are indicated.

From the point of view of the food and beverage manufacturing industry, these environmental pressures can be associated to environmental aspects.

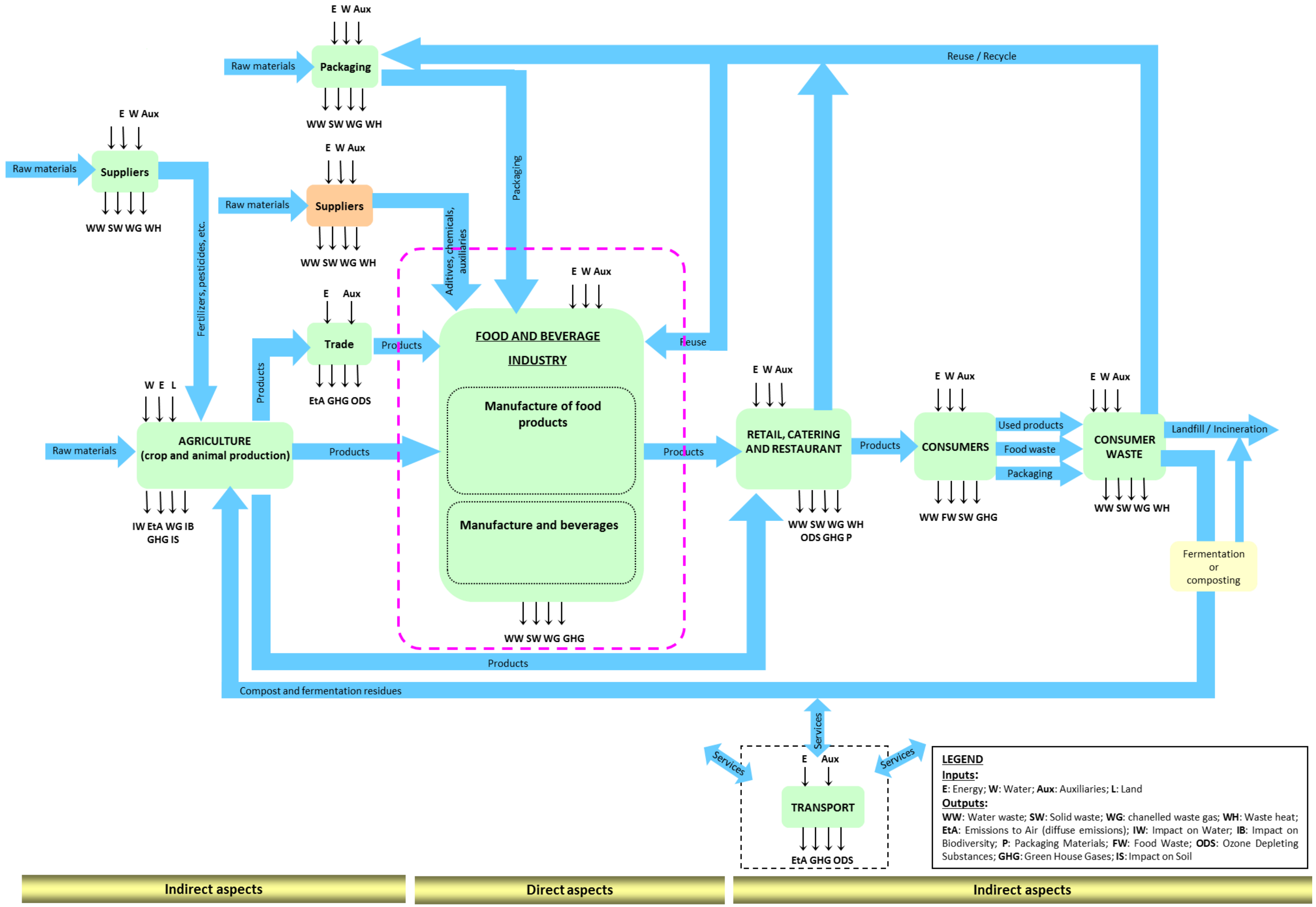
According to the EMAS Regulation, an environmental aspect is an element of an organisation's activities, products or services that has or can have an impact on the environment.

Environmental aspects are distinguished in two categories:

- Direct environmental aspects: those associated with activities, products and services of the organisation itself (over which it has direct management control). These are a food or beverage manufacturer's own operations.
- Indirect environmental aspects: those which can result from the interaction of an organisation with third parties and which can, to a reasonable degree, be influenced by an organisation. These are activities related to the value chain of the products of a food or beverage manufacturer.

The pink dashed line in Figure 2.1 highlights the area corresponding to the direct environmental aspects.

Figure 2.1: Overview of the value chain of the food and drink sector with the associated main environmental pressures



Tables 2.1 and 2.2 summarise the main environmental pressures related to direct and indirect environmental aspects for food and drink manufacturers. It should be stressed that this classification is provided here only for guidance, since each food and beverage manufacturer must assess the nature of each of their own aspects based on their specific situation. For instance, transport operations (and the related fuel consumption) can be a direct aspect for a company operating its own transport fleet and an indirect aspect for companies using third-party transport services.

Table 2.1:. Main environmental pressures linked to direct environmental aspects for food and beverage manufacturers

Inputs	Energy consumption	Energy for the operation of processing machinery (pumps, ventilation, mixers, compressors, refrigeration and cooling units). Fuel consumption for transportation. Energy for heating and high temperature processes (boiling, drying, pasteurisation and evaporation).
	Water consumption	Water consumption for cleaning operations. Water use as an ingredient, especially for non-alcoholic and alcoholic drinks. Process-related water consumption (e.g. for washing, boiling, steaming, cooling).
	Use of chemicals	Use of cleaning and disinfection agents. Use of refrigerants. Additives.
Outputs	Air emissions	Dust, VOCs, refrigerants, emissions from combustion (such as CO_2, NO_X and SO_2).
	Solid waste generation	*Non-hazardous waste* from manufacturing and processing (organic residues, sludge, waste packaging, etc.). *Hazardous waste* from the maintenance of equipment and machinery (packaging containing residues of / or contaminated by dangerous substances, absorbents, filter materials, oil filters, etc.).
	Waste water generation	Process water (from washing, boiling, evaporation, extraction, filtration, etc.). Water from cleaning operations. Service water (cooling water, boiler blowdown, regeneration exchangers, etc.). Sanitary water.
	Noise generation	Noise from the operation of plant, machinery and equipment.
	Odours generation	Odour losses during storage, filling and emptying of bulk tanks and silos. Odour caused by VOCs.

Table 2.2:. Main environmental pressures linked to indirect environmental aspects for food and beverage manufacturers

Inputs	Energy consumption	Fuel consumption for transport. Energy used by consumers for food preparation.
	Resource depletion	Materials used for packaging production.
	Water consumption	Water use in agriculture.
	Biodiversity loss	Loss of biodiversity due to agricultural activities.
Outputs	Air emissions	CO_2, NO_X and SO_2 from transport. Emissions from industrial production of packaging, raw materials, auxiliaries Greenhouse gas emissions from primary crop and animal production.
	Solid waste generation	Food waste (households, wholesale/retail and food service). Packaging waste

Environmental pressures linked to direct environmental aspects

In spite of the heterogeneity of the food and drink manufacturing industry (due to the diversity of the processed raw materials and/or products), the most relevant environmental aspects are the energy and water consumption, solid waste and waste water (FIAB, 2008).

Water consumption

Water consumption of the food and drink manufacturing industry accounts for approximately 1.8% of total water consumption in Europe (FoodDrinkEurope, 2012).

Water in the food and drink sector has many different uses, such as:

1. Raw material, especially for the drinks industry.
2. Cleaning operations.
3. Hot and cold operations (cooking, pasteurisation, cooling, etc.).
4. Auxiliary water (production of steam and vacuum, etc.).
5. Process water (intermediates and products, washing raw materials, etc.)
6. Sanitary water.

Water consumption varies considerably not only in the different subsectors of the food and drink industry, but also within the companies of the same subsector depending on the specific operations and practices implemented. For instance, olive oil production can require about 5 m^3 water/t olive oil produced, while the fruit and vegetable canning industry needs between 7 – 15 m^3 water per tonne of product (European Commission, 2006).

Waste water generation

The main sources of waste water in the food and drink manufacturing sector are the following:

1. Washing of raw materials.
2. Cleaning and disinfection of installations, process lines, equipment and process areas.
3. Cleaning of product containers.
4. Transport operations.
5. Blowdown operations in steam boilers.
6. Freezing/defrosting operations.
7. Backwash from regeneration of waste water treatment plants.
8. Storm water run-off.
9. Once-through cooling water.

The quantity (volume) and composition (pollutant charge) of waste water is variable in the different subsectors and across companies. In general, process and cleaning water are the most relevant and are characterised by high organic matter and suspended solids content. In addition, seasonality plays a very important role in the amount and load of waste water generation in a number of subsectors such as olive oil, wine, fruit and vegetable processing industry etc.

Energy consumption

Energy is used for several processes:

1. Hot/cold operations (cooling, cooking, pasteurisation, etc.).
2. Packaging.
3. Pumps, engines and other process equipment.
4. Auxiliary operations (water purification, compressed air, etc.).
5. Cleaning operations.

Heating and cooling processes involve majority of the sector's overall energy requirements. Heating processes are responsible for around 29% and cooling and refrigeration processes for around 16% of the total energy used in the food and drink sector (European Commission, 2006).

Air emissions

The main emissions to air from the food and drink manufacturing sector can be classified in three groups: channelled emissions, diffuse emissions and fugitive emissions.

Channelled emissions

- Process emissions (frying, boiling, cooking, etc.).
- Emissions from vents from storage and handling operations (transfer, loading-unloading of products, etc.).
- Flue-gases from units providing energy (process furnaces, steam boilers, etc.)
- Air emissions coming from emission control equipment such as filters, absorbers, etc.
- Exhaust air from general ventilation systems.
- Discharges of safety relief devices (safety vents or valves).

Diffuse emissions

- Emissions from flares.
- Emissions from the process equipment and inherent to the operation of the facility.
- Working losses from storage equipment and during handling operations.
- Secondary emissions, from the handling or disposal of waste.

Fugitive emissions

- Odour losses during storage or filling/emptying of tanks and drums.
- Storage tank vents.
- Stripping of malodorous compounds from wastewater treatment plants.
- Pipework leaks.
- Fumigations.
- Steam losses during storage, filling/emptying of tanks, (including hose decoupling).
- Burst discs and relief valve discharges.
- Leakages from flanges, pumps, seals, and valve glands.
- Settling ponds.
- Building losses (through windows, doors, etc.).
- Cooling towers and ponds.

The main air *pollutant*s are the following ones:

1. Dust (raw material reception, storage, etc.).
2. VOCs, coming from the cooking process and odour (cooking, fermentation, etc.).
3. Refrigerants.
4. Combustion products, such as CO, NO_x and SO_2 (fermentation, heating and cooling processes, etc.).

Emissions of greenhouse gases (GHG) and, in particular, CO_2 from on-site thermal energy generation are also very important. According to FoodDrinkEurope (2015), food and drink manufacturers have made significant efforts to improve their energy performance and to reduce their GHG emissions, decreasing emissions by 17% between 1999 and 2008, while the production value increased by 35%.

Odours generation

Odours are considered diffuse emissions and their measurement is complicated. Instrumental odour measurements exist, but the quantification of odour is still mainly based on olfactometry.

In most Member States, odour is considered a health and safety issue rather than an environmental problem. In addition, it can be treated as a local problem linked to the proximity to an urban area (European Commission, 2006).

Noise generation

Noise is related to some operations carried out in the food and drink sector such as materials handling and storage (using vehicles), peeling, homogenisation, grinding, extraction (fans, cooling towers, steam valves, etc.) (European Commission, 2006).

Solid waste generation

Food and drink manufacturers aim at using the most of the agricultural resources they put into food production and increasingly find uses for their by-products/co-products, not only as food, but also as animal feed, fertilisers, cosmetics, lubricants and pharmaceuticals among others. This is particularly relevant in some subsectors such as cheese, beer, meat, etc. 85 million tonnes of by-products are produced annually in the European Union representing the 3.25% of food processing residues (CIAA, 2007). Production of by-products/co-products is very important to reduce the amount of waste generated.

The food and drink manufacturing industry generates small amounts of hazardous waste that generally come from the cleaning and maintenance of installations (waste oils, chemical containers, their cleaning and/or disinfection, etc.), from laboratories (chemicals), etc.

As for non-hazardous waste the organic waste (peels, rejected fruits/vegetables, hulls, bones, pomace, lees, etc.), sludge (if applicable) and packaging waste (paper, cardboard, glass, plastic, metal and wood) are the most relevant.

Chemical products consumption

Chemical products are used in cleaning and disinfection as well as partitioning techniques (deionisation, extraction, etc.). Some agents used in the food and drink sector are chlorine based products, caustic soda, ammonia, etc. and their use is strictly controlled for food safety and hygene reasons.

Environmental pressures linked to indirect environmental aspects

The indirect environmental aspects (downstream and upstream) are the issues not associated to the direct operations of food and drink manufacturers but on which they have a considerable influence. Agricultural production, transport and logistics operations and food preparation by consumers are responsible for the greatest contribution to the overall environmental impacts of the food and drink value chain. The food and drink manufacturing sector plays a key role in addressing these aspects given its influence throughout the value chain and its strategic position between primary production and consumers.

Agriculture

The primary production phase is very often the most important in the overall life-cycle environmental impact of food and beverage products. Environmental pressures linked with agriculture range from air emissions to water pollution and from biodiversity loss to water use. Food and drink manufacturers are able to influence agricultural practices through sustainable supply chain management.

Transport

Transportation by all modes (road, rail, sea or air) plays an important role in the supply and distribution chain for food and drink manufacturers. For example, food transport accounted for 28.8% of the total transport industry in France (CIAA, 2007).

The main environmental pressures associated with transportation are energy consumption and the emissions from combustion (CO_2, CO, NO_x, SO_2, etc.).

Food preparation by consumers

Consumers generate a significant environmental impact during the transport, storage and preparation of food and drinks, and they generate a large amount of waste.

The main environmental pressures are the consumption of energy by consumers and the generation of waste. The first is mainly linked to cooking, cold storage and washing operations. As for the large amount of waste generated by consumers, this is mainly food waste resulting from meal preparation and leftovers, food that has expired or gone bad, and packaging waste. At EU level, around 90 million tonnes of food waste are produced annually (FoodDrinkEurope, 2012). Packaging represents around 5% of total waste generation in the EU, with the food and beverage manufacturing industry accounting for around two thirds of total EU packaging waste by weight (CIAA, 2007).

2.3. Environmental aspects addressed

This document is aimed at giving guidance to food and beverage manufacturers on how to improve the environmental performance for each of their most relevant environmental aspects.
The following two tables present the way in which the most relevant environmental aspects for food and beverage manufacturers and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries (FDM BREF)[5]. For the aspects covered in this document, the tables mention the best environmental management practices (BEMPs) identified to address them.

Table 2.3: Most relevant direct environmental aspects for food and beverage manufacturers and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Industrial processes and related operations	Emissions to water	• Reference to BAT in FDM BREF
	Emissions to air (NO_x, SO_x, VOC, particulate matter)	• Reference to BAT in FDM BREF
	Solid waste generation	• Reference to BAT in FDM BREF • BEMP on avoiding food waste in food and beverage manufacturing
	Water consumption	• Reference to BAT in FDM BREF
	Energy consumption, GHG emissions (CO_2)	• BEMP on deploying energy management and energy efficiency throughout all operations • BEMP on integrating renewable energy in manufacturing processes
Refrigeration	Energy consumption, GHG emissions (refrigerants)	• BEMP on improving freezing and refrigeration
Cleaning operations	Water consumption, use of chemicals, waste water generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations
Transport and logistics	Energy consumption, GHG emissions, emissions to air (CO_2, CO, SO_2, NO_x, particulate matter etc.)	• BEMP on transport and logistics
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• Reference to BAT in FDM BREF • BEMP on improving or selecting packaging to minimise environmental impact

[5] For more information on the content of the Best Available Techniques Reference Documents and full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Table 2.4: Most relevant indirect environmental aspects for food and beverage manufacturers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, emissions to air etc.	• BEMP on sustainable supply chain management
Agriculture	GHG emissions (CO_2,CH_4), biodiversity loss, emissions to air, eutrophication, water consumption	• BEMP on sustainable supply chain management • Reference to the Agriculture – crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact
Transport and logistics	Energy consumption, GHG emissions, emissions to air (CO_2, CO, SO_2, NO_x, particulate matter etc.)	• BEMP on transport and logistics
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact

These environmental aspects were selected as the most relevant for food and beverage manufacturers. However, the environmental aspects to be managed by specific companies, and whether each aspect is direct or indirect for a specific company, should be assessed on a case-by-case basis. Environmental aspects, such as hazardous waste, biodiversity or materials for areas other than those listed could also be relevant.

In addition to the BEMPs listed above, there is also an overarching one on "performing an environmental sustainability assessment of products and/or operations", which can help to improve the environmental performance for all aspects listed above.

Reference literature

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3. BEST ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE WHOLE FOOD AND BEVERAGE MANUFACTURING SECTOR

3.1. Introduction

In this chapter a range of best environmental management practices suitable for the whole food and beverage manufacturing sector are presented. Direct environmental impacts or indirect environmental impacts on which food and beverage manufacturers have a considerable influence are covered. The BEMPs presented investigate environmental performance assessments, sustainable supply chain management, packaging, cleaning operations, transport and distribution, freezing and refrigeration, energy efficiency, use of renewable energy and avoid food waste in manufacturing.

the BEMP **performing an environmental sustainability assessment of products and/or operations** presents the way in which frontrunner food and drink manufacturers carry out carbon footprinting and/or Life-Cycle Assessments (LCA) of their products and/or operations to identify hotspots, priority areas for action and define a strategy for reducing their environmental impacts. The following BEMP, on **sustainable supply chain management**, explains how food and drink manufacturers can work with their suppliers to improve the environmental sustainability of their products and/or apply green procurement (e.g. buying certified raw materials). The third BEMP is about how to **improve the design of the packaging to minimise its environmental impact**, presenting a range of measures which can be implemented. The BEMP **environmentally friendly cleaning operations** presents the way to adopt environmentally friendly practices in cleaning operations (reduction of water and energy consumption, use of more environmentally friendly chemicals etc.) while the BEMP **improving transport and distribution operations** is applicable for those companies responsible for the transport and distribution of their products, focusing on the choice of transport mode, intermodality, load factor, vehicle efficiency etc. Since cooling and freezing are among the most energy intensive processes of food and beverage manufacturers, i**mproving freezing and refrigeration** is a BEMP which deals with improving equipment, facilities, and management of refrigeration and freezing, enhancing sustainability and environmental performance. The BEMP on **deploying energy management and energy efficiency throughout all operations** tackles the essential aspect of reducing the energy consumption in production processes, which is the first measure a food and beverage manufacturer should consider when developing an effective energy management strategy. The following BEMP on the **integration of renewable energy in production processes** instead focuses on on-site generation of renewable energy which can be integrated into the production processes in several subsectors (e.g. brewing and cheese manufacturing), for both electricity and heat generation. The BEMP **avoid food waste in food and beverage manufacturing** reports how food and beverage manufacturers can avoid food waste, implementing a broad range of measures, from fitting the order to the production needs, optimising the production process, turning unused fractions into by-products e.g. for animal feed, etc. In addition, considerations on how to reduce food waste generated by unforeseen stops of the production lines are also presented. Finally, there is also a BEMP **linking this document to the Reference Document on Best Available Techniques in the Food, Drink and Milk industries** (FDM BREF).

3.2. Performing an environmental sustainability assessment of products and/or operations

Description

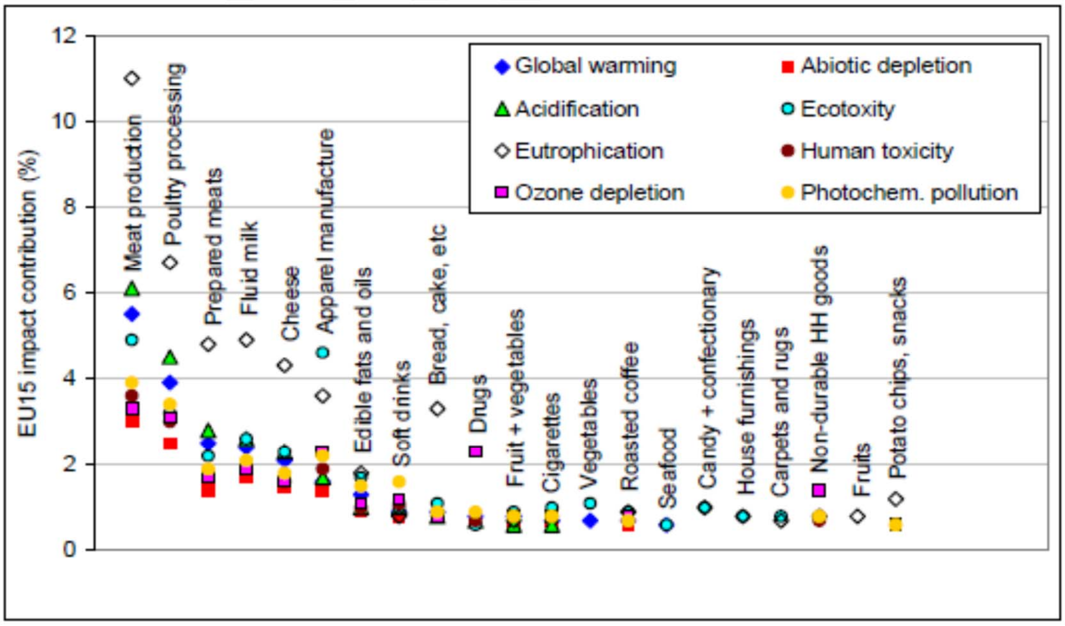
Food and drink manufacturing contributes to a range of environmental impacts including greenhouse gas emissions, air and water pollution, waste generation and biodiversity loss. In 2006, the JRC estimated that food and drink products accounted for 20 to 30% of the environmental impacts from total consumption in the EU-25 (European Commission, Directorate General Joint Research Centre, 2006). A more recent publication (Fassio, 2012) states that the EU food and drink industry is responsible for:

- 23% of global resource use
- 18% of greenhouse gas emissions
- 1.8% of Europe's total water use (excluding agriculture)
- 5.3% of industrial final energy use globally
- 90 million tonnes of food waste each year.

The same report adds that a third of food leaving the field is never consumed and points out that the food and drink sector is among the largest producers of wastewater which has its own environmental impacts when treated (e.g. energy and chemicals consumption).

Figure 3.1 presents the relative contribution of the production and consumption of a range of food and drink products in Europe to various environmental impacts. It will be noted that meat and dairy products are especially significant.

Figure 3.1: The relative contribution of different product groups to eight environmental impacts in the EU-15



Source: Food SCP Round Table (2012)

This BEMP describes how frontrunners assess the impact of their products and operations using carbon footprinting and/or life-cycle assessments (LCAs) to identify priority areas for action, or 'hotspots', and thus define a strategy for reducing these effects.

A key consideration is the precise way in which such analyses are carried and the many assumptions upon which they rest. As FoodDrinkEurope (2012) points out:

'assessing the environmental performance of food and drink products is challenging due to their complex supply chains and diversity. Existing methodologies leave much room for interpretation, which has led to a wide variance in results and a proliferation of inconsistent communications about the environmental performance of food and drink products'

Table 3.1 gives an idea of the variability in results that can occur when assessing the environmental impacts of a food product. This uncertainty reflects different boundaries, regional differences and methodologies adopted.

Table 3.1: Literature review for beef

Year	Country	Kg CO_2eq/kg beef	Remarks	System boundaries
2011	Romania	33.0	Dairy cattle producing meat and milk	At slaughterhouse gate with packaging
2011	Ireland	21.2 19.2 18.3	National Steer beef Bull beef	
2006	UK	15.8 18.2 25.3 15.6 16.4	National Organic Suckler Lowland Upland	
2009	Sweden	28.0		
2010	France	30.5 26.6	Calf Integrated cow calf to beef	
2010	EU	27.3	Dairy bull calf / steer	
2012	Switzerland	24.9 27.8 43.3 41.9	Bull fattening PEP Organic bull fattening Suckler cow PEP Organic suckler cow	At slaughterhouse gate with packaging
2013	Switzerland	16.2 15.2	Conventional Organic	No packaging
2013	Argentina	11.3	Conventional	No packaging, no slaughtering waste in the LCI
2013	Global	24.5 90.4	Dairy herd Beef herd	

Source: SENSE (2013)

For this reason, the European Commission's *'Roadmap to a Resource Efficient Europe'* report stresses the need for a:

'*Common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life cycle'*

Several guidelines have been established for the environmental sustainability assessment of specific product categories and organisations through various processes. A number of these are discussed below and are product-focused tools, namely PEF, Environmental product declaration and EcodEX, while others are focused on organisations, such as OEF, the Global Reporting Initiative and CDP.

PEF/OEF (ENVIFOOD protocol)

The European Commission aims to address the issue of inconsistency in environmental impact assessment through the introduction of the Product Environmental Footprints (PEF's) and Organisation Environmental Footprints (OEF's) (European Commission, 2013a; European Commission, 2013b). These Footprints are intended to be harmonised across the EU, science-based and founded upon internationally agreed standards, e.g. ISO. The ENVIFOOD Environmental Assessment Protocol forms the current tranche of pilot testing focused on food and drink products and was adopted by the multi-stakeholder Sustainable Consumption and Production Round Table (SCP RT). The 18 participants in the ENVIFOOD pilots can be regarded as frontrunners and are shown in Table 3.2.

Table 3.2: Participants in the ENVIFOOD pilot test

Organisation	**Product(s)**
Granarolo (Italy)	Mozzarella cheese packed in polyethylene bag
Carlsberg Italia	Beer products
Campden BRI (Research organisation, Hungary)	Soy and beef products
European Bottled Water Federation	PET and returnable glass bottles for still and sparkling water
Coop Italia	High quality milk (1lt)
Nestlé	Purina Gourmet Pearl Chicken (cat product), NaturNes (baby food product), Nescafé (coffee)
UNESDA	Non-alcoholic drinks
Federación Española del Vino (Spain)	Wine
Barilla	American Sandwich Nature / Husman / Pasta/ Tarallucci / Tomato sauce
ReMa-MEDIO AMBIENTE, S.L. (LCA Consultancy, Spain)	5 wine products
CTME (Technology Centre Foundation, Spain)	Bottle of red wine
Swedish Institute for Food and Biotechnology	Meat, dairy or fisheries products
Primary Food Processors	Starch, sugar, oilseed crushing and vegetable oil

Organisation	Product(s)
	refining, or a selection of these
Gallina Blanca Star	Chicken stock cubes
FEFAC	Compound feed for terrestrial species and aquafeed
FEDIAF	'Concept' dry and wet pet food products, followed by real products on the market
FERRERO	Lemon Ice The (ESTATHE LEMON T3x24) and chocolate praline (ROCHER T30x72)
Mondelēz International	Several coffee products

Source: Food SCP Round Table (2014)

The PEFs / OEFs are being developed using the methodologies detailed in ISO 14040 and ISO 14044. ISO 14040 was first published in 1997 and focuses on environmental management – life cycle assessment – principles and framework and ISO 14044 on the Requirements and Guidelines. These standards have four key steps:

1. Goal and scope definition
2. Inventory analysis
3. Impact assessment
4. Interpretation

The SENSE (Harmonised Environmental Sustainability in the European food and drink chain) project, coordinated by AZTI Tecnalia in Spain, is on-going (2012 to 2015) and is evaluating existing environmental impact assessment methodologies to deliver a new integral system which can be linked to monitoring and traceability data. The system integrates a data gathering system, a methodology for environmental impact assessment, a set of Key Environmental Performance Indicators to simplify the LCA development process for SMEs and has developed a certification scheme concept. The organisers acknowledge that (Ramos et al, 2014):

'*Nowadays the calculation of the potential environmental impact of products can lead to great benefits to the industries which, in most cases, can lead to brand differentiation. However, most of the industries in the food sector, especially SMEs, neither have a strong background nor the capability to assess the sustainability of their products'*.

The SMEs involved in the project are shown in Table 3.3 and these six companies are considered frontrunners.

Table 3.3: SMEs involved in the SENSE project

Organisation	Product(s)
Zumos Valencianos del Mediterráneo (Zuvamesa)	Fruit juice producer
Tunay Gida	Fruit juice producer
Provac Impex SRL	Meat producer
Calion Prod SRL	Dairy processing factory
Fjardalax	Seafood producer

Environmental Product Declarations

An Environmental Product Declaration, EPD®, is a means of communicating environmental performance. It is a verified document that reports environmental data of products based on life cycle assessment (LCA) and other relevant information and in accordance with the international standard ISO 14025 (Type III Environmental Declarations). The contents in the EPD must be in line with the requirements and guidelines in ISO 14020 (Environmental labels and declarations – General principles). Any environmental claims based on the EPD are recommended to meet the requirements in ISO 14021 (Environmental labels and declarations – Self-declared environmental claims) and national legislation and best available practices in the markets in which they will be used. The international standard ISO 14021 states that only environmental claims that can be supported by up-to-date and documented facts may be used. Vague claims, such as "environmentally friendly" should be avoided.

Organisations that have developed EPDs include:

- **Barilla**
- **Granarolo S.p.A**
- **Lantmännen**

The French food and drink industry association (ANIA[6]) has led on a national environmental declaration pilot. Working alongside the French Environment and Energy Agency (ADEME[7]) and the French Standards body (AFNOR[8]) they have developed a 'stakeholder platform' which offers a general environmental footprinting methodology (BPX 30-323) and product category rules enabling manufacturers to calculate the impact of their products in order to communicate this to consumers. One output from the study is the 'ProxiProduit' system allowing consumers to scan the barcode of products to obtain environmental information such as GHG emissions, biodiversity and water use.

The Global Reporting Initiative

The Global Reporting Initiative (GRI) was founded in 1997 and involved the development of a Sustainable Reporting Framework (including reporting guidelines and sector guidance) where companies report the economic, environmental, social and governance performance of their activities. The Food Processing Sector Supplement (FPSS) covers key sector-specific issues, including:

- Sourcing practices
- Community investment
- Impact of governmental support
- Labour and management relations
- Practices that promote healthy and affordable food
- Customer health and safety
- Product information and communication to consumers

[6] 'ANIA' stands for 'Association Nationale des Industries Alimentaires'

[7] 'ADEME' stands for 'Agence de l'Environnement et de la Maîtrise de l'Energie'

[8] 'AFNOR' stands for 'Association Française de Normalisation'

- Animal welfare including breeding and genetic, animal husbandry, transportation, handling and slaughter

The Swiss multinational manufacturer Nestlé is among those reporting in GRI. Table 3.4 shows data submitted and the impacts of its products, including the packaging, since 2003.

Table 3.4: Direct and indirect GHG impacts reported to GRI by Nestlé

GHG emissions	**Year**				
	2003	2009	2011	2012	2013
Direct GHG emissions (mtCO_2eq)	4.7	4.0	3.81	3.71	3.99
Direct GHG emissions (kg CO_2eq per tonne of product)	142	97	84.2	77.7	76.5
Indirect GHG emissions (mtCO_2eq)	n/a	3.0	3.23	3.39	3.81
Indirect GHG emissions (kg CO_2eq per tonne of product)	n/a	73	71.5	71.1	73.2

Source: Nestlé, 2014 pers.comm

Other manufacturers that report into the scheme include:

- Barilla
- Coca Cola Enterprises
- Ferrero International
- PepsiCo
- Unilever

CDP

The CDP, formerly the Carbon Disclosure Project, is a global climate change programme benchmarking the performance of large corporations. Businesses involved in CDP include:

- PepsiCo: In 2009, the soft drinks and snacks manufacturer asked agricultural suppliers from the UK and continental Europe to report to them, through the CDP process, on their greenhouse gas emissions and climate change strategies. This initiative identified the best performing suppliers, such as Lantmännen, and a 'shared learning' programme of work (CDP, 2009).

- Diageo: A case study highlights that in 2013, the alcoholic drinks company had a disclosure score of 98 and a performance band rating of 'A' (CDP, 2013).

Additionally, within the CDP the Cool Farm Tool (CFT) was developed in 2008 by Unilever, the University of Aberdeen and the Sustainable Food Lab. The purpose of the CFT is to provide a decision support tool to help farmers measure, understand and manage greenhouse gas emissions from their farms and to measure progress over time (Unilever, 2010).

Sectoral initiatives

Some environmental assessment initiatives are specific to certain sub-sectors such as:

- A life cycle assessment of greenhouse gas emissions from the global dairy cattle sector (by the Food & Agricultural Organisation of the United Nations, FAO, and International Dairy Federation, IDF).
- Guidance on reporting GHG emissions in the beverage industry (by the beverage industry environmental roundtable, BIER).
- A carbon footprint study for yeast (by the Confederation of EU Yeast Producers, COFALEC)

Business initiatives

Additionally, large corporations may develop their own assessment methodologies. For example, **Nestlé** recently developed 'EcodEX', a multidimensional tool for assessing greenhouse gas emissions, as well as water, energy and biodiversity impacts from across the whole lifecycle of packaging and whole products. The tool is now freely available for other manufacturers to use.

Other single impact initiatives

Systems addressing a single impact include ISO 14067 and, in the UK, PAS 2050 (latest version from 2011), both of which focus on carbon footprinting. Similarly, the World Resources Institute and World Business Council for Sustainable Development have developed the GHG Protocol Initiative 'Product Life Cycle Accounting and Reporting Standard'.

The original PAS 2050:2008 was written to create a consistent way of assessing the greenhouse gas emissions associated with the full life cycle of goods. Businesses who have undertaken LCAs using the PAS 2050 methodology include:

- Innocent
- PepsiCo (e.g. for its Walkers crisps brand in the UK)

Achieved environmental benefits

The carrying out of an environmental sustainability assessment cannot itself lead directly to environmental benefits, but for frontrunner manufacturers the exercise is a critical first step in a strategy to enhance the sustainability of products and operations. Simply put, an organisation cannot reduce its negative impacts without first understanding what they are and where they occur in its processes.

The Italian company Barilla, which makes products such as pasta and snacks, uses the Environmental Product Declaration tool to calculate the environmental impacts of its products. In order to improve the accuracy of its assessments Barilla requests actual, or 'real world', impacts data from suppliers rather than relying on secondary / generic LCA databases. This proactive approach then allows Barilla to work with suppliers in various ways to lower these impacts (EPD, nd). Barilla also seeks to reduce impacts in the consumption phase of products by recommending that customers reduce the time they cook their pasta for, and the amount of water used.

The Clemens Härle brewery in Germany performed an LCA to identify hotspots in its processes. It later became the country's first brewery to produce all of its beer from 100% renewable energy, achieving annual savings of 900 tCO_2 (The Brewers of Europe, 2012).

Appropriate environmental indicators

As mentioned, performing an environmental sustainability assessment will not itself produce benefits; however the effectiveness with which this BEMP is carried out can be monitored in a variety of ways. For instance:

- Percentage of total sites or products assessed using a recognised assessment protocol
- Number of sites or products assessed using a recognised assessment protocol

Cross-media effects

Just as an assessment in itself cannot improve the environmental performance of company, nor can it produce negative environmental outcomes. But the actions taken as a result of any analysis can be harmful if the assessment is based on faulty assumptions, incorrect data values and inappropriate system boundaries or if it ignores other important parameters. For instance, in order to cut food waste and other impacts (e.g. energy used in refrigeration) associated with storing large quantities of perishable raw materials, a manufacturer may choose to move to 'just-in-time' inbound delivery of smaller quantities of ingredients as and when needed. However, the effect of this may be a net rise in greenhouse gas emissions resulting from an increased number of truck deliveries.

Operational data

The Food SCP Working Group workshop (5^{th}-6^{th} July 2011) outlined the importance of the Life Cycle Inventory (LCI) data being robust, reliable and relevant. International and national methodologies, such as ISO 14044, PAS 2050 in the UK or the ILCD (International Reference Life Cycle Data System) Handbook, underline the quality requirements for both primary and secondary data.

Frontrunner companies, such as Barilla discussed above, will aim to use primary data. However, members of the Food SCP Working Group highlighted situations where this approach may not be possible or appropriate:

- Environmental LCA consultants Quantis suggested that the appropriateness of secondary data depends on time and financial constraints and that the highest quality LCA is achieved when you correlate the resources required for analysis and the significance of the data
- The trade association FoodDrinkEurope and Coca-Cola Europe suggested that primary data may have a shorter shelf life than secondary data due to the frequency with which variables change, such as, a change of supplier.
- FoodDrinkEurope and Nestlé stressed that if the impact being measured is relatively small, a conservative data estimate can suffice.

The workshop concluded that it is important to stress that primary data are preferable and that, where used, that secondary data are of the highest quality.

Applicability

When undertaking an environmental sustainability assessment, manufacturers may need to grapple with a number of challenges, and not every company will be able to resolve these. Key factors to consider include:

- **Complexity of the product:** Many products, such as frozen ready meals, may be made using a wide variety of ingredients from different suppliers. Gathering supplier-specific impacts data for each raw material may not be practical, or indeed appropriate since the supplier of a particular ingredient may change frequently. In such cases, it may be more appropriate to focus only on the major materials, processes or parts of the supply chain likely to be responsible for the greatest environmental impacts.

- **Cost, time or expertise constraints:** As noted below, it can be expensive and time-consuming to undertake full LCAs, particularly for more complicated products which may dissuade smaller companies from trying. However, in these situations it may still be feasible to focus on 'hotspots' or use simplified LCA approaches.

- **Manufacturer's influence in the supply chain:** Certain environmental impacts may also be beyond the power of the manufacturer to change, even if they can be quantified. This is especially true for smaller processors who may have little chance to influence their suppliers. Similarly, a manufacturer's influence may be low for certain product types. For instance, anecdotal evidence suggests that for many chilled ready meals, the consumer's decision whether to heat the product in a conventional oven or a microwave will have the greatest bearing on the product's lifetime energy impacts, significantly outweighing the effect of any low-energy measures implemented during manufacture (Chilled Food Association, 2014 pers. comm.). As mentioned above, the manufacturer Barilla has tried to address a similar issue for its pasta products by seeking to influence the consumer's behaviour. The extent of a manufacturer's influence should be considered when setting the assumptions upon which an environmental sustainability assessment is based.

Economics

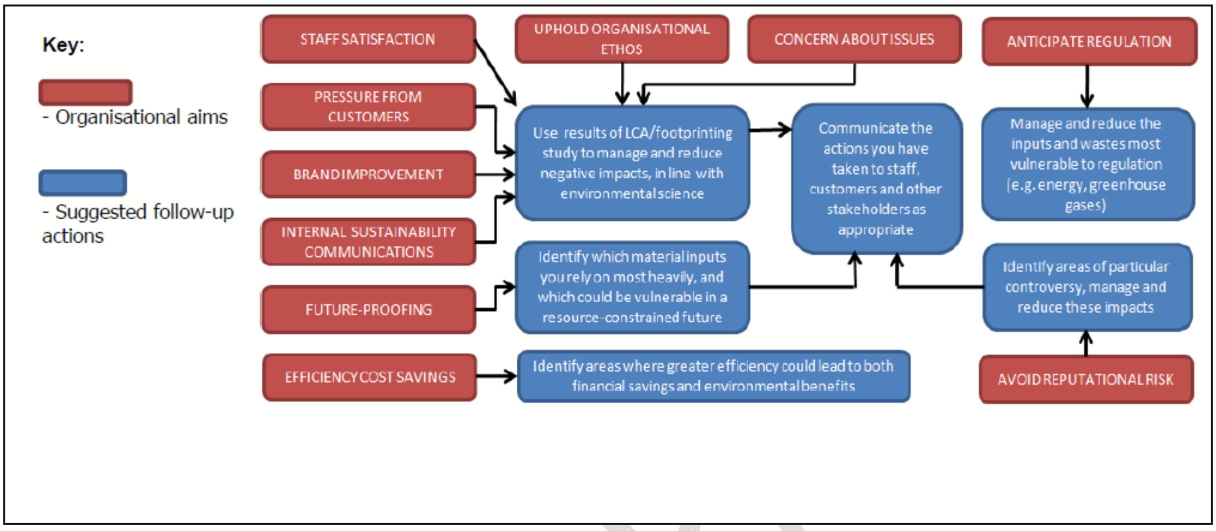
Implementing a comprehensive LCA can be expensive. According to one source (Grilli, 2013), the EC's PEF costs EUR 50,000 per product. In the UK, the retailer Tesco abandoned a project to calculate (and publish) the carbon footprint of all its products. The company instead undertakes a hotspot analysis.

For this reason, FoodDrinkEurope (2013) reports that the development of the sectorial ENVIFOOD Protocol *'has created more user-friendly and affordable tools for the assessment and voluntary communication of environmental impacts along the food chain'.*

Driving force for implementation

WRAP (2013) suggests a number of reasons for food and drinks businesses undertake a sustainability assessment– as well as ways the results can be used (Figure 3.2).

Figure 3.2: Drivers for carrying out an LCA or footprinting study



Source: WRAP (2013)

Which of these driving forces are most important will vary with each company but given that many if not most environmental impacts (e.g. water, energy and raw material consumption, waste disposal.) entail a financial cost, a key driver for carrying out a sustainability assessment is to identify and reduce any unnecessary costs ('Efficiency Cost Savings' in Figure 3.2).

For larger organisations with a significant public profile, aspects such as 'Brand improvement', 'Reputational Risk' and CSR concerns will also be important. Companies that can demonstrate that they take their environmental impacts seriously will maintain a positive image in the eyes of consumers, NGOs, investors and other stakeholders. Countless studies demonstrate the importance of being seen by customers to be 'green'; one example is a recent survey by the European Commission (2013c) which reports that 54% of respondents occasionally buy environmentally-friendly products and 26% often buy them.

Security of supply is another key driver, especially for larger manufacturers relying on vast quantities of raw material, energy, water or other inputs which may be procured from multiple locations around the globe. Frontrunners are more mindful of future risks to supply, such as the changing availability of inputs, tightening regulatory regimes, and geopolitical instability, and will want to identify and address potential vulnerabilities ('Future proofing' in Figure 3.1). A good example comes from Nestlé which enters an inflated 'notional' price for water into the EcodEX tool when deciding whether to make an investment in a new manufacturing process. This is to hedge against potential future shortages in supply and hikes in the water prices (Nestlé, 2014).

While smaller frontrunners will also consider future risks to supply, in general they are more likely to be motivated by procurement pressure, particularly from larger retailers - or larger manufacturers – upon whom they might depend for business. These larger customers may themselves be assessing and improving their own supply chains and thus expect suppliers to provide data on environmental impacts.

Regulation, actual or anticipated may be another factor, with laws requiring manufacturers to measure and report on the sustainability of their operations.

Reference organisations

Table 3.5 provides a summary of the frontrunner companies and the initiatives they are involved in.

Table 3.5: A summary of the frontrunner companies and their initiatives

Organisation	ENVIFOOD	SENSE	EPD	GRI	CDP	Business Initiatives	Single impact initiatives
Granarolo (Italy)	*		*				
Carlsberg Italia	*						
Nestlé	*						
UNESDA	*						
Barilla	*		*	*			
Gallina Blanca Star	*						
FEFAC	*						
FEDIAF	*						
FERRERO	*			*			
Mondelēz International	*						
Zumos Valencianos del Mediterráneo (Zuvamesa)		*					
Tunay Gida		*					
Provac Impex SRL		*					
Calion Prod SRL		*					
Fjardalax		*					
Lantmännen			*				
Nestlé				*		*	
Coca Cola Enterprise				*			
Pepsico				*	*		*
Unilever				*	*		
Diageo				*	*		
Innocent							*

Reference literature

nd = no date

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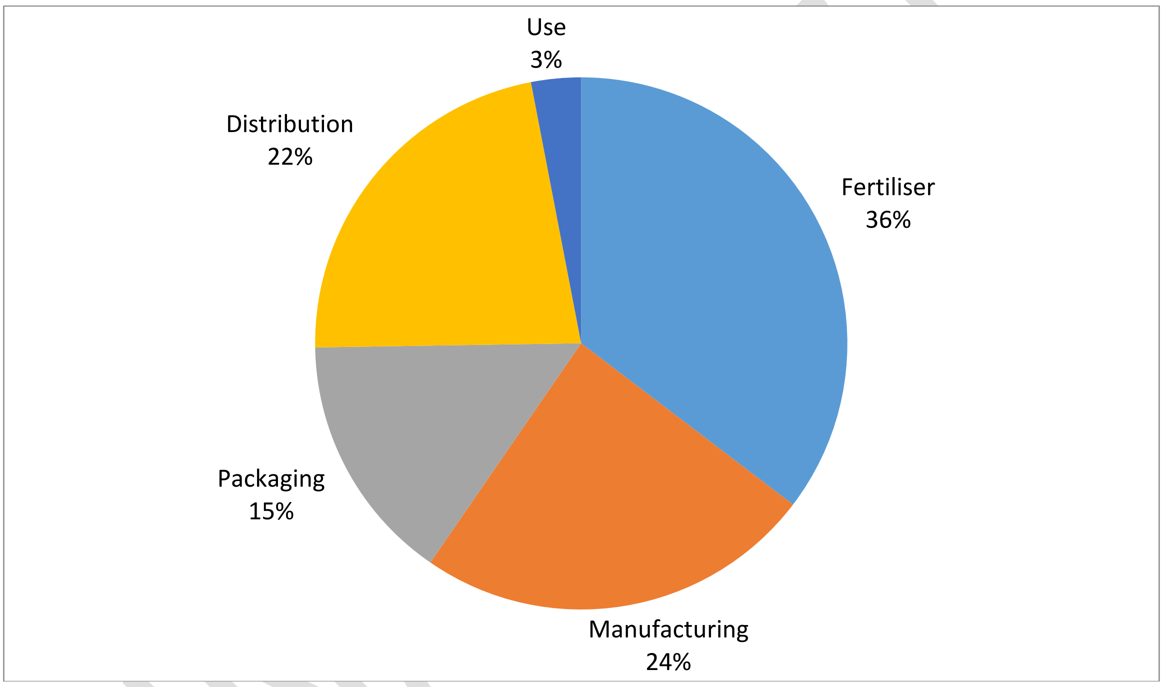
3.3. Sustainable supply chain management

Description

Primary food production has been cited by the UK Government and others as accounting for about one-third of the total food chain's carbon footprint. Collectively, the industries which process, manufacture, distribute and sell food account for a further third and consumers are responsible for the remaining third (Parliament.UK 2012a). These estimates are supported in a recent life cycle assessment (LCA) undertaken for **PepsiCo**'s Tropicana orange juice brand. As Figure 3.3 shows, agricultural fertiliser alone accounts for 35% of the product's total impact.

Figure 3.3: PepsiCo's Tropicana Orange Juice life cycle assessment (PepsiCo 2010)



The way manufacturers procure their supplies, particularly ingredients, is therefore significant in terms of environmental impact. Frontrunner manufacturers, especially larger ones, recognise that, thanks to their purchasing influence, they are often in a position not only to improve the impacts of their products and processes, but also those of their suppliers[9].

This BEMP examines three ways that frontrunners manage their supply chain to be more sustainable:

1. Green procurement

[9] The manufacture of retailer 'own label' products is outside the scope of this BEMP having already been covered in the 'Best Environmental Management Practice in the Retail Trade Sector' available at http://susproc.jrc.ec.europa.eu/activities/emas/documents/RetailTradeSector.pdf The focus here is on the manufacturers themselves who use their own influence to manage their supply chain, rather than being managed themselves by their own retailer customers.

2. Adapting recipes to remove unsustainable ingredients
3. Improving the performance of existing suppliers

These are each now described in turn although a frontrunner may not restrict itself to just one but may choose a multi-option approach (presented below in more detail). In such a case, a more comprehensive and complete sustainable supply chain management can be achieved.

Finally, different considerations on sustainable sourcing of ingredients can be contemplated when dealing with water, for those food and beverage manufacturers using substantial amounts. How to best manage the sustainable souricing of water is outlined as the last item in this section of the BEMP.

Green procurement

With green procurement, frontrunners use rules, certifications, standards, ecolabels or the results of sustainability assessments (see Section 3.2) – developed internally or externally - to guide purchasing strategies. Although the particular ingredients and other raw materials procured may not change, the manufacturer may switch supplier so as to cut environmental impacts. Voluntary commitments and standards for sustainable sourcing include initiatives for many raw materials, both wild and cultivated, whose cultivation and/or harvesting is considered problematic – both socially and environmentally.

Among the more prominent not-for-profit initiatives and certification schemes available for manufacturers to guide purchasing decisions are:

- The Roundtable on Sustainable Palm Oil,
- UTZ certification (cocoa, coffee and tea)
- The Rainforest Alliance certification (food, beverages and paper products derived from forest environments)
- Marine Conservation Society certification
- Global GAP
- The Sustainable Agriculture Initiative (SAI) Platform

The larger manufacturers have themselves developed tools and guides for encouraging green procurement such as the SAI Platform, launched in 2002 by **Danone**, **Nestlé** and **Unilever** to promote sustainable agriculture. The Platform, which today unites some 50 actors in the agrifood sector (Danone, 2013), publishes a practitioners guide on sustainable sourcing of agricultural raw materials.

Danone's 'Forest Footprint' policy is an example of best environmental practice in green procurement. It starts with a corporate commitment to eliminate 'the deforestation impacts of its supply chain, and to a reforestation programme, between now and 2020' (Danone, 2013). The policy evaluates deforestation risks related to the raw materials used directly or indirectly and suggests actions guided by a risk assessment and in collaboration with the NGO Rainforest Alliance. Six key commodities have been identified as priorities:

1. paper and cardboard packaging,

2. palm oil
3. soy for animal feed
4. wood energy
5. sugar cane
6. bio-sourced raw materials for packaging.

Similarly, the Food & Drink Federation (FDF), a trade association representing UK manufacturers, has produced a five-point guide to sustainable ingredient sourcing to help its members manage risks throughout the supply chain (Stones, 2012). The FDF guide is designed to assist small and medium-sized businesses with limited resources to develop effective procurement practices and is currently being piloted with two small Scottish manufacturers, **Dean's of Huntly** and **Innovate Foods**, in partnership with Resource Efficient Scotland. The FDF is also developing a new tool with WRAP (UK Waste & Resources Action Programme) to help manufacturers of any size trade off the risks and impacts of different raw materials commodities in their supply chain (Food and Drink Federation, 2014).

Adapting recipes to remove unsustainable ingredients

An approach closely related to green procurement is the changing of product recipes so as to avoid the use of ingredients deemed unsustainable. In this case, an ingredient may be substituted with a similar one or removed altogether. Again, the decision as to which ingredients should be removed or substituted is guided by internally or externally formulated rules, standards and/or analyses.

The FDF guide discussed in the previous section also includes options to switch ingredients.

M&J Seafood in the UK was asked by the National Trust – a conservation charity - to completely review their fish and seafood offering. In particular, they wanted to review the key issues regarding origin, sustainability and capture methods, followed by a complete product review (M&J Seafood, 2013).

Improving the performance of existing suppliers

A different approach in sustainable supply chain management is for the manufacturer to continue procuring ingredients from the same suppliers, but to attempt to improve the suppliers' performance. This can be done in three main ways:

a. Requiring certification of suppliers and/or their products according to existing sustainability standards such as those previously listed.
b. Imposing own standards/requirements
c. Cooperating with existing suppliers to improve their environmental performance

The Swiss-headquartered food and drinks giant **Nestlé** is an example of a manufacturer taking a multipronged approach to sustainable supply chain management. For instance:

- It adopts *the principles of 'green procurement'* in using its own sourcing guidelines when procuring twelve 'priority commodities' such as milk, coffee, cocoa, palm oil and soy.
- The company also recently rolled out *EcodEX (Ecodesign for Sustainable Product Development and Introduction),* an LCA-based tool enabling product development teams to systematically assess the environmental performance of a product faster and earlier in

the design process, and to make fact-based decisions. EcodEX allows different scenarios to be compared using accurate data specific to the food and beverage industry as well as indicators that meet ISO requirements.

- *It has developed a 'suppliers code' or 'responsible sourcing audit programme'* against which it regularly audits suppliers, via independent third-party assurance companies, to ensure compliance. Where suppliers are struggling, Nestlé claims to work with them to improve rather than simply switching, a philosophy it brands 'Creating Shared Value' (Nestlé, 2013a).
- *Farmer Connect Programme.* Supporting farming communities in sourcing agricultural raw materials, providing technical assistance on sustainable production methods and optimising the delivery of raw materials to the factories (Nestlé, 2013b).
- *Sustainable agriculture initiative.* Sharing best practices and lessons learned.

Illycaffè SpA (illy) with global headquarters in Trieste, Italy, reports that it manages the entire coffee supply chain. This approach is certified by an independent third-party body (DNV) and through the Responsible Supply Chain Process, which certifies that it (Illycaffé 2014):

- purchases 100% of its green coffee straight from coffee growers;
- activates a knowledge transfer to coffee producers in order to constantly improve their product's quality;
- guarantees a payment higher than market average to reward the coffee growers.

The Italian company **Barilla** offers an additional example of working closely with suppliers. As discussed in Section 3.2, this manufacturer of pasta and other baked goods strives to use 'real' rather than standard LCA values for ingredients such as durum wheat products, and these are gathered directly from the supplier. This relationship can then be harnessed in a targeted ways to drive down the values.

In January 2013, the breakfast cereals maker **Kellogg** launched its 'Origins Farmer' programme supporting European farmers who grow grains for Kellogg, enabling access to best practice (Kellogg 2014). Kellogg's uses the following approach to responsible sourcing:

1. All suppliers: self-certify to the Kellogg's global supplier code of conduct through the supplier management portal
2. All direct and indirect suppliers: will be internally assessed based on the inherent risk of their crop, product and / or country
3. All 'high-risk' suppliers: will be asked to sign up for Sedex (see below) and complete a self-assessment to further clarify risk
4. Any suppliers that still demonstrate 'high risk': will be asked to provide or complete an audit for verification of compliance with Kellogg's global supplier code of practice

Danone is endeavouring to promote more sustainable agricultural practices across its worldwide supply base. Initiatives include (Danone, 2013):

- The 'DanRISE evaluation tool' for evaluating dairy farm sustainability, developed by the University of Bern (Switzerland, which covers diverse dairy production models from subsistence farming to large farming operations. Recently tested in six countries (in Europe, America and Asia), the tool addresses Health, Economy, Nature and Social dimensions.

- Collaborations with other large manufacturers 'to define a shared vision of sustainable milk production'.
- A guide to adopting sustainable agriculture for the subsidiaries and their partners around the world has been published, in cooperation with more than 20 international experts in the field.
- The 'FaRMS' (Farmers Relationship Management Software) programme which covers 50% of direct milk intake (across 14 subsidiaries) and represents almost 3,500 million litres of milk. FaRMS supports producers who implement best environmental practices and includes systematic monitoring of farms across nine key environmental criteria (e.g. waste management, use of crop protection products, energy and water consumption).

Like other large multinational manufacturers, **Mondelēz International**, is also taking a proactive approach to improving the sustainability of those supplying its core ingredients, such as cocoa, coffee and wheat (Mondelēz International, 2013). For instance, in 2008, the corporation created 'Harmony', a sustainable partnership with multiple players across the wheat chain including farmers, millers, scientists and NGOs. The initiative aims to promote local biodiversity and better environmental practices in wheat production, and now involves 1,700 European farmers who are committed 'to follow more respectful agricultural practices' including:

- adhering to proper soil management,
- limiting fertilisers and pesticides,
- preventing excessive water use
- dedicating 3% of wheat field surface to sowing flowers to attract bees, butterflies and other pollinators.

As of 2013, 44% of Mondelēz International's Western European biscuits were made with Harmony wheat with a target of 75 % by 2015. Reported environmental benefits include:

- farmers using approximately 20% less pesticides vs. standard agriculture
- 10 million more bees counted!

Sedex (Supplier Ethical Data Exchange) (Sedex 2014) facilitates the selection of more sustainable suppliers and drives overall improvement in the supply chain. This not for profit membership organisation launched in 2004 provides a collaborative platform for sharing ethical supply chain data, easing the burden on suppliers. Sedex offers a secure, online database allowing members to store, share and report on information in four areas:

1. Labour Standards
2. Health & Safety
3. The Environment
4. Business Ethics

While suppliers do not have to meet a minimum environmental performance threshold to join Sedex, their participation demonstrates transparency and a willingness to improve. In addition,

Sedex offers users a self-audit tool with results measured against similar organisations on the database, to deliver
a high, medium or low risk profile. Sedex now covers 25 industry sectors and has over 30,000 supplier members.

Many food and drinks frontrunners will consult Sedex when deciding on a supplier or as a tool for driving improvement. For instance, the UK drinks maker **Diageo** reports that in 2014 it audited 17% of 'potential high risk' supplier sites registered on Sedex, up from 12% in 2013 (Diageo, 2014). Another recent example is **Lion** whose portfolio includes brands of alcohol, dairy and soy beverages in Australia and New Zealand. In December 2013, the manufacturer partnered with Sedex to establish a database of suppliers and a process for monitoring ethical sourcing governance and controls. Like Diageo, Lion's stated aim is to identify opportunities to drive improvements across its network of suppliers (Lion, 2013; Durrant, 2014).

Multi option approach

Frontrunners in sustainable supply chain management can also combine two or three of the above mentioned single approaches in order to achieve an even better environmental performance of the supply chain. Firstly, a food and beverage producer can change or develop new product recipes in order to avoid the use of unsustainable ingredients. As seen above, an ingredient may be substituted with a similar one or completely removed. Secondly, for the ingredients and products needed, food and beverage manufacturers can use rules, certifications, standards, ecolabels or the results of sustainability assessments to guide the purchasing strategies. Finally, for the suppliers identified, food and beverage manufacturers can work in cooperation in order to improve their environmental performance.

For instance, in the case of Lebensbaum, (organic tea, spices and coffee producer), an integrated supply chain management and vendor rating system has been implemented. The approach aims at sustainable procurement of products, ensuring their quality, and also includes sustainable long-term partnerships with suppliers improving their environmental performance.
The system integrates both suppliers of crops and packaging material and sets binding and development oriented environmental and social criteria.
The system comprises:

- a binding Code of Conduct for all suppliers,
- a request for external certification of the products according to certain available standards,
- a regular detailed survey of the management standards and practices applied by suppliers,
- a vendor rating system,
- a monitoring and auditing system,
- cooperation with suppliers for improving their environmental performance.

At all stages four dimensions are integrated: quality, reliability, environmental and social performance. The system ensures 100% procurement from suppliers meeting the sustainability requirements of Lebensbaum and that 100% of crops are sourced from organic farming. In addition, the system continously improves the relations with suppliers through long-term cooperation and specific social and environmental development targets (Lebensbaum, 2015 pers. comm.).

Sustainable water sourcing

Different considerations on sustainable sourcing of ingredients can be borne in mind when dealing with water. Water can be the main ingredient for a number of companies in the food and beverage manufacturing sector, such as those producing drinks (e.g. beer, soft drinks). However, water has different characteristics compared to the traditional ingredients addressed so far in this BEMP. In fact, water is usually supplied from nearby sources and different tools compared to those presented above are needed to ensure its sustainable sourcing. Companies in the food and beverage manufacturing sector requiring substantial amounts of water for their production processes can improve their environmental performance by establishing water stress mitigation risk measures for protecting the local ecosystems and communities. An assessment of the risks the water sources are encountering due to the production site should first be carried out. Afterwards, a water resource sustainability programme can be put in place, detailing specific actions that can be taken to support the preservation of the local water sources. Such measures can mainly include action to preserve the watershed level and can be carried out in cooperation with local administration and organisations. Companies can identify measures which could contribute to replenish the water they use thanks to, for example, rainwater harvesting, improving agricultural water use efficiency (especially in developing countries), establishing state of the art waste water treatment plants, and protecting and restoring the natural environment in order to re-establish the natural water cycle.

Achieved environmental benefits

The manufacturer **United Biscuits** cut the salt content by up to 60% and saturated fat by up to 80% in its 'McVitie's biscuits' brand. The reformulations yielded a 40% reduction in use of palm oil and reduced rainforest destruction while adding GBP 4 million (aproximately EUR 5 million) to sales value, with sales of biscuits up by more than 5% (Product Sustainability Forum, 2013b).

Unilever, achieves its stated target of ensuring that 100% of the agricultural raw materials it uses are 'sustainably sourced', by working closely with farmers, notably through the 'Knorr Sustainability Partnership Fund' which contributes funds towards complex sustainable agriculture projects that its suppliers would otherwise have been unable to tackle. Table 3.6 shows Unilever's progress towards this 100% target for a number of key raw materials.

Table 3.6: Unilever's progress on sustainable sourcing

Raw material	% sustainably sourced by end 2013
Palm Oil	100%
Paper/Board	62%
Soy	12-25%
Tea	53-83%
Fruit	25%
Veg	76%
Cocoa	70%
Sugar	49%
Sunflower Oil	23%
Rapeseed Oil	39%
Dairy	31%

Source: SAI Platform, 2013

Danone, is also working with suppliers to improve performance. In 2008, it launched its 'Nature' programme in France with the reduction of environmental impacts among its commitments. **Danone Dairy France** is now collaborating with 3,000 farmers to understand and improve their impacts on biodiversity and global warming. Part of work involves research into alternative feed for cows which aims to reduce methane emissions by up to 10% (Added Value, 2012).

In the UK, the oven potato chips manufacturer **McCain Foods** similarly works with its farmers to reduce the environmental impact providing continuous feedback to growers thus allowing them to target improvements. McCain Foods recently developed a new potato variety which cut irrigation needs from ten times per season to eight. In addition, the requirement for fertiliser and pesticides was reduced while improving yield (Stratos, 2013).

McCain Foods also collaborated with a competitor PepsiCo-Fritolay (who own the Walkers potato crisps brand) to improve the agricultural practices of potato suppliers using the 'Cool Farm Tool' (CFT) (Haverkort & Hillier, 2011). CFT is a spreadsheet computer programme originally developed for farmers by Unilever and the University of Aberdeen (CFT 2014) for calculating the amount of greenhouse gas generated in the production of one tonne of crop. By varying parameters, users of the tool can understand the best ways to cut emissions. The tool was also used by the American manufacturer **Heinz** to target tomato procurement from 270,000 acres in California. CFT estimated average on-farm emissions at 23kg CO_2eq per US short ton. The tool identified that increasing adoption of both reduced tillage and cover crops had the highest reduction potential – these measures were deemed feasible in the Californian context, and have since been adopted (Heinz, 2012).

Nestlé has worked with farmers and government officials to fund training and support for new water technologies to reduce the impact of raw materials, and a programme involving new technology to decrease water consumption has produced dramatic results. Coffee suppliers just a few years ago used an average of 40 litres of water for each kilogram of coffee produced. Now that ratio is down to 3-5 litres of water per kilogram of finished coffee, a saving of almost 300,000 cubic metres of water annually (Sustainable brands 2013).

In 2009, **Innocent Drinks** undertook a project to identify how climate change would impact on the growing of the fruit they use for their smoothies. Subsequent trials commenced in 2010 to identify the farming practices that would help mango trees in India adjust to the changed climate. The initial results at the end of the first harvest season showed (Innocent 2013):

- A reduction of 50% in agrochemical use;
- 25% to 50% greater fruit retention and also a slightly larger fruit size

Finally, implementing measures which allow increased water sourcing sustainability improves the levels of watersheds and reduces water stress to natural environments.

Appropriate environmental indicators

An appropriate indicator for this BEMP might be a measure of how a manufacturer's environmental impacts per unit of production have lowered as a result of engaging suppliers. A good example of this is **Heinz**'s use of the Cool Farm Tool in the USA, discussed above, which allowed it to identify, quantify and then adopt opportunities to reduce greenhouse gas emissions from tomato cultivation.

Conversely, with an activity-based practice such as sustainable supply chain management, it is not always possible to measure the direct environmental benefits. Implementation can at least be monitored for instance by:

- Percentage of suppliers engaged in sustainability programmes
- Percentage of ingredients or products (e.g. packaging) sourced via green procurement
- Percentage of ingredients or products (e.g. packaging) meeting the company's specific sustainability criteria or complying with existing sustainability standards
- Percentage of suppliers with environmental management systems in place

An example is given above in **Table 3.6** which reports **Unilever**'s progress towards its goal of procuring 100% of its key ingredients from sustainable sources.

Cross-media effects

Marks and Spencer (M&S 2013) reports that:

'All social and economic needs as well as environmental impacts have to be considered as falling within the scope of sustainable food production. This should also include consideration of the benefits and disadvantages resulting from different production systems such as organic, genetic modification, high animal welfare regimes and intensive agriculture and livestock farming'

Switching to apparently more sustainable ingredients can potentially have negative effects. For instance, alternatives to palm oil such as soya and rapeseed oil may entail more intensive land use (Balch, 2013)

Operational data

Local sourcing is seen as one means of sustainable procurement. For example, **Bernard Matthews**, a British manufacturer of turkey products, focused on increasing its local supplier base and in 2011, 94% of its ingredients were sourced from the UK.

Local sourcing of food and drink is also a priority for the Welsh Government which reports clear benefits from increasing the amount of local food and drink purchased in Wales (Welsh Government 2012):

- money is reinvested in local communities
- 'food miles' – the distance food has to be transported - are reduced
- carbon emissions are lowered

The Welsh Government developed the Local Sourcing Action Plan. Some highlights include:

- The proportion of people in Wales who purchase Welsh food has increased to 85% - its highest ever level.
- Purchase of Welsh produce by public sector bodies in Wales has increased by 65% since 2003.

A report produced by Northumbria University in the UK highlights seven broad categories of constraint that need to be considered when developing a local sourcing strategy (Emerald Insights 2013):

1. constraints due to the nature of the market;
2. due to scale and the nature of products;
3. constraints related to employment and skills;
4. institutional constraints;
5. constraints in supply chain relationships;
6. certification, policy and regulatory constraints; and
7. constraints around personal beliefs and anthropomorphism.

Applicability

Green procurement

The green procurement approach assumes that 'green' choices can be made. The UK government reported on 'choice editing' whereby retailers limit the range of produce they make available to customers. For example, they may restrict the sale of produce with a high environmental impact, such as, out of season produced or imported goods. It was argued by the Food Ethics Council that retailers pursuing choice editing strategies are likely to be at a competitive disadvantage unless they are positioned as leaders in the ethical market (Parliament.UK 2012b).

Adapting recipes to remove unsustainable ingredients

The specific product manufactured will govern whether or not ingredients can be removed or recipes adapted. For example, in the wine industry there is little leeway to change basic ingredients such as the type of grape used due to regulation, standards and customer expectations, but scope may exist to vary certain 'processing aids and additives', such as those for removing cloudiness. (Wine and Spirits Federation, 2014 pers. comm.)

Improving the performance of existing suppliers

A number of situations exist where manufacturers may be unable to influence the performance of their suppliers. The main barrier may simply be a lack of influence in the relationship. This is especially true for small and medium-sized manufacturers who procure raw materials from much larger suppliers; in such cases the latter suppliers may choose to resist or ignore calls from these smaller customers to improve performance. Similarly, if there is only one supplier for a specific and vital ingredient in a recipe, the purchaser may have little power to change the supplier's performance.

A different problem is encountered in the purchase of ingredients across lengthy or complex globalised supply chains. A good example is procurement of fish and other seafood from Asia. The fish may have been netted illegally, in a marine reserve, for example, by a small vessel, perhaps loaded onto larger ships where it is mixed in with other fish before being landed at port and further mixed, before finally being transported to a European manufacturer. In such situations, it is impossible for the manufacturer to trace the supply chain in order to identify who originally netted the fish, let alone influence the method of capture.

A final important consideration is the availability of resources in the broad sense. Even where a supplier is receptive to change, both the manufacturer and supplier may need to invest significant time and money in improving environmental performance. Not only may complex and expensive environmental assessments be needed but the changes they simply, such as investment in new equipment, may be onerous and require technical expertise beyond the capability of either the manufacturer or supplier.

The foregoing discussion suggests that this approach to sustainable supply chain management is most likely to apply in the following situations:

- Short, simple supply chains
- A large manufacturer and a smaller, more receptive, supplier – one or both of which have considerable financial and/or technical resources

Sustainable water sourcing

Measures to improve water sourcing sustainability are applicable to companies in the food and beverage manufacturing sector requiring substantial amounts of water for their production processes. Sometimes companies of limited size may encounter difficulties in engaging with local administrations and organisations in order to cooperate on any of the measures planned. Howvwer, a number of actions aimed at preserving the watershed, which can be carried out without their support, are also possible.

Economics

Illy reports that the investment to monitor and provide the green coffee supply chain with the specific support activities cost EUR 3.2 million over the three years from 2011- to 2013.

As discussed above, a new lower saturated fat and salt reformulation boosted sales of the McVitie's biscuits brand by more than 5% adding GBP 4million (aproximately EUR 5million) to its sales value, although **United Biscuits** invested over GBP 14 million in the project (Product Sustainability Forum, 2013b).

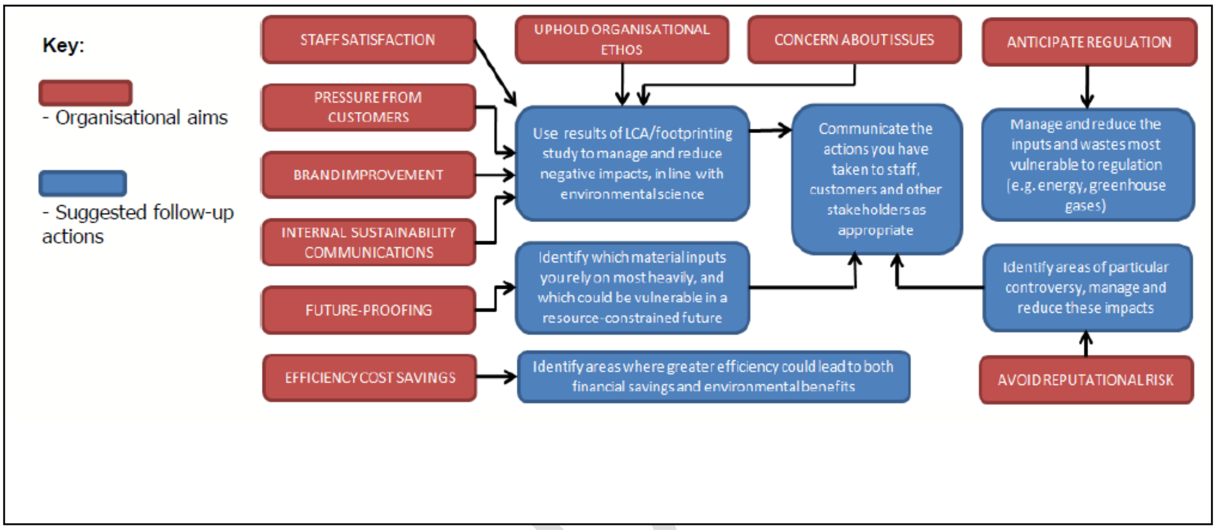
As the **Danone Dairy France** example demonstrates, the substantial investment of time and resources in working closer with suppliers can pay off financially with boosted sales (Added Value, 2012), although a crucial success factor was that the initiative was communicated clearly to customers.

Driving force for implementation

Consumer pressure is becoming a significant driver for sustainable procurement. For example, the Ministry of Economic Affairs (2014) in the Netherlands reports that Dutch consumers are becoming more environmentally conscious with sales of food produced in an environmentally friendly way rising by 10 % in 2013. The sales of sustainable seafood and eggs are especially on the increase with one in every three eggs or seafood products having a certification label on pack.

BEMP 3.2 (on environmental sustainability assessment) included a flow chart developed by WRAP identifying the key drivers for carrying out an assessment. This is worth reproducing here (Figure 3.4) as the motivating factors for sustainable supply chain management – indicated by the red 'organisational aims' – are, arguably, identical. The actions taken - the blue 'suggested follow-up actions' – can equally be applied to suppliers' operations so as to address unsustainable practices.

Figure 3.4: Drivers for sustainable supply chain management (WRAP 2013)



The relative importance of drivers will vary with the manufacturer but frontrunners will be attentive to, and seek to address, *all* of these imperatives. For the largest companies, 'future proofing' is a particular concern. Unilever, for example, purchases 12% of the world's black tea supply and the continuing prosperity of its tea business depends on ensuring the future stability of this resource (Stratos, 2013).

There may be other driving factors too. For instance, the reformulation of the McVitie's brand by **United Biscuits** was initially driven by health rather than environmental concerns (Product Sustainability Forum, 2013b). While for **McCain Foods** 'improved yield' was a key benefit of close cooperation with potato growers (Stratos, 2013) which, in addition to reducing environmental impacts per unit of product (e.g. the use of pesticides, fertilisers, water, etc.) also saves costs.

Productivity gains also drove, or at least were an added benefit of, **Danone Dairy France**'s 'Nature' initiative. By working with suppliers to improve environmental performance through 'diagnostic audits', the manufacturer could improve the farmers' quality, productivity and competitiveness. Furthermore, Nature, which was accompanied by a targeted publicity drive, 'achieved 17% awareness amongst Danone consumers and boosted image perceptions of the brand by 20% amongst those who remembered the campaign.' The Nature-branded yogurt product 'went from negative year on year sales to double-digit growth following the campaign' (Added Value, 2012).

Reference organisations

The frontrunners in the three areas of sustainable supply chain management focused on in this BEMP are:

Green Procurement

- Danone
- Nestlé
- Unilever

Removal of unsustainable ingredients

- M&J Seafood

Improving performance of existing suppliers

- Barilla
- Danone
- Heinz
- Illycaffè
- Innocent
- Kellogg
- McCain
- Mondelēz international
- Nestlé

Sustainable sourcing of water

- Coca-Cola
- PepsiCo

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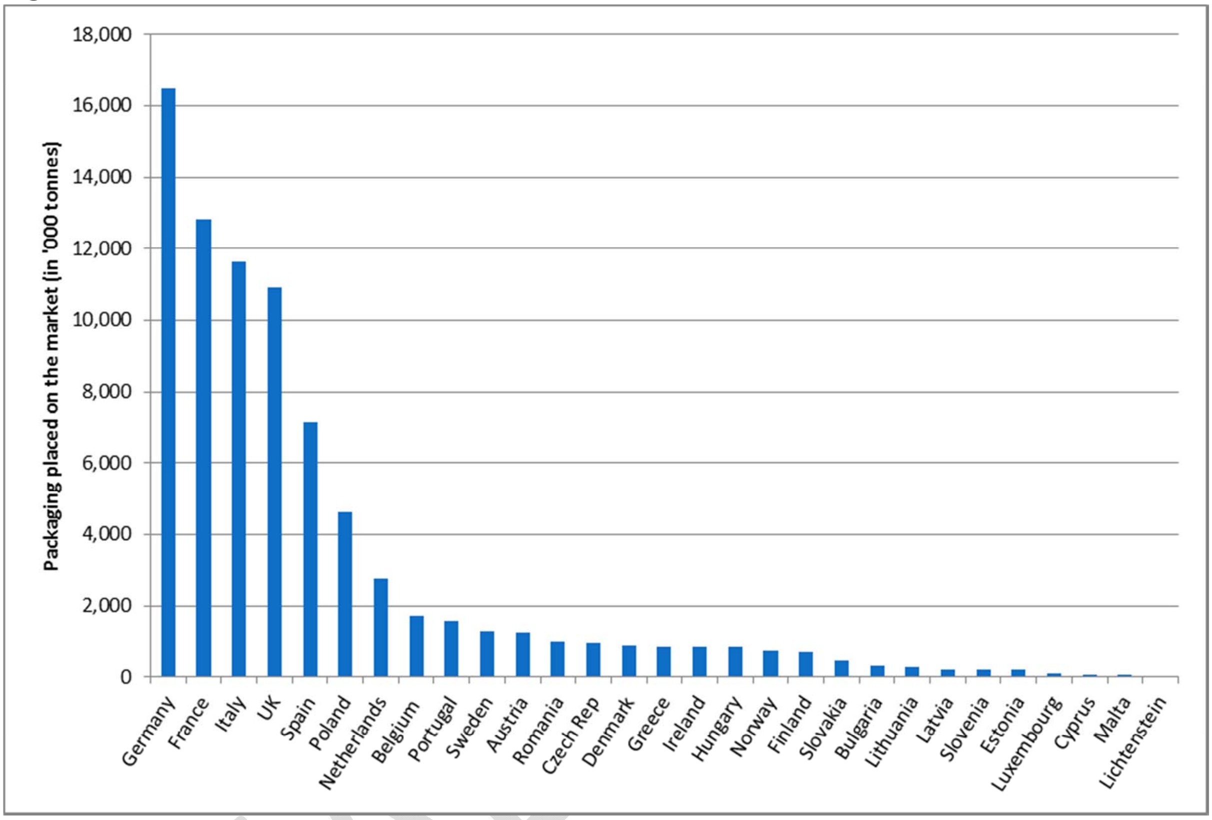
3.4. Improving or selecting packaging to minimise environmental impact

Description

On a global scale, the food and drink supply chain represents the most significant sector in terms of the volume and value of packaging used, with an estimated value of around EUR 280 billion (70%) of the total EUR 400 billion market (Pera technology, 2014). In 2011, over 80 million tonnes of packaging was placed on the market from the EU27 countries, with Germany, France, Italy and the UK accounting for nearly 65% of the EU27 total, see Figure 3.5. Food and drink manufacturers account for approximately two-thirds of the total EU used packaging by weight (Food and Drink Europe, 2014).

Figure 3.5: Total packaging placed on the market (in thousand tonnes) (EUROPEN 2014)



The European Organisation for Packaging and the Environment (EUROPEN) reports that over the past twenty years, considerable progress has been achieved in the end-of-life management of packaging, largely through extended producer responsibility (EPR) schemes for packaging waste (EUROPEN, 2014). Across Europe numerous national systems are well-established to collect and separate different waste packaging materials for re-use, recycling, or energy recovery.

This BEMP describes how frontrunners improve the design of the packaging they use (i.e. primary, secondary and tertiary) to minimise its environmental impact throughout the product life-cycle. Defra (2009) defines eco-design as 'designing product and packaging systems to ensure products (including their packaging) can be produced, distributed, used and recovered with minimum environmental impact at lowest social and economic cost.' This is particularly pertinent within the food sector where the relationship between the packaging and the product is so interdependent. Table 3.7 shows the list of factors that need to be considered when designing packaging and highlights the complexity of the design process.

Table 3.7: A summary of the functions of packaging (EUROPEN, 2013)

Functions of packaging	Descriptions
Protection	• Prevent breakage (mechanical protection) • Prevent spoilage (barrier to moisture, gases, light, flavours and aromas) • Prevent contamination, tampering and theft • Increase shelf life
Handling	• Transport from producer to retailer • Point of sale display
Waste reduction	• Enable centralised processing and re-use of by-products • Facilitate portioning and storage • Increase shelf life • Reduce transport energy
Unitisation	• Provision of consumer units • Provision of retail and transport units
Convenience	• Product preparation and serving • Product storage • Portioning
Promotion	• Description of product • List of ingredients • Product features and benefits • Promotional messages and branding
Information	• Product identification • Product preparation and usage • Nutritional and storage data • Safety warnings • Contact information • Opening instructions • End of life management

This BEMP outlines seven approaches to minimise the environmental impact of packaging:

- Eco-design tools
- Lightweighting
- Bulk packaging
- Refills
- Returnable packaging
- Packaging using recycled material
- Bio plastics

However, packaging is key to preserve food products and avoid food waste at consumer level. In 2013, the European Economic and Social Committee (EESC 2013) reported that food waste amounted to 89 million tonnes a year in the EU27. EUROPEN has created a task force to promote the role of packaging innovation, technologies and solutions contributing to a reduction in food waste. Innovations such as modified atmosphere packaging (MAP), hermetic seals, portion sizes for different lifestyles and households, messages for an optimised storage of the food product and colour changing labels to help consumers with use by dates are some of the methods developed. Therefore this BEMP also covers three of these approaches:

- Modified atmosphere packaging
- Optimum portion-size for different lifestyles and households
- Messages on packaging recommending optimised storage of the food product

<u>Eco-design tools</u>

Eco-design tools are used at the initial stage of packaging development and are a means of simulating the environmental performance of the packaging. A number of tools are available for free, such as:

- BEE (environmental assessment of packaging) which is a software that helps to assess the environmental impact of a packaging system for its global life cycle, identify the optimisation opportunities and compare selected alternatives (BEE, 2015).
- Pack4ecodesign which is a tool to check the environmental impact of your packaging, see the optimisation actions possible and simulate their benefits online (Pack4ecodesign, 2015).

Three companies that use different eco-design tools are **Barilla, Nestlé** and **Mondelēz International.**

Barilla

In 1997 the Italian pasta and baked goods manufacturer Barilla began to produce in-house 'Guidelines for Sustainable Packaging Design' which sought to (Barilla, 2014):

- minimise the volume of materials used,
- favour the use of recyclable packaging,
- maximise transport efficiencies (truck saturation),
- use paper packaging from sustainable forests

Then, in 2007, Barilla introduced its 'LCA Packaging Designer', a computer-based tool allowing the comparison of different packaging solutions to select those with the least environmental impact whilst preserving product quality. Thanks to this tool, and other improvement projects, in 2013, Barilla reached the point where 98% of its packaging was technically recyclable (compared to 85% in 2008).

Nestlé

Driven by its corporate objectives to offer products that are better for the environment along their value chain, the Swiss multinational Nestlé also uses bespoke software tools for product and packaging design. EcodEX[10], as the most recent tool[11] is known, facilitates the rapid assessment of

[10] EcodEX stands for 'Ecodesign for Sustainable Product Development and Introduction'

the environmental performance of products in the design process, helping fact-based decision-making.

EcodEX evaluates five environmental impact indicators, representative of the food and beverage sector:

- greenhouse gas emissions,
- land use,
- freshwater consumption,
- abiotic depletion
- ecosystems quality.

Developed in conjunction with the Italian information technology company Selerant, the tool allows different scenarios to be compared using accurate data specific to the food and beverage industry and according to methodological guidelines following ISO requirements and the latest initiatives in the field of life cycle assessment.

Typical examples of its use might be:

- assessing the environmental impacts of switching the packaging used for instant coffee from glass jars to pouches,
- ingredient sourcing,
- source reduction of packaging materials
- end of life options available for packaging materials.

Although initially only focusing on packaging (using the PIQET – Packaging Impact Quick Evaluation Tool), since 2012 eco-design has been extended to assessing the impacts of the whole packed food product (using the EcodEX tool). Scenarios take into account every stage of the product's supply chain from raw material production, product manufacturing to transportation, distribution and storage, and consumption up to disposal at end of life. According to Nestlé, almost every single product category has been assessed using eco-design tools during 'innovation or renovation' exercises.

Mondelēz International

Mondelēz International has also employed an eco-design tool for optimising the packaging it uses. The company claims that its proprietary 'Eco-Calculator™' tool creates 'more environmentally conscious packaging' by taking into account:

- the percentage of post-consumer recycled materials in a pack, and
- the amount of energy and greenhouse gas emissions associated with creating and disposing of a pack.

The tool relies on data from the U.S. Environmental Protection Agency, the US Department of Energy and packaging industry groups. Since 2013, Eco-Calculator has been web-based facilitating access to teams around the world and making it faster to update.

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[11] Before EcodEX, Nestlé used a different tool called 'PIQET.' Developed in 2008 with an Australian company, PIQET was completely phased out at the end of 2014 (Personal communication, Nestlé, Switzerland)

Lightweighting

Lightweighting is the process by which the mass of packaging material used per unit product is reduced without compromising the packaging's function (or the product's safety or quality). It is a long established means of reducing the environmental impact of packaging. According to FoodDrinkEurope, between 1990 and 2011:

- the weight of a 1.5 litre plastic water bottle has been reduced by 40%,
- the average thickness of foil used for chocolate and coffee by 30%,
- 33cl cans by 55%, and,
- glass by up to 60%.

Bulk packaging

The term 'bulk packaging' in the context of this BEMP refers to the unit size of raw material packaging being delivered to the food manufacturer. The UK manufacturer of pasties and other baked goods, **Ginsters**, is a frontrunner in raw material packaging minimisation, with a focus on bulk procurement of raw materials. Examples include the following (Ginsters, 2014, pers. comm):

- Switching to using bulk re-usable containers with a 1 tonne capacity for margarine rather than smaller consignments in cardboard cartons.
- Procuring flour in tankers rather than 25 kg sacks. The flour is pumped straight into a 70 tonne capacity flour silo.
- Delivery of potatoes from a local farm to the factory in a large truck fitted with a conveyor belt which enables the potatoes to be conveyed directly into the plant without any packaging
- Sourcing liquid egg, milk and cream in 500-1000 litre collapsible metal or plastic stillages Pallecons (supplied by CEVA Logistics). The Pallecon has a minimum capacity of 500 litres. The milk comes in a disposable bag, but the traditional method would have been to source milk in 6-10 litre bottles generating significantly more waste.
- Procurement of beef stock in 1000 litre IBCs (intermediate bulk containers) rather than the traditional 5 litre containers.

Refills

For decades, refillable packaging has been commonplace in Europe, especially for beverage containers such as soft drinks, milk and beer. Such refillable packaging can be used several times; therefore companies need to establish a collection system together with a washing and sanitisating facility in order to be able to reuse the containers. In these cases, among the aspects to consider include the labelling and the ink used on the refills which should ensure an easy recycling process for the containers, making sure that once processed they can be easily removed. A more recent development is the use of lightweight refills. For example, the instant coffee maker, **Kenco**, is notable for its introduction of 'Eco Refills' made from foil, which allow customers to re-use the same container at home. The Kenco Eco Refills use 81% less energy than glass to manufacture. Refills appear to have been a success, in 2013 it was reported that sales of instant coffee refill packs had grown 54% on the previous year (Convenience Store, 2013).

Returnable packaging

This BEMP focuses on returnable secondary and tertiary packaging. For example, the Swedish 'Eurocrate' system was introduced in the mid-1990s with funding from the EU's LIFE programme, where single-trip wooden packaging for food and drink products was replaced with reusable plastic pallets and crates.

Packaging using recycled material

Optimising the quantity of recycled material used in packaging can have a significant environmental benefit. For example, Berryman (2014) reports that every 1,000 tonnes of recycled glass that is used to produce new glass containers saves:

- 345,000 kWh of energy
- 314 tonnes of CO_2
- 1,200 tonnes of raw materials

The European Aluminium Association states that (European Aluminium Association 2013):
'*As the energy required to recycle aluminium is about 5% of that needed for primary production, the environmental benefits of recycling are obvious'*.

Novelis has developed aluminium sheet with 90 % recycled content enabling beverage can manufacturers to have a product made of 70% recycled material. Novelis estimates that current market levels of recycled content in aluminium beverage cans is around 40-50% (Food Production Daily 2013). **Nestlé** reports that in 2011 it used 27 % recycled material in its packaging (Nestlé 2014, pers . comm). Similarly, **Danone** claims that 25 % of all its packaging is produced from recycled materials, and it is aiming to achieve a rate of 25 % recycled material in the PET bottles it uses as packaging by 2020 – this is an ambitious target given the technical difficulties in the closed loop recycling of PET packaging. At the end of 2013, the proportion of recycled PET in packaging used within the Danone Waters division (including brands such as Volvic, Evian and Bonafont) stood at 9% (Danone, 2013).

When using recycled materials for packaging, food safety must be ensured by choosing suitable options for food and beverage products.

BioPlastics

Bio-based plastics, where part or all of it comes from renewable sources, are focussed on reducing the dependency on fossil fuel-based resources. Businesses that have introduced such packaging include the follwing:

PepsiCo has developed the world's first 100% plant-based, renewably sourced PET bottle and the world's first fully compostable bag for its snack brand 'SunChips' and planned to use potato peelings for its 'Walkers' packets from 2012.

Coca-Cola claims greenhouse gas savings of 30,000 tonnes CO_2eq through the introduction of bottles containing PET plastic derived from plant material. A wider potential benefit of the initiative was to stimulate the plant waste market to develop polymers from other sources (WRAP 2013).

Danone is also piloting the use of new bio-plastic packaging produced from sugar cane, sugar cane waste and corn, which do not compete with food production. The packaging is being trialled in the Volvic, Actimel, Activia, Danonino and Stonyfield brands (Danone, 2013).

Lebensbaum, an organic tea, coffee and spices producer, uses a compostable packaging film made of 100% GMO-free bioplastic (wood based cellulose, sourced largely from sustainably managed forests (>90% FSC or PEFC) (Lebensbaum, 2015 pers. comm.),

Bioplastics can improve the environmental performance of packaging, however, in some situations this might not be the case. Bioplastics have lower GHG emissions and non-renewable energy use per kg of material compared to their fossil fuel based counterparts. However, the agro-based indicators (eutrophication, water use, ecotoxicity) are worse for bioplastics (Nestlé, 2015). In addition, the comparison between traditional fossil fuel based plastic and bioplastics should take into account material quantities that provide a similar performance and not the comparison per kg, which is not conclusive (Nestlé, 2015 pers. comm.).
Therefore, the choice of the type of bioplastic and the amount used should be carefully assessed in order to ensure an improved environmental performance.

Modified atmosphere packaging

In 2013, the European Economic and Social Committee (EESC 2013) reported that food waste amounted to 89 million tonnes a year in the EU27. EUROPEN has created a task force to promote the role of packaging innovation, technologies and solutions contributing to a reduction in food waste. Innovations such as modified atmosphere packaging (MAP), hermetic seals, different portion sizes for different lifestyles and households and colour changing labels to help consumers with use by dates are some of the methods being developed.

Table 3.8 shows an example of the extended shelf life that can result from a move to MAP. It can be seen that in many cases the shelf life can be more than doubled.

The Vacuum Skin Packaging (VSP) of high value products, such as red meat, is particularly popular in the UK and Swedish company MicVac has developed a new vacuum packaging technology that allows cooked ready meals to be stored in chilled form for 30-45 days, depending on their content (Euroasia Industry 2011).

The Swiss company Freshpoint is working with Ciba/BASF on the development, marketing and worldwide sales of the company's time temperature indicators. They have produced a range of labels that can be applied directly to a food product's packaging, such as the CoolVu TTI, which displays the total temperature history of the product to which it is attached (Euroasia Industry 2011).

Table 3.8: Typical shelf life in air and using modified atmosphere packaging. (BOC 2012)

Food Type	Typical shelf life in air	Typical shelf life in MAP
Raw red meat	2-4 days	5-8 days
Raw light poultry	4-7 days	16-21 days
Raw dark poultry	3-5 days	7-14 days
Sausages	2-4 days	2-5 weeks
Sliced cooked meat	2-4 days	2-5 weeks
Raw fish	2-3 days	5-9 days
Cooked fish	2-4 days	3-4 weeks
Hard cheese	2-3 weeks	4-10 weeks
Soft cheese	4-14 days	1-3 weeks
Cakes	Several weeks	Up to 1 year
Bread	Some days	2 weeks
Pre-baked bread	5 days	20 days
Fresh cut salad mix	2-5 days	5-10 days
Fresh pasta	1-2 weeks	3-4 weeks
Pizza	7-10 days	2-4 weeks
Pies	3-5 days	2-3 weeks
Sandwiches	2-3 days	7-10 days
Ready meals	2-5 days	7-20 days
Dried foods	4-8 months	1-2 years

Optimum portion-size for different lifestyles and households

Food and beverage manufacturers can adapt the size of packaging of their products to better cater for different lifestyles and households. Indeed, an important source of food waste is leftovers from products sold in quantities bigger than needed. If products are sold instead in sizes that better match the needs of different categories of consumers, this source of food waste can be reduced. Some food and beverage manufacturers are considering these aspects when designing or choosing their packaging. When optimising the portion-size, the environmental impact of increased amount of packaging for small-portions must be taken into consideration.

Messages on packaging for optimised storage of the food product

Food and beverage manufaturers can include on the packaging of their products guidelines on how best to store them closed or once opened, in order to reduce their spoilage and consequently reduce food waste generation.

In addition, packaging can also include an indication on the optimum time for cooking in order to avoid over cooking and consequently reduce the energy consumption.

Achieved environmental benefits

According to Nestlé, almost every single one of their product categories has been assessed using ecodesign tools during 'innovation or renovation' exercises. Up to 2013, Nestlé had undertaken 15,500 different scenarios using EcodEX, PIQET and other ecodesign approaches, saving more than half a million tonnes of packaging (and saving EUR 830 million in packaging costs). In 2013 alone, 66,594 tonnes of packaging material were cut using eco-design tools saving around EUR 131 million (Nestlé, 2014). EcodEX is now available for other companies to use by accessing the Selerant website (http://www.selerant.com/main/en-us/solutions/ecodesign.aspx)

Examples of environmental savings from **Mondelēz International e**co-design projects include:

- the conversion of Cadbury Dairy Milk bars in Australia from traditional foil and cardboard packaging to a new, single-layer flow wrap which saved 1,270 tonnes of packaging.
- the re-launching of Jacobs Velvet instant coffee in a lighter-weight glass jar saving 4,536 tonnes of glass.

Overall, between 2010 and 2013, Mondelēz International has eliminated 21,772 tonnes of packaging material from the supply chain – and is close to achieving a goal of cutting 22,680 tonnes of material by 2015 (Mondelēz International, 2013).

Examples of frontrunner work in the area of lightweighting include:

- **Heinz** in 2007 developed a new can end that was 0.18mm thick, a 10% reduction on the previous ends. This reduction saved 1,400 tonnes of steel each year equating to GBP 404000 (IGD, 2007).

- **Vranken-Pommery Monopole** (FT.com 2008) was the first big champagne group to adopt the 835g champagne bottle instead of the standard 900g bottle and reported that it can load 4,000 more bottles on every truck.

- **Kingsland** worked with **Quinn Glass** to reduce the weight of a standard wine bottle to 300g, a reduction of nearly 30%. The three key hurdles that they had to overcome were (Food and drink innovation network 2010):
  - the impact resistance needed to be the same as standard bottles
  - the glass needed to be evenly distributed in the manufacturing process
  - the aesthetics of the bottle had to match the standard bottle to satisfy consumers.

- In the UK, **Cott Beverages** a producer and packager of soft drinks demonstrates a good example of best practice in minimising secondary shrink wrap packaging. Motivated by its involvement in the Courtauld Commitment, in 2012, Cott reduced the LDPE (low density polyethylene) shrink wrap the manufacturer used as secondary packaging around canned beverages from 50 to 38 microns and reduced the shrink wrap gauge from 60-70 microns on PET bottles to 50-55 microns. The project achieved the following environmental benefits (WRAP, 2014):
  - reduction in LPDE film used at two sites by a total of 115 tonnes per year[12]
  - reduction of carbon footprint by 308 tonnes CO_2eq across the whole business (and 61 tonnes CO_2eq on Cott branded products alone)

[12] 1 tonne of LPDE = 2.681 tonnes of CO_2eq

- The Scottish soft drinks manufacturer **A G Barr** is among many UK retailers and manufacturers motivated to improve packaging as a result of signing up to the WRAP-sponsored Courtauld Commitment. A G Barr cut the carbon impact of its 2l, 500ml and 250ml bottles by 1,869 tCO_2eq in 2010, saving 505 tonnes of plastic through the installation of sophisticated bottle blowing and filling technology. The 500ml and 250ml bottles alone saved 316 tonnes of plastic, and are amongst the lightest within the carbonated soft drinks market. The cost saving from reduced plastic requirements may also have been a motivating factor for A G Barr, although this needed to be offset against the capital investment in new equipment (Product Sustainability Forum, 2013a).

- The French manufacturer **Danone** has targeted reduction of packaging at source as 'a number-one priority wherever possible', optimising the weight of packaging across the board, while maintaining product quality and the service provided to consumers. Recent technical innovations include removing the cardboard from yogurts sold in multi-packs and cutting the weight of bottles. For example, the Danone Waters China subsidiary cut the weight of the large 600 mL format bottles used for the 'Mizone' brand by more than 25% between 2004 and 2012. Between 2010 and 2013 alone, the Mizone brand has saved more than 8,500 tons of PET (Danone, 2013).

- By 2004, The Swedish 'Eurocrate' system had 1,753,000 crates in circulation resulting in annual packaging waste savings of over 28,000 tonnes (Defra, 2011). Other estimated savings included reductions in:

    - lorry journeys of 260,000 km/yr (equal to 180 tonnes of carbon dioxide)
    - energy consumption by 52 million KWh/yr
    - the volume of damaged goods by at least 20%
    - transportation costs by 25%

Appropriate environmental performance indicators

Typical environmental indicators include:

- Packaging related CO_2eq per unit weight of product manufactured
- Volume/weight packaging per unit weight of product manufactured. An example of this is provided by the drinks manufacturer **Britvic** which achieved a 61% reduction in PET plastic per litre when it concentrated some of its squashes (Product Sustainability Forum, 2013b).
- Percentage of packaging which is recyclable
- Percentage recycled material content in packaging
- Weight of packaging per unit of product
- Average density of product category in kg (net) product per litre of (gross/packaged) product

Cross-media effects

For many food products, a minimum amount of packaging is essential for protecting the contents during transportation throughout the supply chain including at the consumer stage. If packaging is eliminated altogether then physical and microbial damage to the product may occur resulting in food waste. For example, FoodDrinkEurope (2012) reports that cucumbers with just 1.5 grams of wrapping have been found to maintain freshness for 11 days longer than those that are unpackaged.

While use of renewable materials such as bioplastics may improve product sustainability, unintended negative environmental consequences should be considered including the local impacts of growing the raw material (e.g. sugarcane) (Product Sustainability Forum, 2013a). Some frontrunner food and drinks manufacturers, e.g. **Danone**, **Coca-Cola**, **Heinz**, **Nestlé**, **Unilever**, have formed the Bioplastic Feedstock Alliance with the World Wildlife Fund to encourage the responsible development of bioplastics.

Similarly, new composite lightweight materials may be lighter – and thus consume less resources in their manufacture - but they may also be less recyclable at the end of life or more energy intensive to produce. This downside may offset any environmental benefits achieved from lightweighting; beer bottles made from PET/nylon are a well-known example of this.

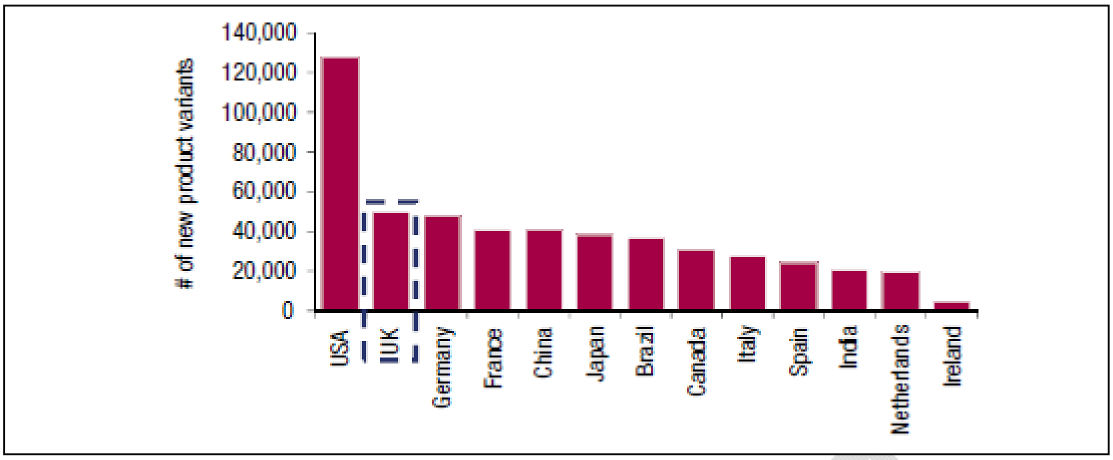
The environmental performance indicator measuring performance in terms of the environmental impact or packaging weight per unit of production (e.g. kg of packaging per kg of product) can discourage smaller product formats from being developed. However, smaller formats can be useful to avoid overbuying by consumers and/or to avoid consumers having to throw away part of a product, especially with products with a short open life. The whole life cycle impact should be considered which trades off the additional impact of packaging against the reduced food waste generated.

Operational data

Table 3.7 shows the complexity of the packaging design process and this is compounded by the high level of new product development (NPD) in the food and drink sector, advancements in packaging technology, ever tighter demands on food safety and changing consumer profiles. The high rate of NPD may drive certain packaging innovations, particularly a reliance on design tools such as **Nestlé**'s EcodEX. For manufacturers making a small number of rarely-changing products, investment in such tools is probably not practical. Within the EU, the UK appears to have the most innovative markets in terms of NPD based on the number of product variants[13] launched between 2005 and 2011, lying slightly ahead of France and Germany (Figure 3.6).

[13] The variants may refer either to brand new product launches or to product updates or to the same products but with varied properties (e.g. different taste, packaging) (FDF, 2011)

Figure 3.6: New product variants by country (2005-2011) (Food and Drink Federation 2011)



Conversely, those businesses with rarely changing product ranges may choose to focus on the more traditional means of reducing the environmental impact of their packaging through such interventions as lightweighting, diversion from landfill and increasing recycled content.

Lightweighting efforts are also evidenced for tertiary packaging. For instance, stretch wrap made of LDPE (low density polyethylene) plastic film represents a significant packaging waste material in the food and beverage manufacturing sector and offers an opportunity to cut waste. Stretch wrap is often used to waterproof and stabilise consignments on truck pallets.

Research by WRAP (Waste & Resources Action Programme) found that film applied to standard pallet loads varied from 300g per pallet to more than 1,000g if manually applied (WRAP, nd). At the upper end of this range the stretch wrap is likely to be too loosely applied. Industry experts point out that to be most effective, the wrap needs to be pulled to its maximum stretch in order to reduce its latent elasticity and improve 'lay-on force'. This ensures performance and reduces the likelihood of goods tipping out and being damaged in transit. Optimal stretching of stretch wrap - effectively lightweighting the packaging – also cuts packaging waste per unit of consignment.

Applicability

The use of refillables, and reusable and returnable transit packaging systems has been shown to work best in short, simple and localised supply chains where the return rate can be maximised. An example of this is the successful refillables schemes operated by small breweries in Germany (and enforced in national law) using deposit return systems (DRS). However, this approach does not work for complex or fragmented supply chains, for example, where production is centralised in a small number of plants.

While procurement of bulk raw materials reduces transit packaging waste, the approach is not applicable to all ingredients. For instance, due to the size constraints of processing machines at its facility, the UK pie and pasty maker **Ginsters** referenced above, is unable to procure cheese in portion sizes larger than 20kg slabs. In addition, bulk supply lends itself best to ingredients which are either processed by the receiving manufacturer in high volumes or which have a longer life and thus are unlikely to expire before use.

A key constraint for lightweighting packaging can be consumer perception. For example, the aforementioned Kingsland / Quinn glass lightweighting project had to overcome the consumer mind-set that heavier bottles equated to better quality wine.

Economics

EUROPEN estimates that food and drink producers pay estimated annual fees of up to EUR 3.1 billion to Extended Producer Responsibility (EPR) schemes in Europe and this is reflected in an overall recovery rate of 76% and recycling rate of 63% (EUROPEN, 2013).

The cost implications of redesigning packaging are critical. Certain innovations such as the lightweighting of packaging while offering financial savings on raw material use in the long run will require substantial upfront capital investment in new equipment. For instance, in the UK, the soft drinks manufacturer **A G Barr** cut the carbon impact of its plastic bottle packaging by lightweighting it with new blowing and filling equipment (Product Sustainability Forum, 2013a). For glass lightweighting, manufacturers may have to move from a 'blow + blow' process to a 'press + blow' process which provides better glass distribution (i.e. more uniform wall thickness) but represents a significant capital investment.

More evidence of the financial benefits of lightweighting comes from **Heinz.** The company recently worked with its can end supplier Impress and steel supplier Corus to reduce the thickness of 'Easy Open' can ends by 10% to 0.18mm thick (Heinz's previous ends were already the thinnest available). As a result of the trial, 1,400 tonnes less steel was used annually saving Heinz GBP 404000/yr. Part of the cost savings came from the fact that 18% more of the redesigned cans could fit on each pallet during distribution. In addition, each lorry load of filled cans with the new end weighs 83kg less, meaning improved fuel efficiency. If the whole UK canning industry switched to the thinner ends an estimated 28.8 million kWh in energy could be saved, equating to 2,340 tonnes of CO_2 emissions per year (IGD, 2007).

Driving force for implementation

Packaging Europe reports that in the 1980s and 1990s, sustainability was generally speaking a supply chain push issue as manufacturers responded to regulatory changes such as the introduction of the European Packaging Waste Directives. Packaging Europe states that regulatory issues are still significant drivers but now with greater pressure from both consumers and regulators (Packaging Europe 2013).

EUROPEN stresses that the key driver is cost and states (Food Production Daily 2013):

"Whatever we do in terms of prevention, in reducing packaging through the whole value chain, is reducing, on the one hand, the cost factor; and on the other hand, the CO_2 footprint which is indirectly a cost factor".

According to WRAP, the key business drivers for addressing packaging sustainability include the increasing cost of raw materials and concerns over security of supply (Product Sustainability Forum. 2013b). Often larger companies will make public voluntary commitments, externally or internally formulated, on packaging as part of a CSR strategy. For instance, the US confectionery manufacturer **Mars** stated an ambition to increase the recycled content in its packaging by 10% by 2015.

The competition between the different packaging materials is also a key driver especially when comparing the environmental merits of glass, plastic and metal cans in the beverage sector. EUROPEN highlights the fact that each material has its own individual environmental characteristics (EUROPEN, 2013b):

- For glass: one tonne of recycled glass saves 1.2 tonnes of raw materials and avoids 700kg of CO_2 emissions; for each 10% of recycled glass, the energy saving is 30%.
- Plastic: while over 50% of all European goods are packaged in plastic, it accounts for only 17% of all packaging by weight.
- Corrugated board packaging: currently has a recycled content in Europe of 85%
- Aluminium and steel: 70% of rigid metal packaging was recycled in Europe in 2010, saving between 70 and 95% of the original energy used to produce it
- Beverage cartons: In 2012, 88% of the main raw materials used to produce the cartons in Europe is sourced from responsibly managed sources.

Reference organisations

For their use of eco-design tools for the development of their packaging the three businesses below are considered frontrunners:

- Barilla,
- Mondelēz International
- Nestlé

For their packaging lightweighting initiatives the following are considered frontrunners:

- A G Barr
- Cott Beverages
- Danone
- Heinz
- Kingsland
- Vranken-Pommery Monopole

For bulk packaging

- Ginsters

For bio plastics:

- Coca-Cola
- Danone
- PepsiCo

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3.5. Environmentally friendly cleaning operations

Description

Cleaning operations can account for up to 70% of a food and beverage manufacturing site's total water use and effluent volume (Environmental Technology Best Practice Programme, 1998), and are also responsible for a significant portion of a site's energy consumption; In the dairy sector, for instance, more than half of a typical milk processing plant is devoted to cleaning equipment and pipes (Innovation Center for U.S Dairy, 2010).

This BEMP describes how the best performing manufacturers implement environmentally friendly practices in their cleaning operations so as to reduce water and energy consumption or to use more environmentally friendly chemicals. Two types of cleaning should be considered here:

1. Cleaning processes during the preparation of raw materials prior to production, and;
2. Cleaning of production equipment between batches or recipes.

In both cases, the cleaning operations can be very intensive in their use of water, energy and chemicals.

Frontrunners implement this BEMP in a number of ways, including:

- Implementing and optimising of Cleaning In Place (CIP) systems
- Optimising manual cleaning operations
- Minimising or avoiding the use of harmful chemicals
- Better production planning
- Better plant design

Implementing and optimising Cleaning In Place (CIP) systems

CIP is a hygiene technology widely used by larger food and drink manufacturers during scheduled cleaning and wash downs to remove surplus product and bacteria from vessels and pipework while minimising interruptions to the process.

Tamime (2008) defines CIP as:

The cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of the surfaces or circulation of cleaning solutions under conditions of increased turbulence and flow velocity.

CIP reduces water, detergent, heat and energy use during the cleaning process; promotes the use of chemicals with more desirable environmental characteristics and minimises production downtime which in turn cuts the food and packaging wastage associated with the starting up and slowing down of production. CIP is typically practised for the cleaning of production equipment, the second of the two purposes referred to above.

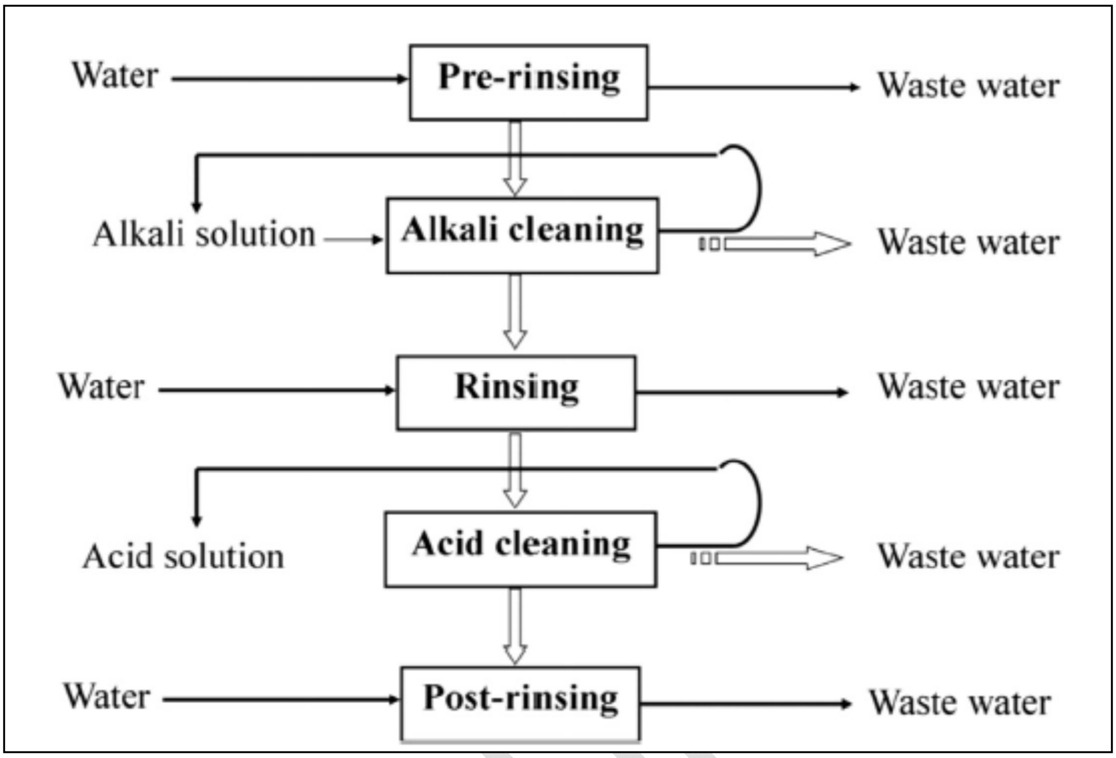
In fully automated systems, computer software can be used to coordinate the CIP cycle which typically involves detergent solution for cleaning, disinfectants and sterilisers, other additives such as ozone (see below) or a 'pig', an object which dislodges solid material prior to cleaning (Product Sustainability Forum, 2013a).

An innovative new 'ice pigging' method using ice slurry has recently been rolled out with significant environmental and productivity benefits. This method involves using crushed pumpable ice as a semi-solid object to clean pipes. Rather than flushing food pipes and tanks with liquid water (prior to the use of detergents such as caustic soda), the ice slurry is driven through the system which is far more efficient in mechanically recovering residual product. In effect, the ice scrapes the pipes and tanks and recovers useable food product, rather than the organic material being lost in the effluent. The ice pigging method has the huge advantage that the ice can be driven throughout the system, around bends, through narrow diameters, across heat exchangers, etc. whereas standard pigs can only be used across straight pipes. However, ice production is an energy intensive process, requiring about 9.15 kWh per 50 kg pig, even if more efficient techniques are under development. Nevertheless, the water and product savings achieved with the ice-pigging method counterbalance the higher energy consumption (Carbon Trust, 2015).

The method was piloted in 2011-12 by the manufacturers Premier Food and General Mills with funding from Defra (UK Department for the Environment, Food and Rural Affairs) and has been proven to work in the manufacture of various foods including dairy products, curry sauces, sausages and tomato purees. Ice pigging is commercialised and is especially used in the water industry. However, many other sectors in the food and beverage manufacturing sector could benefit from the implementation of this cleaning technique.

CIP is nothing new in the food and beverage industry but many companies, conscious of the risks associated with failure (i.e. contamination of product), tend to factor a high level of contingency into their CIP programmes, over-using water and energy and wasting product. CIP programmes in the food and beverage sector are traditionally composed of multiple steps. The initial rinse with water serves a mechanical purpose in physically dislodging as much of the food product remaining (although as discussed below this step is less effective than the 'ice pigging' method). The hot alkali solution (typically caustic soda – i.e. sodium hydroxide) is designed to kill microbes and remove the remaining COD. The system is flushed again with water to remove the caustic soda and sometimes an acid wash (typically nitric or hydrochloric acid) is used, especially in the dairy sector, to remove unwanted minerals such as calcium, before a final post-rinsing with water (Figure 3.7).

Figure 3.7: Conventional cleaning steps in the CIP process in the dairy industry



Source: Paul et al. (2014)

The best performing companies therefore seek to optimise CIP systems and maximise savings without compromising function. Ways to optimise CIP include the following (Environmental Technology Best Practice Programme, 1998; WRAP, 2012):

- *Optimising process design and configuration* - simple systems use the vessel to be cleaned as a detergent reservoir whilst the more complex are multi-channelled with tanks for detergent, pre and post rinses, and sometimes disinfectant;

- *Optimising control and measurement of detergent temperature and concentration* – for instance, by installing automatic dosing systems.

- *Optimising the application of mechanical action* (e.g. wiping, rubbing, brushing, flushing and high-pressure jets) to improve the effectiveness of the cleaning.

- *Use of real time cleaning verification* - i.e. monitoring critical parameters (e.g. temperature, chemical concentration) and indicators of effectiveness in removing soil (e.g. turbidity, surface cleanliness, flow) in real time allows adjustments during the cycle to ensure efficiency while avoiding the temptation to 'over clean' and thus waste energy, water and chemicals. The monitoring is typically done by fitting electrode conductivity sensors in the process pipe work, although a verification system that uses a coloured chemical to detect the organic contamination indicative of ineffective cleaning has also been recently developed (Thonhause GmbH, 2014, pers.comm.).

- *Re-use of final rinse water for pre-rinse and recycling of detergent* – the recirculated detergent must be filtered to avoid the need to dump dirty detergent solution regularly down the drain.

- Use of *turbidity detectors* to recover product from pipework prior to cleaning.

- Use of *spray devices* designed to clean effectively with the minimum volume of water.

- *Regeneration of caustic soda – the 'Green CIP' method* (see below)

- *Ice pigging* (see above and achieved environmental benefits)

Optimising the resource efficiency of manual cleaning operations

Small and medium-sized manufacturers may not have the resources to implement sophisticated automated systems like CIP, but scope exists to improve resource efficiency of manual cleaning operations in many low-cost or free ways including (Environmental Technology Best Practice Programme, 1998):

- staff training and awareness-raising;
- better monitoring of the consumption of water and energy used in cleaning;
- water pressure controls and water-efficient spray nozzles for hoses;
- improved chemical formulations and application;
- cleaning of equipment as soon as possible after use to prevent wastes hardening
- regular servicing and maintenance - to identify and rectify faulty, inefficient or leaking equipment;
- dry clean-up – i.e. manual removal without waste water from the floor and machinery prior to cleaning (which ultimately lowers the organic concentration of effluent)

Frontrunners in the food and drinks sector will also plan their manual cleaning programme to better match particular machinery or types of soil with the correct cleaning methodology and materials. This can significantly impact on the quality, speed and cost of cleaning (Bailey, 2013). Traditionally, facilities are cleaned by a group of cleaners following an intuitive and simple 'sequential method':

1. remove debris to another area,
2. rinse surfaces,
3. apply detergent,
4. rinse again,
5. finish with sanitiser.

However, this has the following disadvantages:

- the team can only work as fast as the slowest member
- the team lacks the flexibility to respond to short-term needs
- an area or piece of equipment may be unnecessarily cleaned 'because it is on the schedule'
- some areas or equipment may be left for too long before they are cleaned with the result that contamination builds up and food particles may be harder to remove.

Frontrunners, especially those with extended or continuous production, use a more flexible approach called 'cluster cleaning' and 'event cleaning' which balance food safety with economy, equipment is cleaned when necessary and not before. The staff involved in cluster cleaning have clearly defined roles, each waiting for the right time to complete their part of the process quickly and efficiently, and without impeding any other cleaner. By this approach, each area of production is cleaned as soon as it falls idle, reducing plant downtime and increasing profitable production time. With event cleaning the process is further refined, with surfaces examined frequently by an experienced operative, to assess the scheduled clean time using pre-set criteria. Only then, if needed is the surface cleaned. Event cleaning is best suited to ancillary surfaces (e.g. guard rails, packaging and wrapping machinery, air conditioning units, corridors, and door or wall touch-points). These advanced cleaning methods can potentially cut labour costs by up to 15 % compared to traditional sequential cleaning regimes (Bailey, 2013).

Minimising or avoiding the use of harmful chemicals

Chemicals such as chlorine, quaternary ammonium compounds, bromine or iodine based products are routinely used to maintain the hygiene of food manufacturing sites. However, these are often potentially hazardous in combination with organic residues (Canut & Pascual, 2007). Moreover, to work safely and effectively, such chemicals typically require large volumes of water and often high temperatures. Then, when cleaning is complete, further treatment with significant associated environmental impact is often needed to clean up any effluent.

Frontrunner companies therefore seek to minimise or avoid the use of such chemicals in a number of ways:

- capturing and re-using cleaning agents (Environmental Technology Best Practice Programme, 1998), as evidenced in the Taw Valley Creamery example below
- using less harmful cleaning chemicals
- using electrochemical activation (WRAP, 2012)
- using biological cleaning agents.

All these approaches can be applied to both manual and automated cleaning systems (e.g. CIP). Two examples of these are described below.

Re-using cleaning agents - A team of French and Canadian technologists have pioneered the regeneration of caustic soda used in CIP, a technology called 'Green CIP' that enables the re-use caustic soda (Utilities Performance, 2014, pers.comm.). Rather than the initial rinse with cold water (see Figure 3.6), in this method the pipes and tanks are flushed through with hot alkali as a first step resulting in a liquid very high in organic matter. The used caustic soda is then passed into the Green CIP process in which a clay-based reagent is used to separate the alkali from the solids which forms a sludge. The Green CIP is not a mechanical process (using membranes or centrifugation), but a 'soft process' of coagulation and flocculation paralleling that in a standard wastewater treatment plant.

The sludge from the Green CIP is sufficiently clean to be spread on farm land as a fertiliser or even fed to animals. Crucially, the effluent from the caustic soda flush does not need to be 'cleaned up' in an expensive waste water treatment plant before being discharged to the municipal drains. Importantly, unlike with a standard wastewater treatment plant which requires a neutral pH, the Green CIP process can function at any pH enabling the cleaning up and regeneration of both alkali, and where necessary, acid effluent. The caustic soda regenerated in the Green CIP process can be re-used multiple times, and tests indicate that the regenerated caustic soda is more effective than virgin alkali in its task of removing solids.

The Green CIP process has already been used by:

- **Actalis** a multinational dairy products maker in a 30,000 tonnes per year capacity plant making mozzarella and ricotta cheese in Buffalo, New York state, USA – since 2006
- **Danone** in its 'Yoplait' plant on the French island of Réunion in the Indian Ocean – since 2012

Utilities Performance Group has now worked with a PhD student in northern France to collect more technical data on the Green CIP process to prove its safety, effectiveness and environmental performance before industrial scale up on the European continent. Green CIP has been successfully used by manufacturers making dairy products (yogurt, cream, and ice cream), meat products, soups, chocolates and alcoholic and non-alcoholic beverages.

Using less harmful cleaning chemicals - The use of ozone as a cleaning agent is a particularly promising technique (Canut & Pascual, 2007; OzoneCIP Project, 2007) which does not produce any harmful residues. The highly oxidative, and thus anti-microbial, properties of ozone (O_3) are well-established. Ozone in water solution can destroy the cell membrane of pathogens by oxidising the phospholipids and lipoproteins and has the advantage of itself quickly breaking down into harmless oxygen. Ozone is effective against a wide range of microbes including bacteria, yeasts, moulds, viruses and spores (Khadre et al., 2001). The incorporation of ozone-enriched water in CIP - and other cleaning processes - has the advantage over traditional disinfectants that no residues are left and the ozone is applied cold. This reduces the volume of water necessary to rinse detergents from the plant and the energy associated with heating the water. Ozone can also be used in dry settings (Environmental Technology Best Practice Programme, 1998). As a result ozone is increasingly being used by frontrunners in a number of subsectors (especially winemaking).

<u>*Better production planning*</u>

Better production planning and scheduling so as to minimise the number of discrete cleaning episodes needed between product changeovers will also offer significant time, environmental and financial savings. This includes improving demand forecasts in order to avoid abrupt changes in production requiring the equipment to be cleaned. Cleaning at non-optimum times is likely to result in larger amounts of food waste given that the process would not have come to an end, and therefore more residual food is likely to be present in the production equipment. This would also result in increased use of water and detergents to eliminate the larger amounts of residual food that need removing.

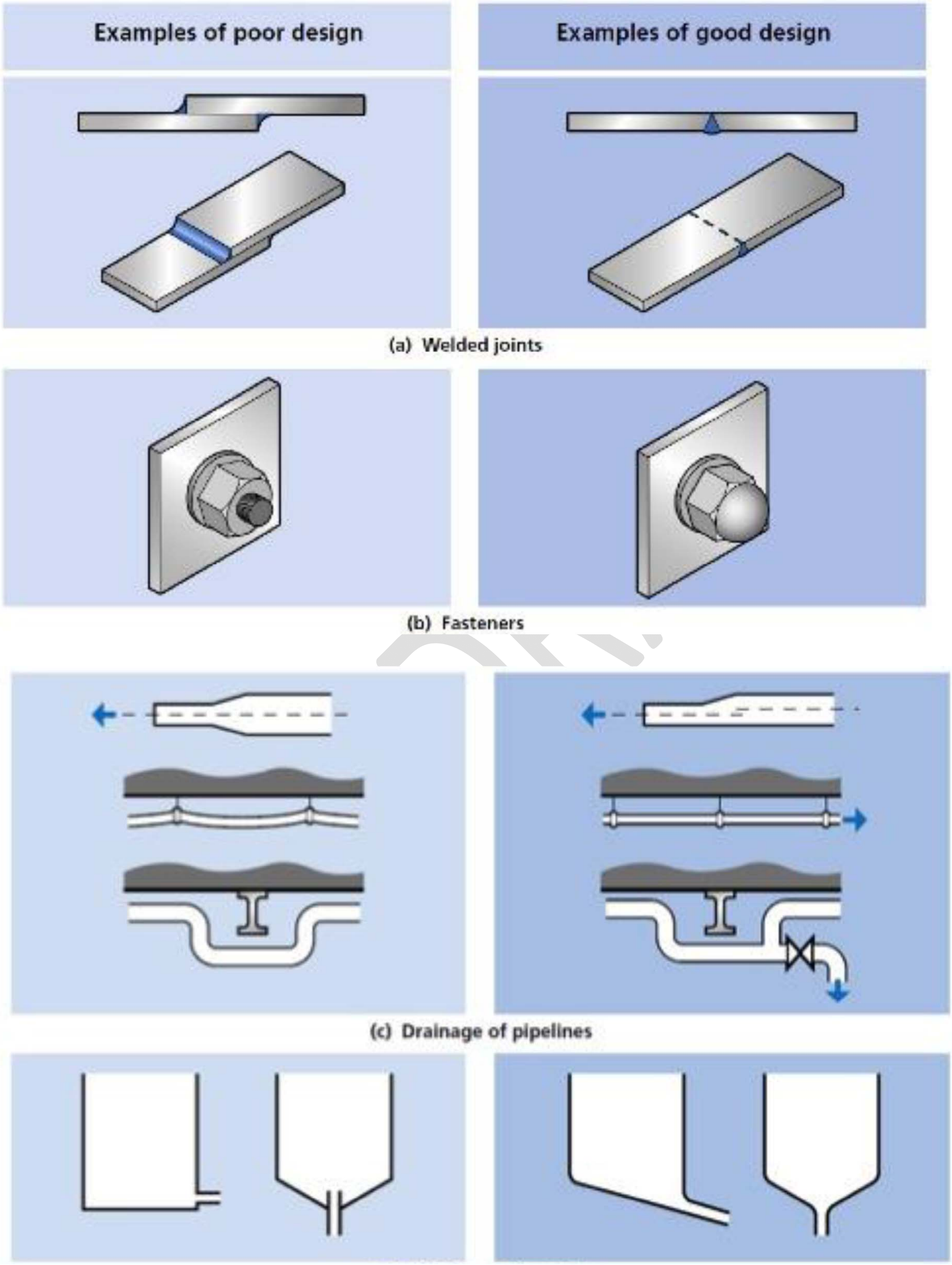
Another example is better planning in production plants where allergen free foodstuffs are produced, as well as regular products. In these cases, planning production shifts so that the allergen free products are scheduled first which reduces the need for thorough cleaning when moving the non-allergen-free equivalent which would otherwise be required to avoid cross-contamination. This would result in reduced use of both water and detergents. This approach can also be generalised to non-allergen-free food stuff. Optimised production planning can allow the next batch of ingredients to be used as a cleaning agent, ensuring that there is no need for specific cleaning operations and risk of contamination between different batches.

Better plant design

Improving the design of vessels, pipework, etc. so as to eliminate areas that detergent cannot reach or where fluid accumulates will reduce cleaning time as well as saving water, chemicals and energy (Figure 3.8).

The use of different materials in the construction of processing equipment also facilitates cleaning. An example of this comes from the UK beer producer **Adnams** which reduced water use below the industry average, in part by using stainless steel in brewery construction which can be cleaned with less water (Product Sustainability Forum, 2013c).

Figure 3.8: Designs for efficient cleaning



Source: Environmental Technology Best Practice Programme (1998)

Achieved environmental benefits

Three main benefits resulting from the use of environmentally-friendly cleaning operations have been identified. Water can be saved through the use of CIP systems, electrochemical activation (ECA) and by replacing this with other chemicals such as in 'Green CIP' methodologies. Such cleaning methods also result in significant reduction of energy use; for example, this can be done by switching to lower temperature methods. Chemical usage can be reduced through the use of ECA and CIP systems, this can also be achieved by re-using such detergents.

In addition, certain forms of environmentally-friendly cleaning, notably CIP, have the added benefit of reducing the wastage of food - both raw materials and end products - and packaging associated with the starting up and slowing down of production.

Best reported water savings

The South African brewing company **SABMiller** trialled a new CIP system which uses ECA instead of detergent and disinfectants at its 'Chamdor' brewery. The result was an 83% reduction in water use (WRAP, 2012).

In 2007 **Kraft Foods** – now part of the multinational food and beverage conglomerate **Mondelēz International** – implemented an optimised CIP system, along with other innovations such as the re-use of production waste water, at its Vegemite factory in Australia. The project reduced overall water use by 39%, with the optimised CIP alone cutting annual water consumption by 11.8 million litres with the equivalent reduction in waste water needing to be treated (EPA Victoria, n.d.).

The 'Green CIP' method which has been used by **Actalis** and **Danone** results in up to 50% water savings by replacing the use of water with that of a hot alkali for initial pipe flushing (Utilities Performance, 2014, pers.comm.).

Best reported energy savings

According to the **Innovation Center for U.S. Dairy** more than half of an average[14] milk processing plant's annual energy use of 27,500 million BTUs (British Thermal Units)[15] is devoted to cleaning equipment and pipes to meet necessarily stringent sanitation standards. In 2010-11, the Center began piloting a new lower temperature cleaning technique which cuts fuel and greenhouse gas emissions by 15%, uses less rinse water, and produces less alkaline effluent (Innovation Center for U.S Dairy, 2010).

In addition to the substantial water savings noted above, **SABMiller**'s ECA system at the 'Chamdor' brewery cut energy use by 98% (WRAP, 2012).

The use of biological agents instead of traditional detergents can lower the energy consumption associated with cleaning. Recent work in Ireland, for instance, has identified several enzymes extracted from fungi as potentially suitable for environmentally friendly CIP in the dairy industry. Lab tests showed that the enzymes removed industrial-like milk fouling deposits from stainless steel at the relatively low temperature of 40°C (versus conventional CIP methods which use caustic-based cleaning solutions such as 0.5 to 1.5% sodium hydroxide at 70-80°C). The

[14] 'average' defined here as processing 25 million gallons milk (c. 114 million litres) per year

[15] Approximately 29 million megajoules

researchers report that, when scaled up, the enzymatic CIP procedure would cut energy consumption, decrease chemical usage and reduce the requirement for pH neutralisation of the resultant waste prior to release (Boyce & Walsh, 2012). Similar findings, again in the dairy sector, are reported from experiments carried out in India with enzymes derived from bacteria (Paul et al., 2014).

Within the Italian wine sector, the use of ozone in a non-CIP system is being promoted. The following advantages have been reported (Tebaldi, 2014, pers.comm.):

- no residues are left;
- the consumption of water used in the cellar is lowered and the parameters of wastewater are improved (NB the company also recovers washing water enabling it to save up to 80% of the water used to wash bottles)
- toxic chemical sanitisers are no longer required reducing risks to human and environmental health;
- energy savings in all phases of sanitisation;
- time and personnel costs savings, as to sanitise a bottling system takes only a few minutes;
- reduction in waste; and,
- resistant microbial strains are not produced.

The 'Green CIP' method which has been used by **Actalis** and **Danone** results in a reduction on energy consumption by up to 50% because (Utilities Performance, 2014, pers.comm.):

- waste water treatment is no longer required, and
- the pipes are no longer cooled down with the initial cold water flush and thus no longer need heating up again when production resumes after cleaning (this also saves time which is critical from a financial perspective).

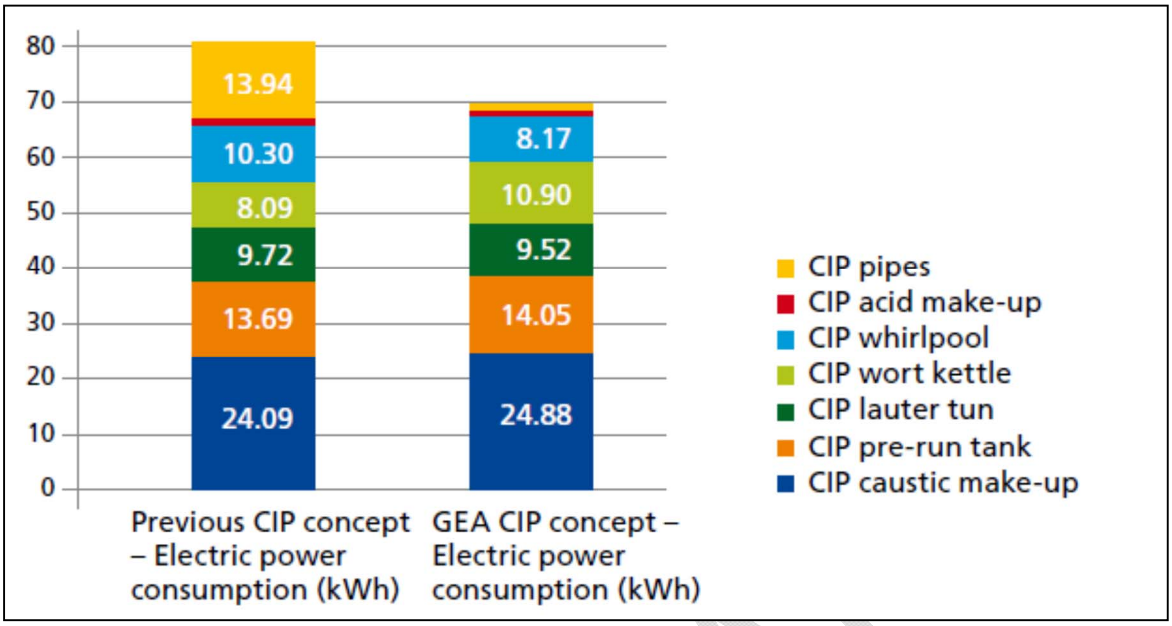
Best reported chemicals savings

SABMiller's ECA system at the 'Chamdor' brewery cut the cost of the chemicals by 99% (WRAP, 2012).

Coca-Cola realised similarly substantial chemicals savings after introducing ECA to the CIP system at its Atlanta Beverage Base Plant (ABBP) in the USA, reducing chemicals usage by 84%. CIP had already cut water use during cleaning by 1,500 gallons per cleaning cycle (WRAP, 2013b).

The German brewer **Gutmann** has been working to optimise CIP at its facility lowering the use of caustic detergent by 30% and acid detergent by 24% (GEA Brewery Systems GmbH, 2010). The optimisation also realised an 18% saving in water use and substantial savings in electricity consumption (Figure 3.9).

Figure 3.9: Electric power consumption per CIP process at the Gutmann brewery, Titting, Germany



Source: GEA Brewery Systems GmbH (2010)

The **Taw Valley Creamery** in Devon, UK, achieved annual savings of 56 m^3 of 60% nitric acid and 2,750 m^3 of borehole water after starting to collect and re-use the acid and water used to clean an evaporator in the plant. A conductivity probe was fitted to monitor the recovered acid's strength and a flow meter fitted to control acid dosing for the next clean. As well as reducing chemical use, the innovation improved the performance of the effluent treatment plant (as it did not need to deal with the acid) and the consistency of the acid dosing process within the cleaning cycle. The payback period was just over a year (Environmental Technology Best Practice Programme, 1998).

The 'Green CIP' method which has been used by **Actalis** and **Danone** results in a reduction in caustic soda use by up to 90% because the same detergent can be re-used multiple times (Utilities Performance, 2014, pers.comm.).

Ice pigging method

There are a number of environmental savings offered by ice pigging (University of Bristol, 2014, pers.comm.: Carbon Trust, 2015):

- Reduction in food wasted – approximately 80% of the material stuck to the pipes which would have been lost to effluent is recovered and sold on
- Reduced water use during the cleaning process by replacing pre-CIP rinse and therefore reduced effluent production
- Reduction in BOD of effluent – which in turn reduces energy and chemical inputs in pre-treating effluent prior to discharge
- Reduction in the use of detergents (such as caustic soda) for cleaning pipes as far more of the food has been removed prior to use; the reduction in caustic soda use also reduces the problem of 'saponification' when the soda reacts with fat residues in the pipe

Appropriate environmental indicators

The cleaning performance of food and beverage manufacturers are monitored using a wide range of quantitative indicators relating to water, energy or time use:

- Cleaning-related energy (kJ) per unit of production
- Cleaning-related water use (m^3) per unit of production
- Waste water generation (m^3) per unit of production
- Waste water generation (m^3) per clean
- Water consumption volume (m^3) per day
- Mass (kg) or volume (m^3) of cleaning product (e.g. caustic soda) used per unit of production
- Share of chemical-free cleaning-agents
- Share of cleaning-agents with recognised environmental certification (e.g. EU ecolabel)

Cross-media effects

While CIP systems are generally efficient in terms of water and energy use, they can result in the discharge of highly-polluted effluents as well as relying on potentially toxic disinfectant chemicals which produce hazardous by products. The use of ozone or ECA in CIP may, however, reduce these impacts.

The use of a molecular sieve in ozone generators separates pure oxygen from other gases in the atmosphere. This prevents the generation of by-products, such as nitrogen oxides and other substances that can be very toxic or lead to uncontrolled or unknown reactions (Tebaldi, 2014, pers.comm.).

The use of ice pigging increases the energy consumption due to the ice production process. However, this is counter-balanced by the many environmental benefits of implementing such a method (Carbon Trust, 2015)

Operational data

Different CIP designs and configurations are available; the choice of these depends on a number of factors such as cost, available space and the type of plant being cleaned and the product being manufactured. The efficiency of such CIP systems with respect to water and detergent use varies widely. Table 3.9 shows the impact of CIP configuration on water and detergent requirements, based on the cleaning of a 3,000-litre vessel.

Table 3.9: The effect of CIP configuration on water and chemical use, based on the cleaning of a 3,000-litre vessel

System	Water (litres)	Detergent (litres)
Boil out system	6,500	45
Total loss	3,000	30
Single use	1,200	3
Partial re-use	1,100	2
Full re-use	600	2

Source: Jeffery & Sutton (2008)

The boil out system represents cleaning without the use of CIP systems; this has the highest use of both water and detergents. The other configurations in CIP systems are those where water and detergents are not reused (total loss) or are reused to some extent. As can be seen, re-use results in considerable savings of both water and chemicals. Multiple reuse systems only impact the amount of water required.

The impact of real-time cleaning verification in CIP is evidenced by the German brewer **Schneider Weisse**. Prior to installation, pipes were cleaned 12 times a day with each clean requiring three water flushes of three minutes each. The new sensors enabled the exact point at which the CIP rinse water was stopped. This enabled the duration of each flush to be reduced to one minute and the overall flush time was cut by 72 minutes per day and the water consumption by $10m^3$ per day (Emerson Process Management, 2009).

Ozone

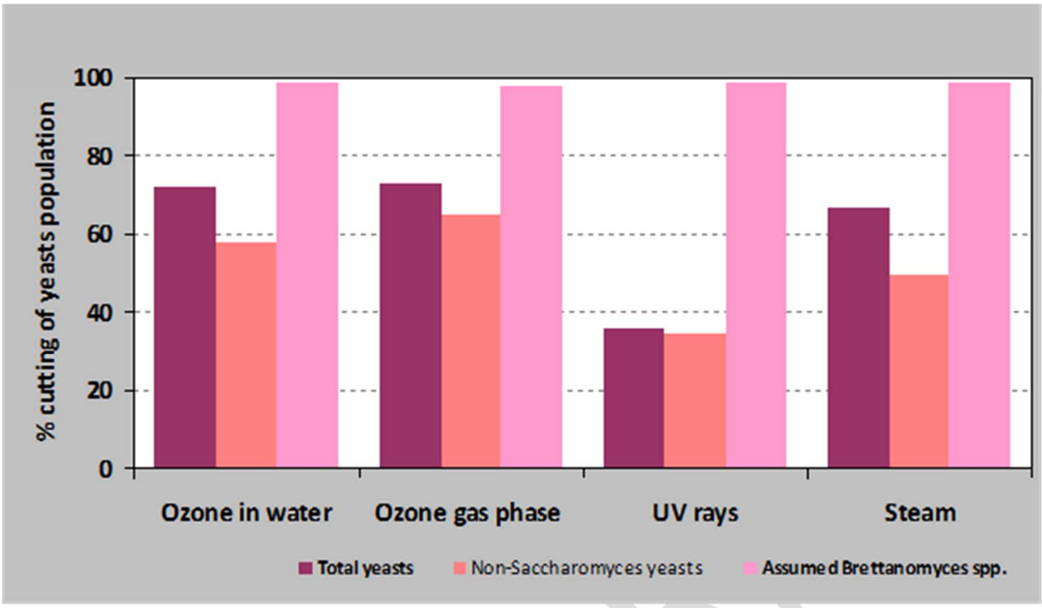
Because of its instability, ozone cannot be stored or transported but rather must be generated on site. A provider of equipment to the Italian wine sector, reports that due to advances in technology, on-site generation of ozone is a viable proposition. The company has developed the 'O-TRE' ozone generator which activates the air with an electric generator. The air is passed through a molecular sieve which separates pure oxygen from other atmospheric gases thus avoiding the production of by-products that can be very toxic or lead to uncontrolled or unknown reactions. The O-TRE generator produces both gaseous ozone and ozonised water which are applied separately (Tebaldi, 2014, pers.comm.).

Ozone acts more rapidly than other chemical products traditionally used in oenology and has demonstrated its effectiveness in treating steel vessels (e.g. tanks, autoclaves) and wooden casks (e.g. barriques and barrels). Ozone has been used in the following applications (Tebaldi, 2014, pers.comm.):

- Washing of grapes for the reduction of pesticides
- Drying for the inhibition of mould
- Sanitisation of surfaces and environments
- Sanitisation of fungi and bacteria in the environment
- Tank sanitisation
- Barrel and cask sanitisation
- Bottling machine sanitisation without rinsing
- Elimination of Brettanomyces bruxellensis
- Wastewater treatment.

The ozone equipment used for cleaning is fitted with safety sensors which, during sanitising, detect the ozone produced and released into the environment. A micro PLC (programmable logic controller) connected to a keyboard programming interface provides a control system. The effectiveness of ozone versus other cleaning agents including steam, UV and caustic soda at removing a variety of microbes is shown in Figure 3.10 and Table 3.10 (Tebaldi, 2014, pers.comm.).

Figure 3.10: Efficacy of ozone compared to alternative 'green' cleaning techniques



Source: Figure provided by Tebaldi, from research at the Technology Transfer Centre - Fondazione Edmund Mach, Trento, Italy, by Raffaele Guzzon.

Table 3.10: Microbial concentrations before and after different treatment cycle phase of stainless steel tanks (600hl)

DESCRIPTION	SAMPLING SITE	CYCLE PHASE	CHARGE OF MICROBIAL (cells/10cm^3)		
			TOTAL YEASTS	TOTAL BACTERIA COUNT	ACETIC ACID BACTERIA
Tank A	Wall	Wash	68	66	56
	Ground	Wash	169	157	120
	Wall	Ozone	31	42	Nd
	Ground	Ozone	36	66	Nd
Tank B	Wall	Wash	32	88	40
	Ground	Wash	33	156	65
	Wall	Caustic soda	18	58	22
	Ground	Caustic soda	36	84	18
	Wall	Ozone	Nd	Nd	Nd
	Ground	Ozone	Nd	Nd	Nd

'Nd' means 'Not detectable'

Source: Table provided by Tebaldi, from research at the Technology Transfer Centre - Fondazione Edmund Mach, Trento, Italy by Raffaele Guzzon.

Table 3.11 shows the effectiveness of ozone in preventing the build-up of a yeast called *Brettanomyces* which in high concentrations spoils wine.

Table 3.11: Impacts of ozone treatment of wooden barrels containing wine

Results in barrels (barriques 225 l) one month after the first treatment				
Withdrawal position	Barrel 1 treated (UFC/dm2)	Barrel 2 untreated (UFC/dm2)	Barrel 3 TC (UFC/dm2)	
A	78000	480000	0	
B	18000	600000	0	
C	680000	1550000	0	
Barrel rather contaminated				
Results in wine one month after the first treatment				
	Barrel 1 treated	Barrel 2 untreated	Barrel 3 witness	
Charge of *Brettanomyces* (cell/ml)	40	1010	0	
Barrel rather contaminated				
Results of the second treatment				
Withdrawal position	Barrel 1 before treatment (UFC/dm2)	Barrel 2 after treatment (UFC/dm2)	Barrel 4 before treatment (UFC/dm2)	Barrel 4 after treatment (UFC/dm2)
A	78000	850	8200	60
B	18000	380	3400	10
C	680000	10300	12000	420
Barrel average contaminated				

Source: Table provided by Tebaldi, from C.R.A – Istituto sperimentale per l'Enologia Asti, Italy. Research by Manuela Cerosimo, Vincenzo Del Prete, Adolfo Pagliara and Emilia Garcia Moruno.

Table 3.12 shows the proportion of the initial yeast population inside wooden wine barrels after sanitizing treatments.

Table 3.12: Reduction percentage after sanitising treatments

Treatment	Total yeasts %	Non-*Saccharomyces* yeasts %	Yeasts on the ground DBDM %
O_3 in water	73±18	70±37	99±2
O_3 gas	73±19	56±34	98±4
UV rays	36±19	30±13	99±1
Steam	67±20	52±24	99±1

NB. Average ± standard deviation of six barrels

Source: Table provided by Tebaldi, from the Experimentation at Technology Transfer Centre - Fondazione Edmund Mach, Trento, Italy. Research by Raffaele Guzzon, Giacomo Widmann, Roberto Larcher and Giorgio Nicolini.

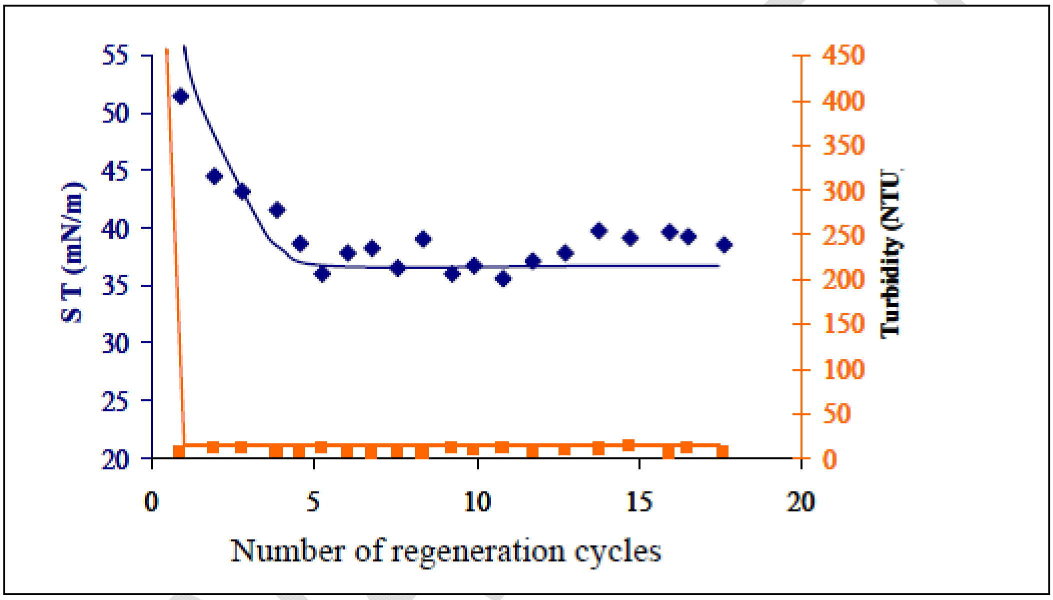
The O-TRE equipment is now in use in the following wineries (Tebaldi, 2014, pers.comm.):

- Cantine Vini Armani (Verona)
- Casa Vinicola Canella (Treviso)
- Tenuta Pakravan Papi (Livorno)
- Vini de Tarczal (Trento).

Regeneration of caustic soda, 'Green CIP'

Figure 3.11 shows the increasing effectiveness of regenerated caustic soda. During the Green CIP process, the regenerated alkali accumulates soluble solids which reduces its surface tension (ST) rendering it more effective at cleaning.

Figure 3.11: Efficiency of caustic soda regenerated by the Green CIP process



Source: Utilities Performance (France)

Minimising or avoiding the use of chemicals

In 2008 Lebensbaum, a company producing organic coffee, tra and spices based in Germany, together with its cleaning services partner LR Gebäudereinigung GmbH (LR Facility Services GmbH) started a pilot project to implement chemical-free industrial cleaning. In this context LR Facility Services developed a concept (called ÖkoClean100) which has continuously been developed further since then.

Fundamentals of the concept are (Lebensbaum, 2015 pers. comm.):

- Cooperation with a facility services operator which is certified according to ISO 14001 and OHSAS 18001.
- Use of environmentally friendly, chemical-free cleaning agents (all agents are ECO Garantie certified).
- Dry-cleaning wherever possible.
- Avoidance of solvents.
- Use of demineralised water for cleaning of windows and building fronts instead of cleansing agents.

- Use of hand washing lotions, soaps and disinfectants with ECO-Cert or ECO Garantie certification.

Implementation of these measures led to:

- Reduced water pollution
- No use of genetically modified organisms and micro-organisms.
- No use of chlorinebased chemicals
- Use of plant-based raw materials from controlled cultivation
- No use of petrochemicals
- No use of raw materials of animal origin
- Fairtrade raw materials (where applicable)
- Use of renewable energy in the production of cleaning agents
- No use of preservatives
- Carbon neutral production of cleaning agents

Additionally the cleaning concept focuses on dry cleaning wherever possible and this has substantially reduced water consumption and waste water generation.

Applicability

The purpose of cleaning is to safeguard the quality and safety of food and drink products so, any changes to cleaning regimes or techniques must ensure that all relevant standards continue to be met.

Cleaning systems need to be tailored to the individual situation since many factors must be considered including the design of the process, the scale, the type of product, available budget and so on. Not all the techniques and savings discussed above are universally available; for instance, CIP systems are not generally suitable for cleaning 'open' vessels (Environmental Technology Best Practice Programme, 1998).

For smaller manufacturers, substantial investment in the latest, most sophisticated technology may not be warranted by the relatively small financial savings available to them. For instance, the example of the brewer **Adnams** referenced above required the re-installation of pipework and tanks in a new material, stainless steel, which may be beyond the economic scope of smaller manufacturers. Similarly, retrofitting of plants to introduce CIP in the first place may not be feasible (WRAP, 2012).

Economics

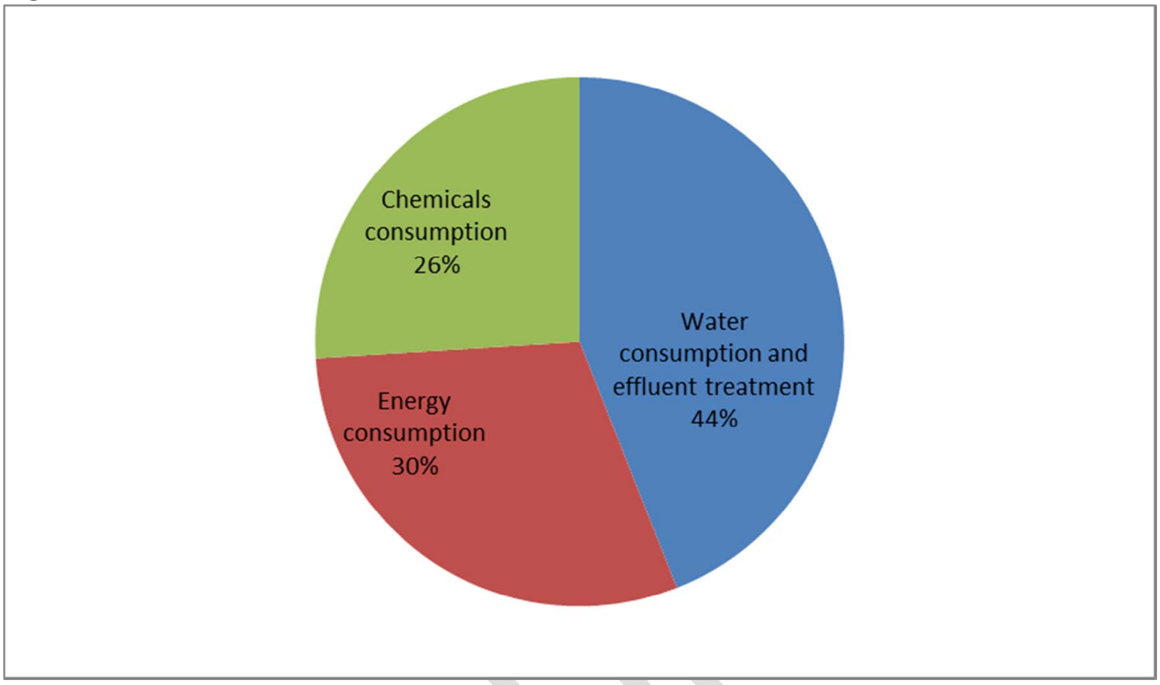
General points

Advanced cleaning techniques, especially CIP, offer manufacturers several economic benefits including:

- cutting the considerable costs of downtime (see below)
- cutting the cost of energy, water, chemicals and effluent treatment
- cutting the cost of food waste which might otherwise have arisen during production interruptions
- reduction of labour requirements.

Excluding labour costs and lost product costs, Figure 3.12 shows the typical breakdown of cleaning costs, suggesting that opportunities to cut water should be a priority.

Figure 3.12: Costs associated with cleaning at a food and drink manufacturing plant



Source: Environmental Technology Best Practice Programme (1998)

CIP requires substantial upfront investment in both new equipment and in the training of staff on the new and often complex systems. The project discussed above to install a CIP system at **Kraft**'s Australian 'Vegemite' factory took a reported four years and AUD 3.2 million of investment (approximately EUR 2.3 million), although due to the large production volume, the payback period in this case was relatively short at just three years (WRAP, 2013).

Optimised control of CIP

Once CIP systems are installed, however, improvements can be relatively inexpensive and yield significant further gains. According to The Brewers of Europe, Vienna's **Ottakringer** brewery optimised its CIP to lower chemical in the effluent 'without significant investment' (The Brewers of Europe, 2012). Less recently, **Coors Brewing Ltd** upgraded its CIP at its Burton-on-Trent plant in the UK with programmable logic controller (PLC), variable speed pumps and updated software allowing CIP operations to be customised in terms of time, volume, pump speed and chemical dosage. The changes saved GBP 42,000/yr (about. EUR 50,000) in chemical, water, effluent and electricity costs. Further improvements to road tanker CIP cut an additional GBP 3,000/year (about EUR 3,750). Within 41 months the investment had been recouped (Envirowise, 2006).

Substantial savings from environmentally friendly cleaning are available in other subsectors beyond brewing. For instance, the technology company Siemens claims that its 'SIMATIC PCS 7 system' for flexible and precise CIP, when installed in dairies, can reduce costs by up to 30% (Siemens, n.d.).

Ozone cleaning

Other forms of sustainable cleaning discussed above can also incur significant upfront costs. For instance, the **OzoneCIP Project** (2007) lists the following equipment as necessary for implementing an ozone-enriched CIP system whose costs will depend on the precise installations to be cleaned:

- gas feed preparation system,
- ozone generator,
- injector,
- reaction tank,
- dissolved ozone measurement device,
- ambient monitoring device,
- residual ozone destructor for the reaction tank and out-gassing system,
- control unit
- circulation pump.

However, the savings from the significantly reduced consumption of energy, water and chemicals - and potentially lower local costs and taxes associated with reduced effluent levels - may help offset these. In addition, the ozone equipment has relatively low maintenance costs (OzoneCIP Project, 2007).

The estimated cost of bottle washing is EUR 2 per cubic metre of water consumed, when this is carried out with chemicals (Tebaldi, 2014, pers.comm.). Table 3.13 shows the polluting power and volume of discharges over a year for a typical winery with an annual wine production of 20000 hl. Given that this process uses 8395 m^3/yr, switching to ozone would save EUR 16800 each year. Further knock-on savings would be available from avoiding the need to clean effluent prior to flushing it into the municipal sewage system which normally involves significant quantities of energy and disinfectant.

Table 3.13: Water consumption and pollution levels in a winery

Operation type	Duration	Waters used		BOD_5	Equivalent population	Period
	d	$m^3\ d^{-1}$	$m^3\ year^{-1}$	$kg\ d^{-1}$	n.	
Cleaning of premises and equipment	30	20	600	4,8	99	Autumn
Must defecation	3	3,6	10,8	104	3600	Autumn
Cleaning of defecation tank	2	4,1	8,2	14,7	271	Autumn
1st transfer	2	3,6	7,2	296	5466	Winter
Tank cleaning after 1st transfer	3	4,1	12,3	24,9	462	Winter
2nd transfer	2	4,1	8,2	46,7	865	Spring
Tank cleaning after 2nd transfer	5	2,4	12	6,7	123	Spring
Bottles washing	365	23	8395	0,4	10	Full year
Total water			9053,7			

Source: Adapted by Tebaldi from Farolfi (1995)

Similarly, the industrial scale use of biological cleaning agents, such as enzymes, in food and beverage manufacturing is not anticipated to be any more expensive than using traditional CIP chemicals such as sodium hydroxide or caustic formulated detergents and offers substantial energy and water-related cost savings (Boyce & Walsh, 2012)

Regeneration of caustic soda, 'Green CIP'

Installation costs for Green CIP equipment are broadly equivalent to those which a food and beverage manufacturer would otherwise have spent on building an on-site wastewater treatment plant. However, the regeneration of caustic soda offers substantial additional financial benefits as a result of (Utilities Performance, 2014, pers.comm.):

- shortening the downtime by between 5% and 20% due to a faster cleaning process, so increasing productivity and revenue accordingly
- the reduction in caustic soda requirements
- cutting energy consumption
- cutting water consumption
- lower taxes due to avoiding discharge of effluent to sewage plants
- subsidies for installing the equipment

Ice pigging

The cost of using ice pigging has not yet been determined since only a few sectors have been implementing this technique. However the process' inventor reports that the method offers food and beverage manufacturers significant financial savings (University of Bristol, 2014). These include:

- Of the food product which would previously have been lost in the effluent, 80 % can be recovered for sale. This can translate into huge savings depending on the value of the product being recovered. For instance, a factory making cream or butter might be able sell recovered product for up to EUR 2 per litre.
- Reduction in downtime during the CIP process from around 30 minutes to about 10 minutes, which translates into extra production time and substantially increased revenue.
- Reduced use of chemicals and water and their associated costs for supply and disposal.

A recent Carbon trust case study on the use of ice-pigging in the dairy industry demonstrated that the payback time for its installation in a custard-like product production line of batches of 500 litres is between 1.6 and 2.2 years. The calculations take into account the capital costs for the installation of the plant and also the operational ones (including increased energy consumption) (Carbon Trust, 2015).

Minimising or avoiding the use of chemicals

The cost of cleaning operations when avoiding or minimising the use of chemicals has been demonstrated not to generate extra costs for the company, compared to traditional cleaning (Lebensbaum, 2015 pers. comm.).

Driving force for implementation

The opportunity to reduce costs, especially those associated with energy, cleaning chemicals, water and, above all, downtime, is likely to be among the greatest drivers for adoption of this BEMP. An indication of the financial impact of downtime is given in Lea (2012) which reports that for one

Italian snack food company production costs were EUR 3500 per hour. Emerson Industrial Automation (n.d.) puts downtime costs for the food and beverage industry at between USD 20000 (about EUR 15000) and USD 30000 (around EUR 23000) an hour. Higher estimates still have been reported, varying from USD 44000 (around EUR 34000) per hour to as much as USD 1.6 million (around EUR 1.2 million) per hour for some businesses (Marathon, 2010), although these higher figures may apply to non-food manufacturing.

With water, a double financial savings benefit can be gained in that manufacturers can not only cut the costs of water consumption but also those of treating waste water effluent prior to discharge to municipal sewage systems.

It should be borne in mind, however, that the 'true' value of water is typically underestimated in its monetary cost, so water prices are currently not yet thought to be a major motivating factor. Some companies nevertheless recognise that future water scarcity is likely to change this situation and, to hedge against such risks, are already assigning higher notional values to water when considering investment in new equipment (Nestlé, 2014, pers.comm.).

Regulatory compliance is also likely to play a role as manufacturers are legally required to 'clean up' effluent prior to discharge. Thus, any strategy to reduce the volume and toxicity of effluent is favoured. Local environmental enforcement agencies can also play a mentoring role in motivating best practice, with the innovations at the **Kraft Foods** 'Vegemite' factory in part encouraged by Environment Protection Authority Victoria (EPA Victoria, n.d.).

Voluntary agreements and initiatives have also been demonstrated to motivate the implementation of sustainable cleaning operations in the sector. A good example from the UK is the Food and Drink Federation's Federation House Commitment (FHC), a voluntary agreement sponsored by WRAP (Waste & Resources Action Programme). One signatory to FHC is **Tulip**, a British meat processor, which used 7.1% less water in 2011 than in 2010. Environmentally friendly cleaning delivered some of the water efficiency improvements, with $20m^3$/day saved through amended cleaning-in-place systems. The company's goal is to cut water use by 15% by 2015 (Product Sustainability Forum, 2013d).

The need to maintain product quality and safety are additional drivers for minimising the use of water cleaning products which can sometimes be viewed as contaminants. This is certainly the case in the manufacture of dry products such as soluble coffee, chocolate powder, milk powder and so on (Nestlé, 2014, pers. comm.). In general, the best manufacturers seek to rapidly clean up water spillages, and ideally to avoid them in the first place so as to prevent the build-up of pathogens (Chilled Food Association, 2014, pers.comm.).

Product quality is also sometimes a driver for the adoption of novel cleaning methods. For instance, in Australia, ozone is used successfully on an industrial scale as an alternative to chlorine for disinfecting the oak barrels used for ageing the wine. The ozone is preferred not only for being more effective than chlorine at controlling certain microbial species that cause defects in the wines but also because it avoids the presence of substances such as trichloroanisol which cause cork taint problems (Canut & Pascual, 2007).

Reference organisations

The following companies are the frontrunners described in this BEMP:

- Actalis – introduced green CIP
- Adnams – incorporated a review of cleaning protocols within their equipment design
- Cantine Vini Armani – uses the O-TRE ozone generation system
- Casa Vinicola Canella – uses the O-TRE ozone generation system
- Coca Cola – uses Electrochemical Activation (ECA) in its CIP system instead of detergent and disinfectants
- Coors Brewing Ltd – developed a customisable CIP system.
- Danone – introduced green CIP
- Gutmann – undertook an initiative the lower caustic detergent use.
- Kraft Foods (Mondelēz) – Introduced an optimised CIP system
- ÖkoClean100- provider of green chemicals and green cleaning operations
- Ottakringer– Introduced an optimised CIP system
- SABMiller – uses Electrochemical Activation (ECA) in its CIP system instead of detergent and disinfectants
- Schneider Weisse
- Tenuta Pakravan Papi – uses the O-TRE ozone generation system
- Tulip – undertook a water reduction programme focussed on its cleaning processes
- Vini de Tarczal – uses the O-TRE ozone generation system

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3.6. Improving transport and distribution operations

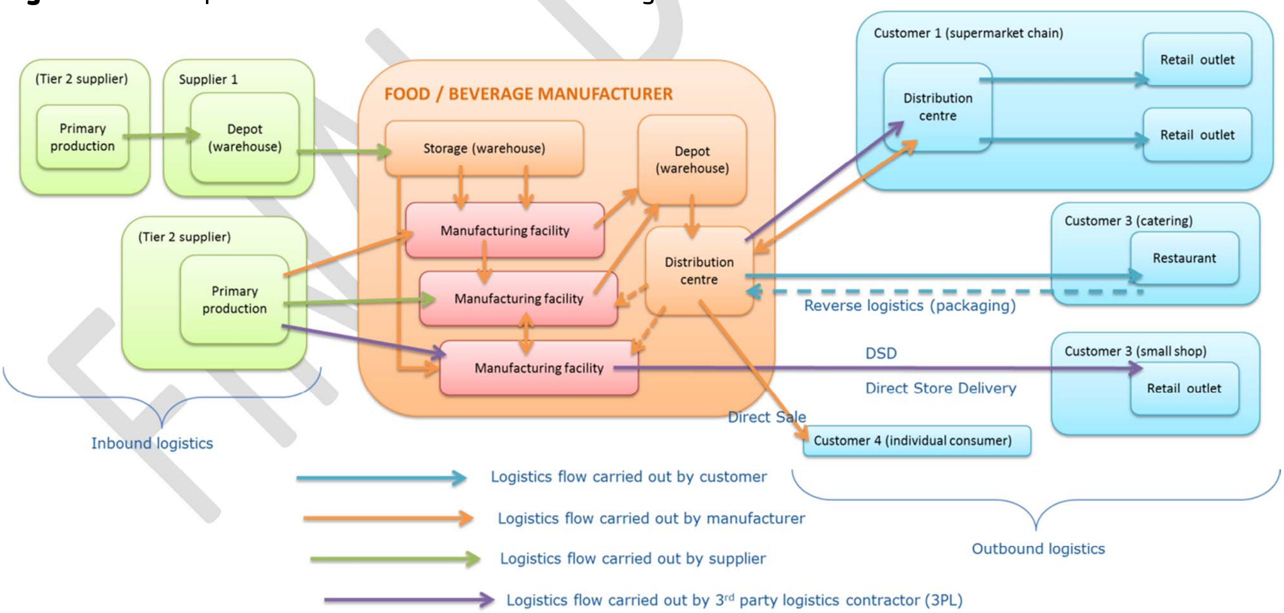
Description

<u>Introduction</u>

Agri-food is an important sector in European logistics. The logistics of the agricultural and food sectors covers 19% of transport within the EU and 25% of the international EU transport [Eurostat/TLN 2008 (data 2007)].

The primary function of efficient transport and logistics (T&L) operations is the safe, punctual delivery of merchandise from suppliers to the manufacturer (inbound logistics) and from the manufacturer to customers, typically retailers' distribution centres (DCs) and stores (outbound logistics). These functions are instrumental to the commercial success of food and drink manufacturers, and can be either carried out internally or outsourced in whole or part to third-party logistics (3PL) service providers. Furthermore, some of these functions can also be carried out by either suppliers or customers themselves, depending on individual arrangements, in which case they would be addressed by the relevant sections of the *Sectoral Reference Documents* on Agriculture or on Retail Trade[16]. Additional operations within the T&L scope include the storage of input materials at the facility (pre-manufacture), the storage and transport between different manufacturing sites (if applicable) and the storage and preparation of orders at the facility (post-manufacture) or in offsite distribution centres or warehouses. Figure 3.13 below represents a simplified flow of typical logistics and introduces a few notions in use throughout the BEMP:

Figure 3.13: Simplified food and drink manufacturer logistics flowchart



As already highlighted in this simplified example, the logistics function can be carried out by a number of different parties in the supply chain, under the direct or indirect control of the food and drink manufacturer itself. Therefore, depending on the extent to which the manufacturer is in

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[16] NB. The current chapter has been largely based on the content and structure of the Transport and Logistics section of the Retail Trade SRD.

charge of its T&L operations, the techniques described below will be directly or indirectly applicable. The organisation of the distribution chain can also vary according to the product, the demand and the required delivery time. For example, some fresh products may have short-cycle logistics (including for instance direct store delivery – DSD) whereas others may be stocked in warehouses for a period of time, with additional costs incurred.

Optimised T&L operations contribute to extend the shelf life of products and avoid unnecessary environmental impacts attributable to the disposal of late-delivered perishable food, including impacts arising from compensatory production. The T&L operations underpinning deliveries are becoming ever more complex, owing to an increasing number of products, an increasingly globalised network of suppliers, and trends towards inventory minimisation and just-in-time deliveries. However, there is considerable scope to reduce the significant environmental impacts associated with T&L operations themselves without compromising critical primary functions. In fact, some improvement options involving logistical collaboration may allow for a higher frequency of efficient deliveries, which is especially relevant for perishable products.

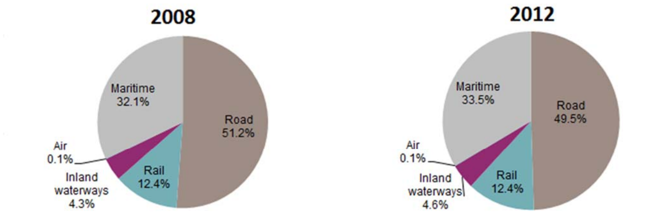
Food and drink manufacturing T&L operations are typically responsible for a relatively small share of the lifecycle environmental impact of products, but represent a significant source of the environmental impact over which manufacturers have either direct control or significant influence through contracts with third-party logistics (3PL) providers. Meanwhile, although typically making a small contribution to most product environmental footprints, T&L can make a substantial contribution to the environmental footprints of particular products. As an example, Rizet et al. (2008) calculated that ship transport from New Zealand dominates the life cycle energy demand of apples sold in France. Aside from GHG emissions and the associated climate change, the major sustainability pressures associated with goods transport are:

- air pollution (acidification, ozone formation, and other human health effects);
- resource depletion (predominantly oil);
- water pollution (e.g. heavy metals and PAH runoff from roads, chemical spillages);
- ozone depletion (from leakage of refrigerants used for transportation);
- road accidents;
- congestion of passenger transport corridors;
- noise.

Manufacturers may not account for the full range of environmental impacts associated with their T&L operations; more fundamentally, many manufacturers still do not reliably monitor and report on some basic indicators of T&L efficiency – e.g. fuel/energy consumption normalised per unit load delivered, and per load-km travelled, or the share of different transport modes. In part, this is because a large portion of T&L activities in the food and drink sector are outsourced to third-party T&L providers, in which case emissions may not be known or accounted for by the manufacturer.

Overall within Europe, the transport and handling of goods remains a major contributor to the environmental impact. Following the financial crisis, recent data indicate that freight volumes are now almost back to their pre-2008 levels. The modal share of EU transport (internal and external) has changed little over the period, with road still making up about half of the tonne-kilometres (tkm) travelled (see opposite).

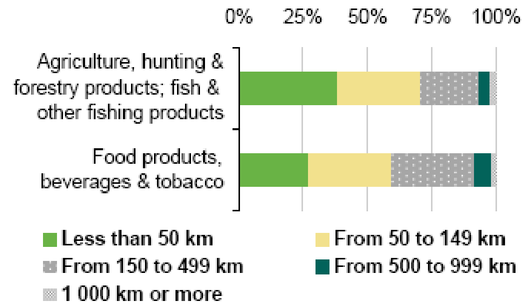
Figure 3.14: Freight transport in the EU-28 modal split based on five transport modes (% of total tonne-kilometres) *Source: Eurostat (2014)*



(*) Air and maritime cover only intra-EU transport (transport to/from countries of the EU) and exclude extra-EU transport.

Regarding food and drink transport more specifically, the sector accounts for a small but growing share of intra-EU transport both for inbound and outbound products (opposite), with significant average distances travelled (see below).

Figure 3.15: Annual road freight transport by distance, EU27, 2009; *Source: Eurostat (2011)*



(1) Excluding Malta.

Table 3.14: Road & rail transport of agricultural, fishing, food, beverage and tobacco products, EU-27, 2009 ; *Source: Eurostat (2011)*

	Road (1)		Rail (2)
	National	Intra-EU	
Transport quantity (million tonnes)			
All products	14 257	459	1 340
Products of agriculture, hunting & forestry; fish & other fishing products	1 078	52	69
Food products, beverages & tobacco	1 503	66	22
Share of transport (% of all products)			
Products of agriculture, hunting & forestry; fish & other fishing products	7.6	11.3	5.1
Food products, beverages & tobacco	10.5	14.4	1.6

(1) Excluding Malta.
(2) Greece, 2008; Luxembourg and the Netherlands, not available.

Scope of the BEMP

This BEMP focuses on Transport & Logistics operations, which include the storage of goods in warehouses and other facilities. Energy consumption in storage facilities makes a small but significant contribution to the environmental impact of T&L operations, and can be minimised by the implementation of many of the best practice techniques described in BEMP 3.7 on refrigeration and BEMP 3.8 for energy management. Waste management, including disposal and recycling, also necessitates T&L operations, although these are not covered explicitly in this BEMP. This chapter's cross-cutting BEMP on packaging is also of relevance to the current scope, in particular regarding load optimisation (see relevant section below). Finally this BEMP covers a number of areas also relevant to the adjacent upstream and downstream sectors, addressed in the Sectoral Reference Documents on the Agriculture – Crop and Animal Production sector; and the Retail Trade sector.

Relevant factors such as town planning, public transport infrastructure and pricing and vehicle emissions are outside the scope of this best environmental practice document. This BEMP considers customer transport emissions where they are relevant to manufacturer practices with respect to optimising T&L operations.

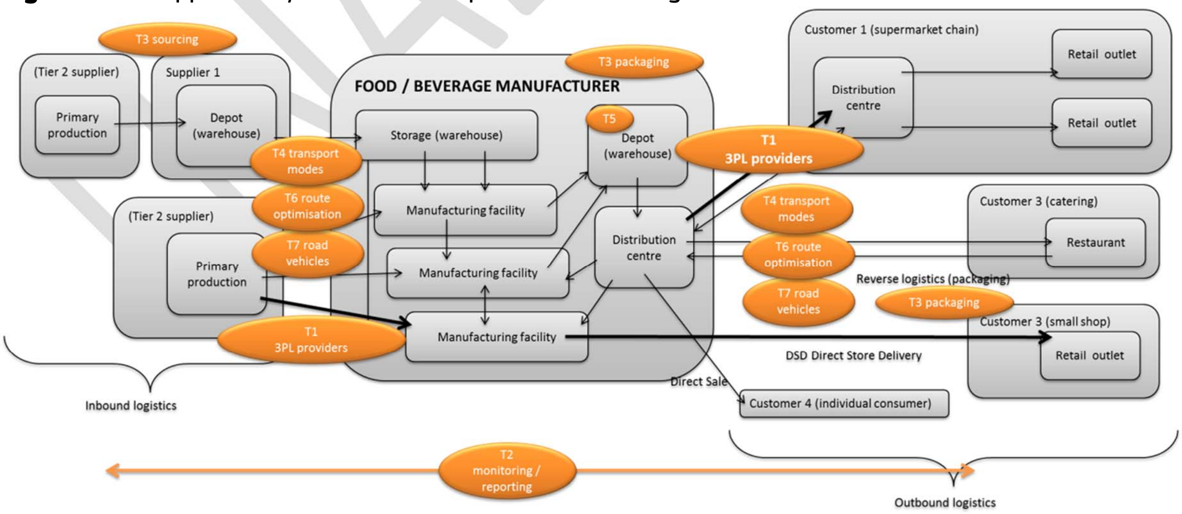
Techniques overview

The seven techniques outlined in this BEMP aim to improve the environmental impact of the T&L function, from a more strategic/general level down to operational considerations.

- T1: Green procurement and environmental requirements for transport providers
- T2: Efficiency monitoring and reporting for all transport and logistic operations
- T3: Integrating of transport efficiency into sourcing decisions and packaging design
- T4: Shift towards more efficient transport modes
- T5: Optimisation of warehousing
- T6: (road transport) Route optimisation: optimisation of network, route planning, use of telematics and driver training
- T7: (road transport) Minimisation of the environmental impact of road vehicles through purchasing decisions and retrofit modifications

Depending to what extent the scope of their T&L operations is covered internally vs. outsourced to third parties, the different techniques described will be more or less relevant to individual manufacturers (e.g. by and large, while T1, T2, T3 and T5 are applicable to most situations, T4, T6 and T7 are especially relevant for manufacturers who operate their own transport fleet). Based on Figure 3.13, Figure 3.16 below highlights the areas of relevance in the logistics chain considered within this BEMP's techniques. Many products have long and complex value chains, and it is important to consider the impact of transport when assessing overall product impacts to inform sourcing decisions and improvement options. There is however considerable opportunity for manufacturers to optimise T&L operations through integration with supplier and customer T&L operations.

Figure 3.16: Applicability of T&L techniques across the logistics chain



Manufacturers can get involved at different levels to control various factors important for T&L efficiency through key decision points. Some basic steps can be taken to increase the efficiency of road transport per tkm (from driver training to aerodynamic modifications). Further steps, requiring additional engagement on the part of manufacturers (or 3PL providers), include increasing vehicle load factors, reducing empty running, and minimising route distances through optimised route planning. More advanced options include optimisation of the distribution network to accommodate efficient long-distance transport modes and generate new opportunities for load maximisation and back-hauling – including through the coordination of transport and logistics requirements with suppliers and other businesses. Finally, a fully integrated approach to transport and logistics considers the consequences of sourcing decisions and store locations on goods transport and customer transport, respectively (balanced against other sustainability criteria). This is summarised in Table 3.15 below.

Table 3.15: Portfolio of manufacturer approaches and best practice techniques to improve the efficiency of transport and logistics operations

Approach	Best practice technique	Key components
I. Prerequisites	1. Green procurement and environmental requirements for transport providers	Procurement of certified transport providers
		Requirements for transport providers
	2. Efficiency monitoring and reporting for all transport and logistics operations	Data collation
		KPI reporting
		Benchmarking
II. Integrated approach to product sourcing (see supply chain assessment in BEMP 3.3)	3. Integration of transport efficiency into sourcing decisions and packaging design	Regional/local sourcing
		Product / packaging volume minimisation
	4. Shift towards more efficient transport modes	Rail
		Inland waterways
III. Strategic planning		Shipping
		Larger trucks (including double deck trucks)
IV. Operational optimisation	5. Warehousing optimisation	Warehousing footprint
		Refrigeration
	6. Optimisation of distribution network. optimised route planning, use of telematics and driver training	Reverse logistics: packaging, waste, supplier deliveries
		Direct routing
		Strategic hubs & platforms
		GPS route optimisation
		Driver training
		GPS cruise control
		Night-time deliveries
	7. Minimisation of the environmental impact of road vehicles through purchasing decisions and retrofit modifications	Aerodynamics
		Low rolling resistance tyres
		Euro V and efficient engines
		CNG/biogas
		Mild hybrid
		Low-noise trucks

T1: Green procurement and environmental requirements for transport providers

Small manufacturers tend to outsource T&L operations to third party (3PL) providers. Large manufacturers often have in-house T&L departments that perform secondary distribution from factories or warehouses to customers' facilities, but rely on third party providers for at least some primary distribution operations (e.g. ocean shipping). Therefore, green procurement of T&L operations is the primary technique for T&L improvement that is applicable to SMEs in particular. For large manufacturers, green procurement and specific requirements are an integral component of improving T&L operations, and a prerequisite for the best environmental management practice techniques subsequently referred to in this BEMP.

Large manufacturers may also outsource secondary distribution operations to 3PL providers. From an environmental improvement perspective, there are positive and negative effects of extensive T&L outsourcing for large manufacturers (Table 3.16). Essentially, outsourcing can ensure that T&L operations are managed by specialist experts with a strong incentive to maximise efficiency and the potential to coordinate efficient distribution across multiple clients. However, outsourced T&L providers may not have a remit for, or a strategic overview of, all manufacturer T&L operations, and do not have a remit to identify integrated sourcing and transport solutions. In addition, manufacturers may have stronger CSR and marketing incentives to implement environmental improvement options which can be paid for over a longer period of time. The balance of these aspects is heavily dependent on specific circumstances, including features of supply networks for particular manufacturers, and the T&L provider client base.

Table 3.16: Positive and negative aspects of manufacturers using a 3PL provider, versus in-house T&L services

Positive aspects	Negative aspects/limitations
Specialist management expertise in T&L operations	May not be fully responsible for, or have a strategic overview of, all manufacturer T&L operations
Possible coordination of distribution across clients to realise optimised loading and back-hauling	May not have sufficient client density to optimise loading and back-hauling
Strong cost incentive to optimise operational efficiency	CSR incentives may be weaker than for manufacturers (lower public profile)
Efficient providers of low-volume T&L requirements (small manufacturers)	Identification and realisation of integrated transport and sourcing solutions is outside remit

This technique describes best practice wherever manufacturers use outsourced providers. Essentially, manufacturers should use third party certification or improvement programmes, contract requirements and selection criteria to ensure that purchased T&L operations:

- are environmentally efficient;
- can be incorporated into environmental monitoring and reporting systems for manufacturing;
- follow the best environmental management practice techniques outlined in this BEMP.

The development of environmentally sound product source locations (T3), and the selection of efficient transport modes (T4) and the development or selection of efficient distribution networks (T6) either influence or involve green procurement decisions wherever third party T&L providers are involved. This technique is therefore cross-cutting for many manufacturers.

There are few widely applicable third-party standards specifically representing good environmental performance for T&L providers. However, there are some general and specific third-party-verified reporting standards applicable to T&L providers, some of which also require a basic level of environmental management. With respect to general environment-related standards, formal environmental management systems such as ISO 14001 and EMAS may be required of T&L suppliers. Meanwhile, two examples of third party (primarily reporting) standards specific to T&L operations, and used by manufacturers, are:

- Clean Shipping Project
- US Smart Way Programme.

The Clean Shipping Project (http://www.cleanshippingproject.se/index.html) was initiated in Sweden, and is aimed at improving the environmental performance of the shipping industry by requiring shipping providers to report on their environmental performance across 20 criteria (including chemical, water and fuel use, and waste control, CO_2, NO_x, SO_x and PM emissions), and to achieve basic minimum standards. The primary objective of the project is to empower users of T&L operations, including manufacturers, to select providers with better environmental performance.

The Smart Way Programme (http://www.epa.gov/smartwaylogistics/) is run by the US Environmental Protection Agency, and requires transport providers to report emissions data on a yearly basis, in addition to complying with environmental and fuel efficiency targets.

Meanwhile, in the related sector of retail trade the European Retail Roundtable (ERRT) Way Ahead Programme (http://www.way-ahead.org/ evolved) from the Environmental Performance Survey. The primary objective of this programme is to facilitate the information exchange between transport providers and manufacturers (or other stakeholders). It is based on a standard questionnaire for transport providers, which aims to identify implementation of various management options relevant to environment and safety. These include:

- extensiveness and frequency of driver training;
- driver-level fuel consumption and reward system;
- percentage of alternative fuel used;
- percentage of fleet using an alternative technique;
- details of speed limit policy and control system;
- details of idling policy and control system ;
- percentage of fleet using low rolling resistance tyres;
- details of tyre pressure monitoring system;
- age distribution of trucks;
- environmental management system implementation level.

T2: Efficiency monitoring and reporting for all transport and logistics operations

In order to improve the environmental efficiency of T&L operations, it is first necessary to define, measure and benchmark relevant indicators. Monitoring energy consumption and associated CO_2 emissions is integral to efficiency optimisation and to the reporting of key environmental performance indicators in CSR reports. The major objectives of T&L monitoring are to:

1. enable calculation of the total environmental burden (e.g. t CO_2eq yr^{-1}) attributable to manufacturing operations;
2. calculate products' environmental footprints (e.g. PCF);
3. benchmark and improve the efficiency of T&L operations.

In the first instance, these objectives can be achieved by applying generic energy use and emission factors to various stages of the transport chain (e.g. average data for different modes of transport: Table 3.19 and Figure 3.17). Table 3.17 refers to the basic data required to begin assessing T&L performance (specific performance indicators are subsequently defined in Table 3.25). Objective 1 can be realised with only basic data, for example total fuel use across T&L operations. This may be used to identify absolute performance trends over a number of years, but does not provide insight into efficiency and improvement options. Objective 2 may be realised using basic data such as average transport distance by different modes for particular product groups, and default emission factors. Where T&L operations are outsourced, manufacturers may need to establish specific reporting requirements (T2) in order to obtain the data necessary to realise Objectives 1 and 2 above.

To effectively realise Objective 3, and enable the identification of improvement options, detailed information on the actual performance of T&L chains is required. For a truck fleet, this would include the vehicle size distribution, average loading factors for different sizes, distribution of EURO emission standard compliance, etc. To compare the **efficiency** of alternative modes, vehicle sizes or loading rates, performance must be expressed in units normalised for distance travelled by weight/volume (e.g. per tkm). To compare the performance of alternative sourcing options, distribution network options, or routing options, performance must be expressed in relation to the final weight or volume delivered (e.g. per t or m^3 delivered). This latter measure indicates the absolute performance of T&L operations and can be used to reflect the cumulative effect of all techniques described in this BEMP.

Table 3.17: Key input data for monitoring T&L operations

Description	Ideal units	Alternative units
Punctuality in delivery	% on-time deliveries	
Reliability of the preparations	% delivered in acceptable condition	
Total fuel consumption	MJ primary energy	Litres (diesel)
Transport CO_2	t CO_2	
Transport by mode	tkm by mode	km by mode
EURO standard compliance	% of truck fleet	
Transport distance by product	km (average)	
Volume delivered	m^3 or tonnes	Pallets(*)
(*) 120 × 80 cm pallet.		

The range of environmental pressures associated with T&L operations are presented in this section. Ultimately, many of these pressures are correlated with energy consumption and can be directly calculated from data on the type and quantity of fuel consumed (e.g. CO_2 and SO_x emissions). Fuel consumption data should be readily available to T&L managers (either within manufacturing organisations, within T&L providers, or within supplier organisations), and can easily be normalised according to the quantity (tonnes, m^3, pallets) of goods delivered and distance transported. Therefore, the energy and CO_2 intensity of transported goods are the two primary indicators of environmental performance recommended for manufacturers in this section.

Some frontrunner manufacturers also report on non-CO_2 emissions such as NO_x and PM from their dedicated fleets, and the total distance travelled by rail. Frontrunner manufacturers require third party transport providers to participate in standardised reporting programmes.

The UN Global Reporting Initiative (GRI) has produced a pilot document (UN, 2006) on reporting for the T&L sector which includes sector-specific indicators that are additional to standard GR3 reporting guidelines. Some of these indicators are listed in Table 3.18, and are largely based on descriptions of actions to improve T&L performance or mitigate against environmental impacts. Manufacturers are referred to the UN GRI reporting guidelines, some technical aspects of which are included under 'Operational data', below. This technique focuses on the technical aspects of best practice for manufacturers' monitoring and reporting of T&L environmental performance.

Table 3.18: Indicators proposed for the transport and logistics sector in the UN GRI pilot document

Aspects	New indicators
Fleet Composition	Breakdown of fleet composition. (See Annex 1 for details)
Policy	Description of policies and programmes on the management of environmental impacts, including: • initiatives on sustainable transportation (e.g. hybrid vehicles) • modal shift • route planning.
Energy	Description of initiatives to use renewable energy sources and to increase energy efficiency. In describing initiatives to increase energy efficiency, reporting organisations should explain how they are benchmarking their energy efficiency to assess improvements.
Urban air pollution	Description of initiatives to control urban air emissions in relation to road transport (e.g. use of alternative fuels, frequency of vehicle maintenance, driving styles).
Congestion	Description of policies and programmes implemented to manage the impacts of traffic congestion (e.g. promoting off-peak distribution, new inner-city modes of transport, percentage of delivery by modes of alternative transportation). Note: 'Impact' refers to environmental, economic, and social dimensions.
Noise/vibration	Description of policies and programmes for noise management/abatement.

Aspects	New indicators
Transport infrastructure development	Description of environmental impacts of the reporting organisation's major transportation infrastructure assets (e.g. railways) and real estate. Report the results of environmental impact assessments.

T3: Integration of transport efficiency into sourcing decisions and packaging design

Transport is an important consideration within sustainable sourcing decisions and can make a substantial contribution to the life cycle environmental impacts of particular products. As an example, airfreight can lead to a near tenfold increase in the carbon footprint of asparagus flown from Peru to Switzerland (cf. Retail Trade SRD), while cane sugar shipped from Paraguay has a considerably lower carbon footprint than sugar produced from sugar beet grown in Switzerland. Similarly, a UK study showed that, outside the summer growing season, tomatoes imported from Spain have lower life cycle energy requirements than tomatoes grown in heated greenhouses in the UK (McKinnon and Piecyk, 2009). In the latter two examples, minimisation of transport distance and associated environmental impact conflicts with optimisation of life cycle environmental performance. Consequently, simple metrics such as 'food miles' (kilometres travelled by that food) are not necessarily a reliable indicator of sustainability (AEA, 2005).

Reducing the T&L environmental impact through sourcing decisions for individual product groups should therefore be informed by a fully integrated assessment of all product impacts. A number of food and drink manufacturers favour seasonal and locally grown products, which can reduce both T&L and overall lifecycle impacts where it avoids long-distance transport and does not necessitate the use of heated greenhouses.

The remainder of this section details the packaging improvements that can be made by manufacturers specifically to improve T&L efficiency (see also BEMP 3.4 related to other aspects of packaging). A large proportion of (in particular outbound) logistics is limited by volume rather than weight. Lumsden (2004) presents data on general cargo transport in Europe, showing that long-distance trucks are, on average:

- 92 % loaded according to number of pallets;
- 82 % loaded by volume;
- 57 % loaded by weight.

The aim of optimising packaging is therefore to avoid "moving air around" and to instead focus on delivering the payload as efficiently as possible.
Packaging changes can optimise the shape and overall density of packaged products, thus enabling a greater mass of product to be loaded into transport containers/vehicles. Another aspect of T&L operations which could be addressed thanks to packaging design is to ensure that the correct temperatures for preserving the food products are maintained. Since the shelf life of most perishable food products are temperature-dependent, the expiration date of the food product is determined by assuming the product will be transported and stored at the recommended temperature range throughout the shelf life. However, there are limited ways to determine if the

shelf life of the food product has been reduced by exposure to higher temperatures during transport and distribution (ASTM, 2014). Time Temperature Indicators (TTI) are smart labels designed to monitor food product temperature history, individually and cost-efficiently, and reflect quality throughout the cold chain (Vaikousi et al., 2009). Close temperature monitoring is especially important when dealing with products which require a cold distribution chain (Kerry et al., 2006). The use of TTI systems could lead to a better control of the cold chain during T&L operations, help optimise product distribution, improve shelf life monitoring and management and thus reduce product waste and benefit the consumer (Taoukis, 2008).

While not explicitly covered in this technique, "reverse logistics" or the prioritisation of return routes to send back reusable / refillable packaging or waste/by-products (described in greater detail in BEMP 3.4) is also part of a well-designed packaging strategy, usually centred on secondary or tertiary packaging (for retail goods) but also on primary packaging (for professional/bulk customers).

T4: Shift towards more efficient transport modes

Mode of transport is the most important determinant of specific transport efficiency on a per tonne-kilometre basis. Most environmental impacts arising from goods transport are closely related to energy consumption and energy source, both of which are strongly dependent on mode. Table 3.19 provides an overview of the efficiency, roles and restrictions inherent to different modes of goods transport. Shifting goods transport to more efficient modes for as much of the transport distance as possible is the primary mechanism by which the environmental impact of T&L operations can be reduced. The possibility to make such shifts may be limited to primary distribution, from supplier distribution centres to manufacturer facilities: the first and final kilometres almost exclusively necessitate road transport. Modal shifts therefore result in intermodal transport, and require optimisation of distribution networks to accommodate multiple modes (e.g. integration into the rail network). Shifting from smaller to larger trucks, including trucks with double-deck trailers, is included in this technique owing to the considerably greater efficiency of larger (see Figure 3.17). Modal shifts can be an important component of product sourcing decisions intended to minimise T&L and product lifecycle environmental impacts.

Table 3.19: Various attributes of different modes of goods transport

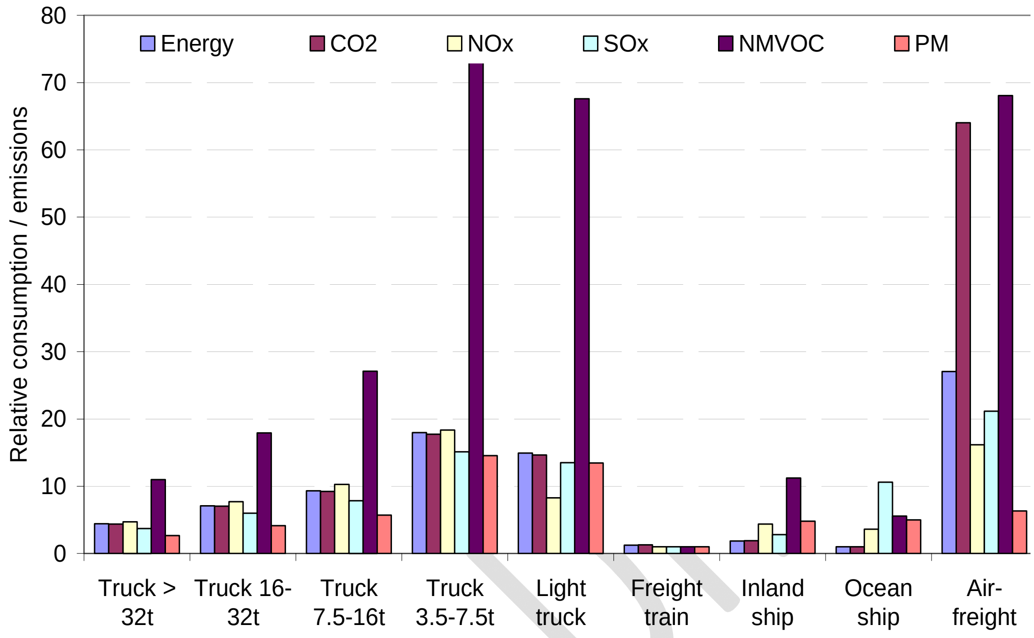
Mode	gCO_2/tkm (assumptions)	Source	Role and restrictions
Road (truck)	51 (60 % load factor)	NTM (2010)	An essential component of goods transport, responsible for the final stage of delivery to stores. High flexibility, relatively low cost, but use of large trucks may be restricted by national and local (e.g. city) regulations.
	109 (25-tonne truck, 57 % load factor and 21 % empty running)	ADEME (2007)	
	62 (overall average)	McK&P	
	72 (>35-tonne truck)	WBCSD/WRI (2004)	
Rail	1.8 (electric trains, France)	ADEME (2007)	The most efficient land-based goods transport, well suited for
	55 (diesel trains)	ADEME (2007)	

Mode	gCO_2/tkm (assumptions)	Source	Role and restrictions
	40 (average for electric trains)	WBCSD/WRI (2004)	delivering to distribution centres and potentially fast, but restricted by rail network coverage and route capacity constraints. High costs of infrastructure and loading/unloading to road transport make rail a cost-effective option for longer distances only.
	20 (diesel trains)	WBCSD/WRI (2004)	
	26.3 (average, all trains)	Tremove (2010)	
	22 (average for all trains)	McK&P	
Maritime	8.4 (average for deep-sea container vessel)	BSR (2010)	Low-cost transport, flexible transport well suited to carrying large volumes over long distances. Slow, and requires goods unloading and transfer to/from land-based modes at ports.
	5 (large tanker)	Defra (2009), NTM (2010)	
	13.5 (small container vessel)	Defra (2009)	
	10 (ocean transport)	WBCSD/WRI (2004)	
	35 (short transport)	WBCSD/WRI (2004)	
	14 (average for maritime transport)	EEA (2010)	
Inland waterways	31 (little variation)	McK&P	Low-cost, efficient transport, but restricted by waterway network coverage and capacity.
Air freight	570 (long-haul)	WBCSD/WRI (2004)	Fast transport for products with a short shelf life. Restricted to airport hubs. Relatively expensive and highly polluting.
	800 (medium-haul)	WBCSD/WRI (2004)	
	1580 (short-haul)	WBCSD/WRI (2004)	
	602 (average)	McK&P	

Metrics commonly used to compare the specific efficiency of different transport modes are MJ energy consumed per tkm and kg CO_2eq emitted per tkm (e.g. Table 3.19). However, other important environmental pressures vary considerably across modes of goods transport (Figure 3.17). The specific performance of different modes across a range of environmental pressures vary widely when direct and indirect (fuel processing and electricity generation) emissions are considered. The high energy consumption of air freight translates into a carbon footprint over 60 times greater than that of ocean-shipping, when the radiative forcing index of high-altitude emissions is considered. There is also a significant variation in emissions of non-methane volatile organic compounds (NMVOC), with light trucks and aircraft emitting approximately 70 times more than trains per tkm. The environmental performance of trucks is highly dependent on their size, and other factors including:

- loading efficiency
- average age profiles and EURO compliance profiles
- driving patterns (e.g. a higher share of urban driving for smaller trucks).

Figure 3.17: Comparative energy consumption and emissions across freight transport modes, expressed as a multiple of the lowest emitting mode on a per tonne-km basis (2010 average from Tremove, 2010 and IFEU, 2010).



NB: Air freight CO_2 based on long haul RFI of 2.73.
Source: TREMOVE (2010) and IFEU (2010)

The high sulphur content of the heavy fuel oil used in marine transport compared with other fuels is somewhat offset by the inherent fuel efficiency of this mode, so that SO_x emissions from marine transport are comparable to road transport, but considerably higher than for rail and inland waterway transport. The overall environmental performance ranking of the transport modes approximates to the energy efficiency ranking, with the exception of ocean ships relative to freight trains, where a lower specific energy consumption for ships is more than offset by high specific emissions of SO_x, NO_x and PM. Based on environmental performance, Table 3.20 contains a proposed order of preference for the different transport modes, from most preferred (freight train) to least preferred (air freight).

Table 3.20: Proposed prioritisation ranking of transport modes, based on environmental performance

Ranking	Transport mode	Ranking	Transport mode
1	Freight train	5	Medium truck
2	Ocean ship	6	Small truck
3	Inland waterway	7	Air freight
4	Large truck		

T5: Optimised warehousing

This technique builds on a number of independent aspects, some of which are already partially covered under the energy and refrigeration BEMPs in particular.

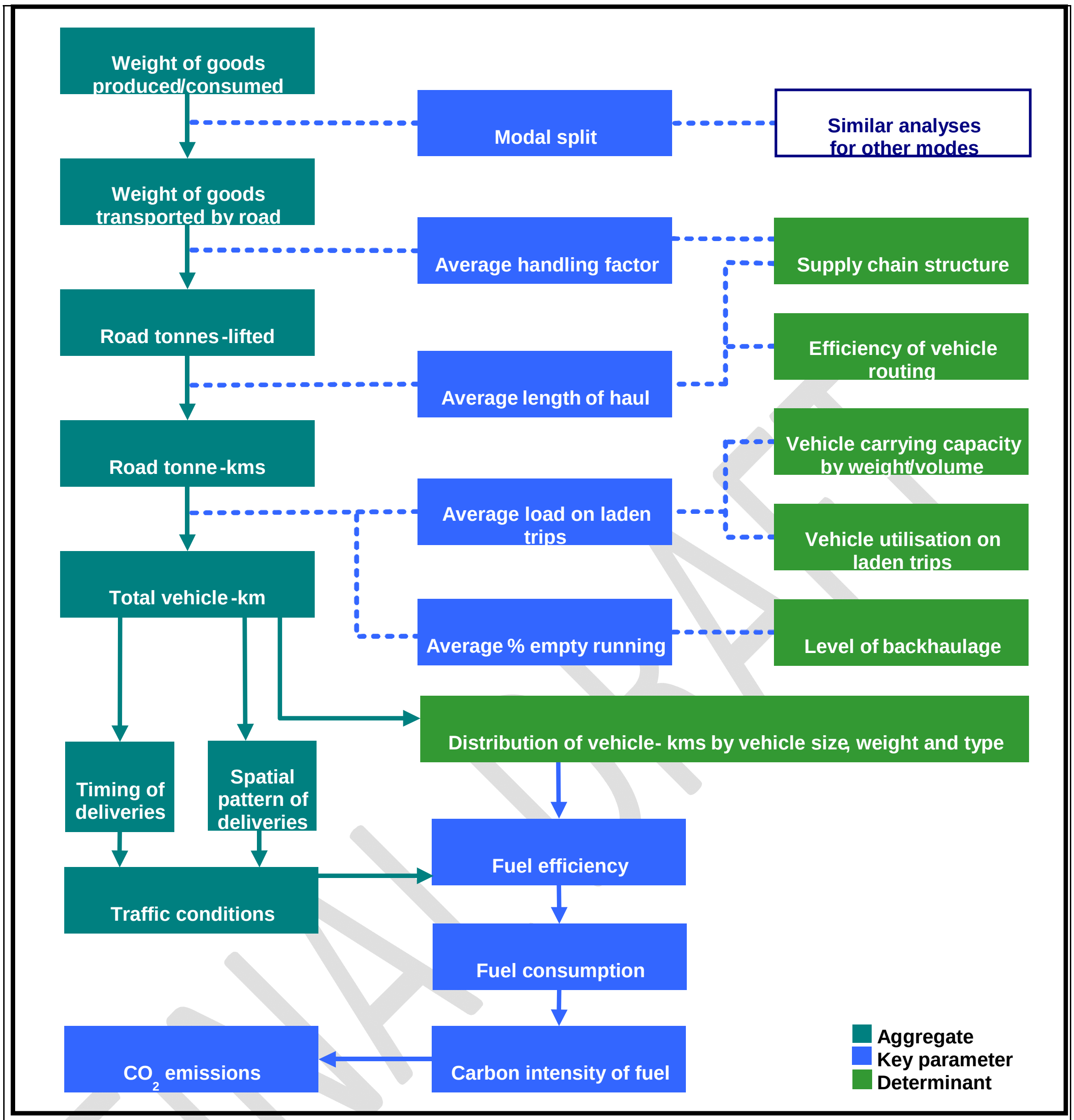
While cost considerations will be the main drivers of storage decision making, the key aspects to consider in the minimisation of the environmental impact of warehouses can be grouped in the following categories:

- Strategy and location:
  - aim to position distribution warehouse to minimise delivery distances
  - dimension warehouses to maximise volume utilisation
  - minimise the size requirements for temperature-controlled storage space
- Warehouse construction and refurbishment:
  - implement high environmental standards for warehouse construction (insulation, water usage)
- Management:
  - raise staff awareness concerning energy and water saving measures
  - promote the systematic reuse of packaging and transport materials e.g. pallets
  - develop a recycling policy especially regarding packaging streams
- Energy and resource use:
  - install insulating panels to minimise heat/cooling loss through loading docks
- Optimise lighting e.g. with natural lighting, use of motion sensors
  - use electric forklift trucks instead of propane powered ones

Road transport (T6 and T7)

Figure 3.18 provides a more detailed overview of the inter-relationships between key factors determining the efficiency and GHG emissions of road transport - an essential component of the transport chain for all manufacturers. It includes factors such as *total vehicle tkms travelled*, which are determined not just by the average distance and weight of goods transported, but also by the average weight of the truck relative to the load (i.e. average truck size, load factor, and empty running).

Figure 3.18: Factors affecting road transport efficiency and CO_2 emissions



Source: McKinnon and Piecyk (2009)

T6: Route optimisation: optimise network, route planning, use of telematics and driver training

In summary, there are four primary objectives for road transport optimisation and planning:

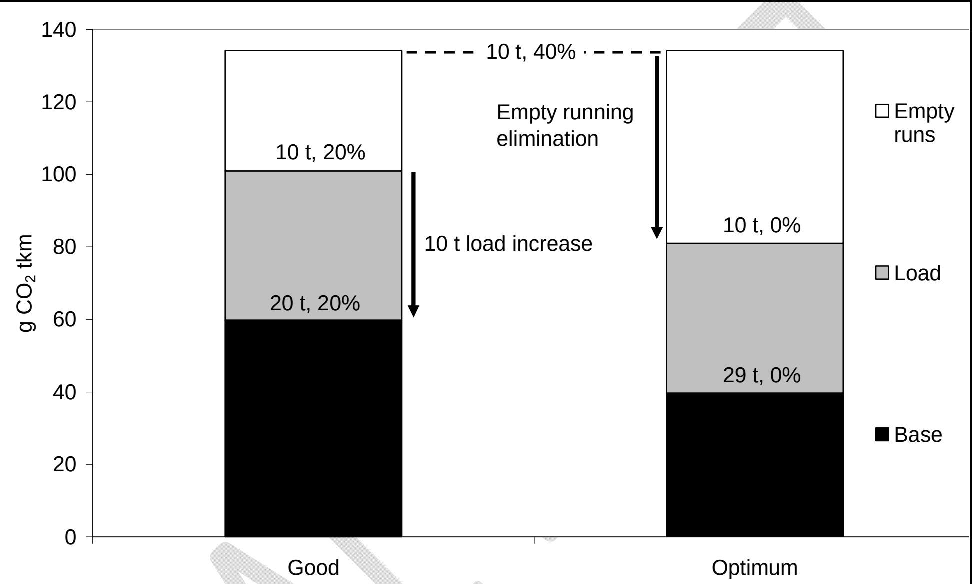
- enable use of efficient modes for long-distance routes
- increase load factors
- reduce empty running (increase back-loading)
- reduce tkms.

Load factor optimisation

For a given transport mode, load factor and empty running are key determinants of specific energy consumption and GHG emissions (Figure 3.19). If a 44-tonne truck with a 29-tonne net load capacity operates with an average load of 10 tonnes over 60 % of the distance it travels (i.e.

40 % empty running), the specific GHG emissions for transported goods would be 134 g CO_2 tkm^{-1} (Figure 3.19). If that truck operates with an average load of 20 tonnes over 80 % of the distance it travels, the specific emissions would be 59.8 g CO_2 tkm^{-1} (55 % lower than the above case). If that truck could be operated continuously at full capacity, specific emissions would amount to just 40 g CO_2 tkm^{-1} (Figure 3.19). The relatively low density of many goods in the food and drinks sector restricts the achievable weight-based load efficiency (Lumsden, 2004), but there remains considerable scope for improvement, especially when combined with packaging optimisation and load balancing made possible through cluster networks.

Figure 3.19: Effect of increasing load and reducing empty running on specific CO_2 emissions for a 44-tonne gross load (29-tonne net load) truck



Source: Based on data from McKinnon and Piecyk (2010).

There are a number of approaches to distribution network optimisation which may be implemented separately or in combination. Three of the major approaches are summarised in Table 3.21. The third and most appropriate approach which overlaps with route planning, is highly dependent on product-specific factors including the location and how scattered the suppliers are, and product transport requirements (especially cooling requirements and time limits).

Table 3.21: Three major approaches to efficient distribution network design

Approach	Description
Centralised hub network	Modify distribution network so that it is based on centralised hubs located and designed to accommodate intermodal transfer and load optimisation.
Consolidated platforms	Arrange consolidation points (strategically located warehouse or nominated supplier) where a group of neighbouring suppliers can deliver goods for forwarding to the retailer in consolidated (optimised) loads.

Approach	Description
Direct routing	For some products, it may be possible to coordinate production with demand so that intermediate storage and distribution can be avoided.

Road transport is an integral part of manufacturing T&L operations, necessary for inbound transport from suppliers to manufacturing facilities and outbound distribution to customers. In the context of a particular distribution network with predetermined primary transport, the efficiency of T&L operations can be further improved by route planning (including use of telematics), more efficient driving techniques, and finally vehicle modification as described in T7.

The complexity of coordinating T&L operations to ensure punctual store deliveries necessitates the use of specialised vehicle routing software, based on optimisation models, to route and schedule transport activities for large fleets. This software takes into account the multitude of logistical factors that must be considered, including: driver hours-of-service rules, pick-up and delivery schedules, vehicle size constraints, vehicle-product compatibility, equipment availability, vehicle-loading dock compatibility, route restrictions and empty mileage. Vehicle routing schedules can reduce the total distance travelled by trucks on multi-drop delivery rounds by between 5 % and 10 % (UK DfT, 2005). Manufacturers can maximise the benefit of such software by extending the parameters considered beyond transport from DCs to stores, to include:

- transport from suppliers to DCs (integration of upstream transport);
- waste transport (integration of downstream transport);
- traffic avoidance (out-of-hours deliveries).

Table 3.22 provides an overview of the main methods to improve T&L efficiency included in this technique. In addition to increasing load efficiency and reducing empty running, manufacturers can extend the daily delivery window, and use telematics and driver training to improve truck fuel efficiency.

Table 3.22: Some of the main methods applied for route planning

Method	Description
Supplier back-loading	After store delivery, collect goods from nearby suppliers on return journey to DC
Reverse packaging	At store, fill truck returning to DC with reusable packaging (e.g. pallets) and (recycling) waste.
Extended delivery window	Deliveries planned to avoid times of traffic congestion.
Telematics	Optimise speed and route to avoid traffic based on real-time traffic information from GPS
Driver training	Driver training in efficient and safe driving techniques. May be accompanied by incentives.

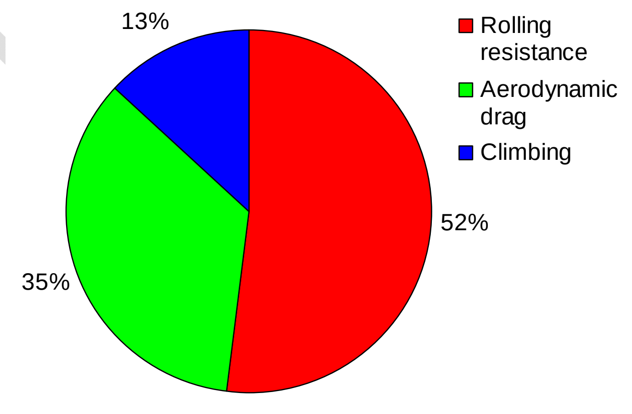
T7: Minimisation of the environmental impact of road vehicles through purchasing decisions and retrofit modifications

Road transport is an integral part of T&L operations for the food and drink sector, necessary for transport from suppliers to manufacturing facilities and final distribution from manufacturing facilities to the customers' warehouses, restaurants or shops. Whether or not manufacturers have taken measures to reduce the distance goods are transported (T3), to shift to more efficient modes (T4), and to optimise routing and driving efficiency (T6), a number of measures can be taken to improve the efficiency of trucks. Various features can be specified when purchasing vehicles in order to maximise their operational efficiency, and thus reduce fuel costs and environmental impact. Many features can be retrofitted to existing road vehicles to improve their efficiency. Using larger vehicles, such as trucks with double-deck trailers, is considered a modal shift and is included under T4.

The internal combustion engine is inherently inefficient, and most fuel energy is lost through friction and heat losses. For large 44-tonne HGVs, of the 30 % to 40 % of fuel energy that is converted into motion, half is used to overcome rolling resistance and a third is used to overcome air resistance (Figure 3.20). In the medium term, there is considerable potential for efficiency improvement through the use of alternative drive trains, such as electric motors, in particular for smaller delivery vehicles. In the short term, natural gas and biogas may be used instead of diesel in large trucks, with CO_2 savings of 10–15 % and over 60 %, respectively (Table 3.23). Biodiesel made from waste oil can result in similar CO_2 savings to biogas.

There remains considerable debate over the potential for crop-based biofuels (e.g. ethanol from corn and sugarcane, biodiesel from rape-seed oil and palm oil) to reduce environmental impact owing to their agricultural land requirements, and impacts associated with high chemical and energy inputs. If adequate procedures are developed to certify the sustainability of biofuels from different sources, or second generation biofuels are commercialised based on low-input woods and grasses that do not require productive agricultural land, biofuels could make an important contribution to reducing the environmental impact of transport. In the meantime, crop-based biofuels are excluded from this best practice technique.

Figure 3.20: Energy demand from a 44 t HGV over a typical driving cycle in the UK



Source: Ricardo (2010)

Table 3.23 provides an overview of the main measures that can be taken to improve truck (primarily HGV) fuel efficiency. Based on Figure 3.20, reducing aerodynamic drag and rolling resistance are the two primary objectives of many vehicle design features and retrofit modifications. For a 44-tonne HGV, a 22 % reduction in aerodynamic drag translates into an 8.7 % reduction in fuel consumption, whilst a 10 % reduction in rolling resistance translates into a 5.5 % reduction in fuel consumption (Ricardo, 2010). Improved aerodynamic trailer design and retrofitted aerodynamic modifications can significantly reduce fuel consumption and costs – by up to 10 % for vehicles frequently driven at higher speeds. By 2009, M&S had increased the number of aerodynamic 'teardrop' trailers in their fleet to over 300 (M&S, 2010). Reducing rolling resistance through choice of tyres and correct inflation can achieve similar benefits. Replacing diesel-driven auxiliary power units for trailers with electric units can also result in significant efficiency savings.

New vehicles will be compliant with high EURO emission standards (currently EURO V/VI), but when purchasing used vehicles it is important to select the most efficient vehicles that comply with the highest possible EURO standard (preferably EURO V or EURO VI). The most effective way to improve EURO emission standard compliance is to replace the fleet's oldest trucks. Use of selective catalytic reduction in combination with urea additives that react with exhaust gases considerably reduces the NO_x emissions of modern HGVs, to ensure compliance with EURO VI standards (Table 3.24).

A number of companies including manufacturers are trialling trucks powered by biogas. Meanwhile, electric vehicles are being introduced for urban deliveries.

Table 3.23: Portfolio of measures to improve truck efficiency and/or reduce environmental impact

Measures	Description	Applicability	Cost	Fuel/CO_2 saving
Aerodynamic trailer	'Tear-drop'-shaped trailer	Vehicle (trailer) purchasing		10 % (depending on speed)
Aerodynamic fairings	Retrofit add-ons to reduce drag. Greatest effect from cab fairing and collar	Retrofit	EUR 285 – 2000	0.1–6.5 %
Spray-reducing mud flaps	Reduce spray and air resistance	Retrofit	EUR 2 per unit	3.5 %
Low-rolling resistance tires	Similar cost to ordinary tyres, but shorter lifespan. For long-distance routes	Retrofit		Up to 5 %
Single wide-base tyres	Replace double tyres with single wide-base tyre. Also reduces weight, so increases possible payload. Not allowed on trucks over 40 tonnes	Retrofit	NA	2–10 % (depending on number of axles fitted)

Measures	Description	Applicability	Cost	Fuel/CO_2 saving
Automatic tyre inflation	Automatically inflates tyres according to conditions. Benefit depends on: (i) range of conditions; (ii) existing (manual) monitoring efficiency	Retrofit	EUR 11 500	7–8 % (based on % of trucks with under-inflated tires)
Electric/ alternative fuel bodies	Replaces diesel-driven trailer equipment with electric (or nitrogen-) driven equipment	Vehicle (trailer) purchasing	Up to 15 % additional trailer cost, but lower maintenance	10–20 % of trailer fuel use
Electric vehicles	Best suited to urban driving (less than 160 km per day), and smaller (less than 12-tonne) trucks	Vehicle purchasing	EUR 90000 for a 7.5-tonne vehicle	40 %, depending on electricity source
Mild hybrid	Stop-start systems and use of braking-energy for battery recharge. Suitable for LGVs and urban driving	Vehicle purchasing	EUR 700 option on some LGVs	6 %, depending on driving cycle
Full hybrid	Large battery recharged by braking-energy, used to power vehicle at times. Expensive and not well developed for trucks.	Vehicle purchasing	NA	20 % urban driving, 7 % long-distance driving
Automated transmission	Mechanical efficiency of manual shifts, with optimised automated changes	Vehicle purchasing	EUR 1100–1700 option	7–10 %
CNG engine	Engine that runs on compressed natural gas.	Vehicle purchasing	20–25 % more expensive than diesel engines	10–15 %
Biogas engine	Engine that runs on biogas (tolerant of contaminants in fuel)	Vehicle purchasing	Additional EUR 30 000–40 000 for HGV, EUR 5 000–6 000 for vans.	Over 60 %
Source: Ricardo (2010).				

Achieved environmental benefits

T1: Reporting on environmental performance and implementation of environmental management practices encourages third-party T&L providers to implement the improvement options, and realise associated environmental benefits, described throughout this BEMP. In particular, this technique can encourage T&L providers to:

- use cleaner (lower-sulphur content) shipping fuels;
- use more efficient and cleaner (e.g. EURO V) trucks;
- use alternatively powered (biogas or hybrid) trucks;
- shift towards more efficient transport modes.

T2: A comprehensive monitoring and reporting system for goods-transport will enable manufacturers to identify and improve the efficiency of (cf. relevant subsections): product sourcing (T3); modal splits (T4); route planning (T6); vehicle design and modification (T6). Improved efficiency in each of these areas will translate into reduced environmental pressures, as described in the subsequent sections. Detailed monitoring of truck loading efficiency at different stages of transport can inform the optimisation of packaging and of the distribution network according to the supplier cluster concept.

T3: Avoiding airfreight and reducing transport distances can considerably reduce the environmental impact of T&L activities, and can considerably reduce the overall life cycle environmental impact of products that can be efficiently produced closer to the point of sale. The specific global warming impact of airfreight is 60 times greater than that of ocean shipping.
Increasing packaging density can improve the overall efficiency of T&L operations and lead to reduced T&L traffic, thus reducing the entire range of impacts associated with T&L activities.

T4: Shifting towards more efficient modes can result in a range of environmental benefits, as indicated by Figure, mostly in terms of energy / CO_2, air pollution and noise.

T5: Optimised warehousing yields numerous benefits related mostly to the lower energy use and greenhouse gas emissions linked to building operation but also shorter distance travelled through better payload management.

T6: By reducing the number of vehicle km travelled, and ensuring a higher proportion of these vehicle kms are travelled in free-flowing traffic conditions, optimised routing can significantly reduce fuel consumption and associated emissions of $CO_{2,}$ $SO_{x,}$ NO_x, VOCs and PM.

More efficient driving techniques can reduce fuel consumption by up to 10 % (Ricardo, 2010), though real-life experience may yield slightly lower results.

Telematic systems can reduce fuel consumption and associated emissions by approximately 5 % for long-distance HGV transport and up to 15 % for urban LCV transport (Climate Change Corporation, 2008). Ricardo (2010) estimates that one telematic application with predictive cruise control can reduce fuel consumption by 2 % to 5 %.

T7: Fuel and CO_2 reductions attributable to various improvement measures are listed in Table 3.23. In particular, use of natural gas and biogas to power HGVs could result in CO_2 savings of 10-15 % and over 60 %, respectively (Ricardo, 2010). For natural gas and biogas powered trucks, emissions of all the major air pollutants should be lower than comparable petrol or diesel engines.

Ricardo (2010) reports fuel consumption reductions of up to 24 % during trials at constant speed for aerodynamic trailers with integrated vehicle aerodynamic systems, and real-world fleet savings of 9 % achieved by DHL and 16.7 % achieved by STD. Aerodynamic trailers used by retailer Marks & Spencer's, developed in 2008/9, reduce fuel consumption by 6 % (M&S, 2010).
Table 3.24 presents the large reductions in emissions associated with higher EURO standards for heavy duty diesel engines used in HGVs, in particular for NO_x and PM.

Table 3.24: Emission limit values for heavy duty diesel engines associated with various EURO standards, expressed per kWh engine output, and year of introduction

Tier	Date	Test	CO	HC	NO_x	PM	Smoke
			g/kWh				m^{-1}
EURO I	1992	ECE R-49	4.5	1.1	8.0	0.36	
EURO II	1998		4.0	1.1	7.0	0.15	
EURO III	2000	ESC + ELR	2.1	0.66	5.0	0.1	0.8
EURO IV	2005		1.5	0.46	3.5	0.02	0.5
EURO V	2013		1.5	0.46	2.0	0.02	0.5
EURO VI	2013		1.5	0.13	0.4	0.01	
NB: Values are for steady state testing (ECE R-49), European Stationary Cycle (ESC) and European Load Response (ELR). From summary data presented in DieselNet (2009).							

Appropriate environmental indicators

The most relevant environmental performance indicators for this BEMP are the following:

- kg CO_2eq emitted during transport per: tonne, m^3, pallet, or case (according to relevance) or kg CO_2eq per net amount of product delivered
- Total energy consumption of warehouse (kWh/m^2/yr) normalised by relevant unit of throughput (e.g. kg net product).
- L/100 km (vehicle fuel consumption) or mpg; or: kg CO_2eq /tonne·km.
- % of truck empty runs
- % of deliveries carried out through back-hauling

Below, further relevant indicators and more details and information are provided for each of the techniques presented in this BEMP.

T1: The most appropriate indicator of environmental performance with respect to environmental (reporting) requirements for third party T&L providers is:

- the percentage of transport supplied by third-party T&L providers that complies with specified standards, requirements, or best practice techniques outlined in this document.

T2: Absolute T&L impact, expressed as **total fuel use or tonnes CO_2 emitted by all T&L operations**, is a key component of absolute business impact that should be used as a sustainability indicator alongside business performance indicators to comply with transparency requirements in annual reports. It should be interpreted in the context of business performance and does not necessarily reflect the efficiency of T&L operations.

A wide range of indicators can be used to identify specific aspects of T&L performance, following the collation of the basic data specified in Table 3.17, and preferably additional data. Selecting the most appropriate indicators depends on the purpose of the monitoring and/or reporting. Ultimately, the environmental performance of T&L operations is measured by metrics such as kg CO_2 per tonne or m^3 product delivered (Table 3.26). However, a number of important efficiency indicators may be used by manufacturers to identify specific aspects of performance that could be improved, such as load factors and routing distances (Table 3.25).

Table 3.25: Key efficiency (specific performance) indicators for T&L operations

Description	Units
Load factor	% volume capacity utilised
	% weight capacity utilised
Energy intensity	MJ/tkm
	MJ/m^3.km
	MJ/pallet.km
CO_2 intensity	CO_2eq/tkm
	CO_2eq/m^3.km
	CO_2eq/pallet.km
Volume-weighted average routing distance	km

Table 3.26: Final environmental performance indicators for T&L operations

Units
kg CO_2eq./t
kg CO_2eq./m^3
kg CO_2eq./pallet
kg CO_2eq./case

Variations of the indicators specified in Table 3.25 and Table 3.26 may be used for specific purposes, e.g. to calculate the specific fuel consumption of the food delivery fleet relative to the total number of customer locations serviced. However, such indicators do not allow for an accurate comparison *across* manufacturers, and should not substitute the indicators proposed in Table 3.25 and Table 3.26.

T3: Improvements in packaging density can be reflected in **weight-based**([17]) final T&L performance indicators listed in Table 3.25 and Table 3.26 above:

- kg CO_2eq per tkm
- kg CO_2eq per net tonne of product delivered.

A relevant additional indicator is: Average density of product category in kg (net) product per litre of (gross / packaged) product

([17]) Improved packaging density will not be reflected by volume-based indicators (e.g. kg CO_2eq/m^3 delivered). Therefore, the best indicator to reflect improved T&L efficiency associated with modified packaging is MJ or kg CO_2eq per tkm transported or per tonne delivered.

Environmental performance improvements associated with integrated sourcing decisions involving T&L impact reductions should be expressed as net life cycle environmental performance improvements for particular products. These may be expressed as lifecycle GHG emissions, but should include other environmental indicators where relevant (e.g. water footprint in relation to local water resource pressure). Manufacturer performance can be expressed as:

- number of product groups where sourcing or packaging has been modified specifically to reduce T&L and lifecycle environmental impact.

T4: Modes should be compared by assessing total (direct plus indirect) emissions per tkm transported, especially GHG emissions (CO_2 eq in Table 3.19), but also other emissions (Figure 3.17).

Manufacturer performance with respect to implementing or using more efficient transport modes is most accurately conveyed through statistics on the percentage of goods transported via such modes. Two proposed indicators are:

- percentage of total product transport (tkm), from first-tier suppliers to stores, accounted for by specified more efficient modes
- percentage of international product transport (tkm) accounted for by specified more-efficient modes.

Where these indicators cannot be calculated, alternatives are:

- percentage of overland transport between first-tier suppliers and manufacturer's distribution centres, by sales value, accounted for by specified more efficient modes
- percentage of international product transport, by sales value, accounted for by specified more efficient modes.

T5: Total energy consumption of warehouse ($kWh/m^2/yr$) normalised by relevant unit of throughput (e.g. kg net product)

T6: Intermodal shifts, increased loading efficiency, and reduced empty running associated with distribution network optimisation will be reflected in transport efficiency indicators (Table 3.25 above):

- percentage of transport by different modes
- average load efficiency percentage (volume or mass capacity)
- average empty running percentage (truck km)
- g CO_2eq/tkm.

The above indicators are important to identify the most appropriate improvement options. The full effect of distribution network optimisation, including a reduction in the overall transport distance, will be reflected in final performance indicators (Table 3.26), in particular:

- kg CO_2eq per m^3 delivered product.

Manufacturers often refer to absolute reductions in GHG emissions attributable to specific improvements (e.g. Table 3.21).

Increased loading efficiency and reduced empty running associated with routing improvements, and more efficient driving associated with telematics and driver training, will be reflected in transport efficiency indicators (Table 3.25):

- fleet average percentage load efficiency (volume or mass capacity)
- fleet average percentage empty running (truck km)
- fleet average g CO_2eq per tkm.

The above indicators are important to identify the most appropriate improvement options. The full effect of improved logistics, telematics and driver training will be reflected in final performance indicators (Table 3.26), in particular:

- kg CO_2eq per m^3 delivered product.

Manufacturers may refer to absolute reductions in GHG emissions attributable to specific improvements (e.g. Table 3.22). The most appropriate indicators of manufacturer management performance for this technique are:

- percentage of drivers continuously trained in efficient driving techniques
- percentage reduction in T&L GHG emissions achieved through implementation of specified options (i.e. back-hauling waste or supplier deliveries, telematics, driver training and incentive schemes, out-of-hours deliveries)
- outsourcing of T&L operations to a third party provider implementing this technique.

T7: Vehicle efficiency is reflected in distance-normalised indicators. Two relevant indicators that can be used to monitor the effect of improved vehicle design are:

- l/100 km (vehicle fuel consumption) or mpg
- kg CO_2eq/tkm.

Neither of these indicators isolates the effect of vehicle efficiency improvements from other factors, in particular loading efficiency. Improved *loading* efficiency will negatively affect the former indicator and significantly positively affect the latter indicator (Figure 3.19). The effect of alternative fuel use (biogas, electricity) requires the reporting of lifecycle kg CO_2eq per km or tkm.

Vehicle performance in terms of air pollution is not measured directly but can be inferred from vehicle EURO emission standard compliance. Similarly, the percentage of low-noise vehicles that enable more efficient night-time deliveries, and the percentage of alternatively fuelled vehicles (excluding biodiesel and ethanol owing to sustainability concerns), are useful indicators of improved environmental performance. Application of aerodynamic improvements and fitting of low rolling resistance tyres also indicate improved efficiency. Thus, five indicators for the environmental performance of the delivery fleet are:

- percentage of vehicles within transport fleet compliant with different EURO classes
- percentage of vehicles, trailers and loading equipment compliant with PIEK noise standards, or equivalent standards that enable night-time deliveries
- percentage of vehicles in transport fleet powered by alternative fuel sources, including natural gas, biogas, or electricity

- percentage of of vehicles within transport fleet fitted with low rolling resistance tyres
- percentage of vehicles and trailers within transport fleet designed or modified to improve aerodynamic performance.

Cross-media effects

T1: Requirements for third party T&L providers should relate to the major environmental pressures associated with T&L operations.

T2: Energy consumption and CO_2 emissions correlate strongly with overall environmental pressure from transport operations, but may deviate in some instances. In particular, heavy fuel oil used in shipping results in high SO_x and NO_x emissions relative to CO_2 emissions (Figure 3.17). Optimisation of T&L operations should account for any indirect effects on secondary transport providers, product sourcing, and customer travel.

T3: It is environmentally preferable to source some products from distant warm climates where they may be more efficiently produced (e.g. sugar). Sourcing optimisation must be informed by a comprehensive and integrated product assessment to ensure that there are no major cross-media or indirect counter effects, such as pressure on water resources. Social considerations, in particular the creation of quality employment in developing countries (Fairtrade certified products), may conflict with reducing product life cycle impacts through closer sourcing.

In some cases, increased product density may require additional packaging layers, or a change in packaging material, which should be balanced against reduced transport pressures using an LCA or similar assessment.

T4: Intermodal transport may necessitate longer routing distances, but this effect is unlikely to outweigh the substantial environmental benefits possible from shifting the mode of primary transport.

Shifting goods transport to LHVs is only environmentally beneficial if it replaces transport in smaller trucks. There are possible indirect negative effects of shifting towards LHV transport, in particular the indirect displacement of rail transport (see Economics).

T5: There are no significant cross-media effects associated with this technique.

T6: The only significant cross-media effect likely to arise from measures described in this technique (ecodriving) is elevated emissions of NO_x from engines under lighter loading as a consequence of more efficient driving techniques (EMCT, 2006).

T7: The cross-media effects that could arise from this technique are based on the material and energy inputs and associated emissions linked to the manufacture of a new, modern lorry which would be purchased to replace an older, more polluting one. However it is unlikely that the replacement/purchasing decision would be based on the implementation of this technique alone.

For electric vehicles and biofuel, the impact of electricity generation and biofuel production should be accounted for and compared with the impact of the supply and combustion of fuel used in conventional vehicles. This may require a full 'well-to-wheel' LCA for proposed and conventional vehicles/fuels.

Operational data

T1: For large manufacturers who outsource parts of their T&L operations, green procurement of these operations is a cross-cutting technique that should be considered within subsequent techniques described in this BEMP. Requiring T&L providers to report basic environmental performance data is an integral part of T&L monitoring and reporting best practice (T2). Shifting towards more efficient distribution networks and environmentally preferable transport modes (T4) often necessitates the selection of better-performing T&L providers (e.g. train operators in place of lorry operators, shipping operators in place of airfreight operators), and may be regarded as green procurement..

T2: In terms of appropriate units, tkm is an indicator which is widely used in statistical publications to convey T&L efficiency, but which is rarely reported by manufacturers. Sustainability reports usually refer to final T&L performance in terms of fuel consumption or CO_2 emitted per m^3, per case , or per item delivered. McKinnon (2009) found that 'wooden pallets' or 'roll cages' were the units most commonly used by UK companies participating in a transport benchmarking study. Many shipments are volume-limited rather than weight-limited (Lumsden, 2004), and measures to improve load efficiency (e.g. dense packaging of products) will not be reflected positively by volume-normalised reporting. To improve transparency and comparability within the constraints of data availability, it is recommended that transport efficiency be assessed in relation to tkm transported where possible, and final performance in relation to volume (m^3 or pallet or case) delivered.

Where shipping units are reported as 'Twenty-foot Equivalent Units' (TEU), they can be converted into tkm based on the factors proposed by IFEU (2010):

- light goods: 6 tonnes per TEU
- medium-density goods: 10.5 tonnes per TEU.

The UN GRI pilot document for the T&L sector (UN, 2006) contains a number of specific recommendations for T&L energy reporting (in addition to standard GR3 reporting guidelines). Energy consumption should be reported:

- in joules
- separately for individual mobile (e.g. air, sea, road, rail) and non-mobile (e.g. office, warehouse) sources
- according to source
- normalised using units such as cubic-metre-kilometre, tonne-kilometre, delivery item, freight unit (e.g. TEU-km)
- include all energy used to produce and deliver energy products purchased by the reporting organisation (including indirect and electricity generation emissions).

Table 3.27 includes some conversion factors relevant for the calculation of T&L energy use. Emissions of CO_2 can be calculated from standard emission factors applicable to different fuel types, assuming complete oxidation during combustion. Non-CO_2 emissions are heavily dependent on the specific combustion technology, conditions, and abatement technology and so cannot be calculated from standard default emission factors applied to fuel type. Where operating conditions are specified more precisely, non-CO_2 emissions may be estimated from emission factors published by various sources (e.g. IPCC, 2006; IFEU, 2010; Tremove, 2010).

Table 3.27: Some characteristics of major transport fuels, including <u>direct</u> CO_2 emissions from combustion

Fuel	Density	Energy content	CO_2
	kg/l	MJ/l	kg/l
Gasoline	0.72	32.1	2.24
Diesel, MDO, MGO	0.83	36.0	2.63
Biodiesel	0.83	38.1	2.79
Kerosene	0.80	35.3	2.52
Heavy fuel oil	0.98	40.4	3.07
NB: MDO = Medium-Density Oil; MGO = Medium-Grade Oil *Source:* IPCC (2006) and IFEU (2010)			

When comparing alternative fuel options, and for completeness of reporting, the indirect emissions associated with fuel supply chains should also be accounted for (Table 3.28). For example, gasoline combustion is associated with low direct emissions of SO_x, but high indirect SO_x emissions attributable to processing, compared with diesel – based on IFEU data presented in Table 3.28. Where transport is powered by electricity, emissions can be calculated from country-specific electricity emission factors.

Table 3.28: <u>Indirect</u> emissions arising during the extraction, processing and transport of different fuels, expressed in relation to one kg of fuel

Fuel	Efficiency*	CO_2	NO_x	SO_2	NMVOC	PM
		kg/l	g/l	g/l	g/l	g/l
Gasoline	75 %	0.4824	1.52	4.18	1.52	0.21
Diesel, MDO, MGO	78 %	0.390	1.49	3.64	1.26	0.19
Biodiesel	60 %	0.739	5.25	1.36	0.95	0.60
Kerosene	79 %	0.36	1.41	3.44	1.21	0.18
Heavy fuel oil	79 %	0.392	1.65	3.91	1.44	0.21
(*) Final energy related to primary energy. *Source:* IFEU (2010), based on Ecoinvent (2009).						

Blanco and Craig (2009) found that transport emissions calculated from actual data were, on average, 27 % higher than emissions predicted from standard emission factors, for various transport chains. To improve the accuracy of energy consumption or energy efficiency calculations, and to ensure that monitoring data both incentivise and reflect routing optimisation, it is important that transport distance be accurately accounted for.

Shipping distances are often 10–21 % greater than direct port-to-port distances, owing to multiple port calls (Blanco and Craig, 2009). Air freight distances are at least 4 % greater than direct airport-to-airport distances. To calculate typical air transport distances, IFEU (2010) proposes the following formula based on the shortest distance between two points, the Great Circle Distance (GCD):

Real flight distance = (GCD – 185.2 km) x 1.04 + 185.2 km + 60 km

In addition, GHG emissions from air transport should be multiplied by the appropriate Radiative Forcing Index (RFI) factor, depending on the altitude, in order to more fully reflect their climate impact (Table 3.29).
Meanwhile, road and rail transport distances are highly dependent on the road and rail network in relation to the points of origin/destination. In the EcotransIT model, country-specific topography is considered in energy consumption and emissions factors for heavy goods vehicles (IFEU, 2010), with deviations of 5 % lower (relative to the European average) for 'flat countries' (Denmark, the Netherlands and Sweden) and 5 % higher for 'mountainous countries' (Switzerland and Austria). The effects of factors such as those listed above highlight the need for **activity-specific data**, and can be particularly important when calculating the net potential benefit of transport modal shifts (T4).

Table 3.29: Radiative Forcing Index factor applied to aircraft GHG emissions, depending on altitude (flight altitude and distance)

Flight distance (km)	% of flight above 9000m	Average RFI factor
500	0 %	1.00
750	50 %	1.81
1000	72 %	2.18
2000	85 %	2.53
4000	93 %	2.73
10000	97 %	2.87
Source: IFEU (2010).		

T4

It is important that the net impact of modal shifts is assessed on a door-to-door basis, accounting for any increases in routing distance, goods transfers, and secondary modal shifts. For example, shifting the primary transport mode from road to rail for a particular product group may necessitate a longer route, transfer of goods from train to truck, and road deliveries from the train depot to the DC or stores. Handling and transfer of goods makes a minor contribution to transport GHG emissions (Blanco and Craig, 2009), calculated at 5 % in a worst-case scenario of ship to train transfer using trucks (CN, 2010). The CO_2 reduction associated with intermodal shifts is dominated by:

- the energy intensity of the replaced and replacement mode
- the carbon intensity of the power source for the replaced and replacement modes
- load factor differences between the replaced and replacement modes.

There is currently debate over the potential for Longer Heavier Vehicles (LHVs) to reduce the net environmental impact of goods transport in Europe. In a recent European Commission study (EC, 2009), it was estimated that 60-tonne LHVs could be up to 12.5 % more efficient than 44 tonne vehicles per tkm transported. However, potential reductions in road-transport costs associated with LHVs could result in a shift of goods transport away from rail towards road (see Figure 3.21). Based on the prioritisation of transport modes outlined in Table 3.18, shifting goods transport to LHVs is only beneficial if it is from smaller trucks, but in any case is likely to be limited in the short term owing to LHV bans in a number of European countries.

T6:

Intermodal transfers may be restricted, or at least complicated, by varying load unit dimensions (Lumsden, 2004). Standardisation of load unit dimensions would accommodate full intermodality, and enable the use of modular combinations such as truck trailers. Given that food and drink goods transport is often volume-limited, further improvements in weight-based load efficiency may require trailer designs and combinations with a greater volume capacity at a given weight capacity.

Fuel savings realised by driver training diminish over time and it is necessary to continuously train drivers, for example through annual refresher courses. Manufacturers may also implement a driver benchmarking system to maintain interest and encourage competition in efficient driving. This may be based on basic fuel consumption per truck or real-time monitoring systems that monitor truck and driver efficiency. Drivers may receive part of the fuel savings they achieve through more efficient driving.

Night-time delivery may necessitate the use of silent trucks and unloading facilities, depending on the location of the facility.

Some opportunities to achieve significant efficiency-related savings through route planning and driving techniques are restricted by legislation. For example, platoon driving, whereby HGVs follow one another closely on motorways to form a train, can be achieved using safety sensors and active safety features. It has the potential to reduce fuel use and CO_2 emissions by 20 % on motorway journeys, but contravenes current road regulations.

T7: The actual fuel efficiency and environmental benefits associated with the measures listed in Table 3.23 are highly dependent on vehicle use and operational conditions. For example, aerodynamic improvements will achieve significant fuel savings for vehicles that frequently travel at higher speeds, whilst hybrid and electric vehicles will achieve significant fuel/energy savings for vehicles that spend most of their time in urban areas making frequent stops. Meanwhile, biogas is a promising 'green' fuel for trucks, but widespread use will depend on the development of biogas availability and distribution.

Compressed natural gas, LPG and biogas are considerably less dense fuels than petrol and diesel. Trucks running on these fuels require fuel tanks of a higher capacity (up to four times higher) than conventional trucks and that are reinforced to maintain necessary fuel pressurisation. Appropriate specialised refuelling infrastructure is required, at least at truck depots, but also along long-distance transport routes. Similarly, electric delivery vehicles (vans) will require recharging within vehicle depots, as recharging networks are in the early stages of development.

Applicability

T1: This technique is applicable to all manufacturers. It is the primary technique for influencing T&L environmental performance for manufacturers who rely entirely on third-party T&L providers (e.g. most small manufacturers).

T2: Any manufacturer can estimate the environmental impact of their T&L operations based on average energy consumption and emission factors, at least based on assumptions about third-party T&L routing.

T3: This technique is applicable to all manufacturers.

Larger manufacturers can calculate more detailed energy and environmental performance metrics for T&L operations, based on data collation systems for in-house operations and reporting requirements imposed on third party T&L providers and suppliers.

T4: All large manufacturers can take some action to shift from more to less polluting transport modes, at least based on vehicle size. There are opportunities for most large manufacturers to shift some of their product transport from road to rail or water.

Achieving large-scale shifts in food and drink goods transport from road to rail and inland waterways will require improvements in national rail infrastructures and greater cross-border coordination by operating companies.

National policy (e.g. road pricing) can have a significant influence on manufacturers' decisions regarding transport mode. In Switzerland, HGVs have been subject to a statutory charge since 2002.

T5: All manufacturers operating storage facilities can apply best practices from this technique.

T6: Any large manufacturer with a distribution network (i.e. distribution centres) can implement this technique. Any third party T&L service provider can implement this technique.

T7: All manufacturers, suppliers, customers and T&L providers operating trucks can specify vehicle design features, or retrofit modifications, to improve vehicle efficiency. Purchasing HGVs capable of running on CNG and biogas can result in large emission savings at acceptable costs, but may be restricted by the refuelling infrastructure available within different Member States. Similarly, the purchase of electric delivery vehicles is highly dependent on the available recharging infrastructure.

The greatest benefits associated with silent trucks are realised where the legislative restrictions on standard trucks are greatest. Manufacturers with operations in built-up residential areas, especially city centre locations (e.g. bakers), are therefore likely to benefit most from silent trucks. Such retailers also have the greatest opportunity to achieve benefits from the use of hybrid and electric vehicles.

Economics

T1: As demonstrated in subsequent sections, many techniques that reduce the environmental impact of T&L operations are associated with improved efficiency and reduced costs. Therefore, more environmentally sound third-party T&L providers, and those complying with specific environmental requirements, do not necessarily provide a more expensive service. Where there is a price premium associated with better performers, this should be balanced against the positive marketing effect of a good (environmentally responsible) reputation.

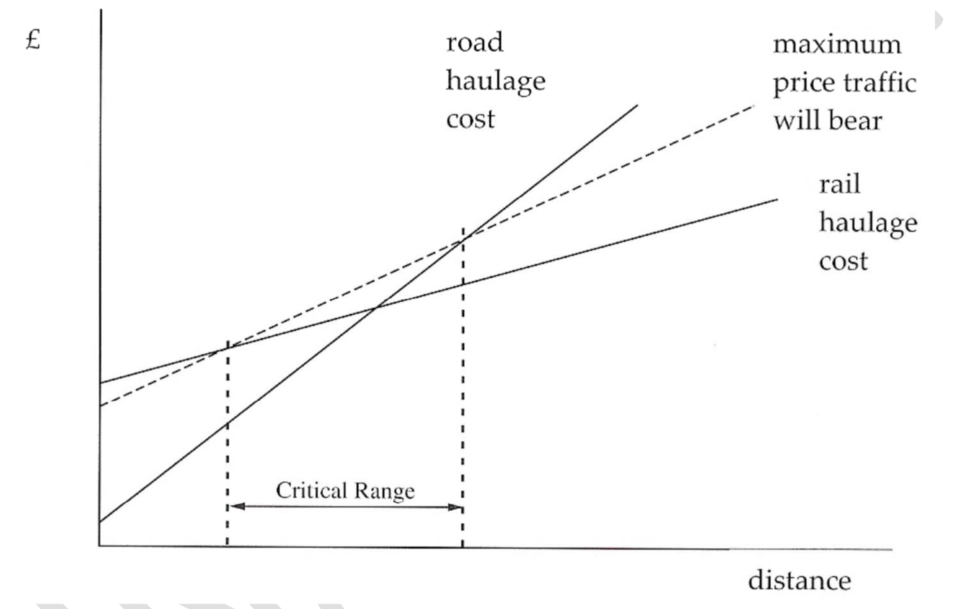
Where manufacturers work with third-party T&L providers and suppliers to implement improvement options, for example by providing finance for investment, economic benefits associated with efficiency gains can be reflected in annually-updated contracts.

T2: The exact costs of implementing a monitoring and reporting system for T&L operations are not known, but are expected to be small compared with the potential economic benefits of more efficient T&L operations. This applies to both manufacturers and third party providers.

T3: Life cycle costing should be applied to determine net costs. Possible increases in sourcing and packaging costs may be offset by possible reductions in T&L, storage and in-store display and handling costs.

T4: Investment in the distribution network necessary to achieve intermodal shifts may be recouped by savings in transport costs. Rail is more likely to offer cost savings compared with road for longer distance transport.

Figure 3.21: Comparison of the costs of road and rail transport over an increasing distance



Source: Harris & McIntosh (2003)

T6: Driver training costs between EUR 170 and EUR 340 per driver (Ricardo, 2010). Based on an average fuel cost of EUR 50 000 per year for an average European long-distance truck (Volvo, 2010), a 5 % fuel saving would translate into EUR 2 500 saved in the first year alone.

Software and manpower costs associated with route optimisation are highly variable. For large manufacturers, these costs are likely to be small compared with routing distance reductions and fuel cost savings. Similarly, telematic system installation costs are likely to be small compared with efficiency improvements and fuel cost savings (see driver training example, above).

Efficient route planning (particularly in coordination with suppliers) can reduce the size of the fleet required, and thus reduce capital investment. Efficiency dividends may be shared between cooperating parties.

T7: As indicated in Table 3.23, vehicle modifications can result in substantial fuel and cost savings. The payback periods for most of the retrofit investment costs specified in Table 3.23 are favourable, often shorter than two years based on conservative estimates of potential fuel savings and average European truck operations.

For some of the vehicle purchasing options, especially alternatively powered vehicles, the payback periods are highly dependent on national fuel taxation and road tolling policies - in particular taxation on gas-based fuels relative to petrol and diesel.
However, as indicated in the operational data section, investment in low-noise transport and loading equipment increased capital costs by 15 %, but reduced overall transport costs by more than 20 %.

Driving force for implementation
Annual sustainability reports document a recent and increasing focus by manufacturers on the measurement and improvement of transport efficiency and the associated carbon footprint. Based on a case study of transport for the European chemical manufacturing sector, which is regarded as a leading sector in terms of transport efficiency, McKinnon and Piecyk (2010) concluded that measuring and reducing the carbon footprint of *transport operations* is at an early stage and that there are many opportunities to achieve short to medium-term savings. They emphasised the importance of companies working closely with transport providers.

Realisation of cost-saving opportunities in T&L operations often requires an initial investment, and a significant barrier to this is the low profitability of the T&L sector in recent years (Climate Change Corp, 2008). Conversely, the major driver of this decline in profitability – an increase in fuel prices that accounts for up to 40 % of operating costs – also provides a major incentive for efficiency improvement in terms of business planning and risk mitigation. Therefore, there is usually a strong medium-term business case for manufacturers to invest in T&L infrastructure, and to provide financial support for T&L providers to make these investments in return for competitively-priced and stable contract agreements. The drivers for manufacturers to reduce the energy consumption and environmental impact of their T&L operations may be summarised as:

- fulfilling corporate social responsibility duties including reporting (e.g. operation carbon footprint);
- realising cost-saving opportunities associated with efficient T&L operations;
- reducing exposure to energy price volatility (risk management);
- realising cost-effective carbon footprint reductions;
- reducing potential future liabilities associated with carbon pricing;
- improving their marketing positioning and public image;
- reducing their overall (reported) environmental burden, or that of particular product groups;
- calculating products' environmental footprints.

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3.7. Improving freezing and refrigeration

Description

The use of refrigeration and freezing is widespread across the food and drinks supply chain, and especially in manufacturing, transport, bulk storage and retail. Although most of the cooling is used in refrigerators, freezers and cold stores, refrigeration is also commonly used for cooling and heating in air conditioning systems (Carbon Trust, 2011a). In Europe, 75 % of all industrial refrigeration capacity is installed in the food industry, equating to around 60-70 million cubic metres of cold storage for food (Masson et al, 2014). Cooling is among the most energy-intensive processes in the sector with up to 60% of a manufacturer's electricity used in refrigeration (Table 3.30), and up to 70% of the energy cost accounted for by refrigeration (Table 3.31).

Table 3.30: Importance of refrigeration related to total electricity use

Industry sector	Electricity used for refrigeration
Liquid milk processing	25%
Breweries	35%
Confectionery	40%
Chilled ready meals	50%
Frozen food	60%

Source: Carbon Trust Networks Project (2007)

Table 3.31: Importance of refrigeration related to total energy cost

Industry sector	Energy costs accounted for by refrigeration
Meat, poultry and fish processing	50%
Ice cream manufacturing	70%
Cold storage	90%
Food supermarkets	50%
Small shops with refrigerated cabinets	70% or over
Pubs and clubs	30%

Source: Carbon Trust (2011b)

Thus, any improvements to equipment, facilities, and management of refrigeration and freezing would substantially enhance the industry's environmental performance. This BEMP describes what frontrunner food and drinks manufacturers do to optimise their cooling operations.

The Carbon Trust reports that typical sources of energy savings are good maintenance (25%), housekeeping and control (25%), and more efficient equipment (50%). In addition, up to 20% of such savings can be achieved through improvements that require little or no investment (Carbon Trust 2011b). Key opportunities include:

- *Smarter temperature selection.* For example, frozen food products must be kept below -18°C, so to achieve this limit, manufacturers of such products will generally set their thermostats to -23°C or lower allowing a safety margin. This buffer is selected to account for doors to the freezers being opened or perhaps for high ambient temperatures.

But for every extra degree of cooling, significant additional energy is consumed, thus some frontrunners will accept a slightly warmer temperature, perhaps -21°C. This is enabled by improvements to air curtains and freezer door seals, and acceleration of the opening and closing of freezer doors (British Frozen Food Federation, 2014, pers.comm.). Similarly, frontrunners will avoid grouping products (or ingredients) requiring different storage temperatures in the same cooling space as some of the goods will be kept at unnecessarily low temperatures.

- *Precooling of product.* Rather than placing recently heated products directly into a chiller, significant amounts of energy can be saved by allowing these first to cool in ambient conditions. Letting a soup at 100°C cool to 30°C before placing it in a (domestic) refrigerator can save up to 75% of the heat load (Carbon Trust Networks Project, 2007).

- *Minimising the volume of products or ingredients kept in cold storage* and thus the space which needs to be cooled. Under the principles of lean manufacturing, the inventory should be kept to a minimum. Not only is energy consumption in cooling minimised but other negative environmental impacts are reduced such as food wastage associated with expired products.

- *Avoiding temperature leakage* (e.g. by replacing leaking door seals).

These principles can be applied retrospectively to existing cold stores through upgrades but the best results are typically achieved when new facilities can be designed and built from scratch. Key opportunities requiring significant investment include the following:

- *Switching away from hydrofluorocarbons* (HFCs) to natural refrigerants with lower global warming potential (GWP), especially ammonia and carbon dioxide but also some hydrocarbons used in modular packaging chillers.

- *Installing more sophisticated cooling systems.* The best example of this is seen in carbon dioxide-based cooling systems where 'transcritical' rather than 'subcritical' cooling is used (Star Technology Solutions, 2014, pers.comm.).

- Another potential approach to maintaining the best performance of cooling equipment is to agree a *'leak-free warranty'* with the equipment supplier, as evidenced by **Coca-Cola Enterprises** (CCE). Under this five-year agreement from 2009, two suppliers of Turbucor chillers at five manufacturing sites are responsible for repairing equipment, carbon off-setting the emissions and topping up refrigerants in the chillers in case of leakage (Coca-Cola Enterprises, 2014, pers.comm.). CCE decided against an immediate switch to natural refrigerants, and this warranty approach helps in the short term to reduce the risks posed by the release of high GWP refrigerant gases to the atmosphere.

- *Improving equipment and layout*, including investment in existing refrigeration plants and careful selection of new plants.

- *Recovery and reuse of waste heat.* This can be done in two ways:

- Waste heat generated from the refrigeration unit can be used as a heat source; for example, to preheat water in order to reduce the energy use of the boiler (Carbon Trust, 2011b).
- Waste heat from other processes can also be used for refrigeration, through the use of absorption refrigeration. This technique makes use of heat, instead of electricity, to provide cooling. Heat sources used in absorption refrigeration vary; examples are methane, solar energy or recovered waste heat (U.S. Department of Energy, 2012).

In addition, recently, interest in supercooling and superchilling has grown as alternatives to chilling and freezing. Both processes aim at improving shelf life, reducing energy consumption and increasing the food safety of the products stored thanks to temperatures ranging usually between -1 °C and -4°C. However, further research is required to make the technology more suitable for the preservation of food, investigating the quality and sensorial attributes of the stored products.
There are many examples of food and beverage companies moving towards natural refrigeration systems. For example, at **Unilever** almost all production facilities and cold stores use ammonia refrigeration systems. This is particularly suited for such use given ammonia's high efficiency in large-scale applications (Refrigerants, Naturally!, nd.). The new **Arla** dairy production facility in the UK includes an ammonia refrigeration system, with a cooling capacity of more than 7.5MW (Masson et al., 2014).

In the case of both new and old equipment, management of information on cooling loads, energy use and leak rates as well as regular inspection and maintenance of the cooling equipment are of primary importance to reduce energy use and cost. Some examples of this are provided below.

- *Compressors:* In refrigeration units compressors are used to raise the refrigerant pressure so that heat is ejected to ambient air, thus cooling the refrigerant. This is the most energy-intensive part of refrigeration systems. The higher the compressor temperature is set, the higher the energy required to run the system. Traditional condenser control systems are set at a fixed temperature, and therefore are set to run during the worst-case scenario, i.e. at the warmest time of the year. Changing the compressor control so as to reduce the temperature setting in cooler weather offers great energy-saving potential.

- *Condensers:* These are the parts of refrigeration systems which reject heat from the refrigerant. Energy savings can be achieved by simply keeping the condensers clean. Condensers that are blocked with debris must operate at a higher temperature to achieve the same results, thus consuming more energy (Carbon Trust, 2011b).

Achieved environmental benefits

According to the Product Sustainability Forum, a UK initiative sponsored by WRAP (Waste & Resources Action Programme), the environmental savings potential from optimising refrigeration in the grocery supply chain is considerable (see Table 3.32).

Table 3.32: Environmental savings potential from optimising refrigeration in the grocery supply chain

	Refrigerant GHG emissions	Energy
Existing systems	50%	25%
New systems	>90%	40%

Source: Product Sustainability Forum (2013)

As mentioned above, such savings can be achieved through low-cost solutions involving better maintenance, housekeeping and control. For example, better temperature settings by separating products which need to be stored at different temperatures or by taking into account ambient temperature can result in a 4% energy saving for chill temperatures and 2% for low temperatures by increasing the temperature setting. For instance, where a Product A requiring 5°C is stored with Product B needing -5°C, the freezer will be maintained at the 'lowest common denominator' of -5°C. Thus, Product B will be kept 10°C cooler than necessary wasting perhaps 15% to 20% of power input (Carbon Trust Networks Project, 2007). Cleaning of condensers results in energy savings of up to 10 % (Carbon Trust, 2011b).

Refrigerants which have been conventionally used to date have both high global warming potential (GWP) and ozone depleting potential (ODP). Therefore the release of these gases in the atmosphere through leakage or incorrect disposal has strong detrimental effects on the environment and climate change. Table 3.33 shows the GWP of conventional fluorinated refrigerants compared to that of carbon dioxide and non-fluorinated hydrocarbons. The data show that the natural alternatives presented have 20-year GWPs that are thousands of times lower than those of CFCs, HFCs and HCFCs. Another natural refrigerant available for use is ammonia; this has a GWP and ODP of zero. Moreover, ammonia refrigeration systems generally achieve higher energy efficiency than HFC equivalents (Masson et al., 2014).

Table 3.33: Global warming potential (GWP) of fluorocarbons and natural refrigerants (CO_2 and hydrocarbons)

Gas	Lifetime (years)	20 year	100 year	500 year
CO_2	1	1	1	1
CFC-11	45	6730	4750	1620
CFC-12	100	11000	10900	5200
HCFC-141b	9.3	2250	725	220
HFC-134a	14	3830	1430	435
Cyclopentane	weeks	<3	<3	<3
Isobutane	weeks	<3	<3	<3
Propane	months	<3	<3	<3

Source: Greenpeace (2009)

Appropriate environmental indicators

The most relevant environmental performance indicators for this BEMP are the following:

- percentage use of natural refrigeration systems
- coefficient of performance (COP)
- coefficient of service performance (COSP)
- energy efficiency ratio (EER)
- energy demand for refrigeration per unit product / per cooled area

Cross-media effects

Certain natural gas refrigerants may be toxic to humans, particularly ammonia which has the added risk of being flammable. However, the characteristic pungent odour of ammonia makes it easy to identify even in concentrations as low as 3 mg/m^3 of air. In addition, ammonia is lighter than air therefore it rises quickly (Eurammon, 2011).

Another environmental consideration is the negative impact of disposal of existing cooling systems when upgrading to new, more efficient, systems. These impacts may outweigh the improved efficiency offered by new equipment if premature disposal occurs or if the end-of-life treatment of the equipment is not managed properly. Determining the point at which it offers a net environmental benefit to switch to new equipment is not straightforward; although in general the older the equipment being replaced the more likely it is that the replacement makes good environmental sense.

Operational data

Nestlé is among the first manufacturers to commit to switching to natural refrigerants in all its large cooling systems. Its chocolate factory in Halifax in the UK demonstrates best practice in that when the manufacturer switched from the F-gas R22[18] to ammonia in 2009, it also installed a new integrated cooling and heating system. This enabled the waste heat from the new cooling equipment to heat water used elsewhere in the factory. The plant was redesigned with compressors for the refrigeration plant also acting as heat pumps maintaining water at temperatures of more than 60°C. This provided significant energy savings and is estimated to have cut annual greenhouse gas emissions related to energy consumption by 119100 kg (Star Refrigeration, 2010).

Many other companies have reported energy savings after adopting ammonia refrigeration technology. For example, **Mlekpol**, the largest dairy producer in Poland reported 25% energy savings compared to previous solutions at two of its plants. **Milka**, the Swiss chocolate producer owned by **Mondelēz International**, reported an increase in energy efficiency of 30% after employing ammonia chillers in one of their German factories (Masson et al., 2014).

Other refrigerants such as water, CO_2, NH_3/CO_2 and HC/CO_2 are also in use in the food and beverage industry. For example, **Mack**, a Norwegian beer company is in the process of installing two transcritical CO_2 chillers at its production plant (Masson et al., 2014).

Heat recovery from refrigeration for other uses, such as preheating of boiler feed water can result in savings in boiler energy consumption of up to 30% (Carbon Trust, 2011b). **Vlevico**, a meat

[18] Chlorodifluoromethane

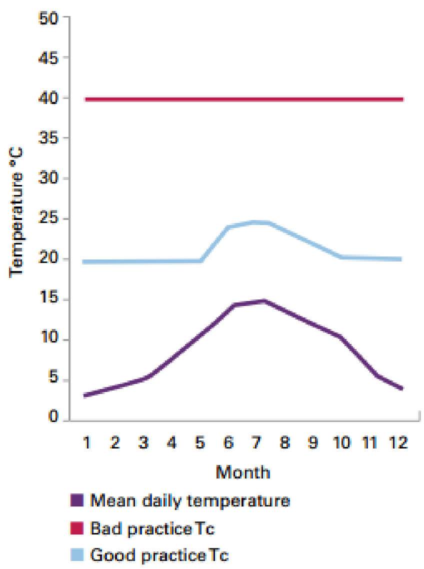
packing company in Belgium owned by the **Colruyt** group, recently installed a new ammonia-based refrigeration system with heat recovery capabilities. This has resulted in energy savings worth EUR 371000 per year and reduced CO_2 emissions equivalent by 1602 tonnes per year. A Norwegian ice cream plant using a transcritical CO_2 cooling and freezing system with heat recovery and hot gas defrost capabilities achieves an emission reduction of 1000 CO_2 eq. per year (Masson et al, 2014).

Since January 2012, the Italian coffee producer **Illy** has been recovering heat from its coffee roasters for use in its plant heating system. More recently, in 2013, the company invested in technology to make use of this waste heat during the summer months, when heating is not required, as a power source for cooling water for conditioning of the plant. The absorption refrigeration unit uses one of the most common refrigerant/absorption mixtures: ammonia/water. This new technology accounts for 50% of the air conditioning needed at the plant and results in around EUR 60000 savings per month when cooling is needed (Illy, 2014, pers.comm.). The **GICB winery** in the south of France has installed an absorption chiller in its cellar powered by solar energy and resulting in energy costs of just €280/year (Masson et al, 2014).

The **Salcheto winery**, based in Tuscany, invested in a geothermal cooling system for chilling its wine cellar. The temperatures required for red wine production are not very low therefore this technology has resulted suitable for the company's needs (nova Agricultura, 2012). The energy demand for running the geothermal cooling system is 10% lower than that previously in use (Salcheto winery, 2014 pers. comm.).

As already mentioned, maintenance and settings are of utmost importance in running refrigeration systems. For example, better setting of the compressor temperature results in significant savings. It is best practice to set the temperature according to the ambient temperature, as can be seen in (Figure 3.22). This will only require an engineer to fix the temperature setting (Carbon Trust, 2011b).

Figure 3.22: Effect of seasonal temperature on condensing temperature (Tc)



Source: Carbon Trust (2011b)

Regular cleaning of condensers is also required to ensure these are running efficiently. If these are likely to accumulate debris or leaves, it is possible to fit a removable condenser screen to avoid this problem. In addition, when purchasing a new refrigeration plant, it is good practice to buy a large condenser as this also offers energy savings (Carbon Trust, 2011b).

Evaporators should be defrosted regularly. This can be done with timers, or intelligent controls can be fitted to detect when defrosting is necessary and send this information to request that a defrosting operation is carried out. Pipes should be insulated to avoid condensation forming on the surface (Carbon Trust, 2011b).

Ammonia as a refrigerant has mostly been used in large-scale industrial refrigeration plants, particularly in the food and beverage industries. Given the extensive use of this refrigerant, the evaporation temperature ranges from -50 °C to +5 °C. These refrigeration plants can be designed in one or two stages. The most common type of compressor in use is the screw compressor (Eurammon, 2007).

Applicability

Various applicability issues need to be considered. For instance, ammonia is not compatible with copper so special motors and steel or aluminium piping may be required which in turn diminishes the advantages of enhanced heat transfer (Ansbro, nd). Carbon dioxide meanwhile, due to the fact that relative high pressures are required for it to function as a refrigerant, is better suited to lighter commercial applications and in vending machines (Staub, 2004).

Another issue is that the layout of existing facilities may preclude necessary changes to optimise cooling performance.

When manufacturers switch to natural refrigerants, certain types of equipment may be HFC-dependent and may no longer function. For example, when a new heat pump was installed at **Nestlé's** factory in Halifax, UK, which used ammonia as the refrigerant, the project team had to completely re-design the pump (Star Refrigeration, 2010)

Smart temperature strategies, such as the example given above of raising freezing stores to -21°C, may not always be applicable; for instance, manufacturers of ice creams must maintain lower temperatures (e.g. -25°C) to protect the quality of their product (British Frozen Food Federation, 2014, pers.comm.).

Another barrier is that many manufacturers may be unable to monitor energy consumption specific to their freezing and refrigeration equipment if electricity metering is on a site-wide basis. In rare cases frontrunners may install sub-meters on specific equipment but this tends not to apply to cooling technologies since these are 'closed systems' with no need to top up the refrigerant (British Frozen Food Federation, 2014, pers.comm.).

Transcritical carbon dioxide cooling systems have the drawback that they work best in cooler ambient temperatures and so are less applicable in warmer countries (e.g. southern Europe). In addition, there is a shortage of technicians skilled in servicing these systems which have more complicated controls (British Frozen Food Federation, 2014, pers.comm.).

As mentioned, **Coca-Cola Enterprises** (CCE) has agreed a leak-free warranty with the supplier of chillers. However, many manufacturers, especially smaller ones may not have the purchasing influence to demand such an agreement and even the soft drinks giant found that most suppliers would refuse to offer such a warranty, and only then for specific cooling equipment (Turbocor chillers) and for a limited period of five years (when the equipment has a life of 15 years or more). When the warranty expires in 2014/15, CCE will continue with the service contact and maintain the chiller to a high standard to minimise the risk of leakage (Coca-Cola Enterprises, 2014, pers.comm.).

Economics

Masson *et al* (2014) provide numerous examples of savings and paybacks from switching to natural gas refrigerants. For instance, the **Daniel Thwaites** brewery in the UK installed a reciprocating compressor using ammonia and as a result increased output from 310 kW to 400 kW with improved energy efficiency and saving around EUR 2,500 per week in electricity costs. The investment paid back in less than 18 months.

The new dual-function heating and cooling compressor installed in 2010 at **Nestlé's** Halifax plant reportedly consumes GBP 120000 (about EUR 155000) less electricity per year than the previous cooling only plant. The capital cost of the project will be recovered within four years (Star Refrigeration, 2010; Star Refrigeration, 2012).

Natural gases also have the advantage over HFCs of being cheaper. In the USA, both ammonia and carbon dioxide cost perhaps USD 1 per lb (about EUR 1.75/kg)[19] while R-134a[20], an HFC, costs USD 10 per lb (around EUR 17.50/kg) (Ansbro, nd; Staub, 2004). However, this consideration is perhaps less significant than others given that the gases are not consumables.

Illy reported investing EUR 400000 for the absorption cooling machinery installed in 2013. As mentioned above, this new technology results in savings of EUR 60000 per month when cooling is required, therefore the capital cost of the project will be recovered within five years. In addition, by collaborating with their suppliers, Illy secured a deal to pay for this equipment in instalments throughout the payback period (Illy, 2014, pers.comm.). Investment for the **Salcheto winery** geothermal plant was considerably lower, and amounted to EUR 40000 (Salcheto, 2014 pers. comm.).

The most efficient cooling equipment is not cheap. A capital investment of up to GBP 1 million (about EUR 1.3 million) is typical for a frozen food manufacturer seeking to upgrade its cold store. The life of the plant may be up to 20 years (British Frozen Food Federation, 2014, pers.comm.). When it comes to freezing, the amount a frontrunner is prepared to invest in cooling technology will depend on the value of its products and the speed with which it needs to be frozen. Those making seafood products with a relatively high unit value will typically use liquid nitrogen

[19] The units conversion was performed on Google (25 September 2014)

[20] 1,1,1,2-Tetrafluoroethane

equipment able to freeze the product to -200°C within seconds, while those making lower value items such as Yorkshire puddings will rely on ammonia as the refrigerant which may take 40 minutes to freeze the food. With products such as red meat, freezing times of up to two hours are acceptable (British Frozen Food Federation, 2014, pers.comm.).

Evidence does however suggest that significant energy savings can be realised without the need for such investments. Star Technology Solutions, a UK cooling systems supplier, participated in a study for the UK's Food Storage and Distribution Federation in which thirty facilities were visited to check for opportunities to improve energy efficiency. Most facilities could improve energy efficiency by up to 15% through such simple free or low cost measures as adjusting set points, timers, compressors or calibrating the duty sensors. The payback for some of these measures was immediate. In general, if the equipment has not been serviced in four or five years a servicing visit is likely to yield these savings. In cases where equipment needs to be replaced – perhaps as a result of the Montreal Protocol[21] – the difference in efficiency could be as high as 20-40% with paybacks of 3 to 18 months.

Driving force for implementation

Perhaps the greatest driver of change in the sector has been the much anticipated, and recently confirmed, EU rules for a 'fast phase-down' of HFCs (also known as 'F-gases') in new air conditioning and refrigeration equipment. The global warming potential (GWP) of F-gases are up to 23000 times greater than equivalent amounts of carbon dioxide. The new regulations, already informally agreed by EU ministers, will reduce the use of F-gases by 79% by 2030 (ClickGreen, 2014). From 2022, the servicing of equipment using F-gases will be prohibited. So, although the refrigerants themselves will not be banned immediately, if a leak occurred the machine could not be serviced. Many frontrunners who want to avoid the risk of a leak are already switching from F-gases to natural refrigerants.

Corporate responsibility may also be a factor. For instance, **Nestlé**'s decision to switch to natural refrigerants for all new factory process refrigeration equipment was part of a global commitment to reduce the environmental impact of its operations (Star Refrigeration, 2010). Although relating to point-of-sale, rather than manufacture, the 'Refrigerants, Naturally!' initiative should also be considered. Launched by **The Coca-Cola Enterprise**, **Unilever** and **McDonald's** and now including **PepsiCo**, the initiative promotes a shift to alternative HFC-free solutions for cooling technology that protect both the climate and the ozone layer (FoodDrinkEurope, 2012).

The use of more efficient cooling equipment is also driven by the need to cut costs. With energy costs rising inexorably, any opportunities to improve efficiency will be seized. However, an important caveat should be made here. While frontrunner manufacturers will invest in a certain amount of freezing and refrigeration equipment on site in order to protect the life of recently-

[21] Entering into force in 1989 and amended over subsequent years, the Montreal Protocol on Substances that Deplete the Ozone Layer is designed to reduce the production and consumption of ozone-depleting substances, notably chlorofluorocarbons (CFCs) widely used as refrigerants, in order to reduce their abundance in the atmosphere, and thereby to protect the earth's ozone layer. Under the Protocol, the removal of equipment using banned substances is staggered over several decades. More information is available here: http://ozone.unep.org/new_site/en/montreal_protocol.php.

manufactured products or frequently used ingredients, the principles of lean manufacturing favour minimisation of inventory (i.e. on-site storage). For this reason, frontrunners (or their retailer customers) will typically contract out the transport and storage of products to separate specialist companies. A manufacturer may run a cold store with a capacity of perhaps 500 pallets (e.g. **Aunt Bessie's** Yorkshire Puddings in the UK), but a specialist cold store may house 30000 pallets or more (e.g. **Reed Bordall** for frozen goods in the UK) (British Frozen Food Federation, 2014, pers.comm.). Due to the huge energy consumption of such operations, anecdotal evidence suggests that it is generally these contractors rather than manufacturers who are driving improvements (British Frozen Food Federation, 2014, pers.comm.).

Another important consideration relates to the scheduled upgrades of cooling equipment. Given the high capital cost of new cooling plants manufacturers are unlikely to replace recently installed machinery. But many cold stores in the industry are very old (up to 30 years old) so the need to install newer and more reliable equipment – and often to demolish the building and 'start again' - is a common pretext, if not a motivating factor, for upgrading to the latest technologies (British Frozen Food Federation, 2014, pers.comm.).

Reference organisations

- Arla – switch to an ammonia refrigeration system
- Coca-Cola Enterprise – introduction of a leak-free warranty
- Daniel Thwaites – installation of a reciprocating compressor using ammonia
- GICB winery – installation of an absorption chiller
- Illy – recovering heat from its coffee roasters for use in its plant heating system
- Mack – installing transcritical CO_2 chillers
- McDonald's – part of the 'Refrigerants, Naturally!' initiative
- Milka, part of Mondelēz International – switch to an ammonia refrigeration system
- Mlekpol – switch to an ammonia refrigeration system
- Nestlé – switch to an ammonia refrigeration system
- PepsiCo – part of the 'Refrigerants, Naturally!' initiative
- Salcheto Winery – installed a geothermal cooling system for chilling its cellar
- Unilever – switch to an ammonia refrigeration system
- Vlevico, part of the Colruyt group – switch to an ammonia refrigeration system

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3.8. Deploying energy management and energy efficiency throughout all operations

Description

Like all process-based industries, energy represents for food and drink manufacturing businesses both a significant expenditure item and a large driver of environmental impacts. The initial steps in developing an effective energy management strategy involve assessing the drivers of an organisation's energy consumption, monitoring its energy usage, and identifying areas for improvement. Actions will then be deployed to reduce energy demand (through energy efficiency measures) and reduce the impact of energy supply (cf. BEMP 3.9 on "Integrating renewable energy in the manufacturing processes").

Food and drink processing in particular tends to be especially energy-intensive, with energy costs among the top cost items due mainly to the precise temperature-controlled processes specific to the industry (baking, boiling, freezing, sterilisation, etc.). However, a holistic investigation of the energy flows throughout a facility can help achieve significant savings in energy resulting in both cost and GHG emission improvements.

This cross-cutting BEMP does not aim to develop specific process solutions relevant to individual sub-sectors (some of which are developed later in the document) but rather to outline the range of energy efficiency solutions which should be investigated to achieve best practice. Further documentation, both overarching and sector specific, can be found in the references. Please note that techniques related to refrigeration are addressed specifically in BEMP 3.7.

It is also worth noting that non-process-specific energy efficiency solutions (e.g. for offices) can also be found in related reference documents, for instance the Sectoral Reference Document on Best Environmental Management Practice for Public Administration[22] (BEMPs on energy in sustainable offices).

Best practice in the area of energy management and efficiency can therefore centre on:

- putting in place a comprehensive energy management system (EnMS) such as ISO 50001, as part of an environmental management system such as EMAS
- installing meters (or smart meters) at single process level, ensuring accurate energy monitoring
- carrying out regular energy auditing and monitoring to identify the main drivers of energy consumption (at process level);
- implementing appropriate energy efficiency solutions for all processes in a facility, in particular taking into account potential synergies in heat/cold/steam demand;.
- investigating and, if possible, exploiting synergies for the production and use of electricity/heat/cold/steam with neighbouring facilities (industrial symbiosis).

[22] http://susproc.jrc.ec.europa.eu/activities/emas/public_admin.html

The table below provides an example of common processes in use in the industry and some potential energy efficiency solutions which can be applied to these:

Table 3.34: Some food and drink processes and relevant applicable energy efficiency solutions

Energy efficiency solutions / **Processes**	Monitoring, measurement and control	Energy efficient installation (e.g. condensing boiler)	Co- / tri- generation	Compressed air optimisation	Insulation	Heat recovery (e.g. heat exchangers)	Efficient lighting (motion sensors, LEDs)	Electric drives and motors
Baking / drying	√	√	√		√	√		
Cooking / boiling / sterilisation	√	√	√		√	√		
[Refrigeration / freezing]*	√		√		√	√		
Cutting/ slicing/ mincing etc.	√			√			√	√
Canning/jarring / packaging	√			√			√	√
Maceration / kneading / fermentation	√		√	√	√	√		√
Storage	√	√	√		√		√	√

*NB refrigeration / freezing are addressed in more detail in BEMP 3.7

Achieved environmental benefits

Reducing energy consumption has a number of beneficial environmental impacts, especially in the most common case where energy demand is met with fossil sources. It helps reduce the upstream emissions of greenhouse gases and air pollutants associated with fossil energy extraction and transport, but also reduces direct emissions on the premises, potentially improving local environmental and working conditions.

Appropriate environmental indicators

Global indicators for the improvement of energy usage can be considered, for instance:

- Overall energy use per unit, weight or volume of output product (e.g. annual kWh / tonne output product).
- Overall energy use per facility space (kWh / m^2 of productive facility).
- Net energy use per unit, weight or volume of output product (e.g. annual kWh / tonne output product) i.e. overall minus recovered and renewable energy.

In addition, specific indicators can also be relevant, with appropriate metering, such as:

- Energy use for specific processes (e.g annual kWh used in baking or boiling).

Qualitative indicators can also be relevant, e.g.:

- Deployment of heat exchangers to recover hot / cold streams .
- Insulation of all steam pipes.

Cross-media effects

The replacement of obsolete (inefficient/poorly insulated/ill-dimensioned etc.) equipment generates waste and the embodied emissions/energy of manufacturing and installing the replacement equipment also add to environmental impact of implementing some energy efficiency solutions. Therefore these should be considered in a more global strategy relating to the lifetime of production equipment.

Operational data

[Detailed examples are not provided in this BEMP but are available for specific processes. For instance, the Carbon Trust reference guide for energy efficiency in the food and drink industry provides concrete measures to be applied in the fields of Refrigeration, Process measurement and control, Compressed air, Motors and drives, Boilers and heat distribution, Cooking, Distillation, Drying and evaporation, and Energy management.

Case studies for the food and drink sector are available from the Australia energy efficiency exchange, along with information on for example:

Optimising the use of existing equipment in manufacturing
- install effective metering and monitoring to improve data analysis;
- ensure effective shutdown procedures to minimise energy overheads;
- optimise operating temperatures and pressures of equipment and processes;
- minimise heat gain in refrigeration systems and refrigerated spaces;
- minimise heat loss from boiler systems, cooking equipment and pasteurisers;
- maintain existing equipment.

Investing in process innovation and equipment upgrades:
- recover and reuse waste heat;
- purchase more energy efficient equipment and ensure it is correctly sized;
- use lower energy alternatives to create heat/steam;
- consider pasteurisation alternatives;
- using staged cooling.

Applicability

Energy efficiency solutions can be deployed in all facilities, from incremental to in-depth refurbishments. Regular walk-rounds are also recommended to identify new sources of energy waste even in facilities that have already been optimised.

Economics

Energy efficiency in all sectors is the area for environmental improvement with the most attractive business case, as energy savings result directly in lower energy bills as well as a hedge against future energy price increases.

Cost savings are in line with the energy saved with incremental measures delivering quick savings of over 5-10% while more transformational changes will deliver cost savings of 20-30% or up to 50% of the whole energy bill.

On individual cost items, the saving can be even higher (50-90%), e.g. recovery of waste heat to generate steam can altogether obliterate the need for a boiler.

Driving force for implementation

As mentioned above, the drivers for energy efficiency are numerous, they include:

- cutting energy costs;
- cutting greenhouse gas emissions (which may also be associated with specific taxes/levies/permits);
- cutting pollutant emissions;
- improving process efficiency;
- improving working conditions and staff engagement;
- improving public image.

Reference literature

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- Sectoral Reference Document on Best Environmental Management Practice in the Public Administration Sector, and supporting Best Practice report (forthcoming)

3.9. Integrating renewable energy in the manufacturing processes

Description

On-site and nearby generation of renewable energy can be integrated into the production processes of food and beverage manufacturing. The main renewable sources of energy can be divided into:

- Biomass – it can be used for the production of heat or in the combined production of heat and power
- Biogas generated from suitable organic material – it can be employed for generating heat and power.
- Solar thermal systems – they directly generate heat.
- On-site and nearby photovoltaic (PV), small scale wind turbines and other available renewable sources of energy – they can generate on-site electricity

Generation of electricity from renewable sources is already practised and relies on exploiting the locally available renewable energy source to partially or totally meet the electricity demand of the food and beverage manufacturers. The integration of renewable electricity into the existing energy supply is well established and it can be employed directly during the manufacturing of food and beverages, while the excess from production can instead be fed into the electric networks (e.g. national) under certain conditions.

Meanwhile, the integration of renewable heat into the production processes instead is in development but it has large potential in several subsectors of the food and beverage manufacturing sector as its integration is technically state of the art (wherever there is a heating demand, e.g. in beer, wine and cheese manufacturing). Depending on the sector (i.e. the amount of heat and the temperature needed) the renewable heat system (such as solar thermal) can be integrated differently. Firstly, as already highlighted in BEMP 3.8, food and beverage manufacturers can identify where the reduction of heating demand by innovative low-energy technologies and the recovery of waste heat (heat integration) can be achieved. Secondly, in order to meet the heat demand which cannot be covered by waste heat, food and beverage manufacturers can employ renewable heat. To do so, they can identify which processes can be fed with renewable heat, replacing which non-renewable energy source and with which renewable heat technology, according to different temperature needs. PV electrical heating is one renewable heat option (e.g. solar). However, this option is associated with low efficiency (about 15%) compared to the solar heating systems which have an efficiency of about 60%. Therefore, PV electrical heating cannot be considered an alternative to solar heating.

Renewable heat can be generated from solar heating systems, biomass or biogas. The choice of the source of renewable heat is made depending on the local conditions, whether locally produced biomass and suitable feedstock for biogas production are available and/ or if annual solar radiation is considerable.

Renewable solar heating systems

Figure 3.23 shows how a solar heating system can be integrated into a general production process, and is also applicable for food and beverage manufacturing. There are two main options (Muster-Slawitsch *et al., 2014).*

A) Integration at supply level: when high-temperature water networks or steam networks are present, even if the temperature needed at the point of use is considerably lower, the solar heat can be used for heating water at different points of the heat supply system:

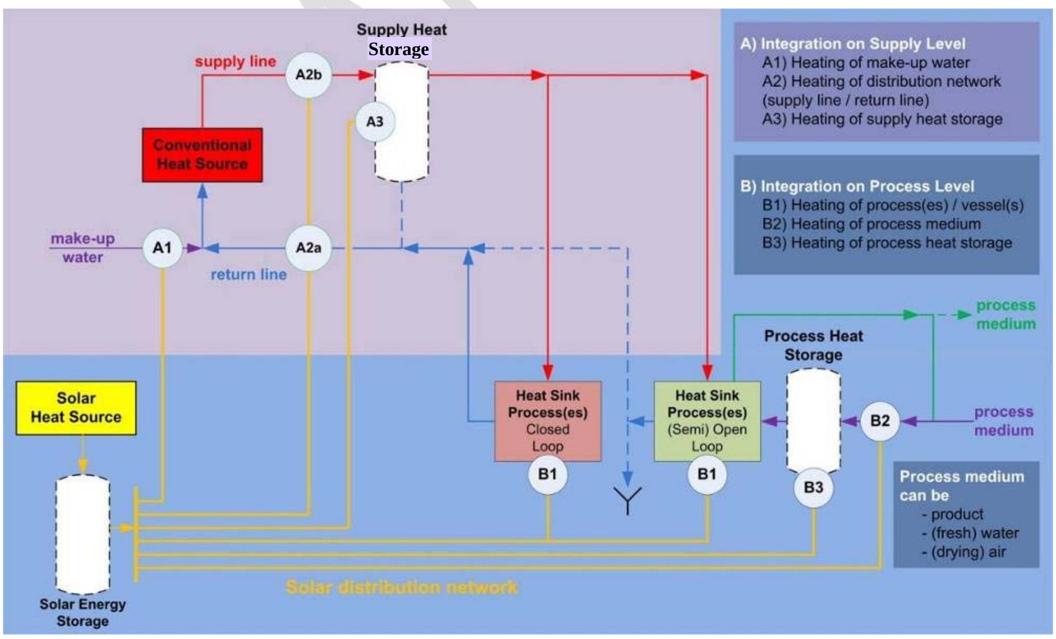
- *Heating feed water in an open or partially open heating system:* In the case of open steam systems, the solar thermal system can be integrated just by adding one single heat exchanger to pre-heat cold demineralised replenishing water before process steam generation.

  In the case of partially open steam networks, the demineralised replenishing (make-up) water is usually mixed with the returning condensate before its degasification with steam, before it can enter the steam boiler. In this way, also less steam is required for degasification of the boiler feed water.

- *Heating feed water in a closed heating system:* The integration of solar heat in closed systems needs other solar technologies (e.g. concentrated, evacuated solar heating systems) because of the high temperatures of the condensate return flow.

B) Integration at process level: In this case, solar heat is used directly in process operations, process media or process heat storage.

Figure 3.23: Integration of solar heating into the industry at the process or supply level



*Source: (*Muster-Slawitsch *et al., 2014)*

The integration of solar heating in a production plant requires two main systems:

Solar thermal collectors

For temperatures below 100°C, the simplest design is the *flat-plate collector* depending on the location of production. The absorbers are black painted metal (copper, aluminium, steel) or plastic plates with a transparent cover placed on the collectors in order to reduce the convection heat losses. In areas where freezing temperatures are reached, a water/glycol mixture with anticorrosion additives is usually used as the heat-carrying fluid. In Europe, this type of collector is typically for hot water solar heating systems.

For temperatures above 100°C, *evacuated tube collectors or concentrating collectors* have been developed. Evacuated tube-collectors achieve a superior performance because the vacuum surrounding the absorber drastically cuts heat losses to the atmosphere. Outlet temperatures above 100°C are easily achieved with a higher conversion efficiency compared with a standard flat-plate collector (AEE INTEC, 2008).

Thermal storage

Thermal storage is generally required when the load profiles of heat availability and demand are different due to the fact that heat supply does not always meet heat demand or there is a need to store the excess heat provided by the solar heating system. The need for thermal storage in solar hot water systems is often short-term and, for this, water tank storage technology is mature and reliable. Thermal storage can also accumulate waste heat generated in certain production processes which can then be employed at a later stage.

The water storage tanks' capacity is calculated according to the supply and demand requirements and storage temperatures.

<u>Renewable heat from biomass</u>

In addition to solar heating systems, another source of renewable heat is biomass in the form of forest residues or waste streams from production. When biomass is available (e.g. in wineries which can use the pruning residues from the vineyard or in a food and beverage production site where forestry residues are easily available), renewable heat can be obtained from the combustion (in a grate furnace or fluidised bed) of the biomass in a heating or CHP system. Depending on the technology used, hot water or steam can be produced and integrated at different levels of the food and beverage production process, as for the heat produced by solar heating systems.

When a food and beverage manufacturer installs a biomass combustion plant, there are two technologies that can be used for the combustion process: fixed bed (including grate furnaces and underfeed stokers) or fludised bed (Van Loo et al., 2012). The choice is based on the type of fuel and nominal capacity of the system. The following main elements are included in a biomass plant:

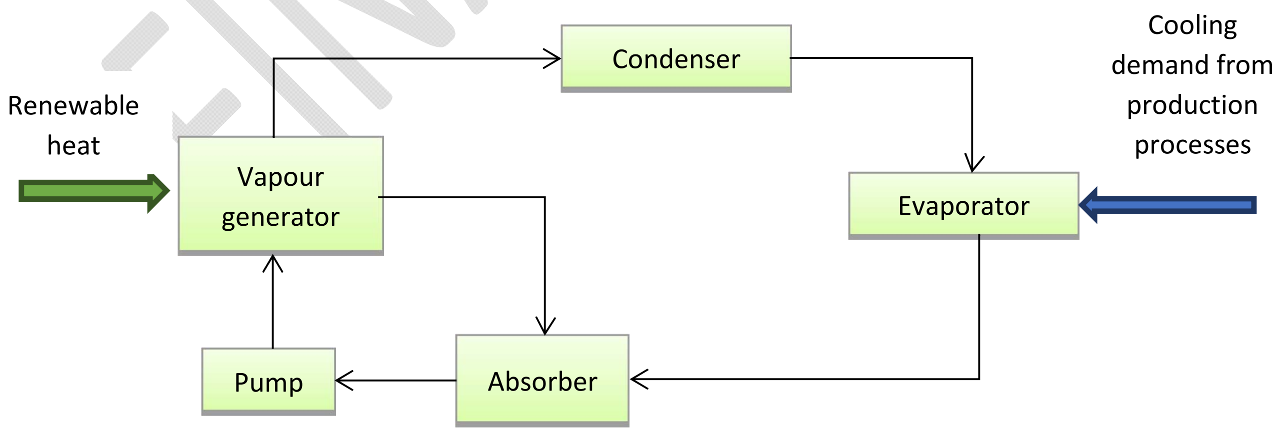
- Biomass storage area.
- Feeder: a conveyor system which feeds the furnace.
- Furnace: the furnace is the key element of the whole system and it should ensure proper biomass combustion. Its design affects the system efficiency and the characteristics of the biomass which can be used.
- Boiler: it should ensure an efficient exploitation of the radiant heat by the generation of hot water/steam. The boiler should be insulated to minimise undesirable heat losses and heat recovery systems can also be installed.
- Flue-gas cleaning system: the aim of the system is to reduce gaseous emissions and pollutants and particles emitted from the combustion.
- Ash disposal system.

Another option for employing biomass is the generation of biogas from suitable feedstock (e.g. citrus waste as presented in BEMP 9.4.1). Food and beverage manufacturers can use suitable organic residues from their production processes (solid waste and waste water) or from nearby sources to produce biogas in an anaerobic digestion plant. Gas produced can then be burned in a gas turbine for the generation of electricity and heat.

<u>Renewable cold production</u>

In some cases, when food and beverage manufacturing necessitates cooling, renewable heat (from solar, biomass or biogas or waste heat streams) can be used in an absorption process able to meet a part or all of the cooling demand of the process. An absorption process consists mainly of an evaporator, an absorber, a generator and a condenser and can use refrigerants such as NH_3 or CO_2 or combinations like NH_3/H_20 or $H_2O/LiBr$. A simplified scheme of the absorption process is presented in Figure 3.24.

Figure 3.24: Refrigeration by absorption process to meet cooling demand



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Achieved environmental benefits

The use of renewable energies for production processes primarily replaces fossil fuels (e.g. natural gas or coal), therefore emissions to air generated during their combustion are reduced.

In the case of solar heating, the efficiency is affected by the energy yield of the solar heating systems, which depends on its geographical location, the season and meteorological conditions, but also on the technology of the solar heating system. The solar radiation on the earth's surface has seasonal variations, which can be 1:2 in the tropics and up to 1:10 in the higher latitudes (IEA, 2010).

Appropriate environmental indicators

The main environmental indicator is the energy provided by renewable energy sources (on-site and off-site heat and electricity), measured as kWh/y, compared to the total energy demand, expressed as percentage. In the same way, another meaningful indicator is the percentage of production energy demand (heat and electricity) met by on-site or nearby renewable energy sources.

Energy provided by renewable energy sources can also be divided into electricity and heat and compared to the plant demand for electricity and heat, respectively. Moreover, the same analyses on the amount of energy provided by renewable sources can be performed at both process and plant level.

Another indicator could be the amount of CO_2 fossil fuel emissions (kg CO_2) saved by the use of renewable energy sources for the production processes.

Cross-media effects

There is no environmental cross media effect from implementing the use of renewable energy sources in the food and beverage production processes. For instance, the life-cycle environmental impact of solar thermal systems calculated in several studies is low, especially if collectors are constructed with recyclable materials. Ardente et al. (2005) calculated the energy and CO_2 payback times of solar thermal systems. These indicators resulted in very short payback times (less than two years) showing the great environmental convenience of this technology. Pehnt (2006) shows that the inputs of finite energy resources and emissions of greenhouse gases are extremely low compared with the conventional system. LCA results for renewable energy systems reveal that the use made of the material resources investigated (iron ore, bauxite) is less than or similar to that made by conventional systems.

Operational data

The use of renewable heat in the food and beverage manufacturing sector can have many different applications, as seen in the description section. Every organisation in the sector should assess the availability of on-site and nearby renewable energies, exploit them and integrate heat and electricity production into the production processes. Examples provided in this section are non-exhaustive and present some of the many options available.

<u>Wine manufacturing</u>

Wineries use energy for different purposes during the winemaking process as well as for HVAC, lighting and cleaning operations. Most of the equipment involved in wine production (for de-stemming, crushing, presses, clarification and bottling processes) is directly or indirectly powered by electricity. Thus, a large percentage of the electricity used in winemaking is needed for cooling, compressed air, pumping and mechanical equipment. However, fossil fuels (e.g. natural gas) can be used in wineries for combined heat, power and cooling (CHCP) systems to supply the different processes.

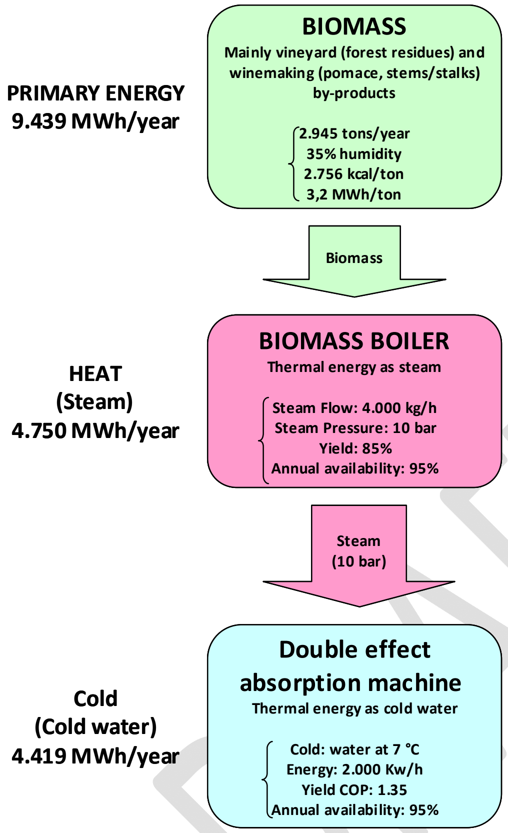
Vineyards cover a wide land surface and their annual pruning generates a large amount of lignocellulosic biomass. Moreover, wineries also generate large amounts of solid organic waste (mainly grape pomace and grape stalks) that has similar characteristics to wood biomass (Marculescu and Ciuta, 2013; Spinelli et al., 2012). Vineyard pruning waste can also be used as biomass in appropriate CHCP systems instead of being comminuted and used as compost or fertiliser. In fact, pruning residues may not be a good fertiliser because of the slow biodegradation (due to the lignin content) and the residues of the phytosanitary treatments carried out in the vineyard. However, the biomass plant should not be located far away from the vineyards where the pruning residues are collected for combustion (Mescalchin et al., 2009).

Many studies that show the techno-economic viability of using biomass from vineyards and wineries as a renewable energy source were published in recent years (Celma et al., 2007; Fernández et al., 2012; Gómez et al., 2010; Marculescu and Ciuta, 2013; Spinelli et al., 2012; Tecnolimpia, 2009 and 2010; Toscano et al., 2013; Velázquez-Martí et al., 2011).

In this context, the energy coming from the biomass of the wine sector is mainly obtained by direct combustion of vineyard pruning residues, grape pomace and grape stalks (Celma et al., 2007; Gómez et al., 2010; Marculescu and Ciuta, 2013; Tecnolimpia, 2009; Toscano et al., 2013). Calorific value is relatively constant among the different biomass sources generated in the vineyard. In fact, the biomass calorific value is around 2900 kcal/kg for grape stalk residues, 3250 kcal/kg for pruning residues, and up to 3500 kcal/kg for grape pomace (Tecnolimpia, 2009).

The use of electricity in those processes needing cooling, such as fermentation and storage, can be avoided or reduced thanks to the introduction of an absorption chiller system which uses the heat generated from biomass. Figure 3.25 presents an example of cold production from biomass in a winery.

Figure 3.25: Example of heat and cold production using biomass coming vineyards and wineries



Source: Miguel Torres S.A. Adapted by the Andalusian Institute of Technology (IAT), 2013.

A wide range of configurations (from small systems to large ones) can be found for wine producers. Operational data are thus conditioned by the winery requirements and the design of both systems (biomass combustion plant and absorption chiller).

Tables 3.35 and 3.36 summarise the main operational data of two examples of wineries using biomass for heat and cold production:

Table 3.35: Examples of the main operational data of two different biomass systems

	Parameter	Explanation	Example 1[1]	Example 2[2]
Biomass	*Size*	Maximum admissible size of biomass (mm).	180x30x30 mm	< 80 mm
	Lower heating value (LHV)	Energy content of the biomass on a dry basis, (kWh/kg).	2.3-4.7 kWh/kg	4.8 kWh/kg (approx.)

	Parameter	Explanation	Example 1[1]	Example 2[2]
	Moisture	Total water content based on total weight (%).	10-50 %	>30 %
	Ash	Total ash content based on total weight (%).	<3%	2%
	Density of biomass	Weight of biomass per unit of volume (kg/m^3)	170-300 kg/m^3	250 kg/m^3
Biomass boiler	*Thermal power*	(kW)	2,628 kW	600 kW
	Energy	Thermal output generated	Steam	Heat Steam
	Efficiency	Thermal energy generated from biomass (%) over the total thermal energy demand	83 %	90 %

Sources: [1]: MIGUEL TORRES SA, 2013; L.SOLÉ S.A, 2013; [2]: Cotana and Cavalaglio, 2008; Cotana et al., 2009.

Table 3.36: Examples of the main operational data of two different absorption chillers

	Parameter	Explanation[1]	Example 1[1]	Example 2[2]
Absorption Chiller	*Power*	Energy produced (kW)	2,000 kW	19 KW
	Warm fluid	Fluid that provides the energy needed for cooling.	Steam	Diathermic oil

	Parameter	Explanation[1]	Example 1[1]	Example 2[2]
	Coefficient of performance (COP)	Index of the efficiency of the chiller: cooling capacity obtained in the evaporator divided by the net heat input.	1.40	-
	Refrigerant	Cooling fluid	Water/Lithium bromide	Ammonia /Water
	Absorbent	Medium that absorbs the refrigerant vapour-releasing heat.	Water	Water

Source: [1]MIGUEL TORRES SA pers. comm., 2013; L.SOLÉ S.A, 2013; [2]: Cotana et al., 2009.

<u>Cheese production</u>

Cheese production relies on heat for several operations, mainly:

- Pasteurisation;
- Cleaning;
- Sterilisation;
- washing of materials (cans, crates, etc.);
- fermentation (including whey pre-heating);
- degreasing.

Renewable heat in the production process can be integrated in different ways as presented in Figure 3.22.

Lesa Dairy, a Swiss company based in Bever, installed parabolic collectors (using thermo-oil as heat transfer fluid) with a thermal power of 67kW (yearly average renewable heat generation of 60MWh). The system generates steam at 4-6 bar which is then injected into the steam supply network of the plant (option A2b in Figure 3.22). The remaining heat demand for steam is met by steam generated from fossil fuel combustion. The renewable heat generated allows 5% of the annual heat demand of the factory to be met (SHIP, 2014).

Emmi Dairy in Saignelégier is another Swiss company which installed parabolic collectors to integrate their heat demand with renewable solar heat. The installed thermal power is 360kW, the system also includes a 15m^{3}storage tank and the solar heat is transferred via a 360kW heat plate heat exchanger and then to either one of two integration points: (a) To the supply side (option A3

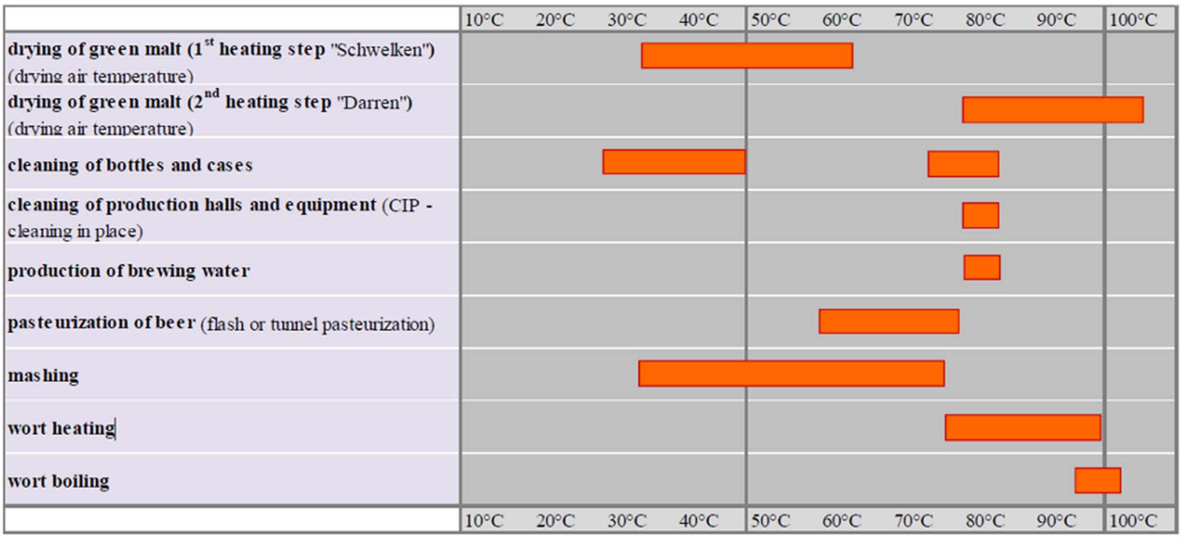
Figure 3.22), into an existing 15m^3 supply heat storage vessel as long as the storage remains above 25% charged (boiler switched off) (b) To the return line to the hot water boiler when the storage goes below 25% and the boiler is switched on. The temperature of the solar loop ranges between 140°C and 180°C. In the Emmi Dairy plant, the renewable heat generated allows 15% of the heat demand of the plant to be met (SHIP, 2014).

Beer production

In the case of manufacturing of beer, solar heat can be integrated into the process. The total average energy required to brew one hectolitre of beer is 116.8 MJ (the average annual production of about 16000 hl per brewery surveyed), and it ranges from 70.6 MJ/hl to 234.1 MJ/hl (The Brewers of Europe, 2012). The brewing sector receives most of its energy from non-renewable sources but there is an increasing reliance on renewable energy (increase from 5% to 5.3% for the period 2008-2010) (The Brewers of Europe, 2012). The most commonly used renewable energy sources in breweries are biogas and solar. Biogas can be produced on site in breweries from wastewater and secondary products (such as the brewers grains), which makes breweries more self-sustainable while turning a valuable co-product into energy.

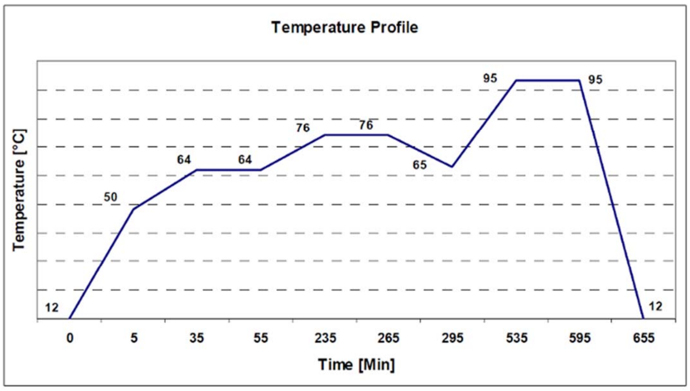
As is shown in Figures 3.26 and 3.27, the entire process heat demand in breweries can be met with heat at a temperature of between 25°C and 105°C at process level.

Figure 3.26: Thermal process and associated process temperatures in brewing and malt houses



Source: Brunner et al., 2008

Figure 3.27: Temperature profile for a typical brewing process during mashing and wort boiling



Source: AEE Intec, 2008

The main energy use in a brewhouse according to EC (2006) both in terms of electricity and heat consumption is illustrated in Table 3.37. The heat recovered when cooling hot wort to cellar temperature is commonly used to produce hot brew water. Vapour condensation from wort boiling is often used to cover the energy demand by preheating wort rather than storing the energy. In returnable bottle packaging the bottle washing and pasteurisation (flash or tunnel) are the most energy intensive processes. In non-returnable bottle filling lines pasteurization is usually the most energy-intensive process. In keg packaging the cleaning of kegs shows the largest hot water requirement and a large waste water stream at a significant temperature (Muster-Slawitsch et al. 2011).

Table 3.37: Energy use in a brewhouse (EC, 2006)

Energy use	Electrical power		Thermal energy	
	kWh/hl	kWh/bbl	kWh/hl	kWh/bbl
Wort production in brewhouse	0.84	1.0	10.2	12.2
Wort production (%)	10.4	10.4	36	36
Total consumption in brewery	8.1	9.7	28.3	33.7

These low-temperature heat demands can be met by using conventional or non-concentrating solar panels (flat-plate or evacuated tube collectors). Moreover, in southern European countries, where direct solar radiation is high, evacuated tube collectors can produce steam to be directly integrated into the production process. It should be mentioned that breweries increase their production in summer-time when more solar radiation is also available.

Muster-Slawitsch et al.. (2011) demonstrated that the potential for solar heat application in breweries is high, as all processes except conventional wort boiling run below 100 °C and flat-plate or vacuum tube collectors meet these temperature requirements. In particular, heating processes like CIP plants, bottle washing machines and pasteurisers may be operated by solar thermal energy, provided that the hot water demand is covered by the available waste heat. However the integration of solar heat at process level may require a substantial retrofit.

According to a pinch analysis in the breweries, based on the identification of the heating and cooling demand potential and following the theoretic potential of heat recovery, the solar thermal potential tends to be highest for the packaging area and the mashing process. Generally, if there is solar thermal energy available at the right temperature, the heat at process level is taken from the solar energy storage tank and pumped to the retrofitted plate heat exchangers. When the temperature in the energy storage tank is lower than the process return flow temperature, the storage is bypassed and the existing steam supply system acts in pararrel as a backup. Continuously running open processes with no mass or heat recovery, such as washing and cleaning operations, have the highest potential for the integration of solar thermal energy. However, recently, it has also been possible to fully feed the mashing process with renewable solar heat, thanks to optimisation of the equipment and the new design of the heat exchangers (Göss brewery – Austria).

According to the Solar Process Heat Project (SO-PRO, 2010) there are the following two as yet unapplied) possibilities to integrate solar heat into brewing industries:

- *Integration of solar heat in washing and cleaning operations*

  Washing and cleaning operations are open systems where contaminated cleaning water is spilled without heat recovery. In this case, the solar thermal system can be integrated easily via an additional heat exchanger to preheat cold water before it enters the hot water storage. For discontinuous load profiles, the storage volume should be large enough to buffer the solar gains at the weekends and support the process at times of low irradiation or at night.

- *Integration of solar heat in industrial baths or vessels*

  Solar thermal systems can be integrated into heat processes where material is heated in an industrial bath, as in the case of bottle washing or pasteurisation. The required water temperature in these baths is relatively low (≈ 65°C) and can be heated with a bath heat exchanger with inlet water at a higher temperature (70-90°C). The Solar thermal system heats the bath via the return flow. Energy produced by the solar thermal system is not usually enough to cover the thermal demand of the bath and therefore a boiler provides the necessary backup heat. When the solar irradiation is not sufficient and the buffer storage temperature is below 70 °C, a three-way valve enables the boiler to heat the bath directly without heating up the buffer storage tank.

  Recently, for the mashing process, it has also been possible to meet the heat demand only with renewable heat. Additional heat exchangers were added on the inside of the tun in order to optimise the efficiency of the system. Moreover, when the solar heat provided is insufficient, the district heating system fed by biomass provides heat in order to meet the demand (Mauthner et al., 2014).

A few examples are presented below regarding the best practices applied in breweries in Europe.

Göss Brewery – Austria

Taking heat requirements into account, attention was paid to the temperature levels used in the heat supply system. Therefore new solutions for the adaption and optimisation of the relevant machinery and processes to make them compatible with the characteristics of solar thermal heat production were essential for the installation in the Göss Brewery.

For example, the mashing tun has been heated by steam running through a heat exchanger on the outside of the mashing tun. Now for the integration of the solar thermal heat, to keep the same process speed, new heat exchanger plates have been added on the inside of the mashing tun. The new heat exchanger allows a hybrid energy supply for the mashing tun where, besides the solar thermal energy, the energy from the district heating system, supplied by a wood chip fired combined heat and power plant, can also be used for the heating of the mash. Moreover, the new internal heat exchangers are fed only with hot water instead of steam, providing all the heat required for mashing (AEE INTEC , 2013).

Large collectors were installed with a total collector area of 1,500 m^2, supplying the mashing process with 480 MWh of energy per year at a temperature of 90°C (Mauthner et al., 2014). Six new heat exchanger plates were installed in the mashing tun to ensure the desired heating time, allowing lower media-heating temperatures and ensuring the same process and product conditions.

Hütt Brewery – Germany

This brewery in Kassel (Germany) has integrated a solar heat system for the brewing process which began operation in May 2010. The solar thermal system consists of 155 m^2 flat-plate collectors which generate part of the thermal energy required for supplying hot water to a maximum of 90°C. The energy transfer medium is a mixture of water-glycol and the water is heated via an external plate heat exchanger. The temperature range solar loop is up to 95°C, and the temperature range process from 40 to 90°C. The energy is transferred to a 10 m^3 buffer storage tank. The annual useful solar heat delivery is 400 MWh/year.

The solar-heated brewing water is then fed into the drawdown tank when its fill level drops below a certain level. However, it can only be filled to 80% of its capacity; since this storage tank is additionally filled with hot water produced using heat recovered during the wort cooling process. Corresponding volumes are kept free during the production times from Sunday evening to Friday noon. The drawdown tank releases hot water to the displacement tank and also supplies the mashing process, which only requires relatively low temperatures of just under 60 °C. During production free periods, the drawdown tank is completely filled with solar heated brewing water. The conventional heat source is a steam boiler.

Source: (BINE, 2010)

Hofmühl Brewery GmbH – Germany

This brewery in Eichstätt is another case of integrating solar energy with process heat. In 2009 it installed a 735 m^2 solar collector surface area with compound parabolic concentrator (CPC) vacuum tube collectors and two patented 5.5 m^3 SLS® stratification buffer tanks connected in series. The system described heats the water up to 130°C.

The system supplies energy to various process stages that requires temperatures of up to 100°C (bottle cleaning, preheating of domestic and process water, and building heating) depending on the maximum water temperature reached in the storage tank. Once the water temperature in the storage tank reaches 110°C, hot water is first used to heat water to 90°C via heat exchanger for the bottle washer, later for domestic hot water at a range of 60-90°C and finally, if required, to space heating in a range 45-65°C. However, when temperature reached is between 50-80°C, then it is used only for heating domestic hot water.

The Hofmühl Brewery brews twice as much beer during the summer months, when more solar energy is available, than in winter. Furthermore, the Hofmühl Brewery has not installed large storage tanks given that most process stages are conducted at a relativly low temperature and the heat requirement is distributed fairly consistently throughout the day and week.

Source: (BINE, 2010)

Neumarkter Lammsbräu - Germany

This brewery and malt house is sited in Neumarkt. The plant, with a very long brewing tradition, produces approximately 70000 hl of beer and 75000 hl of non-alcoholic beverages per year. In 2008, the brewery integrated a solar heat system consistsing of a 72 m^2 (50 kW) field of single-glazed air solar collectors. In this case, solar energy is used to pre-heat ambient air for the drying process in the malt house.

Ambient air is used directly for drying so, no buffer storage is required and the utilisable temperature is favourable. The process requires temperatures of up to 60°C.

Source: (SO-PRO, 2010)

Neuwirth – Austria

This brewery located in Brodersdorf installed a 20 m^2 flat-plate collector and a storage tank of 0.85 m^3. Operation of the system started in 2006. The solar thermal energy is used for bottle washing, pasteurisation and sterilisation. The process temperature range is 50-95°C and the temperature range of the solar loop is 50-95°C.

Source: (AEE INTEC, 2013 pers. comm.)

Applicability

Renewable heat systems are applicable in new and existing food and beverage productions sites with a relevant heat demand. In the case of new plants, the integration of renewables can be part of the overall energy concept. Furthermore, the installation of the renewable heat systems should take into consideration factors such as heat and electricity demand, size of the available space for mounting solar panels/collectors (ground mounted/roof mounted), location of the company, solar collector technology or temperature at which the energy is needed (AEE INTEC, 2013 pers. comm.).

Technically there are no limitations regarding the implementation of renewable heat systems in food and beverage manufacturing. However, the technical feasibility should be analysed in each particular case, given that it will depend, among others, on existing boundary conditions, production process technology and heat distribution network characteristics (e.g. heat exchangers and hydraulic connections for solar heat). This is because it is highly recommended to carry out a preliminary analysis to assess the suitability of solar heat systems prior to decide if it is a possible option (SO-PRO project, 2010).

Preliminary analysis should include the analysis of existing boundary conditions to evaluate if there is any technical restriction (i.e. the available area for collectors or storage tanks, the distance from collector area to storage tanks, the distances from storage tanks to potential supported process, etc.). Moreover, the process characteristics and the heat distribution network should be analysed to determine the feasibility of coupling renewable heat systems with thermal processes and the compatibility with the heat distribution network. The technical suitability of renewable heat systems should also be considered when modifications in the production process, affecting either the thermal load or the load profile, or in the heat generation network are planned.

The applicability of renewable heat systems relies on the availability of the renewable energy source identified. For example, the choice of solar thermal collectors depends on the location of the production site as in southern European countries, for example, direct solar radiation is higher. There, concentrating collectors can achieve higher efficiencies while in central or northern European regions flat-plate or vacuum tube collectors are used.. However, solar heating systems can be combined with other heat sources available in the installations, as is the case of biomass CHP.

Economics

The economics of the renewable energy system are based on analyses of the installation costs and the energy generated. Therefore they depend on local conditions and the type of renewable energy source.

In the case of solar thermal systems, the economic analysis is presented below (SO-PRO project, 2010).

- *Investment cost:* The costs of solar thermal process heat installations (i.e. including planning, collectors, piping, buffer storage and heat exchanger) in Europe range from EUR 180 to EUR 500 per m^2, depending on the technical and country-specific factors. (SO-PRO project, 2010). Data from the Hütt Brewery mention an investment of around EUR 95500 in a 155 m^2 solar thermal system and 10 m^3 buffer storage tank, which amounts to around EUR 600 per m^2 of collector surface area. The Neumarkter Lammsbräu plant made an investment of around EUR 32000 in a 72 m^2 of single-glazed air solar collector, which amounts to around EUR 444 per m^2 of collector surface area (without storage tank).
    - *Maintenance cost:* The annual maintenance is approximately 2% of the total investment cost.
    - *Life-time:* Properly planned and maintained solar thermal systems can have a lifetime of more than 20-25 years (Comunidad de Madrid, 2010).

- *Cost of fuel avoided* considering the efficiency of the fuel heat system and the fuel price rising.
- *Financing*. In some EU countries there exist national and regional subsidy programmes for funding solar thermal investments.

Table 3.38 shows cost figures (low and high) of various solar heating systems in industrial processes in southern/central Europe

Table 3.38: Examples of cost range (low and high) for solar heating systems in industrial process.

	Unit	Low cost	High cost
Typical system price (installed)	*EUR/system*	175000	400000
Collector area	*m^2*	500	500
Effective system price	*EUR/m^2*	350	800
System O&M Cost	*%*	2	2
System O&M Cost during lifetime	*EUR/m^2*	140	320
Total cost- investment and O&M	*EUR/m^2*	490	1120
Expected life time of the system	*year*	20	20

Source: (ESTTP, 2012)

Driving force for implementation

The main driving force for integrating renewable energy systems into food and beverage manufacturing is the reduction in cost related with energy use in a scenario of continuous fuel price increases. Another related driving force is the reduction in CO_2 emissions, which allows the carbon footprint at corporate and product level to be reduced. Investments in solar energy improve the company's market image and can add value to certain special "green" products.

A third driving force is the increased security in energy supply achieved thanks to the use of renewable energies on site and nearby.

Reference organisations

- Miguel Torres S.A.: Winery which uses biomass for renewable heat and cold production.
- Lesa Dairy (Switzerland): Implemented solar heating system in their production process.
- Emmi Dairy (Switzerland): Implemented solar heating system in their production process.
- Göss Brewery (Austria): First solar brew relying only on renewable heat for mashing .
- Hütt Göss Brewery: Solar energy used to heat the cold brewing water from the supply tanks.

- Hofmühl Brewery: Supplies hot water to various process stages thanks to a solar heating system.

- Neumarkter Lammsbräu: Solar energy is used to preheat ambient air for the drying process in the malt house.

- Neuwith Brewery: The solar thermal energy is used for bottle washing, pasteurization and sterilization.

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3.10. Avoiding food waste in food and beverage manufacturing

Description

In 2010, it was estimated that 89 million tonnes of food are wasted each year in the EU-27, a figure which could rise to approximately 126 million tonnes by 2020 if no action is taken (Bio Intelligence Service, 2010). Manufacturing or processing accounts for 34.8 million tonnes or nearly 39% of the waste generated. Figure 3.28 shows the break down by country with over 50% (18.6 million tonnes) of the total food waste from manufacturing being generated in three countries, namely, Poland, the Netherlands and Italy.

Figure 3.28: Annual food waste generation in food and drink manufacturing in EU-27 Member States (Bio Intelligence Service, 2010).

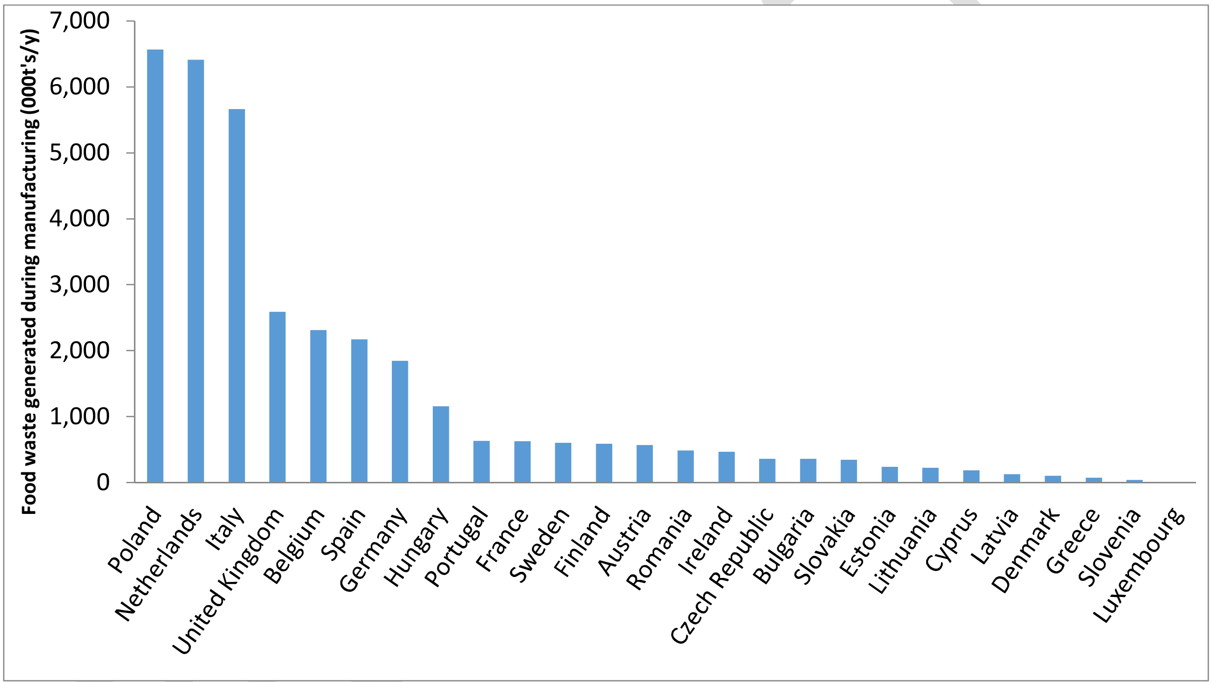

Figure 3.29 reports the food waste hierarchy and, in order to address food waste, avoiding or preventing its generation is the preferred option. This BEMP explores the of frontrunner food and beverage manufacturers to avoid or prevent the generation of food waste.

The food waste estimates shown in Figure 3.28 do not distinguish between avoidable and unavoidable waste. The actions detailed in this BEMP are focussed on those wastes that can be avoided or prevented. Food and Drink Europe describes these preventable wastes using the term 'food wastage' to refer to the decrease in edible food mass that was originally intended for human consumption (FoodDrinkEurope 2014a). The food waste generated at the production facility (unavoidable waste and avoidable waste) can be reduced by optimisation measures which include redistributing to people (e.g. charities, food bancks) the food which cannot be sold but is still edible, extracting valuable by-products for human consumption (e.g. essential oils, pectines, fibres from citrus and apple juice processing) while the remaining suitable part can be used as animal feed (Figure 3.28).

Figure 3.29: The food and drink material hierarchy (UNEP 2014)

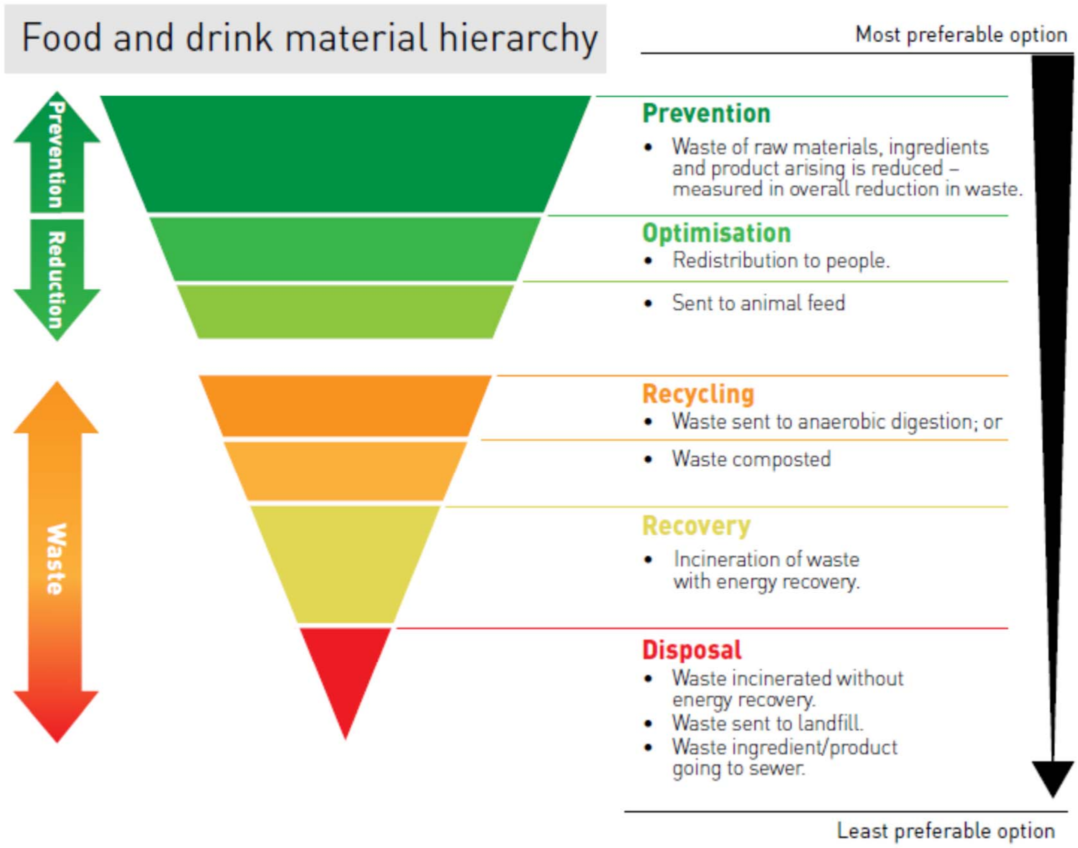

Table 3.39 shows an estimated breakdown of avoidable food waste in the Italian food industry. The total quantity wasted (1.89 million tonnes) is significantly lower than the 5.6 million tonnes shown for Italy in Figure 3.27. (Please note that the year of publication differs for the two datasets and hence no comparative calculations should be made).

Table 3.39: Estimates of waste in the Italian food industry, 2011 (Barilla 2012).

Industrial sector	Quantity produced (thousand t)	Quantity wasted (thousand t)	Quantity wasted (%)
Production, processing, and preservation of meat and meat products	6011	150	2.5
Production and preservation of fish and fish products	232	8	3.5
Production and preserving of fruits and vegetables	6215	279	4.5
Manufacture of vegetable and animal oils and fats	4894	73	1.5

Industrial sector	Quantity produced (thousand t)	Quantity wasted (thousand t)	Quantity wasted (%)
Dairy products and ice cream industry	13484	404	3
Production of grain and starch products	16390	245	1.5
Manufacture of other food products	11977	239	2
Drinks industry	24641	492	2
Total	83844	1890	2.6

Barilla (2012) reports that the main causes of production waste are technical malfunctions and inefficiencies in the production processes and cites the estimated value of the impact this has in Italy is EUR 1178 million per year.

In 2009, Informance International produced a benchmarking report that found that food and beverage manufacturers struggle most with equipment failures, but the best performing manufacturers can minimize those losses: Equipment failures represent 6% of capacity for the best performers versus 16% for the lowest quartile (Noria Corporation, 2009).

Frontrunner companies have implemented Continuous Improvement (CI) programmes to drive down food wastage using techniques such as:

- Total Productive Maintenance (TPM)
- Kaizen
- Value Stream Mapping (VSM)

Moreover, making public the food waste generated and the waste prevention activities in place and foreseen is a useful tool for companies to monitor, identify targets and promote their activities in this field. Public reporting of food waste can also increase companies' environmental reputation and raise consumers' awareness of food waste.

Total Productive Maintenance (TPM)

This involves engaging staff at all levels and functions to maximise the overall effectiveness of production equipment. Table 3.40 shows the six types of losses targeted by TPM. Overall Equipment Effectiveness (OEE) is typically used to measure and monitor the on-going performance of the system OEE is calculated by multiplying the following three elements:

- availability (percentage of planned time the equipment is operating),

- performance (actual throughput versus target throughput, as a percentage) and
- product quality rate (percentage of overall products that are not defects or defective).

Table 3.40: The six major losses that can result from poor maintenance, faulty equipment or inefficient operation.

Type of loss	**Costs to organisation**
Unexpected breakdown losses	Results in equipment downtime for repairs. Costs can include downtime (and lost production opportunity or yields), labour, and spare parts.
Set-up and adjustment losses	Results in lost production opportunity (yields) that occurs during product changeovers, shift change or other changes in operating conditions.
Stoppage losses	Results in frequent production downtime from zero to 10 minutes in length and which are difficult to record manually. As a result, these losses are usually hidden from efficiency reports and are built into machine capabilities but can cause substantial equipment downtime and lost production opportunity.
Speed losses	Results in productivity losses when equipment must be slowed down to prevent quality defects or minor stoppages. In most cases, this loss is not recorded because the equipment continues to operate.
Quality defect losses	Results in off-spec production and defects due to equipment malfunction or poor performance, leading to output which must be reworked or scrapped as waste.
Equipment and capital investment losses	Results in wear and tear on equipment that reduces its durability and productive life span, leading to more frequent capital investment in replacement equipment.

Source: USEPA 2014

Kaizen

Kaizen is the Japanese word for 'improvement', and a 'kaizen event' (also known as a 'kaizen burst' or 'blitz') is a focussed improvement project to cut waste from a specific part of the process. Given the short time-frame, the emphasis is on taking action rather than in-depth analysis of problems. Consequently, Kaizen is best suited to identifying and realising the savings that are typically classified as 'easy wins' or 'low hanging fruit'. The Kaizen philosophy focuses on continuous improvement through incremental change.

Value Stream Mapping (VSM)

Value Stream Mapping (VSM) forms a cornerstone of the lean philosophy where the focus is on the delivery of value to the customer. A definition of lean is (Defra 2012):

'Lean is a way of focusing on what the customer values and is willing to pay for; any activity that does not add to value, as perceived by the end customer, is waste. This waste includes any use of resources – cost, time, movement, material, energy, water, and labour'.

VSM provides a view of an entire process, helping those involved to recognise what is actually happening, to highlight sources of waste, and to plan future improvements. A value stream map is a high-level visual depiction of all the activities involved in delivering goods or services to the customer. Identifying the value stream will reveal those activities which are nont adding value adding (i.e. wasteful), and which can therefore be eliminated. VSM is often considered the most important first step towards the implementation of lean philosophy (Womack and Jones 2003), and can be extended beyond the boundaries of a specific company to entire supply chains. By understanding the relationships which exist within their supply chain, organisations can identify where effort should be focused to encourage further process improvements.

The types of interventions that can realise significant reductions in food waste include:

- Increased visibility of generated wastage quantities through waste audits.
- Moving from the traditional supplier 'push' to a customer 'pull' system to ensure that what is being produced is what the customer wants.
- Improved information flows across the whole supply chain. This is particular important in sales/demand forecasting for products with high demand or supply volatility and for promotions. Improved information flow across the supply chain can lead to food waste reduction e.g. through customer/supplier contractual arrangements aimed at matching supply/demand needs.
- Lower inventory storage time. This is key for short shelf life products or raw ingredients.
- Optimised production yields (i.e. through better training and communication of best practice, performance monitoring or process improvements).

Achieved environmental benefits

The prevention of food waste at the point of manufacture can generate significant environmental benefits throughout the supply chain. From a raw material perspective, less energy, water, etc. is required to produce products that are destined to become waste at the point of manufacture. In a similar way, transportation efficiencies can be improved by reducing the quantity of raw materials being transported that are destined to become waste. Likewise, the processing plant efficiencies will increase and there will be reductions in the quantity of waste that requires managing.

Table 3.41 provides an estimate of the additional environmental benefits that can be achieved by preventing food or drink waste at source rather than managing the waste through recovery, composting or landfill. For example, this shows that an average saving of 4,040 kgCO_2eq per tonne is achieved when moving from the landfilling of waste food to waste prevention.

Table 3.41: Net kgCO_2eq emitted per tonne of waste treated / disposed of (including avoided impacts) by method. (Source: WRAP 2012a)

Waste type	Prevention	Recovery (Combustion)	Recovery (anaerobic digestion)	Composting	Landfill
Food and drink	-3590	-89	-162	-39	450

Staff engagement

The food and drink industry is the largest employer in Europe accounting for 15.5% of total employment with 4.2 million staff (FoodDrinkEurope 2014b). Employee engagement and behaviour change are therefore key opportunities in terms of waste prevention initiatives. Some examples can be found below.

In 2007, **United Biscuits** developed a programme of employee engagement in waste reduction at all of its manufacturing sites resulting in an 18% reduction in food waste in the first eight months of 2008 (FDF 2008).

Similarly, **Greencore** worked in partnership with WRAP at one of their manufacturing sites in the UK and through an employee engagement programme delivered a reduction in annual food waste arisings of 950 tonnes or 12.6% (SA Partners 2013). Measures implemented included:

- Implementing a new process whereby tomato ends were used as diced tomatoes, reducing waste by 97.9 tonnes every year.
- Sending ham ends back for re-usage by suppliers, saving 13.1 tonnes every year.
- Developing methods to re-use sausage ends in stuffing saving 7.8 tonnes per year.

PepsiCo has reduced food losses at its UK sites by over 20% since 2009 (FoodDrinkEurope 2014b). This has been achieved through effective measurement systems, development of solutions to eliminate waste and strong engagement from employees.

Operations consultants Suiko undertook a Kaizen-like approach at **Fox's Biscuits**, where, through employee training, an increase from 74% to 85% in operation equipment effectiveness (OEE) was realised and factory waste was reduced by 26% (Defra 2012). This represents frontrunner performance since Gerresheimer, a German packaging company, measured OEE values on food and beverage production line of 30%- 63% (average 44%) (Gerresheimer, 2012).

Reporting on waste prevention

Businesses that report waste prevention activities in their annual accounts include **Greencore, Mondelēz** and **Unilever**. Table 3.42 shows that **Greencore** has reduced the overall tonnes of waste generated per tonne of product at its manufacturing sites by 3.4% between 2011/12 and 2012/13 (Greencore 2013). **Mondelēz** report that it has reduced net waste by 46% per tonne from 2010 to 2013 (Mondelēz 2013) and **Unilever** use a similar measure and report a reduction in total waste of 66% per tonne of production between 2008 and 2013 (Unilever 2013).

Table 3.42: Reduction of food waste generated per tonne of product at Greencore

Environmental indicator	2011/12	2012/2013	Year on year change
Tonnes of waste per tonne of product	0.153	0.148	-3.4%

Appropriate environmental indicators

The tonnage of food waste generated (sent for recycling, recovery and disposal in Figure 3.28, including food waste used as a source of energy or fertilising material) compared to the volume of finished products is a valid environmental performance indicator.

Additionally, the use of performance measures such as OEE can also be a suitable environmental performance indicator.

Cross-media effects

Moving to a just-in-time (JIT) process for procurement and delivery of raw materials to drive down inventory can result in a reduction in the delivery efficiencies to the production facilities and hence can have a significant impact on fuel consumption. This can be particularly significant for products that are not sourced locally.

The CO_2 emissions associated with different freight transport modes vary significantly. For example, a freight aircraft for intercontinental transport of goods emits 8509.68gCO_2/kg whereas, for a bulk sea vessel the impact is 599.82gCO_2/kg (ITC 2007). Consequently, there can be a trade-off between reducing procurement lead times to minimise wastage and the environmental impact of the transport.

Operational data

For many businesses that have engaged in food waste prevention initiatives without third-party funding the results are often considered to be commercially confidential since they wish to retain the perceived 'first mover advantage' (Defra 2012). Therefore, much of the publically available information on the subject is generated through waste reduction schemes funded by third-party organisations. For example, in 2009, WRAP conducted a performance improvement programme with leading grocery retailers and their trading partners in the UK (Table 3.43) aimed at reducing food and drink waste in the supply chain. The programme was designed to support signatories to the second phase of the Courtauld Commitment. Overall the programme prevented approximately 1,400 tonnes of waste arising as of March 2011, and a further 1193 tonnes were expected to be prevented in the financial year 2011-12. (WRAP 2013). For example, the changing of the timing of order placement on the Ready Meals project resulted in a 223 tonne per year reduction in waste.

Table 3.43: UK retailers involved in the WRAP programme for reducing food and drink waste

Category	**Companies**
Biscuits/snacks/cakes	United Biscuits and Musgrave
Floral	World Flowers and Sainsbury's
Ready meals	Kerry, Noon and Morrisons
Citrus	MM UK and Tesco
Salads	Natures Way Foods and Tesco
Sandwiches	Uniq and Marks & Spencer

Additionally, a review of 26 site waste prevention schemes undertaken in the UK food and drink manufacturing through a WRAP work programme 2010 to 2012) identified 11765 tonnes of food waste opportunities at an economic saving of EUR 8.57 million. The identified interventions included (WRAP 2012):

- Raising awareness. Can generate behavioural change with savings as high as 30% of total waste arisings.
- Review of product range (SKU rationalisation). Can reduce inventory losses by up to 35% and set-up losses by 20%.
- The introduction of Production Ready Packaging. Can reduce raw ingredient losses by up to 2% and 40% for the associated packaging.
- Reduction of raw material yield loss. Can reduce total raw material yield losses by 20%.
- Reduction of product yield loss. Can reduce yield losses by 5%.

- Prevention of overproduction. Can reduce product yield losses by 0.7%.

Applicability

The environmental indicator based on the decoupling of food waste from production volumes is best suited to businesses with a narrow range of products since any change in the product mix can have a significant impact on the results. Additionally, due to the diverse nature of the food industry where no two factories are likely to be exactly the same, it is often difficult/inappropriate to benchmark performance externally.

Economics

Many businesses simply focus on the purchase cost of the raw materials and the waste management costs as the two key savings opportunities in any food waste prevention initiative. However, the undertaking of a robust cost-benefit analysis exercise is key for fully understanding the business case and for maximising the savings potential from any food waste prevention intervention. The costs should include the resources (labour costs) for delivering the work and the hidden benefits should include the labour cost for producing the product to the point of rejection and handling of the waste, the embedded energy and water costs, etc. Quantifying the benefits in this way will ensure that the budget to develop the solution matches the savings opportunity.

For example, in the WRAP waste prevention reviews (WRAP 2012b) a study in a bakery found that the continuous improvement team focused only on the previous weeks major incidents of bread losses. Typical incidents involved major equipment failures that required engineering fixes. A detailed review of the data capturing system found that, in total, major incidents accounted for only 20% of total product losses. A review of total losses over a one-year period found that one issue (fallen stacks of bread) accounted for 20% of total losses, equating to a six-figure financial loss. Knowing the full value of the savings opportunity provided the budget guide for the development of the solution. A solution was developed with a payback of less than three months.

WRAP estimates that the savings that can be made through the prevention of food waste at the manufacture stage is GBP 950 (EUR 1215) per tonne (WRAP 2013a). Typically free or low-cost interventions will be available, i.e. the 'low-hanging fruit' and hence these benefits can be realised at very little cost.

Conversely, many of the lean-type interventions are undertaken by external consultants and Table 3.44 presents costs quoted by Enterprise Ireland (2011) for implementing different levels of lean philosophy.

Table 3.44: Scope and scale of Lean implementation at various levels (Enterprise Ireland 2011)

	Project summary	Key outcomes	Duration	Project cost (EUR)
Lean: Start	Short, cost-reduction project delivered by external Lean provider. Introduction of basic Lean principles and techniques.	Cost reduction targets achieved. Lean approach successfully piloted; Foundation for further Lean or productivity project.	Typically 8-12 weeks	6,300
Lean: Plus	Medium-scale business improvement project(s) delivered by external Lean provider. Significant learning and use by company of Lean techniques, and/or other proven business process improvement methodology which can deliver cost reduction	Significant productivity improvement targets achieved; Embedding of business improvement culture and lean techniques; Support of trained staff; Programme to pursue company-wide improvement.	Typically 30 day assignment days over 6-9 month period	Up to 75000
Lean: Transform	Holistic company transformation programme by external consultancy team.	Company-wide transformation in culture and performance; Business improvement and productivity targets achieved; Sustainable continuous improvement programme established across the business and its supply chain.	1-2 years	Over 100000

Driving force for implementation
The drivers for this BEMP include:

- Cost savings. As stressed previously, Barilla (2012) reports that the main causes of production waste are technical malfunctions and inefficiencies in the production processes and cites the estimated value of the impact this has in Italy at EUR 1178 million per year. Additionally, in the UK WRAP estimates the savings from the prevention of one tonne of food waste at EUR 1215.

- Supply chain pressure especially from consumers and retailers. CSR reports produced by food manufacturers now include the company's performance on waste prevention. For example, the aforementioned environmental performance indicators introduced by Greencore, Unilever and Mondelēz.

- Voluntary agreements – e.g. the **Courtauld Commitment** in the UK. This is a means of putting peer pressure on companies to commit to waste prevention.

- Anticipation of stricter waste legislation

Reference organisations
The reference organisations fall under two main categories: those that have implemented a food waste prevention initiative involving employee engagement and those that have introduced relevant environmental performance indicators associated with waste prevention.

Employee engagement initiatives:

- Fox's Biscuits
- Greencore
- PepsiCo
- United Biscuits

Introduced environmental indicators:

- Greencore
- Unilever
- Mondelēz

Reference literature

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3.11. Link to the Reference Document on Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF)

It is BEMP for all food and beverage manufacturers (NACE codes 10 and 11) to implement the relevant best available techniques (BAT) and consider the relevant emerging techniques presented in the "Reference Document on Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF)"[23].

It is BEMP to aim for the most demanding end of the Best Available Techniques-Associated Emission (or Environmental Performance) Levels (BAT-AE(P)Ls).

The appropriate environmental performance indicators are:

- Relevant BAT are implemented (Y/N).
- Relevant emerging techniques are implemented (Y/N).

[23] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

4. PROCESSING OF COFFEE

4.1. Introduction

Coffee is one of the most consumed beverages worldwide. Brazil is the largest producer and exporter. The 'top 5' sources of EU27 green coffee imports (excluding intra-EU trade) in 2011 were: Brazil (32%), Vietnam (19.9%), India (5.7%), Honduras (5.5%) and Peru (5.5) (ECF, 2012) . Regarding imports by type of coffee in 2011, EU27 imports of 'Arabicas' made up 67% while 'Robustas' accounted for 33%. Among the different sorts of coffee, the leader regarding imports to the EU-27 was green coffee (2.7 million of tonnes).

Table 4.1 reports the amount of coffee imported into and experted from the EU-28 for the years 2012, 2013 and 2014.

Table 4.1: EU28 imports and exports of green coffee and (semi)finished products (in tonnes)

	2012		2013		2014	
	Import	Export	Import	Export	Import	Export
Green coffee (09011100)	2 790 370	21 717	2 811 125	28 307	2 824 469	34 491
Green coffee, decaffeinated (09011200)	3 075	97 325	6 210	105 085	4 881	96 249
Roasted coffee (09012100)	38 540	89 021	41 192	98 422	43 866	104 916
Roasted coffee, decaffeinated (09012200)	3 531	2 811	4 019	2 568	4 324	2 516
Coffee extracts (21011100)	51 106	43 664	48 602	45 064	50 827	47 995

Source: ECF, 2015 pers. comm..

Within the EU-27, Germany, Italy, Belgium (mainly because of the Antwerp port, one of the major ports for coffee), Spain and France were the main importers in 2013. These countries are also the main producers of roasted coffee (see Table 4.2 and Table 4.3).

Table 4.2: Production of green decaffeinated, roasted and soluble coffee in relevant EU countries (tonnes)

	PRCCODE - 10831130 – Decaffeinated coffee, not roasted.		**PRCCODE - 10831150 – Roasted coffee, not decaffeinated.**		**PRCCODE - 10831170 Roasted decaffeinated coffee.**		**PRCCODE - 10831240 - Extracts, essences and concentrates, of coffee, and preparations with a basis of these extracts, essences or concentrates or with a basis of coffee.**	
	2012	2013	2012	2013	2012	2013	2012	2013
Austria	-	-	11 425	10 598	75	51	11 030	-
Belgium	-	-	69 652	50 369	6 006	4 106	-	-
Bulgaria	-	-	11 975	3 163	122	-	209	183
Croatia	-	-	9 814	10 885	21	25	117	106
Denmark	-	-	18 352	17 328	-	-	-	-.
Estonia	-	-	309	443	-	-	-	-
Finland	-	-	49701	45540	-	-	-	-
France	-	-	171 065	160 841	7387	5 395	-	-

Germany	218 338	209 588	522 711	532 541	22 034	22 176	95 644	92 475
Greece	-	-	13 469	13 411	-	-	-	-
Hungary	-	-	-	-	-	-	22 576	18 701
Italy	12 075	11 791	351 261	374 515	19 089	21 371	2 917	3 267
Lituania	-	-	159	164	-	-	-	-
Netherlands	-	-	117284	103508	-	-	-	-
Poland	-	-	52 854	35 209	-	-	33 548	33 441
Portugal	-	-	38 878	38 950	1836	1 886	3 125	2 935
Romania	-	-	20 216	15 163	-	-	-	-
Spain	21 101	22 672	112 656	115 100	16 277	17 425	43 688	29 544
United Kingdom	-	-	24 473	25 032	1 031	1 332	-	60 083
EU28 TOTALS	251 650	244 375	5 623 924	1 781 858	80 252	79 929	330 732	323 472

(the symbol "–" means either 0 tons or data not available)

Source: ECF, 2015 pers. comm.

Table 4.3: Coffee sector of the main producers in the EU-27 (2011)

	Production (a) (in tonnes)[1]	Production (b) (in million EUR)[1]	Industry Sectorc (no of companies)
Germany	517 343	1 741	6 Raw coffee agents 10 Raw coffee importers 3 Stock keepers 56 Roasters 2 Decaffeinators 8 Producers of extracts of coffee
Italy	344 892	2 790	More than 700 companies, employing about 7,000 people (Roasting coffee). But the coffee market is dominated by a few large manufactures with their own private brands.
Belgium	72 287	509	N.A.
Spain	105 411	630	150 companies (95% of total coffee production and distribution in Spain)
France	107 128	738	20 companies (80% of activity)

(1) Roasted coffee, not decaffeinated (PRCCODE – 10831150)

Source AINIA from different sources: a) and b): Eurostat (SBS), 2011; c): web pages from Associations except Italy (USDA, 2010)

There are a number of relevant sustainability initiatives for the coffee processing sector, mainly related to the growing of green coffee (ICO, 2012): Fairtrade certified, Organic certification (International Federation of Organic Agriculture Movements), Rainforest Alliance Certified, SMBC "Bird friendly", UTZ Certified and The Common Code for the Coffee Community (4C).

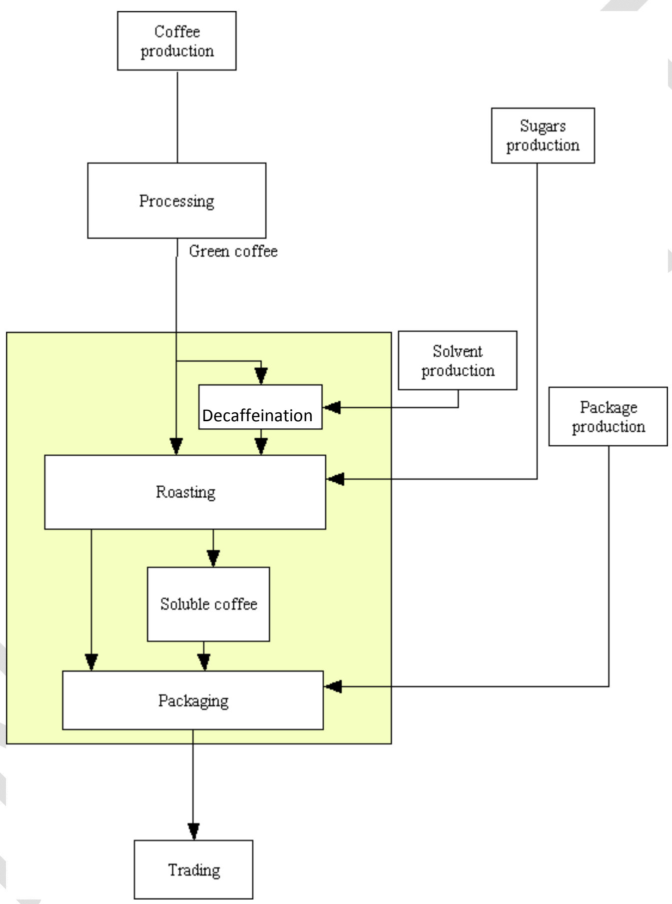
Sales of Fairtrade certified coffee in Europe have increased substantially in recent years. However, Fairtrade coffee still accounts for less than 1 % of the total European coffee market (FAO, 2009).

4.2. Description of the manufacturing of coffee

Primary production and initial processing to obtain green coffee (soaking, depulping, fermentation, washing and drying) are activities carried out in the producer countries outside the EU (e.g. Colombia, Brazil, Ecuador, Kenya). Green coffee is then transported to the EU. Green coffee imports are classified by type, based on the producing countries, into two main coffee categories: Arabicas (e.g. Colombian Milds, Other Milds and Brazilian Naturals) and Robustas.

Figure 4.1 shows the basic life cycle of roasted and soluble coffee. The yellow rectangle includes the operations usually carried out by a European coffee processor such as roasting, grinding, decaffeination, soluble coffee production, packaging and sanitation (cleaning and disinfection) of equipment and installations. All auxiliary processes that take place in the coffee production facilities are also included in these operations, such as those of the boiler plant, cooling plant, water treatment plant, compressed air plant and electricity supply.

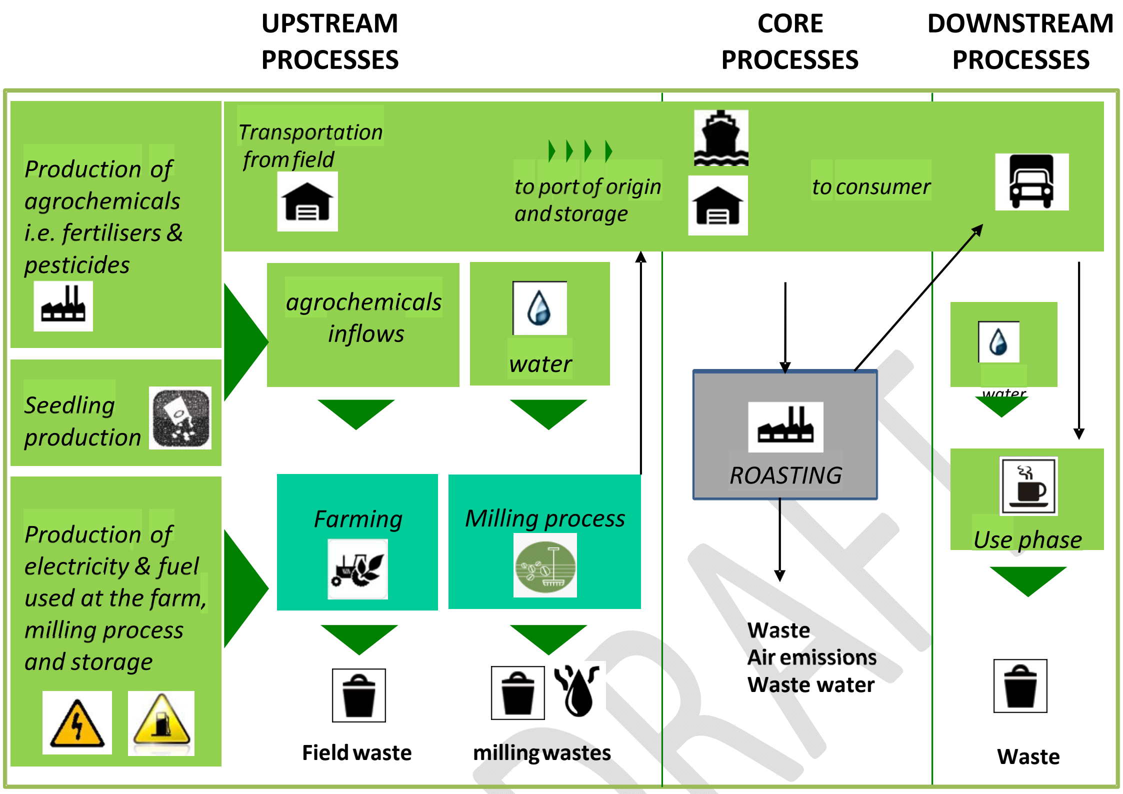
Figure 4.1: Basic life cycle of main coffee products



The life cycle of coffee can be divided into three main phases (upstream, core and downstream processes) as shown in Figure 4.2, where the environmental impacts of each are also illustrated.

- Upstream processes which comprise mainly raw material extraction and input production, farming and milling processes and the related transport activities.
- Core processes, which cover the industrial process and the transportation/distribution of the finished product.
- Downstream processes which include the final use phase.

Figure 4.2: Supply chain for green coffee production



Upstream processes cover the stages presented in Table 4.4, according to the Carbon Footprint-Product category rules[24] (CFP-PRC) for green coffee[25]:

Table 4.4: Life cycle of green coffee production

Life cycle stage of green coffee production	Processes covered
Raw material extraction and input production	- Upstream processes (e.g. production of fertilizers, pesticides, and any other agrochemicals, diesel or natural gas, or manufacturing of packaging)
Farm production	-Coffee cultivation (e.g. activity data, cultivation types, amount of materials and energy inputs and outputs, yields, methods of harvesting, land use, soil and climate types). - Emissions from the cultivation of the coffee including

[24] Carbon footprint product category rules CFP-PCR: Set of specific rules, requirements and guidelines for developing carbon footprint declarations for one or more product categories (ISO 14067). For green coffee, CFP-PCR are available at: http://environdec.com/en/PCR/Detail/?Pcr=8539#.VWMczo7DVE5

[25] The Sustainable Agriculture Initiative (SAI) Platform Coffee Working Group and the Sustainable Trade Initiative (IDH) have partnered up for the development of a common Carbon Footprint Product Category Rule (CF-PCR, 2013) for Green Coffee.

Life cycle stage of green coffee production	Processes covered
	emissions to air, soil and water.
Processing in the coffee mill (or local equivalent)	- Coffee processing (wet or dry processing, amount of materials and energy inputs and outputs). Waste management (husks or water from wet processing). - Emissions to air, soil and water for the processing (wet or dry) phases, as well as from the energy and raw materials used in this process.
Transportation	- Pesticides and fertilisers to coffee growers - Green coffee from agriculture and/or processing to either port of origin or domestic warehouse (any internal transportation, storage at the port) - Energy use for any further grading, cleaning, sorting or climate control, and loading onto the vessel.

Source: Adapted from Environdec, 2013

The next sections describe the processes carried out after coffee harvesting until the coffee is packaged and ready for the market.

Green coffee preprocessing:

Pre-processing of coffee cherries consists mainly of removing the outer pulp and mucilage of the berries and then drying them in order to obtain green coffee seeds. The resulting green coffee is sorted, graded and bagged for transport. This preprocessing is normally carried out in the origin production areas (non EU-countries).

There are two main methods to remove the outer pulp and mucilage of berries in order to obtain green coffee seeds: the wet and the dry methods.

- In the dry method berries are spread out in the sun and turned regularly until dry. The dried pulp is then removed easily. This method is normally used for lower quality seeds.
- In the wet method, coffee cherries are firstly soaked in a prefermentation tank and then transferred to a depulper. Depulped coffee is put into a fermentation tank to eliminate any remains of pulp and the mucilage. The coffee seeds are then washed and dried.

Green coffee processing (roasting)

The raw material for this process is the green coffee and it can have the following stages.

Green coffee beans are heated between 180°C and 240°C for 1.5 to 20 minutes, depending on the degree of roasting required. Moisture is lost and chemical reactions take place in the beans (starches converted into sugar, proteins broken down, partial combustion of caffeol, etc.). Roasting is the stage where all of the typical flavour and aroma of coffee is created. Roasted beans are cooled (normally water is sprayed to cool the beans followed by cooled air) and then destoned (to remove stones which were not removed in the cleaning operation). Whole beans can be packaged in vacuum packs directly or after grinding.

Two additional processes are used to obtain decaffeinated coffee and soluble coffee:

<u>Decaffeination</u>

Decaffeinated coffee undergoes an additional process named decaffeination. It is performed on green coffee beans in industrial plants. There are four methods of decaffeination, each of which use a different substance to extract the caffeine. These four processing methods all share the same basic stages: swelling the green coffee beans with water or steam in order to make the caffeine available for extraction, extracting the caffeine from the beans, steam stripping to remove all solvent residues from the beans (when applied) / regenerating adsorbents (when applied) and drying the decaffeinated coffee beans back to their normal moisture content. (ICO, 2012).

<u>Soluble coffee</u>

Instant or soluble coffee is produced as follows: The first step is to obtain the brewed coffee. Softened water is passed through a series of columns of ground coffee beans at different temperatures, until the coffee extracts reach 20-30% solids. After cooling and filtering, the brewed coffee is then concentrated by means of evaporation, freezing or centrifugation to obtain an extract that is about 40% solids. To preserve the aroma and flavour as much as possible, oxygen is removed from the coffee by means of gases, such as carbon dioxide or nitrogen. Finally, the dehydration phase converts the liquid coffee extract to a dry product (freeze-drying or spray-drying). Additionally, volatile aromatic elements lost along the manufacturing process can be recovered during several stages of the manufacturing process and added to the product.

4.3. Main environmental aspects and pressures

The environmental aspects of the production of roasted coffee, soluble coffee and decaffeinated coffee can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects of coffee producers are shown in Table 4.5.

Table 4.5: Main direct environmental aspects .and pressures of processing coffee

Main environmental aspects	Main environmental pressures	
	INPUTS	OUTPUTS
Green coffee reception and processing		Dust emissions (reception)
Coffee roasting, cooling and destoning	Energy consumption (fuel and electricity) Water consumption (roasting, cooling)	Air emissions (exhaust gases, VOCs, particulate matter), odours Organic waste generation (chaff.)
Coffee grinding and packaging	Energy consumption (electricity) Use of packaging	Dust and odour emissions Packaging consumption
Decaffeination	Solvents use (chemical extraction) Energy consumption (steam) Water consumption (extraction with water)	VOC emissions (chemical extraction) Wastewater generation (extraction with water

Main environmental aspects	Main environmental pressures	
	INPUTS	OUTPUTS
Soluble coffee	Water consumption (solubilisation) Energy consumption (dehydration)	Wastewater generation Organic waste generation (spent coffee grounds)
Cleaning of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals (acid, alkali, detergents and disinfectants)	Wastewater generation Waste generation
Energy supply	Energy consumption (fuel and electricity)	Air emissions (SOx, NOx,...) GHG emissions (CO_2)
Auxiliary process	Fuel consumption (steam production, exhaust gases treatment systems) Electricity consumption (WWTP, compressed, air etc.) Water consumption (steam production) Chemicals use (WWTP, boiler, cooling system)	Air emissions: exhaust gases (CO_2, SO_x, NO_x,...) Wastewater treatment (organic wastes generation) Maintenance (hazardous waste generation)

Overall the most relevant areas are:

- Energy: Energy is consumed mainly in the roasting and the exhaust air treatment systems.
- Air emissions: VOCs (volatile organic compounds), CO, particulate matter, smoke, odour and NO_x are produced during the roasting process. VOC's are also produced when using solvents in the decaffeination stage.
- Organic waste: Coffee chaff is produced in the coffee roasting process and can be used as CO_2-neutral fuel replacing fossil fuels. Spent coffee grounds in the production of soluble coffee products and coffee chaff can be used as co-substrate for improving the quality of bio-based fertiliser (composting).
- Water consumption and wastewater generation can be considered relevant when carrying out decaffeination with water technology, or in the production of soluble coffee products.

Indirect aspects are upstream and downstream activities of the coffee manufacturing industry.

- Upstream activities: The most relevant are primary coffee production, green coffee manufacture and coffee transport while packaging material and production of other ingredients (sugars) and auxiliary material (chemicals, solvents) have a lower contribution.

  Environmental impacts of cultivation

  The cultivation of coffee involves human intervention in rural areas dominated by natural environments, mainly in the tropics and sub-tropics which are some of the earth's most biologically diverse regions. Soil degradation, reduction of biological diversity and overall ecosystem functions are the main concerns. Maintenance of groundwater and surface water resources is vital to human communities and to a healthy ecosystem. Mismanagement of this valuable resource, through sedimentation, chemical or biological contamination can result in significant long-term environmental impacts.

GHG emissions during coffee cultivation are associated with fossil carbon dioxide (land conversion, soil management and energy use), fossil methane emissions, biogenic methane emissions (wet processing water treatment) and nitrous oxide emissions mainly related to the use of fertilisers .

The carbon emissions related to the use of fossil fuel for the production of inorganic fertiliser and operation of machines can be relatively easy allocated to the agricultural production process. Land conversion and preparation are important sources of carbon emissions. The magnitude of these emissions depends largely on the carbon stored in the initial land cover. Emissions associated with the 'short' carbon cycle from biogenic sources should be excluded.

Environmental impacts of pre-processing and transport

The wet processing method is considerably more complex than dry processing and involves the generation of waste water and wet residues generated during the removal of the outer pulp and mucilage of berries.

Table 4.6: Residual flows in dry and wet processing

Processing method	Processing steps for wet processing	Nature of the remaining stream
Dry	The bean is dried for several weeks	n/a
	The skin, pulp and parchment (hull) are removed in one step	Dry residue
Wet	Pulping: Removal of the skin and some of the pulp by machine-pressing the fruit in water through a screen	Polluted water
	Ferment-and-wash or machine assisted wet processing (mechanical demucilaging): removal of the rest of the pulp and mucilage	Wet residue of pulp and mucilage
	Hulling: the parchment layer (hull) is removed by dehulling machine	Hulls (the coffee bean endocarp contains 54% cellulose, 27% pentosans and 19% lignin)

(Source: *CE Delft, 2010)*

The waste water has a high in organic content and is rather acid. A potentially large source of GHG emissions is related to the treatment (disposal) of residues and waste water processing. The residue consists of the outer skin (pericarp/exocarp), the pulp (mesocarp) and the hull (endocarp) as well as some of the silver skin. Dry processing produces a dry residue that is not suitable as fertiliser or compost, but as mulch. Table 4.6 shows the main differences between the two methods.

Tractors and/or relatively small vehicles that have high fuel consumption per tonne-kilometre of transport may be used for transport between the farm and the processing location. Moreover, transport to the harbour is usually not possible with large and efficient lorries.

Typically, the relative contribution of transport to the field/plantation-to-harbour emissions of green coffee is of the order of 5 % to 10%, the energy used in processing contributes typically less than 2% but may be higher in some specific cases and for washed green coffee, the emissions associated with waste water disposal may contribute 10-20% to the total (CE Delft, 2010)

- Downstream activities: waste generation from packaging and energy consumption in transport and use phase.

Reference literature

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4.4. Best environmental management practices

This chapter is aimed at giving guidance to coffee processors on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[26]. For the aspects addressed in this document, the tables mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of coffee processors on all aspects listed in the tables below.

Table 4.7: Most relevant direct environmental aspects for coffee processors and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Green coffee reception and processing	Dust emissions	• Reference to BAT in FDM BREF
Coffee roasting, cooling and destoning	Energy consumption Water consumption Air emissions, odours Organic waste generation Waste water generation	• Reference to BAT in FDM BREF • BEMP on reduction of energy consumption by coffee pre-heating (Section 4.4.1) • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3)
Coffee grinding and packaging	Energy consumption Dust and odour emissions Use of materials (packaging) Waste generation	• Reference to BAT in FDM BREF • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3) • BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Decaffeination	Solvents use Energy consumption Water consumption VOC emissions	• Reference to BAT in FDM BREF

[26] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
	Wastewater generation (for extraction with water)	
Soluble coffee	Water consumption Energy consumption Wastewater generation Organic waste generation	• Reference to BAT in FDM BREF
Cleaning of equipment and installations	Water consumption Energy consumption Chemicals use Wastewater generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Energy supply	Fossil fuel consumption Air emissions GHG emissions	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)
Auxiliary processes	Fuel consumption Electricity consumption Water consumption Chemicals use Air emissions: exhaust gases Wastewater treatment Waste generation	• Reference to BAT in FDM BREF

Table 4.8: Most relevant indirect environmental aspects for coffee processors and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on sustainable supply chain management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions,	• BEMP on transport and

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
	air emissions (CO_2, CO, SO_2, NOx, particulates…)	logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

4.4.1. Reduction of energy consumption through the use of green coffee pre-heating in batch coffee roasting

Description

Coffee roasting has a high demand for thermal energy since roasters typically operate with a hot air temperature stream between 300°C and 540°C and the beans are roasted for a period of time ranging from a few minutes to about 20 minutes.

Roasting machines are usually horizontal rotating drums, centrifugal bowls, fluidised beds or tangential bin roasters where the green coffee beans are tossed around in a flow of hot combustion gases. The roasters operate in either batch or continuous modes and can be indirectly or directly fired. In a batch roaster, the coffee is mixed with hot air and then heated to the roasting temperature. The roasting process is stopped by feeding water into the roasting chamber. The coffee is then emptied into the cooler.

In the roasting operation the heat is transferred to the beans from hot air. Hot air is drawn through the drum by a fan. The gaseous emissions resulting from roasting operations are typically ducted to a treatment system to reduce VOCs (alcohols, aldehydes or organic acids) and particulate matter (roasters are followed by a cyclone that removes the chaff released by the beans). The energy from these air treatment systems is frequently directly exhausted to the atmosphere.

This BEMP focuses on preheating the coffee beans immediately before the roasting operation by means of the heat available in cleaned exhaust gases. This energy-saving technique can be combined with other energy-efficient techniques, such as the partial reuse of the roast gases in the same roasting system either directly (roasters with recirculation) or by means of a heat exchanger (already described in the EC 2006), or to use the roast gases to produce warm water or to heat buildings. Each of the techniques mentioned potentially allows significant energy savings in the roasting operation; from less than 10% in the case of heat exchangers installed in the exhaust gas ducting to approx.30% in the case of roast gas recirculation machines.

Implementing the pre-heating technology, regardless of whether or not it is combined with the previous saving measures, has the advantages of full utilisation in each roast sequence and significant energy savings (in a range of about 10-20% depending on the roasting time, roast degree and exhaust air treatment system).

Green coffee preheating technology

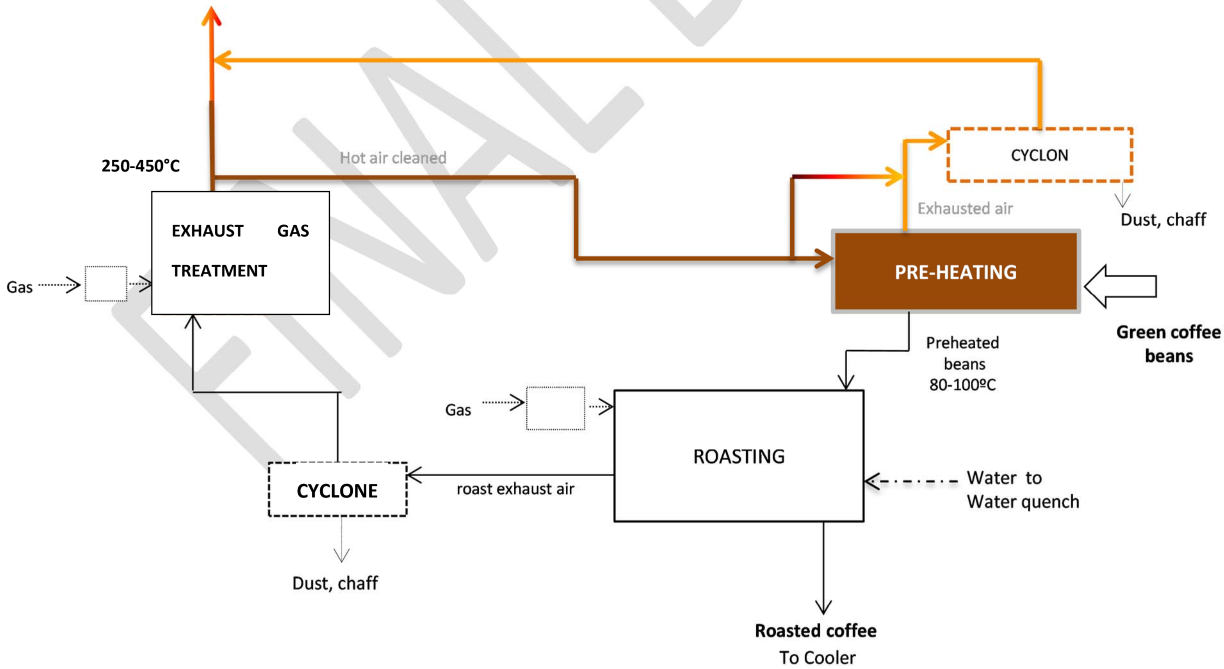
The green coffee pre-heating system can be used only with batch roasters and it is connected upstream of the roaster. This equipment does not require any additional heat energy.

The green coffee is preheated in the preheating stage up to a certain temperature level (80-100°C). A uniform pre-heating of the product is achieved by mechanical stirring. The air is directed via a bypass pipe as soon as the coffee has reached the required temperature.

Figure 4.3 shows a basic scheme of preheating technology, combined with a system for exhaust gas treatment. The hot air cleaned through the exhaust gas treatment is withdrawn from the exhaust gas flow and fed to the preheating stage. It should be noted that the preheating system relies on the temperature at the outlet of the system for exhaust gas treatment, which is usually, depending on the roasting process and exhaust cleaning technology, between 250°C and 450°C (Neuhaus Neotec 2013.).

The hot air utilised for the green coffee pre-heating is exhausted out of the preheating hopper through a fan. Before it is fed back to the normal exhaust air flow, the air is cleaned of solid components (e.g. dust, chaff) in a separate cyclone.

Figure 4.3 Scheme of pre-heating technology



Source: Asociacion de Investigacion de la Industria Agroalimentaria (AINIA)

In the preheating stage the thermal energy stored in the beans not only shortenS the subsequent roasting process but also reduces the quantity of energy applied, which in turn reduces the CO_2 emission.

There are some commercial alternatives that leading suppliers (e.g. Probat-Werke, Neuhaus Neotec and Buhler) offer to reuse roasting hot exhaust gases to pre-heat the green beans achieving a high level of energy efficiency for the process.

Achieved environmental benefit

The environmental advantages using a pre-heating system are the following:

- Reduction of energy consumption.

Since the green coffee enters the roaster preheated, less heating energy is required for the roasting process (depending on the roasting time, degree of roasting, green bean quality, etc.)

- Reduction of CO_2 emissions and carbon footprint

Resulting from the lower energy consumption – and thus the reduced combustion of fossil fuels – the carbon dioxide output can be reduced by up to 25 % (Neuhaus Neotec 2013.).

Appropriate environmental indicators

Appropriate indicators to measure the environmental performance of pre-heating systems are:

- Percentage of heating energy reduction in coffee roasting thanks to the introduction of green coffee pre-heating
- Heating energy used in roasting operations in KWh/tonne of green coffee.
- Specific CO_2 emission measured as kg CO_2eq/tonne roasted coffee and calculated with electricity and fuel consumption (e.g. propane, methane) in roasting operations.

Cross-media effects

The hot air utilised for preheating green coffee is exhausted out of the preheater via a fan, generating emissions to air. This air must be cleaned of solid components (e.g. dust, chaff) in a cyclone or particle filter or dust absorption unit.

Regarding the possibility of generationof odours during the pre-heating step, the temperature for the bean pre-heating process is around 100°C, lower than roasting temperatures and therefore a priori less significant.

Operational data

Mondelēz Gävle plant is located 180 km north of Stockholm and produce 35000 tonne of coffee, which makes it the biggest roastery in Sweden (Mondelēz 2013 pers. comm.).

In 2012 a new generation of centrifugal roaster (capacity is 4 tonnes/hour) with pre-heating technology and equipped with catalytic exhaust cleaning was started up (installed in 2011). The machine features a roasting burner close to the roasting bowl and constant gap control to minimise heating losses.

Green beans are preheated using the exhaust gases to a maximum temperature of 100 °C. Thereby the roasting process uses less energy, resulting in significantly lower propane consumption.

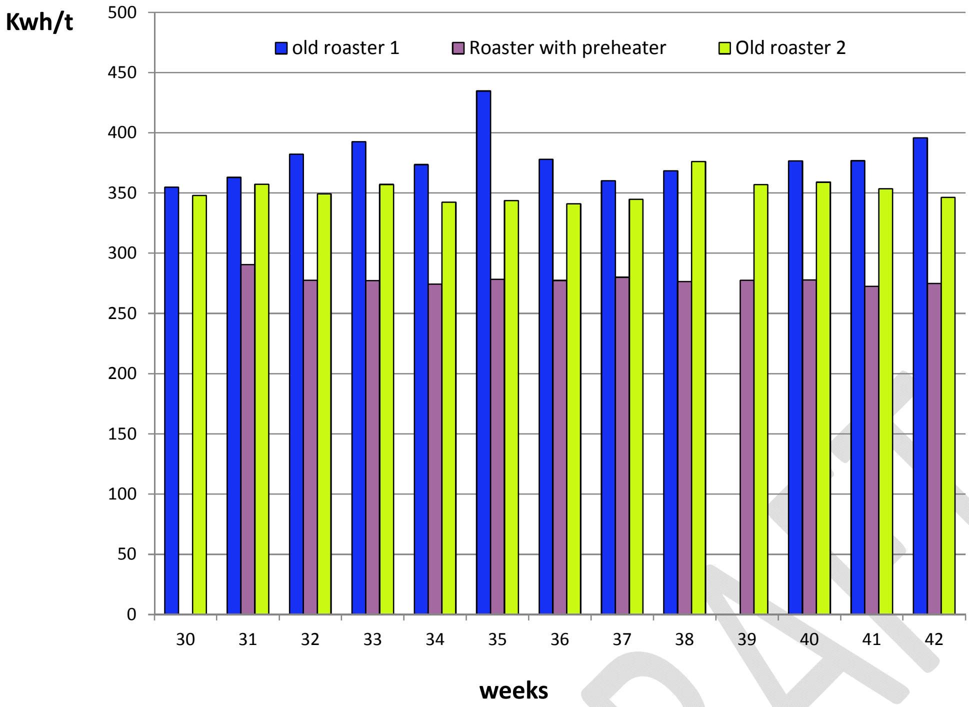
The roasters (R1 and R2) shown in Table 4.9 below are centrifugal roasters with recirculation and catalytic exhaust gas cleaning. The yearly consumption for the three roasters and historical data about the weekly consumption of propane are shown in Table 4.9 and Figure 4.4, respectively.

Table 4.9: Accumulated annual propane consumption in kWh/tonne of green coffee (year 2013).

Roasters (capacity 4 tonne/h)	Start-up	Exhaust cleaning	Propane consumption
R 1 without preheater	1981	catalytic	376.14 kWh/t green coffee
R 3 with preheater	2012	catalytic	279.14 kWh/t green coffee
R2 without preheater	1990	catalytic	355.8 kWh/t green coffee

Source: Mondelēz 2013

Figure 4.4: Weekly consumption of propane in 2013.



Source: Mondelēz 2013

Assuming that the other factors that can affect the thermal energy consumption (roasting time and profile, type of catalyser etc.) are very similar between the three machines, the level of propane consumption for new roaster R3 with preheating technology is between 21.4% and 25.8% lower than the propane consumption in roasters R1 and R2 that are not equipped with preheaters.

Kafferosteriet Löfbergs was founded in 1906 and is now one of the biggest coffee roasters in the Nordic region producing 29,000 tonnes of coffee in 2013. The head office is situated in Karlstad (Sweden), where Kafferosteriet Löfbergs also has one of its main roasting plants. Other roasting plants are located in Viborg (Denmark), Sandefjord (Norway) and Riga (Latvia).

In 2000 and 2002 respectively, Löfbergs changed to two new centrifugal roasters (unitary capacity: 4 tonnes of green coffee per hour) with recirculation, preheating technology and an exhaust gas cleaning system with a low-temperature catalyser (working temperature 450°C). One roaster is equipped with automatic gap adjustment and the second is planned to be retrofitted with the same system shortly (Kafferosteriet Löfbergs 2013).

A central aspect of the redesign was to decrease the carbon footprint, by saving fuel (LPG) through thermal preheating of the coffee, and increase efficiency at the same time.

The level of propane consumption before and after changes of the machines (new roasters with green coffee preheater and low temperature catalyser, was reduced. Depending on the type of coffee produced when the rosters were changed, energy savings of approximately 20% and a 20% increase in throughput were achieved.

All air outlets at this facility go to a central dust absorption unit with tubefilters. From the star valve outlets on the cyclones and the destoner units, all chaff is sent to a pellet press to be pelletised. The dust emissions associated to the preheater system (excluding emissions with roasting exhaust gases), do not exceed 10 mg/m^3.

Lavazza has also recently (2014) installed a new plant recirculating the exhaust gases for pre-heating green coffee. The plant is located in Gattinara, 90 km north-east of Turin, and produces 70000 tonnes of coffee per year. Two new batch roasters (unitary capacity: 5 tonnes/hour) were installed, equipped with recirculation, catalytic exhaust gas treatment and pre-heating technology. Green beans are preheated using the cleaned exhaust gases to a maximum temperature of 100°C. Depending on the type of roasting cycle, the pre-heating system allows heating energy to be recovered and saving of approximately 10% in terms of methane consumption in comparison to a situation without this system (Lavazza, 2015 pers. comm.).

Niehoffs Kaffeerösterei (Lebensbaum group) also installed a new coffee roaster equipped with a coffee pre-heating system (recirculating exhaust gases). Thanks to the improved efficiency of the new roaster and the reduced energy use due to the preheating system the total energy consumption of coffee roasting was reduced by about 29% and the natural gas consumption of coffee roasting decreased by about 55%. The improved energy efficiency due only to the preheating system is insteads in the range of 8-10%. The new roaster uses about 0.45 kWh of total energy per kg of coffee roasted (Lebensbaum, 2015 pers. comm).

Applicability

The pre-heating system can be installed in any new batch roaster but this operation may require considerable space and/or reinforcement of the building structure. Additionally, installing a roaster with the preheating system requires considerable efforts to maintain the same quality of the coffee produced and the application of green bean preheating does not appear to cause any negative influences on the coffee flavour (Mondelez 2013, Kafferosteriet Löfbergs 2013 pers. comm.).
While it is possible to retrofit an existing roaster with a preheater, it has to be recognised that this is more complex than installation in a new coffee roaster. The proportionality of retrofitting must be carefully considered, taking into account costs, space requirements, building work etc..

Economics

The investment cost is linked to the green coffee preheating unit, building costs, transport and assembly costs. These are always customised systems so the cost will be different in each particular project. With the savings in energy costs alone, there will be a yearly payback of the investment in the range of 10 - 15% (Probat Werke 2013 pers. comm.). In addition, a higher output of roasted coffee due to the shorter residence time (increase in production performance) in the roaster could provide a payback of up to 35%.
A new coffee roaster equipped with pre-heating recirculating waste gases with a capacity of 3500 tonnes/year could cost about EUR 800 000 and have a payback period in the range of eight or nine years (Lebensbaum, 2015 pers. comm.)

Driving force for implementation

The main driving force to install a preheating system before roasting is economics. This system can reduce energy costs by up to 25% (Neuhaus Neotec, 2010).

Reference organisations

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5. MANUFACTURE OF OLIVE OIL

5.1. Introduction

Average olive oil production in the EU in recent years has been 2.2 million tonnes, representing around 73% of world production. Spain, Italy and Greece account for about 97% of EU olive oil production, with Spain producing approximately 62% of this amount (EC, 2012).

In terms of oil quality, in 2009 Spain produced 35% extra virgin oil, 32% virgin oil and 33% lampante oil. The respective figures for Italy in relation to these three categories of oil are 59%, 18% and 24%. These percentages change year on year, notably because of climate conditions (EC, 2012).

The EU is the world's biggest consumer (66% share). Spain, Italy and Greece account for around 80% of EU consumption, i.e. 1900 kt. Consumption seems to be stable in the producer countries, whereas it is increasing in the non-producer Member States (EC, 2012).

Consumption models differ in the EU's three main producer countries. In Italy and Greece, the majority of oil consumed is extra virgin, whereas in Spain this category represents less than half of consumption. The general trend is towards the consumption of extra virgin oils (EC, 2012).

Trade within the EU is considerable and continues to rise steadily. In 2010/11 it was around 1,000 kt, i.e. 45% of EU production. Spain is the biggest supplier with 655 kt, while Italy is the biggest buyer with 533 kt (EC, 2012).

EU exports represent approximately 66% of world exports. In 2010/11, exports to third countries amounted to 447 kt, of which Spain sold 225 kt and Italy 160 kt. The biggest markets are the USA, Brazil, Japan, Australia, Russia and China (EC, 2012).

In 2010/11, EU imports accounted for 115 kt, of which the majority is traditionally under inward processing rules and the remainder within the framework of tariff-free quotas with the Mediterranean countries, primarily Tunisia. The new agreement with Morocco has fully liberalised imports from this country (EC, 2012).

The degree of organisation of the olive industry differs greatly from one Member State to another. According to an ongoing study on cooperatives in the European Union, the level of organisation is 70% in Spain, 60% in Greece, 30% in Portugal and only 5% in Italy. Nonetheless, in general these producer organisations are too small to have any weight in the face of industry concentration and the retail chains (EC, 2012).

In Spain, a few big groups control the majority of the olive oil market. Upstream there are 740 processing businesses (mills), including some 950 cooperatives, that produce olive oil, although the majority do not bottle or market oils (EC, 2012).

In Italy, there are some 5,000 mills, whereas downstream the industry is very concentrated with the major bottlers controlling almost half the virgin olive oil market (80% of domestic consumption). In Greece there are approximately 2,200 mills. The majority of the oil put on the market is owned by a few large companies (EC, 2012). In Italy and Greece, the producer customarily retains ownership of the oil after its extraction in the mill, placing some of the production on the market via short distribution channels (EC, 2012).

In view of this, producers and primary processors lack the means to adapt supply to demand and consequently to properly benefit from the full value of their production (EC, 2012).

The oils produced from olives are classified (under the Council Regulation (EC) No 865/2004 and Commission Regulation No 2568/91) as shown in Table 5.1.

Table 5.1: Classification of olive oils

Types of olive oil	Description/ Main characteristics
Virgin olive oil	Oils obtained from the fruit of the olive tree solely by mechanical or other physical means under conditions that do not lead to alterations in the oil, which have not undergone any treatment other than washing, decantation, centrifugation or filtration, to the exclusion of oils obtained using solvents or using adjuvants having a chemical or biochemical action, or by re-esterification process and any mixture with oils of other kinds. Virgin olive oils are exclusively classified and described as follows. (a) *Extra virgin olive oil* Virgin olive oil having a maximum free acidity, in terms of oleic acid, of 0.8 g per 100 g, the other characteristics of which comply with those laid down for this category. (b) *Virgin olive oil* Virgin olive oil having a maximum free acidity, in terms of oleic acid, of 2 g per 100 g, the other characteristics of which comply with those laid down for this category. (c) *Lampante olive oil* Virgin olive oil having a free acidity, in terms of oleic acid, of more than 2 g per 100 g, and/or the other characteristics of which comply with those laid down for this category.
Refined olive oil	Olive oil obtained by refining virgin olive oil, having a free acidity content expressed as oleic acid, of not more than 0.3 g per 100 g, and the other characteristics of which comply with those laid down for this category.
Olive oil – composed of refined olive oils and virgin olive oils	Olive oil obtained by blending refined olive oil and virgin olive oil other than lampante olive oil, having a free acidity content, expressed as oleic acid, of not more than 1 g per 100 g, and the other characteristics of which comply with those laid down for this category.
Crude olive – pomace oil	Oil obtained from olive pomace by treatment with solvents or by physical means or oil corresponding to lampante olive oil, except for certain specified characteristics, excluding oil obtained by means of re-esterification and mixtures with other types of oils, and the other characteristics of which comply with those laid down for this category.
Refined olive –	Oil obtained by refining crude olive pomace oil, having a free acidity

Types of olive oil	Description/ Main characteristics
pomace oil	content expressed as oleic acid, of not more than 0.3 g per 100 g, and the other characteristics of which comply with those laid down for this category.
Olive - pomace oil	Oil obtained by blending refined olive pomace oil and virgin olive oil other than lampante olive oil, having a free acidity content, expressed as oleic acid, of not more than 1 g per 100 g, and the other characteristics of which comply with those laid down for this category.

5.2. Description of the olive oil production process

Olive oil production is carried out in the following facilities:

- **Oil mills** where virgin olive oils are obtained by mechanical or other physical means.
- **Extraction plants** where crude olive - pomace oil is obtained from olive pomace by treatment with solvents or by physical means. This process is one of the current management systems for by-products (pomace or spent olives and moist spent olives) produced in oil mills.
- **Refineries** where refined olive oil is obtained by refining virgin olive oil, and refined olive - pomace is obtained by refining crude olive - pomace oil.

Three different systems can be used in the extraction phase in oil mills to obtain virgin olive oils:

- Traditional system or "pressing system", consisting of the pressing of the paste by means of hydraulic presses. It is a “discontinuous” system because of the necessity to proceed according to “loads” or sequential pressing cycles.
- Three-phase system in which the separation of the oil from the mass is done by centrifugation, using a horizontal centrifuge called a decanter that works continuously.
- Two-phase system, which consists of a variant of the previous one, in which the decanter separates the virgin oil and mixes the spent olives and the waste water in one phase of a pasty consistency called two-phase spent olives, or moist spent olives.

The two-phase systems have only really penetrated Spain (98%) and Croatia (55%).In other olive oil-producing countries such as Cyprus, Portugal and Italy, only around 5% of the mills use the two-phase system; other large producers such as Greece or Malta use mainly the three-phase system although the two-phase system is being introduced slowly (Rincón et al., 2012; PRODOSOL, 2012). Table 5.2 illustrates the main stages of the production of olive oil in olive mills.

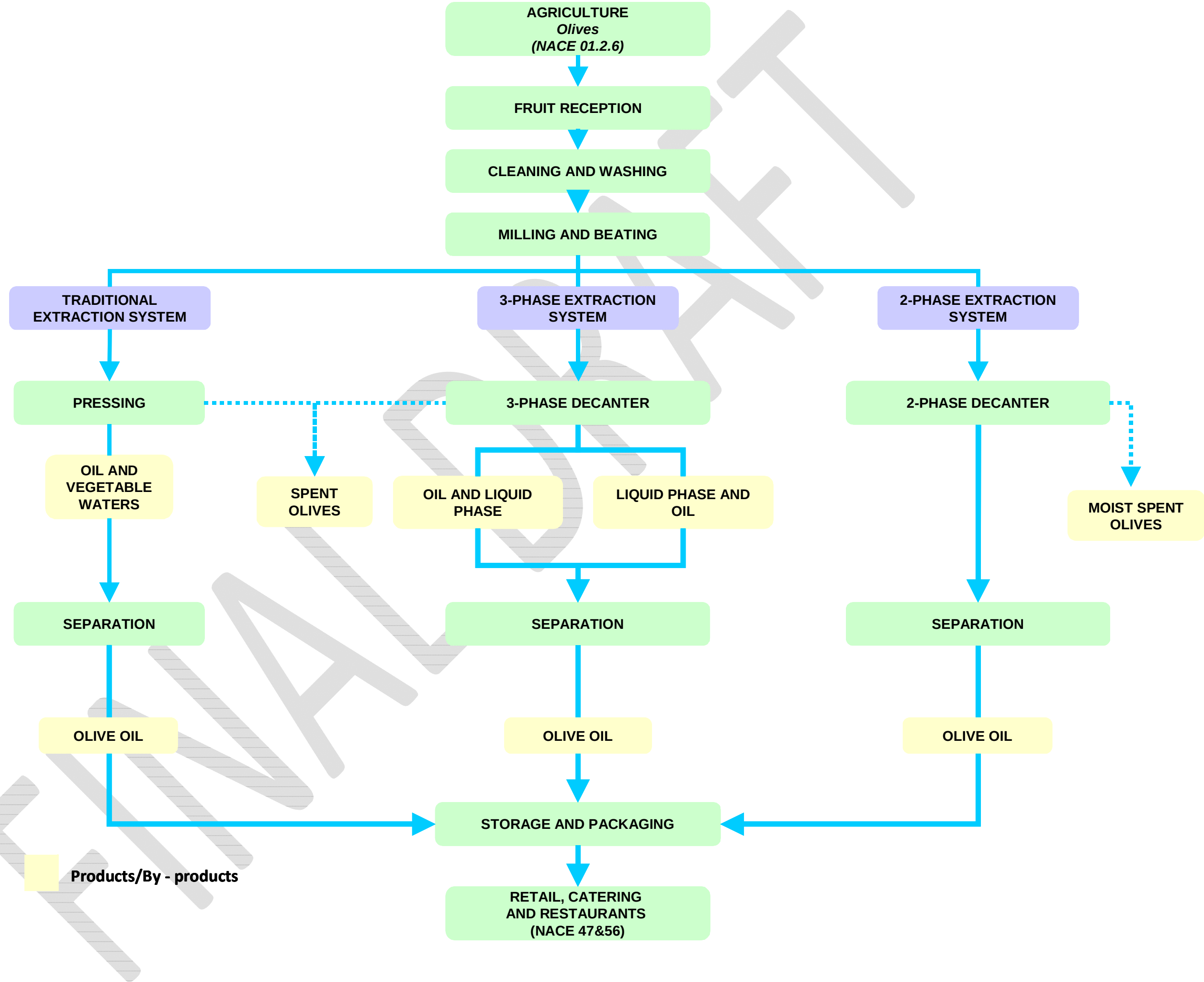
Table 5.2: Main stages of olive oil production in olive mills

Stage	Description
Fruit reception	The olives are received in the installations. The facility consists of an underground hopper which allows unloading from the different lorries

	with a conveyor belt.
Fruit cleaning and washing	Before extracting the olive oil, all foreign objects which come with the olives are removed (leaves, soil, stones, etc).
Milling	Olive tissues are broken in order to form the graze of olives. The milling is carried out by means of stone mills (traditional) or with hammers or disks (modern installations).
Malaxing	Malaxing is carried out in beaters. It consists of a horizontal barrel which has an outer camera where hot water circulates in order to control temperature. The graze of olives moves inside the beater through a device which turns around a shaft.
Extraction	In this phase three different systems can be used as described above: traditional system, three-phase system, two phases system.
Separation	In this phase the solid (fine) and water residues obtained from the previous operation are removed from the olive oil. It is carried out mainly by centrifugation in a vertical high-speed centrifuge. This method is universally widespread. Other methods used, to a lesser extent, are traditional decantation (pots embedded in the ground or small tanks) used before vertical centrifugation or natural decantation in vertical deposits.
Storage and dispatch	The olive oil, which leaves the decanter, is stored in tanks of different capacities and characteristics (warehouses).
Packaging	The packaging is carried out through weight or volume packaging machines. The main packaging materials are glass, metal and plastic.

In addition to these stages in some oil mills, a second extraction is carried out in a decanter of two or three phases. This additional stage is able to recover 40 to 50% of the remaining olive oil, in spent olives or most spent olives. The residual oil content is about 2.3 – 8 % (Civantos, 2008). This process is known as the "repasso" process and usually the oil generated is lampante olive oil.

Figure 5.1: Main stages of olive oil production.



5.3. Main environmental aspects and pressures

The environmental aspects of the production of olive oil can be classified as direct or indirect.

Direct aspects

Table 5.3 illustrates the main direct environmental aspects and related environmental pressures of each phase of virgin olive oil production.

Table 5.3: Main environmental aspects and pressures of virgin olive oil production

Main environmental aspects	Main environmental pressures	
	Inputs	**Outputs**
Fruit cleaning and washing	Energy consumption (electricity) Water consumption	Solid wastes generation (stones, leaves, soil, etc.) Waste water generation
Milling	Energy consumption (electricity)	Waste water generation (in some cases)
	Water consumption (in some cases)	
Malaxing	Energy consumption (electricity and fuel)	Air emissions
	Water consumption	-
Extraction	Energy consumption (electricity)	Solid waste generation (spent olives or moist spent olives, depending on the system used)
	Water consumption (depending on the system used)	Waste water generation (depending on the system used)
Separation	Water consumption	Waste water generation
	Energy consumption (electricity)	-
Packaging	Energy consumption (electricity) Use of materials (packaging)	-
Cleaning of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals (acid, alkali, detergents and disinfectants)	Waste water generation
Energy supply	Energy consumption (fuel and electricity)	Air emissions (SO_x, NO_x, etc.) GHG emissions (CO_2)

Overall, the most relevant environmental aspects are:

- Water consumption and waste water generation in the fruit washing stage.

- Water consumption and waste water generation in the olive oil cleaning stage (separation).
- Water consumption and waste water generation in the extraction stage when a three-phase extraction system is used.
- By-products; spent olives and moist spent olives.
- Energy consumption.

The water consumption in olive oil mills varies widely, both because of equipment requirements (for example, the three – phase system mill needs substantially greater quantities of water) and local operational conditions and practices (Niaounakis. M, C.P. Halvadaki, 2005). Water consumption in olive oil mills ranges as shown in Table 5.4. Likewise the amount of wastewater generated varies (Table 5.5) depending on the extraction system and management practices (water added and segregation of the effluents).

Table 5.4: Water consumption in oil mills

	Traditional system	3-phase system	2-phase system
Water consumption (l/kg olives processed)	0.27 – 0.35	0.75 - 1	0.25 – 0.33

Source: Civantos, 2008

Table 5.5: Average volumes of waste water generated in the different steps of the 3- and 2-phase olive oil extraction processes

Effluent (l/kg olives processed)	Traditional system	3-phase system	2-phase system
Washing of olives	0.05- 0.12	0.05-0.12	0.05-0.12
Extraction	-	0.9	-
Separation/Cleaning of olive oil (vertical centrifuge)	0.62 – 0.69[1]	0.20[2]	0.15[2]
General cleaning	-	0.05	0.05
Total effluents	0.63 – 0.81	1.24	0.25

Source: Own elaboration (Source: Borja, et al .(2006) ; RAC/CP (2000); Werner – Korall (2006))

Olive oil wastewater from oil mills is characterised in general by high BOD_5 and phenolic compound content as well as a high COD/BOD ratio. However, wastewater streams present different characteristics, depending on the variety and maturity of the olives, the climate and soil conditions and the oil extraction method and habits.

[1] Wastewater generated in this stage is composed of vegetation water of the olives and the water added in the process.
[2] When a vertical centrifuge is used.

The main by-product/solid residue generated in olive oil production is the spent olives and moist spent olives. Both contain a certain quantity of residual oil which is not possible to extract by physical means and which is extracted in the extracting plants of olive oil mills.

The energy demand in olive oil mills ranges as shown in table 5.6.

Table 5.6: Energy consumption in oil mills

	Traditional system	3-phase system	2-phase system
Energy consumption (kWh/tonne olives processed)	40 – 60	90 – 117	< 90 – 117

Source: RAC/CP (2000)

However, the electrical energy consumption in an olive oil mill is distributed in the production phases as presented in table 5.7.

Table 5.7 Electrical energy balance

Production stages	Consumption (%)
Reception, cleaning and washing	7.46
Milling	20.60
Malaxing	11.76
Centrifugation[5]	41.39
Storage	4.15
Packaging	1.5
Others	13.15
TOTAL	100

Source: Cooperativas Agroalimentarias (2010).

Likewise, the main thermal energy is consumed in order to heat the water which is used in the following stages:

- malaxing
- extraction, when the three-phase system is used.
- separation (vertical centrifugation)

Indirect aspects

Indirect aspects are related to the upstream and downstream activities of olive oil production. Agriculture and production of packaging are the most relevant in the supply chain. In addition transport and logistics (both upstream and downstream), retail and food preparation by consumers are the other indirect environmental aspects.

[5] Extraction and vertical centrifugation

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5.4. Best environmental management practices

This chapter is aimed at giving guidance to olive oil manufacturers on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk industries (FDM BREF)[27]. For the aspects addressed in this document, the table mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of olive oil manufacturers on all aspects listed in the tables below. In addition, in all production processes, the BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) is applicable and allows energy consumption to be reduced.

Table 5.8: Most relevant direct environmental aspects for olive oil manufacturers and how these are addressed

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
Fruit cleaning and washing	Energy consumption Water consumption Solid waste generation Waste water generation	• Reference to BAT in FDM BREF • BEMP on reduction of water consumption during washing of olives (Section 5.4.2)
Milling	Energy consumption Water consumption Waste water generation	• Reference to BAT in FDM BREF • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Malaxing	Water consumption	• Reference to BAT in FDM

[27] For more information on the content of the Best Available Technique Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
	Energy consumption Air emissions	BREF • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Extraction	Water consumption Energy consumption Waste generation Waste water generation	• Reference to BAT in FDM BREF • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Separation	Water consumption Energy consumption	• Reference to BAT on energy efficiency in FDM BREF • BEMP on water free processing (Section 5.4.1)
Packaging	Energy consumption Use of materials (packaging)	• Reference to BAT in FDM BREF • BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Cleaning of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Energy supply	Fossil fuel consumption Air emissions GHG emissions	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

Table 5.9: Most relevant indirect environmental aspects for olive oil manufacturers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions…	• BEMP on sustainable supply chain management

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
		(Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • BEMP on reduction of water consumption during washing of olives (Section 5.4.2) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, Use of material (packaging)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x, particulate matter etc.)	• BEMP on Transport and Logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

5.4.1. Minimising water consumption in olive oil separation

Description

Olive oil is the oil obtained solely from the fruit of the olive tree (*Olea europaea L.*). It is a key ingredient in the Mediterranean diet, renowned for being healthy, although its popularity has now expanded beyond its area of origin: the Mediterranean basin.

Olive-growing and olive oil production are very important within the EU's agricultural and food sectors. The European Union is the largest olive oil producer; in the year 2011/12 Spain, Italy and Greece alone accounted for 70% of global olive oil production (International Olive Oil Council, 2013). In terms of area, in 2012 olive farming (for both olive oil and table olives) covered 23% of agricultural land in Greece, 7% in Italy and 11% in Spain[28].

Due to the growing popularity of this product over the last two decades, olive growing has become more intensive, using an increasing amount of land and resources. Olive oil production also requires large

[28] These figures were calculated using the Agriculture, forestry and fisheries data from the Eurostat database. Available at: http://epp.eurostat.ec.europa.eu/ [Accessed 23 October 2014]

amounts of water. This is particularly problematic given that it is concentrated in countries and areas where water resources are scarce (European Commission, 2010).

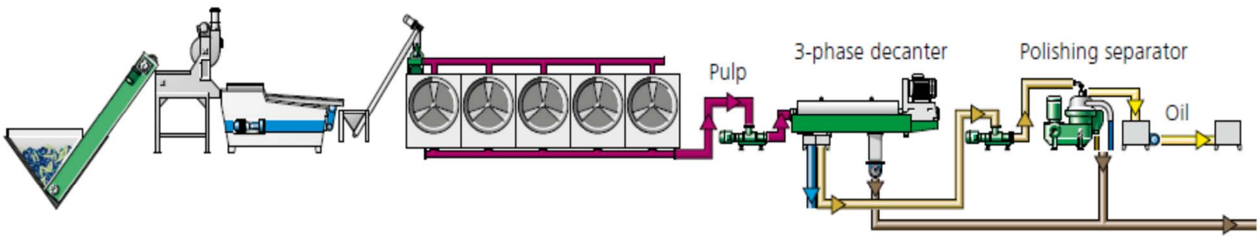
The large volumes of water used for processing result in a significant amount of contaminated waste water. Its management is regulated in European olive oil-producing countries given that uncontrolled disposal of such liquids causes phytotoxicity, water and soil pollution (Olèico+, 2012). Although the waste water from different types and stages of processing varies, it can be described with the following general characteristics (Tsagaraki, 2007):

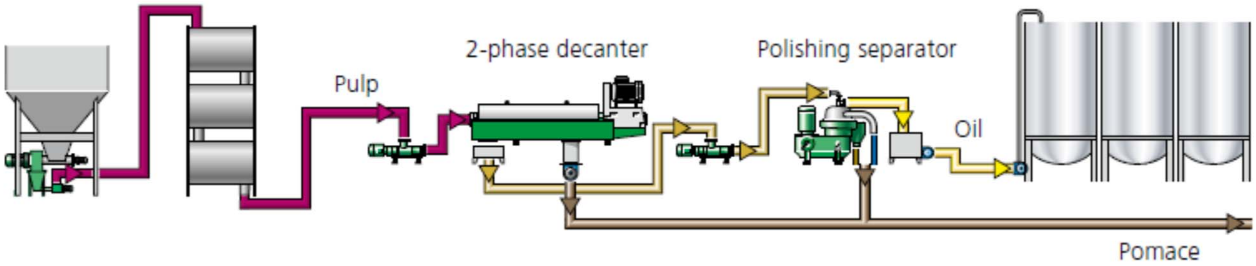
- strong foul odour,
- high degree of organic pollution, with COD values up to 220 g/L,
- slightly acidic pH (between 3 and 5.9),
- high content of non-easily biodegradable polyphenols which are toxic to most microorganisms.

This BEMP focuses on the final stage of olive oil processing: separation (also known as clarification or polishing). The outline of a continuous process for olive oil production is shown in Figure 5.2; the traditional press can also be used for primary extraction. Olives are picked by hand or by automatic means, contaminants such as leaves, stones and soil must be removed through the de-leafing and cleaning stages. The olives must then be crushed to liberate the oil from the fruit's cells. The malaxation stage, which results in liberating more oil from the flesh, is necessary to increase the yield of extraction. The olive oil is firstly extracted from the paste by mechanical means; pressure, centrifugation and percolation technologies are available. Horizontal decanters are the most common choice of extraction machinery in Europe (Di Giovacchino, 2002).

The final processing stage, as mentioned above, is the separation of the olive oil from remaining fine particles and water. This is required to 'clean' the oil of remaining impurities in order to produce higher quality oil. This is usually done through centrifugation; a vertical centrifuge with a rotatory speed of 6,500-7,000 rpm is used for this process (Di Giovacchino, 2002).

Figure 5.2: Continous olive oil extraction process (3-phase system, above, 2-phase system below)





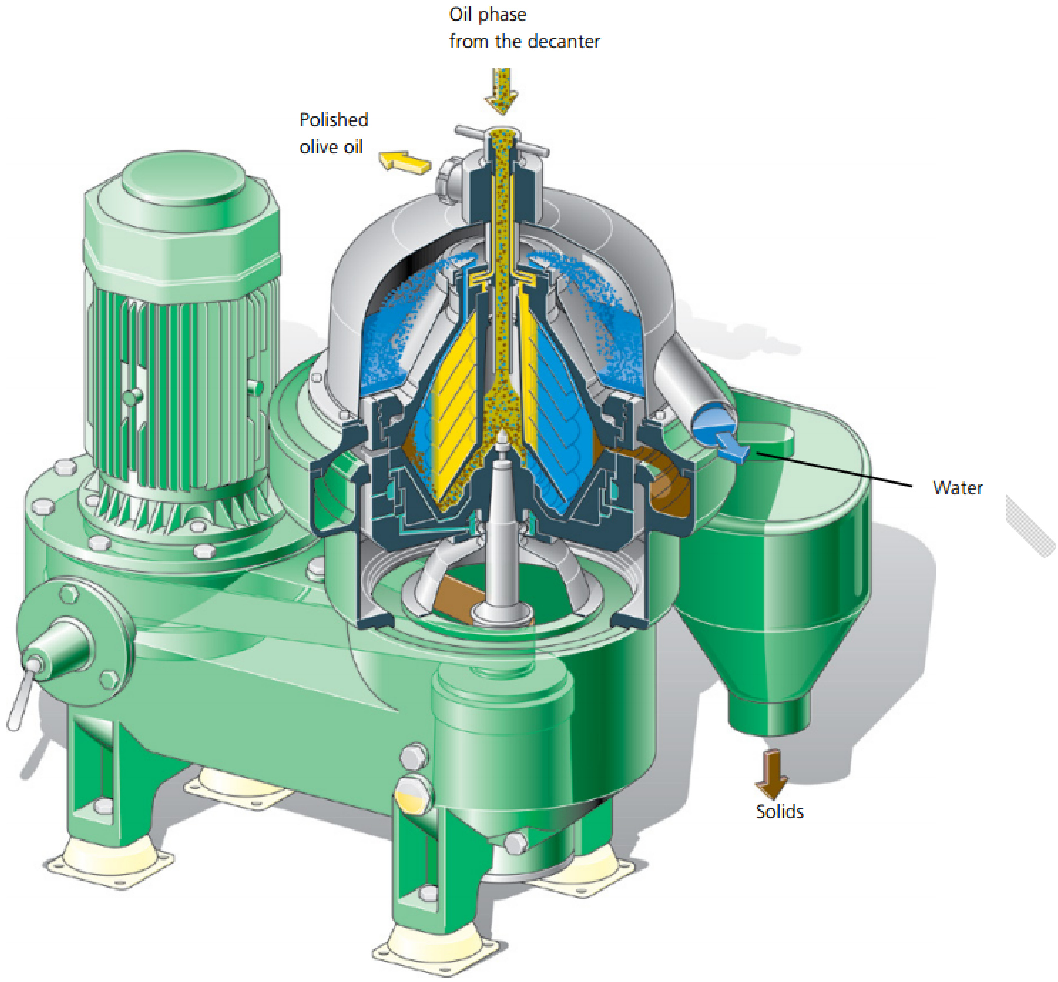
Source: GEA Westfalia Separator Group (nd.))

In the centrifuge, substances with different densities separate along the radial direction. The heavier substances, in this case the fine particles, move away from the centre and are collected in a container, as shown in Figure 5.3. Water, which has a medium density, forms the middle stratum and drains from the centrifuge. The oil, which is the lightest substance, stays in the centre from where it is pumped out (GEA Westfalia Separator Group, nd.).

Warm water is generally added to the previously extracted oil. The water improves the separation of the fine particles from the oil by creating a larger phase separation within the centrifuge. The amount of water required is a fine balance between better removal of the fine particles and preservation of polyphenols within the oil. Polyphenol content is very important for oil quality. Polyphenols are water-soluble; therefore, the addition of water for centrifugation results in reduced content following this process. However the water improves the removal of fine solids (GEA Westfalia Separator Group, 2014, pers.comm.).

The centrifuge must be cleaned periodically to remove the accumulated solids. Machinery with either automatic or manual cleaning is available. If cleaned manually, the centrifuge has to be stopped and cleaned with water; this takes approximately one hour (GEA Westfalia Separator Group, 2014, pers.comm.). Modern technology automatically discharges the accumulated solids whilst in operation (in just few seconds) by automatically opening peripheral holes in the drum (Di Giovacchino, 2002). Some oil can be lost during this operation; however, this is limited in the presence of water which acts as a phase separator between the soil and oil phases (GEA Westfalia Separator Group, 2014, pers.comm.).

Figure 5.3: Oil separation through a vertical centrifuge



Source: GEA Westfalia Separator Group (nd.)

The literature gives varying data with regards to the amount of water used during this separation stage. This will depend on the quality of the oil after extraction, the amounts of impurities present and the centrifuging machinery. In the 1990s, 300 litres of water were added per 1000 litres of olive oil produced (Pieralisi, 2014, pers.comm.). More recent literature provides the following figures:

- between 15% and 50% of the oil volume (Regional Activity Centre for Cleaner Production, 2000).
- an industry source reported that the typical amount of water used in 2014 was 200 litres of water added per 1000 litres of oil (20%) (GEA Westfalia Separator Group, 2014, pers.comm.).

Minimisation of added water has been identified as best practice for this stage of olive oil production. This must be done mindful of the final quality of the olive oil and the efficiency of fine solids removal. This is particularly important given the increasing demand for high quality olive oil (Mili, 2006). Improved technology and research have resulted in lower quantities of water being needed for effective impurity removal (Borja, 2006). According to different sources, the use of water can be reduced down to between 100 litres and 50 litres of water per 1000 litres of oil (10% to 5%) all the way to using no water (GEA Westfalia Separator Group; Pieralisi, 2014, pers.comm.). This will depend on the quality of the oil following extraction.

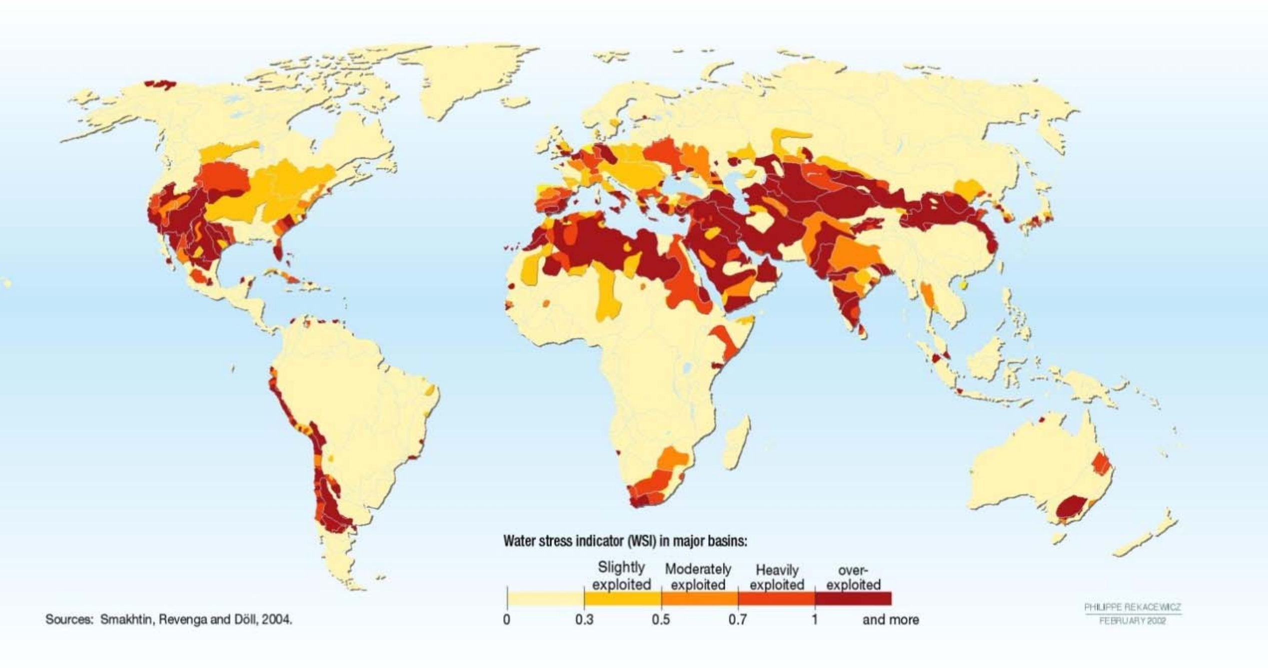
The water is used to aid the removal of impurities in the oil and does not form part of the end product but instead generates waste water. Consequently, the lower the amount of water used, the lower the amount of generated waste water requiring treatment. Several methods to manage such wastes exist, depending on the country of production and the size of the olive oil producer. In Spain it is considered best practice to treat this water from the separator by mixing it in the "repasso" phase with the pomace waste arising from two-phase decanters used in the first extraction, and then dry it in evaporating lagoons. In other countries the solids from the used olive wash water are removed through natural sedimentation and the cleaned water can then be recycled in the initial olive washing process (GEA Westfalia Separator Group, 2014, pers.comm.).

Achieved environmental benefits

This BEMP focuses on the reduction in water used during the separation phase of olive oil production. Therefore, the obvious environmental benefit is that of reduced water consumption. By looking at the data above, the reduction in water use specifically related to the vertical centrifugation of oil will vary according to the initial amounts of water used and the quality of the incoming oil, which dictates the minimum water requirement so as not to compromise the quality of the product. The highest water use cited in the literature is 50% (500 litres of water per 1000 litres of oil) (Regional Activity Centre for Cleaner Production, 2000). If this is reduced to 5% of the oil quantity, it will result in a 90% reduction in the vertical centrifugation step. However, it was reported that the typical amount of water used in 2014 was of 200 litres per 1000 litres of oil (GEA Westfalia Separator Group, 2014, pers.comm.). Therefore reducing this to 5% will result in water savings in this stage of olive oil production of 75%.

This aspect is particularly important as water in the major oil-producing countries is scarce. For example, Andalucía and Puglia, the largest olive oil-producing regions in Spain and Italy respectively (Eurostat, 2014), are both shown as ‘over-exploited’ according to the water stress indicator presented in Figure 5.4. Major producing countries, including Greece, Italy, Spain, and Portugal, but also Morocco, Syria, Tunisia and Turkey outside of Europe have large areas classed as ‘highly exploited’ or ‘over-exploited’ (see Figure 5.4).

Figure 5.4: Water Stress Indicator (WSI) in major basins



Source: UNEP (2008) from Smakhtin (2004)

Reduced water use also results in a reduction in waste generation from the separation process and therefore lower waste water treatment needs. Water added to the oil for centrifugation is used as a means to improve the removal of water (1% to 10% water content) and fine particle impurities still present in the oil following extraction (Pieralisi, 2014, pers.comm.). Therefore, this water plus the removed impurities all result in waste water which must be treated.

Appropriate environmental indicators

The most appropriate environmental indicator for this BEMP is:

Water used in olive oil separation (litres) per weight (tonnes) of olives processed or per unit volume (litres) of olive oil manufactured

Cross-media effects

The waste water from vertical centrifugation can be recycled in the olive washing or added into the “repasso” (the solids exit phase of the two phase decanter) before the pomace is centrifuged again or dried. When lower amounts of water are used, lower amounts of waste water will be generated meaning less of this will be available for recycling. Hence, other water sources must be found for this purpose.

Operational data

Table 5.10 shows the composition of the waste water generated during vertical centrifugation at six Spanish olive oil processing plants. As can be seen, there is some variation in the characterisation of these effluents, particularly regarding COD values and the phenolic content. The latter depends on the degree of ripening of the olives used during processing and on the volume of water used during the first separation process (Borja, 2006). As mentioned above, the lower the amount of water added for separation, the lower the amounts of waste water requiring such treatment.

Table 5.10: Composition and features of the waste water generated during the separation of virgin olive oil at different Spanish olive oil factories located in Cordoba (Co) and Jaen (J) provinces

Factory	pH	Total solids (%)	Ash (%)	Organic matter (%)	BOD_5 (mg/L)	COD (mg/L)	Phenolic content (ppm)
1 (Co)	5.69	0.18	0.04	0.14	790	2,874	373
2 (Co)	5.40	0.15	0.05	0.1	520	5,935	86
3 (Co)	5.67	0.24	0.04	0.2	465	3,805	NA
4 (Co)	5.73	0.33	0.07	0.26	690	4,230	NA
5 (J)	5.11	1.47	0.05	1.42	915	12,078	157
6 (Co)	5.16	0.59	0.1	0.49	790	10,931	NA

Source: Borja (2006); NA – Not available

Applicability

It is reported that the majority of olive oil producers make use of vertical centrifugation technology for clarification purposes (Pieralisi, 2014, pers.comm.). The amount of water used will depend on the quality of the oil coming from the decanter. This can depend on a number of factors, including the amount of oil processed and the quality of the olives. The amount of water can be minimised when the oil contains a low concentration of water and fine particles, thus not affecting the final product quality. In all cases, the quantity of water used should be kept to the minimum amount required to achieve the desired final composition.

Economics

The aim of this BEMP is to minimise the amount of water used during the final clarification in olive oil processing. A clear economic saving is that of water costs. In terms of machinery, no costs will be incurred as different technologies are not required; vertical centrifuges are already owned and used by most olive oil processors (Pieralisi, 2014, pers.comm.).

Reducing water inputs also results in reduced waste water outputs. Therefore, in mills where these are treated chemically or biologically, the cost of such treatments will be lowered given that the amount of waste is also reduced.

Driving force for implementation

Water scarcity is an increasingly important issue in major olive oil-producing countries. In these regions, the major environmental problems associated with olive oil mills are related to water consumed during the production process (Mili, 2006). For this reason, reducing the stress on the water resources and consequently the environmental impact of olive oil production should be seen as a major driver.

Within Europe, around 4.6 million tonnes of olive mill waste water are produced each year, including the waste produced during the final separation of olive oil. This water is highly polluted and is expensive and difficult to treat, causing environmental concern (European Commission, 2010). A reduction in the generation of such waste and its environmental impacts should be considered a major driver to minimise the use of water during olive oil separation.

Historically, the treated waste water reuse in Greece, Italy and Spain has been very low. A study in 2007 (EUWI, 2007) stated that '*The treated waste water reuse rate is high in Cyprus (100%) and Malta (just under 60%), whereas in Greece, Italy and Spain treated waste water reuse is only between 5 % and 12 % of their effluents*'. Consequently, water reduction and the associated reduction in waste water generation should be seen as a major driver in these three countries.

Reference organisations

Frontrunners for this BEMP are:

- OleoAlgaidas SCA Villanueva de Algaidas
- Molino de Genil
- San FRANCISCO from Villanueva

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5.4.2. Reduced washing of olives upon reception

Description

In the production of a high quality olive oil, one of the most important aspects to be taken into account is the characteristics of the olives e.g. variety, ripeness and dirtiness as well as olive health status etc. Therefore the harvest time, the harvesting itself and the olive reception management practices are key factors that can affect the olive oil quality and the subsequent stages of the production process.

In olive oil mills the olives are received and generally classified according to some of their characteristics (depending on the desired final product). Afterwards they are processed separately in order to produce different types of olive oil, mainly according to the olives' initial characteristics and status (e.g. maturity level).

In principle, during the reception stage, the olives are classified according to one or more of the following criteria:

- Variety: to obtain olive oil from specific varieties of olives.
- Level of ripeness.
- Quality: to produce different olive oil qualities.
- Dirtiness: to decide the most appropriate way to remove the impurities from the olives.

After reception, the olives must be adequately prepared (before the milling stage) by removing the impurities (e.g. leaves, stones, mud, dust, residues of possible pesticides.), which are normally collected with them during the harvest (Di Giovacchino et al., 2002).

Two operations are generally used to prepare the olives: cleaning and washing.

- The cleaning stage consists of removing the wastes/impurities which are collected during harvesting (e.g. leaves and twigs). These wastes have a lower density than the olives, so they can be easily removed from the main stream (e.g. by applying an air separation process). This waste stream accounts for 5-10% of the total weight at reception (Civantos, 2008). In parallel, it is often necessary to use branch removers for those branches that cannot be removed by the air separation process (Uceda, 2006; Civantos, 2008).
- The washing stage consists of the removal of those wastes that have a higher density than the olives and/or are adhering to their surface (e.g. stones, dust), by means of a water stream. Those wastes not only affect olive oil quality but can also cause significant damage to the machinery (Uceda, 2006). Washing is usually needed if olives are picked from the soil. The equipment necessary for the washing stage are sieves and/or hydropneumatic equipment or hoses, while the typical capacity range is for example between 20 t/h and 50 t/h in Spain (Civantos, 2008). The washing stage generates wastewater and sludge.

In the olive washing stage, the water use is estimated to represent 15 % to 34% of the total water use within the olive oil mill, depending on the equipment requirements as well as local operational conditions and applied technology/practices (Niaounakis and Halvadaki, 2006). Moreover, at this stage the waste water generated has high BOD levels and requires further treatment before its discharge.

Table 5.11: Common olive washing water composition (Regional Activity Centre for Cleaner Production (RAC/CP), 2000)

	Values
Solids (%)	0.50 - 0.67
Oil content/wet matter (%)	0.10 - 0.16
COD (g/kg)	7.87 - 10.35

In general, when no residues are left on olives from the use of chemicals during the growing season, olives collected from the trees are usually clean (apart from dust), which allows a considerable reduction in their washing at the reception in the olive mill. In this case, the mechanical cleaning stage would still be needed for preparing the olives for the subsequent stages (Humanes and Civantos, 2001). Water used for the washing stage could be collected, stored in a tank/pond, allowing particles to settle, and then it can be recirculated and reused in the washing stage. This would allow further substantial savings of water in the olive oil mill.

It is BEMP for olive oil manufacturers to establish an appropriate cooperation scheme between the olive oil mill and the farmers providing the olives. There are three main olive oil mill types in Europe and therefore this BEMP can be applied differently (European Commission, 2012):

- Small oil mills (which process olives grown on their olive trees): these companies easily control the whole olive oil production process (from the production of olives to the customer) and therefore can implement direct measures to deliver clean olives to the mill (e.g. olives collected from the trees).
- Industrial olive oil producers (which process olives supplied through an appropriate contract with farmers): different prices can be offered for the olives delivered, depending (among other parameters) on the dirtiness of the olives.
- Cooperatives (which process the olives of their members): these organisations establish agreements among their members and among the parameters agreed a low degree of olive dirtiness can be included.

Achieved environmental benefit

The main environmental benefit of this practice is the reduction of the water consumption, which results also in less waste water generation.

When the olives are clean, the water savings achieved thanks to reduced washing range from 15 % to 34% of the total water consumption in the oil mills.

The waste water generated in the washing stage is directly related to water used. However, there are slight differences between the volume of water consumption and waste water generated. These differences are mainly a consequence of water evaporation, water adhesion to the olive's skin and the washing management.

The wastewater generated during the washing stage could be estimated at around 0.05 – 0.12 l/kg of olives, representing around 7 – 20 % of the total wastewater generated in olive oil mills.

Finally, by reduced washing, a decrease in energy use (electricity) is achieved. However, this amount of energy accounts for approximately (only) 7% of the total energy use in the olive oil mill (the highest share of energy consumption takes place during the milling and centrifugation stages) (Cooperativas Agroalimentarias, 2010).

Appropriate environmental indicators

The appropriate environmental indicator is:

Litres (of water used to wash the olives upon reception) / tonne (amount of olives processed).

Additionally, the actual water use should always be monitored and eventually compared with recorded data regarding water use.

Cross-media effects

There are no specific cross-media effects related with this BEMP.

Operational data

Olives collected from trees are usually clean and the harvest time should be carefully assessed in order to obtain a high quality oil and to avoid them falling on the ground.

The optimum harvest time for most varieties can thus be defined as the time when the olives have the highest oil quantity, whilst not dropping in quality and taking care to avoid letting the olives fall on the ground (Consejería de Agricultura y Pesca, Junta de Andalucía; 1996). Optimum harvest time depends on many parameters, such us climate situation, olive varieties and the quality of the olive oil produced.

In this context, the most well-known method to determine the harvesting date, namely the Maturity Index (MI), was developed by the International Olive Oil Council (IOOC). This method is based on the pigmentation of the olive fruit: 100 olives chosen randomly from 1 kg of newly harvested fruit are used for calculation. The calculated values can range from zero to seven, where zero represents deep or dark green, and seven represents black skin and dark flesh throughout (Wiesman, 2009). As an average, an optimum harvest time for most of the varieties ranges from three to four (Wiesman, 2009; Bienes Allas, 2011).

Applicability

This BEMP is applicable to all oil mills. However, as was previously shown, farmers' cooperation is essential.

In addition, olive mills, when receiving olives, must be able to process them separately (dirty and clean olives). For this reason, it would be useful and practical for the olive oil mill to have two different reception lines for processing each kind of olive.

Economics

Taking into account that the dirty and clean olives must not be mixed, it is necessary to set up two different olives reception facilities. Therefore the implementation costs are related only to this.

Driving force for implementation

Reduction of water consumption and waste water generation is the main driving force.

Reference organizations

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6. MANUFACTURE OF SOFT DRINKS

6.1. Introduction

In 2010, manufacture of soft drinks had a turnover of about 140,000 million €, and six countries, namely Germany, Spain, France, Italy, Poland and Romania, accounted approximately for 50% of total number of enterprises in the EU-27 (Eurostat, 2010; Eurostat (SBS), 2012).

The overall production of non-alcoholic beverages (not containing milk) was approximately 15000 million litres. Spain, Italy, France, Germany, Poland and Austria have a leading position among the different EU-27 countries in terms of production (Eurostat, 2010; Eurostat (SBS), 2012).

Excluding sweetened and unsweetened mineral waters, the total amount of EU exports and imports of non-alcoholic beverages not containing milk in 2010 was 586 million litres and 140 million litres, respectively (Eurostat, 2010; Eurostat (SBS), 2012).

Soft drinks are classified into two main categories: (i) carbonated and (ii) still (EC, 2006). This study incorporates the following categories of soft drink products, using the classification proposed by BSDA (2012) and cited in DEFRA (2013):

- **Carbonates** include ready-to-drink drinks and draught dispense (for the hospitality sector) and home dispense (for example, Soda Stream) drinks, mixers including tonic and bitter drinks, orange and shandy; energy drinks; sparkling flavoured water, health drinks and herbal drinks. They cover regular including sparkling juice, low calorie and zero calories. Flavours include cola, lemon, lemon-lime and other fruit flavours.
- **Bottled water** is defined as still, sparkling or lightly carbonated water. It is further characterised as being natural mineral water, spring water or bottled drinking water.
- **Dilutables** include squashes, cordials and powders and other concentrates for dilution by consumers, normally adding 4 parts water to 1 part product. High juice contains a minimum of 40% fruit content (as sold). Regular dilutables include squashes and cordials with a minimum of 25% fruit. Low sugar variants include no added sugar and sugarfree.
- **Still and juice drinks** include high juice drinks (25-99% fruit content), juice drinks (5-25% fruit content) and other still drinks (0-5%) including iced tea, sports drinks, still flavoured water and non-fruit drinks.

The main ingredients of soft drinks are: water, juices, sweeteners (sugar, syrup and artificial sweeteners), acid and flavourings. Depending on the type of drink, it could also include: fruit juice, vegetable extracts, carbon dioxide, preservatives and colour substances. Raw materials production (such as bulk sweeteners and intense sweeteners) is not included in the scope of this study.

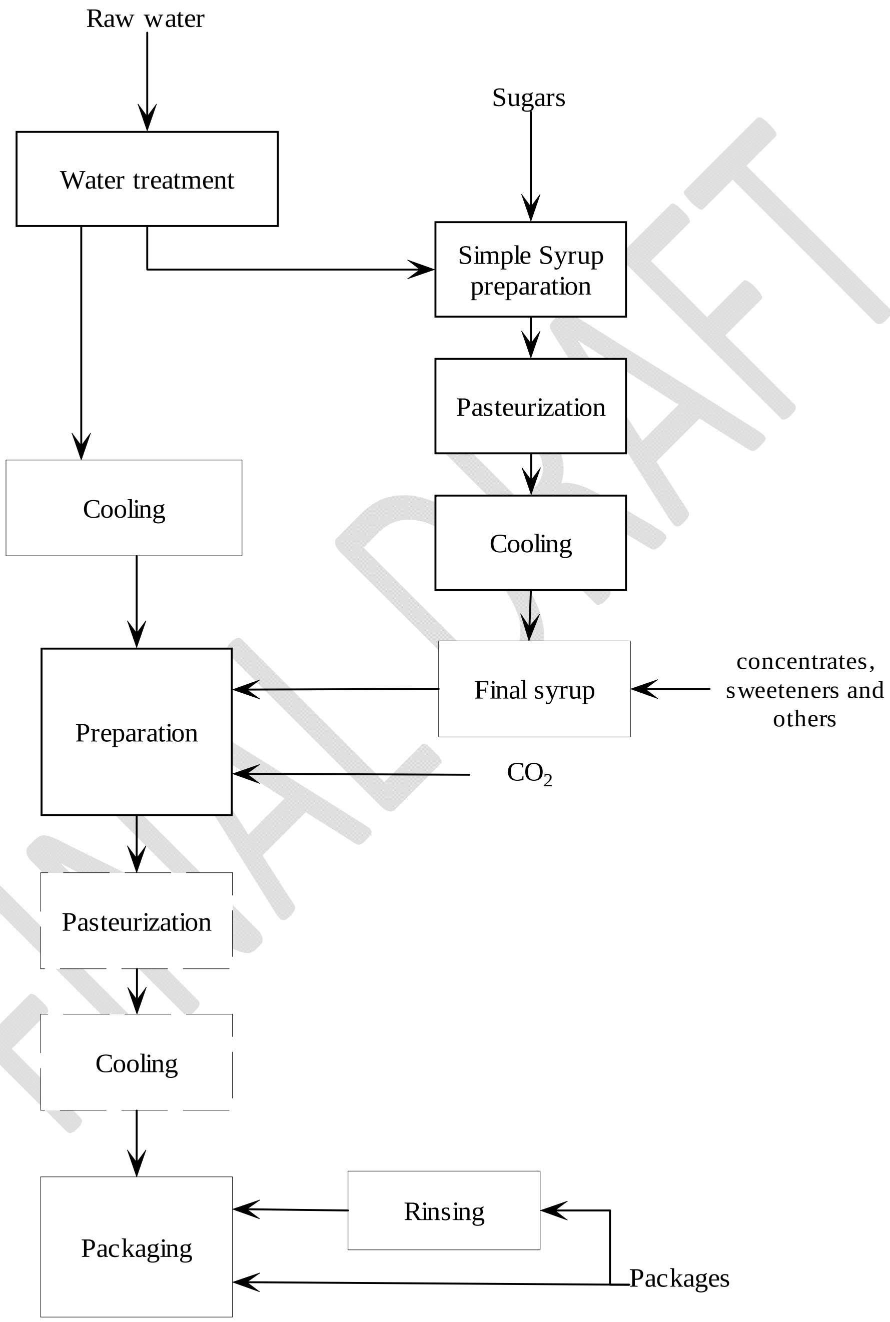
The main ingredient for the production of the soft drinks is the water, which has to be treated properly in order to meet chemical and microbiological standards. Therefore, the quality of the added water influences the treatment process involving several technological alternatives (like decarbonising, deionisation, ion exchange, reverse osmosis, filtering, decolouration, active carbon).

The main target is to produce the basic ingredient called simple syrup, which contains sugar or sweetener. The simple syrup can be filtered or decoloured depending on the quality of the sugar and afterwards it is pasteurised and cooled. Simple syrup is then mixed with appropriate additives (concentrates, vitamins, other sugars, flavours, sweeteners, etc.) and water in order to produce the final syrup.

6.2. Description of the soft drink production process

Producing soft drinks consists of mixing the main ingredients: water, final syrup and carbon dioxide before packaging. In the case of non-carbonated beverages, they are pasteurised in order to ensure proper microbiological quality before packaging (aseptic packaging) or after packaging (pasteurisation tunnels).
The general production processes for the soft drinks are illustrated in Figure 6.1.

Figure 6.1 Flow chart processes for soft drink products.



Source: Instituto tecnologico de la industria agroalimentaria (AINIA)

The packaging process decreases the environmental performance of the soft drinks manufacture. The following list of categories of different soft drink products presents the main environmental aspects due to the implementation of different packaging practices (Steen and Ashurst, 2006; ANFABRA, 2013; Refresco Iberia, 2013 pers. comm.):

- *Carbonated drinks with preservatives*, as is the case of energy drinks, because of the high protein content, require pasteurisation of canned products;
- *Carbonated drinks without preservatives*: require pasteurisation of simple syrup (PET packages) or pasteurisation in tunnels after filling (glass and cans);
- *Still drinks without preservatives (aseptic products)*: require pasteurisation of the product (PET packages) or pasteurisation in tunnels after filling. Nowadays (2014), still drinks with preservatives do not represent a significant share in the soft drinks sector.

Differences among the types of packaging are described below:

Glass bottles**:** Sorting, inspection, thorough washing and disinfection are processes required in returnable glass bottles with the aim of reducing the microbiological contamination of the container and in parallel to remove old labels, ink jet coding etc. A typical treatment for returned glass bottles includes several steps with increasing and decreasing temperatures along the process. For instance the treatment could be the following: pre-warming of bottles to 30°C with rinsing water, pre-rinsing with warm water at around 55°C, immersion of bottles in warm caustic solution (about 1.5% and 60°C) and rinsing with warm water, repeating immersion and rinsing at about 80°C, rinsing at decreasing temperatures (at about 80°C, 60°C, 50°C, 30°C) and final rinsing with clean treated water. In non-returnable glass bottles, a rinser replaces the washer (Steen and Ashurst, 2006).

Cans**:** In canning lines cans are usually sprayed with filtered water to remove any possible debris in their internal walls. Cans are emptied by gravity, so usually long production lines are needed in order to ensure all the rinse water drains from the can. Water is usually filtered and recycled within the line (Steen and Ashurst, 2006).

PET bottles**:** PET bottles are usually placed directly onto the filling line. Firstly, bottles are cleaned by rinsing filtered water into the bottles and then rotated into a vertical upturned position to drain the water. For some products a cleaning agent and sterile water are also used afterwards (Steen and Ashurst, 2006).

Depending on the materials, unit operations can vary, for example, PET is not resistant to high temperatures, and therefore, pasteurisation cannot be applied after filling. Then, if sterilisation of packaging is also required because of the type of product to be filled (still and carbonated soft drinks without preservatives), steam or peroxide solutions must be used. In the case of glass and cans, pasteurisation is carried out in tunnels after filling.

6.3. Main environmental aspects and pressures

The environmental aspects of the production of soft drinks can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects and pressures are illustrated in Table 6.1.

Table 6.1: Main direct environmental aspects and pressures of soft drinks production.

Most relevant direct environmental aspects	**Main environmental pressures**	
	INPUTS	**OUTPUTS**
Soft drink processing	Water consumption (ingredient) Energy consumption (heat and electricity) Use of carbon dioxide	Wastewater generation Air emissions (exhaust gases) Waste generation
Cleaning of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals (acid, alkali, detergents and disinfectants)	Wastewater generation Waste generation
Packaging	Water consumption (rinse) Use of chemicals (cleaning of returnable packages) Energy consumption (power and compressed air) Use of materials (packaging)	Wastewater generation Packaging waste
Water preparation	Water consumption Use of salt, acids, alkalis, additives (decarbonising, deionisation) Energy consumption (electricity)	Wastewater generation Waste generation (filters, membranes, active carbon, sludge)
Energy supply	Energy consumption (fuel and electricity)	Air emissions (SO_x, NO_x, etc.) GHG emissions (CO_2)

Source: Instituto tecnologico de la industria agroalimentaria (AINIA)

Pasteurisation and sterilisation of drinks are steps involving high water and energy consumption. Another relevant factor affecting environmental impacts is related with the types of packages used, including returnable glass bottles and single-use packages (glass, plastic, cans, cartons).

Water

The main ingredient for soft drinks is water. Fresh water needs to be properly treated in order to meet chemical and microbiological standards. The actual consumption of fresh water for the production of standardised water will depend on the initial quality of supply water and the type of treatment systems applied.

Furthermore soft drink industries require large quantities of fresh water for washing bottles, rinsing cans and bottles, cleaning and disinfection of equipment and for other operations such as cooling, or steam production. In addition, considerable differences in water consumption have been reported depending on the type of product, packaging material and the type of packaging used (single-use or packages or returnable packages).

Wastewater
A significant amount of the wastewater generated arises from washing and rinsing packaging and cleaning and disinfection of equipment and installations. Water consumption and wastewater production are major issues in this sector (EC, 2006). Some typical wastewater production figures for the soft drinks sector are shown in Table 6.2.

Table 6.2 Average specific wastewater discharges from soft drink industries.

Product	Specific wastewater discharge (m^3/m^3 of product)
Bottled waters	0.8
Fruit juices	1.5
Carbonates/dilutables	1.4
Carbonates/fruit juices	3.6

Source: EC, 2006.

Energy
Soft drink industry have significant electrical and thermal energy use (Ganji, 2002). The energy used for soft drink production facilities is typically in the range of 0.4-0.6 MJ/l of produced beverage (UNESDA, 2009).
Two of the most demanding operations in terms of energy in a large soft drink manufacturing plant are refrigeration (27%) and compression of air (17%) (Ganji, 2002). Other equipment demanding electricity are: lighting, blowers, and pumps for pumping water and product.
Thermal energy is used mainly in pasteurisation, packaging sterilisation (when required), cleaning and disinfection or warming the containers to avoid condensation.

Packaging
Damaged packages and packaging from suppliers (corrugated board, kraft paper, low-density polyethylene stretch wrap and wood pallets) are the main packaging waste produced in soft drinks plants.

Indirect aspects
The most relevant indirect environmental impacts generated in the upstream and downstream activities are related to:

- production and end use of packaging;
- transport and logistics operations of ingredients and final products;
- retail of the final products;
- use by consumers.

Production of packaging (glass bottles, aluminium cans, aluminium and high-density polyethylene (HDPE) caps, kraft paper and polypropylene (PP) labels) in upstream activities implies high resources and energy consumption, air emissions and waste generation. PET bottles are usually blow-moulded directly onto the filling line.

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6.4. Best environmental management practices

This chapter is aimed at giving guidance to soft drinks manufacturers on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[29]. For the aspects addressed in this document, the table mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of soft drinks manufacturers on all aspects listed in the tables below.

Table 6.3: Most relevant direct environmental aspects for soft drinks manufacturers and how these are addressed

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
Soft drink processing	Energy consumption Water consumption Waste generation Waste water generation	• Reference to BAT in FDM BREF • BEMP on sustainable supply chain (Chapter 3) • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Cleaning of equipment and installations	Energy consumption Water consumption Use of chemicals Waste water generation Waste generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Packaging	Water consumption Energy consumption Use of materials (packaging) Waste water generation Packaging waste	• Reference to BAT in FDM BREF • BEMP on improving or selecting packaging to minimise environmental

[29] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
		impact (Chapter 3) • BEMP on the use of blowers in the drying stage (Section 6.4.1)
Water preparation	Water consumption Energy consumption Use of salt, acids, alkalis, additives Waste water generation Waste generation	• Reference to BAT in FDM BREF
Energy supply	Air emissions GHG emissions Fossil fuel consumption	• BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

Water is the main ingredient of soft drinks and its sustainable supply is very important. It is an ingredient which requires different actions, compared to the other ones, in order to achieve a sustainable supply. Measures for a sustainable supply of water are outlined in the BEMP on sustainable supply chain management.

Table 6.4: Most relevant indirect environmental aspects for soft drinks manufacturers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on sustainable supply chain management (Chapter 3)
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x, particulate matter etc.)	• BEMP on transport and logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

6.4.1. Use of blowers in the drying stage of bottles/packaging

Description

Compressed air is an energy-carrying medium that is very versatile, flexible and safe, and which is commonly used in the soft drink industries for air tools or for more complex operations such as pneumatic controls. However, compressed air systems are very energy intensive.

Compressed air systems consist of an air compressor or a sequence of multiple compressor units followed by aftercoolers, receivers, air dryers, air storage tanks and supply lines. The system feeds a distribution system running throughout the factory to the end-use equipment.

In soft drinks manufacturing installations, the compressed air system supplies compressed air for multiple uses/equipment in a very variable range of pressure requirements. For example, the blow-moulding process requires compressed air ranging from 15 to 43 bar depending on the type and material of the container. Some other packaging equipment such as the machine operating the pneumatic cylinders and the conveyor systems require compressed air close to 7 bar. Finally, in other steps, such as the drying of cans/bottles or rinsing bottles with ionised air, a low pressure (around 0.2 bar) and high speed air streams are required. The relative power consumption of compressed air for drying can be 20-30% of the total compressed air produced (Refresco Iberia, 2014 pers. comm.).

The efficiency of air compressors (the ratio of energy input to energy output) at the point of use can be as low as 8-10 % in many compressed air systems (NCDPPE, 2004; Carbon Trust 2012). Moreover, the delivery of compressed air involves costly systems with frequent maintenance requirements given that in soft drink industries the compressed air must be dry and lubricant-free.

Given its low energy efficiency, the use of compressed air should be restricted to the minimum volume necessary and for the shortest possible duration. Compressed air should be used in cases when significant productivity gains, safety enhancements, or labour reductions are needed (EERE, 2003).

In the soft drink industries, the drying step is carried out after bottle washing, package rinsing or after coldfilling, where condensation is formed on bottles. Drying eliminates the external humidity of the bottles/cans thus preventing problems during labelling, coding, weighting and packaging. It improves the quality of ink jet coding, prevents corrosion and bacterial growth under bottle and can lids, ensures adhesion of heat-shrinkable and pressure-sensitive labels and ensures the highest packaging quality and weighting accuracy. Compressed air is normally used for these operations and depending on the case, air knives, jets and nozzles are used to provide a continuous laminar air-stream. High volumes of air at low pressure are required to dry the packages or conveyor belt systems. The air stream has no specific air quality requirements in terms of humidity or microbiological quality, so does not need to be previously filtered or dried. Compressed air systems provide unnecessarily high-pressure dry air streams (around 7 bar) resulting in high energy consumption.

Significant energy savings can be achieved by using well designed high-velocity blowers instead of compressed air for drying bottles and cans. It is BEMP to install small blowers at the point of use (in can/bottle drying stages and in air ionising rinsing systems) which can replace compressed air-based dryers, producing the same amount of airflow and pressure with a much higher energy efficiency.

The primary difference between the blowers and compressors is the pressure to which they can compress air. A compressor can raise air pressure to a higher level than blowers; in fact the ratio between the discharge pressure over the suction pressure is between 1.11 and 1.20 for blowers while for compressors it is more than 1.20. Blowers are designed to provide large volumes of air at low pressures with lower power consumption (UNEP, 2006).

Blowers can easily replace in a more energy-efficient way the compressed air used for drying operations during bottling and canning in soft drink industries.

Blowers have the additional advantage that they can be fully automated and can automatically stop when the production line stops. Instead, compressed air is produced in centralised systems and the service continues even when the production line stops.

Blowers require very little maintenance and do not require long pipelines like compressed air systems, therefore avoiding the occurrence of air leaks.

Blowers can also be adapted for generating the air flow in ionised air systems. In this case, the high-speed air generated in the blower passes through an ultra-clean filter, and then into a manifold where the air becomes electrically charged.

Achieved environmental benefits

Reduction of electricity consumption is the main environmental benefit associated with the use of high-speed air blowers instead of air compressors in the drying stage.

Energy savings of up to 87% have been reported in the case of soft drink companies which replaced compressor systems with high-speed centrifugal blower systems (Stanmech, 2014).

Energy savings can be higher when inefficient compressed air systems where leakages are present are substituted with air blowers. Air leakages in compressed air systems are difficult to control and increase with time; they can be responsible for up to 10-15% of the total energy consumption of compressed air system (Refresco Iberia 2014). Compressed air systems with long piping systems are also subject to a high energy demand (because of the pressure drop along the line) and therefore if they can be substituted with air blowers the energy savings achieved are considerable (as high as 20 to 30 % of air capacity and power), according to EERE (2003).

Finally, installation of air blowers avoids energy losses when the packaging line is shut down. The shutdown times in packaging lines are very variable, depending on the stops due to change in product formats, cleaning, line malfunction, etc.

Appropriate environmental indicators

The electricity used in package drying operations is only a part of the total electric power used in the entire installation, whilst drying requirements depend on the type and design of the package (can, bottle, etc.) and the technical characteristics of the conveyor belt. So the most appropriate environmental indicator should refer to the energy consumed in the specific blowing stage, expressed as kWh/litre of product..

Cross-media effect

No environmental cross-media effects are generated by the implementation of this BEMP.

Operational data

A wide range of blowers are available on the market. It is reported that they can deliver more air volume at higher velocities and they are able to remove 95% to 100% of liquid from the product's surface. In addition, prevention of bacteria and corrosion is achieved.

Applicability

Blowers can replace compressed air systems for drying bottles/cans in all installations. Blowers can also replace compressed air systems to produce ionised air. In most cases, blowers can be sized according to the available space and necessary air supply flow and pressure.

The combination of blowers and heaters provides considerably faster drying times but can have severe space limitations.

Centrifugal blowers are the blower type most commonly indicated to substitute compressed air in drying operations since they have a good flow/energy consumption rate.

Normally the knives, jets and nozzles installed in the drying systems have to be replaced when air blowers are used instead of compressed air systems. These knives, jets and nozzles are specially designed to increase their performance at lower air pressures (Refresco Iberia 2014).

Economics

Generation of compressed air is one of the most energy-intensive (and therefore expensive) processes in a soft drink manufacturing plant. About 8 kW of electricity is used to generate 1 kW of compressed air.

The investment in blowers for drying or ionised air applications is higher than for compressed air systems but it often has a quick return of investment due to the significant energy savings. The cost of blowers can be very variable depending on the performance characteristics required at the point of use (e.g. air flow and maximum air pressure). Air flow can vary from 5 m^3/h -40 m^3/h and pressure from 0.01 bar to 0.2 bar.

Driving force for implementation

The main driving force for implementation of this technique is the energy savings achieved with blower systems. Other driving forces are:

- Blowers require very little maintenance work.
- Blowers allows the packaging line to be fully automated, so that when the production line stops the blowers do too.
- Individual blowers also fit better with the air stream requirements at the point of use than compressed air system do.

Reference organisations

Coca-Cola Company

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7. MANUFACTURE OF BEER

7.1. Introduction

Europe maintains a strong position as worldwide beer producer. In 2011 the beer production and consumption within the EU-27 was 377 million hectolitres and 354 million hectolitres respectively. In the European Union, Germany has the largest number of breweries, followed by United Kingdom, Italy, Austria and the Czech Republic. In terms of direct employment, Germany, the United Kingdom, the Netherlands, Spain and Belgium are the countries with the highest number of employees in the sector (The Brewers of Europe, 2012a). Some figures for the brewery sector are presented in Table 7.1.

Table 7.1 Main data of the European brewing sector (2011).

Country	Beer production (000 hl)	Beer consumption (000 hl)	Active breweries (No)
Austria	8917	9105	170
Belgium	18571	8574	123
Bulgaria	4820	5100	8
Croatia	3737	3683	6
Cyprus	316	450	2
Czech Republic	18181	15583	55
Denmark	6590	3854	150
Estonia	1360	980	6
Finland	4220	4732	25
France	15910	20000	442
Germany	95545	87655	1341
Greece	3700	4005	17
Hungary	6249	6464	-
Ireland	8514	4721	26
Italy	13410	17715	391
Latvia	1529	1626	-
Lithuania	2922	2935	73
Luxembourg	330	325	3
Malta	127	188.7	1
Netherlands	23644	11974	125
Norway	2346	2426	32
Poland	37854	36007	117
Portugal	8299	5320	7
Romania	16900	17000	20
Slovakia	3123	3997	5
Slovenia	1640	1685	-
Spain	33573	35196	88
Sweden	4491	4806	65
Switzerland	3546	4626	360
Turkey	9212	8244	11
United Kingdom	45694	44843	946

Country	Beer production (000 hl)	Beer consumption (000 hl)	Active breweries (No)
Total EU-27	**377512**	**354618**	**-**
Total EU-27 + 4 (all)	**396353**		**-**

Source: The Brewers of Europe (2012a)

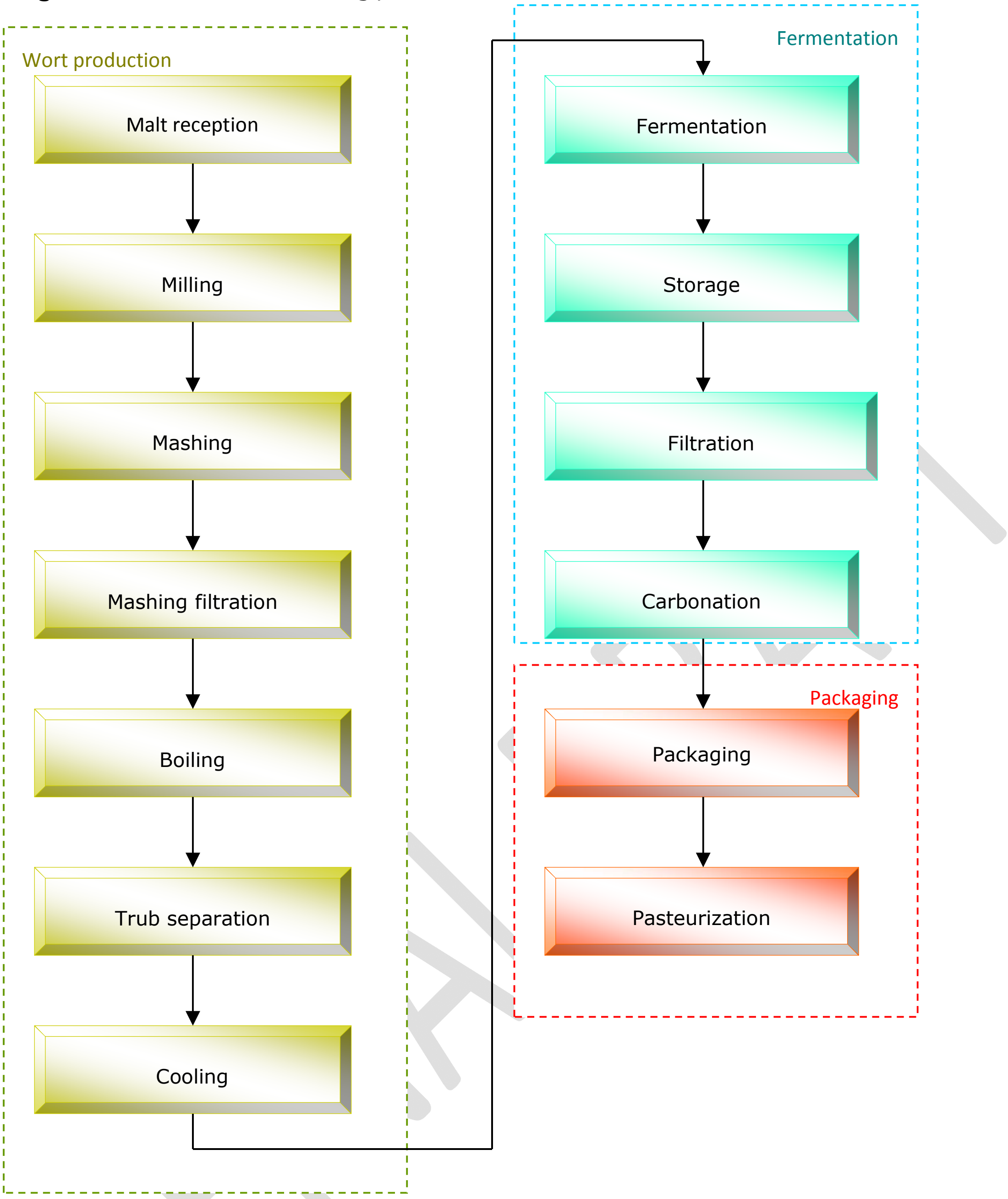
The main inputs for beer production are listed below.

- *Water* is the main ingredient of beer. In some areas, water should be pretreated (prepared) in situ until it reaches the required quality and homogeneity from a microbiological, chemical and organoleptic point of view.
- *Malt* is the most important raw material for the production of beer. In the past, the brewery generally produced the malt itself. Nowadays, this production step is usually performed by commercial malthouses.
- Hops are the female flowers of hop species (Humulus lupulus) which are used to give bitterness and flavour to beer. Hops can also be used in form of extract.
- Yeast is normally produced on-site in the brewing.
- Carbon dioxide can be recovered on site from the beer fermentation stage or acquired from third companies.

7.2. Description of the beer production process

The main beer processing phases are listed below and reported in Figure 7.1:
a) Wort production: malt reception, milling, mashing, filtration, boiling, trub separation and cooling.
b) Fermentation/Beer processing: fermentation and storage/maturation, filtration and carbonation.
c) Packaging: packaging and pasteurisation.

Figure 7.1 Flow chart of brewing process.



Source: AINIA

Wort production:
The grains (malt and other unmalted cereals) are received in bulk, weighed and cleaned and transferred to appropriate silos. Malted barley is ground in order to break the endosperm, causing the least possible damage to the hull. After milling, the malt is mixed with brewing water to form a mash. Unmalted cereals can be added as a supplementary source of carbohydrates. The mash is heated at selected temperatures to release (by enzymatic action) fermentable extract, which serves as substrate for the yeast in the fermentation phase.
The wort is separated from the insoluble solids, the so-called "brewers' grains" which are separated from the wort by straining. The brewers' grains can be used as cattle feed.

The wort is boiled with hops at the stage known as boiling. During this step a number of varied and complex reactions take place, one of which is the solubilisation and isomerisation of the bitter substances and hop oils.
A thick clot material (precipitated protein) is separated from the liquid by heat. This clot is known as the "hot trub". After separation of the trub, the finished wort is cooled to approximately 8-20°C and is then transferred to the fermentation area.

Fermentation
Yeast is added to the cold wort and then aerated to encourage yeast growth. When the main fermentation is completed the yeast is harvested. The beer resulting from the fermentation is subjected to a cooling step, favouring the fermentation of the residual extract and the decantation of yeast and product-clouding substances. Matured beer is normally clarified by filtration, usually diatomaceous earth (kieselguhr) filters, membranes, cardboard, etc. Finally, the beer is carbonated to the required specifications.

Packaging
The beer is pumped from beer tanks to the packaging area where it is bottled, canned or kegged. Returnable bottles require a previous cleaning stage, with hot water and caustic soda. In packaging lines using non-returnable bottles and cans, the bottles/cans are only flushed with water before filling. If using kegs, they must be cleaned and sterilised with steam before filling.

7.3. Main environmental aspects and pressures

Breweries are highly dependent on the quality of the required raw materials (natural resources). Overall, the main environmental pressures of the industry are: water and energy consumption, by-products, waste and waste water management, and packaging. Table 7.2 summarizes the key environmental performance indicators of the European brewing sector over the time period 2009-2010.

Table 7.2 Key environmental performance indicators of the European brewing sector (2009-2010).

	Units	2009	2010
Total production in EU-27 + 3	Million hl	401	399
Production represented (including other beverages)	%	64.8	64.8
Production represented which is not beer ***	%	2.8	2.6
Specific water consumption	hl/hl**	4.4	4.2
Waste water production	hl/hl**	2.8	2.7
Total direct energy	MJ/hl**	119.5	116.8
Renewable energy	%	4.8	5.3
Carbon emissions from brewery (Scope One)	kg/hl**	4.7	4.6
Carbon emissions electricity usage (Scope Two)	kg/hl**	3.3	3.2
Total carbon emissions (Scopes One and Two)	kg/hl**	8.0	7.8
Secondary products: Animal feed	kg/hl**	15.2	15.5
Secondary products: Biogas production	m^3/1,000 hl**	83	92

* Based on 2010 data when compared to 2008
** Per hectolitre of beer produced

*** In some production facilities beer is not the only beverage that is being produced. Data which were gathered represented production of all beverages.
Source: KWA and Campden BRI, 2012.

The most relevant environmental aspects for beer manufacturers can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects and pressures are presented in table 7.3.

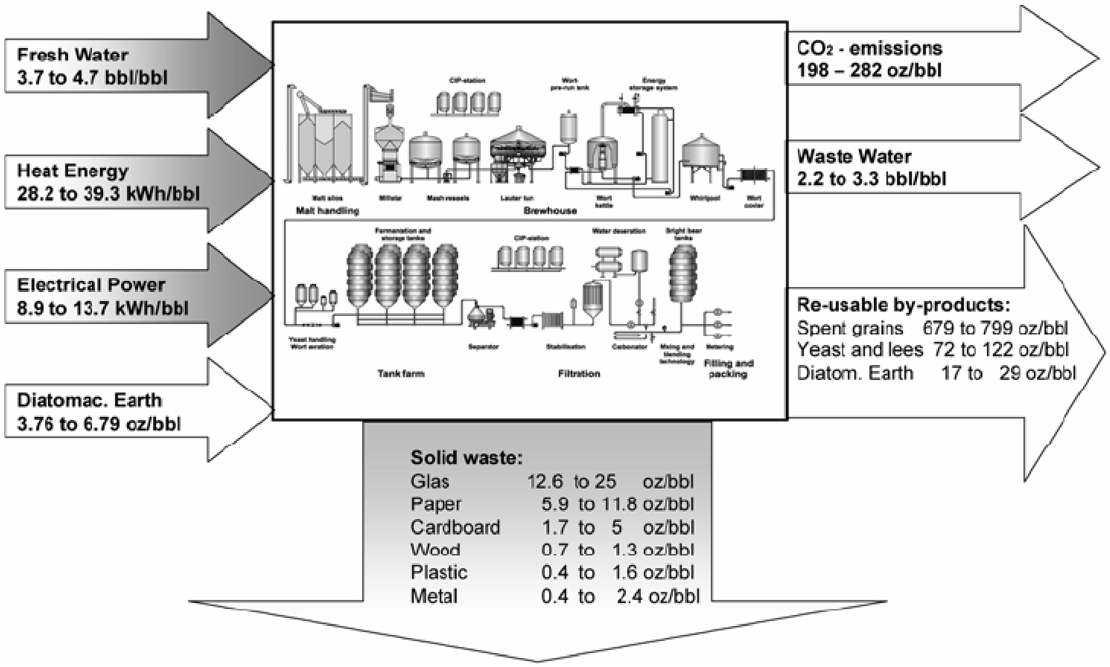
Table 7.3: Main direct environmental aspects and pressures of beer production.

Main direct environmental aspects	Main environmental pressures	
	Inputs	Outputs
Beer production	Water consumption Energy consumption (heat and power) Use of filtration material (diatomaceous earth)	Wastewater production (process and cooling water) Waste production (exhausted diatomaceous earth) Air emissions (dust, fermentation gases (CO_2), water vapour), odour
Cleaning of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals (acid, alkali, detergents and disinfectants)	Wastewater production
Water preparation	Water consumption Use of salt, acids, alkalis, additives (decarbonising, deionisation) Energy consumption (electricity)	Wastewater production Waste production (Filters, membranes, active carbon, sludge, packages etc.)
Packaging	Water consumption (rinse) Energy consumption (electricity) Use of materials (packaging)	Wastewater production Packaging waste
Energy supply	Energy consumption (fuel and electricity)	Air emissions (SO_x, NO_x,etc.) GHG emissions (CO_2)
Auxiliary process	Fuel consumption (steam production) Water consumption (steam) production) Energy consumption (WWTP, compressed air etc.) Use of chemicals (WWTP, boiler, cooling system) CO_2 purification Water preparation (e.g. water consumption, use of salt, acids, alkalis, additives (decarbonising, deionization, electricity use)	Air emissions (CO_2, SO_x, NO_x etc.) Wastewater production Waste production

Source: AINIA

The input-output analysis of the brewing stage is shown in Figure 7.2. In particular, it should be noted that breweries with capacity > 1 million hl/year require approximately 4.35 bl/bbl (average value) of fresh water, a range of 3.76-6.79 oz/bbl diatomaceous earth are required, whilst the generated CO_2 emissions range from 198-282 oz/bbl. Below, an in-depth input output analysis is presented.

Figure 7.2 Input-output analysis for the brewing stage with an output > 1 million hl/year; data from German breweries (Scheller et al., 2008)



Bbl are fluid barrels (1bbl=119.24 litres)

Oz are ounces (1 oz=28.35g)

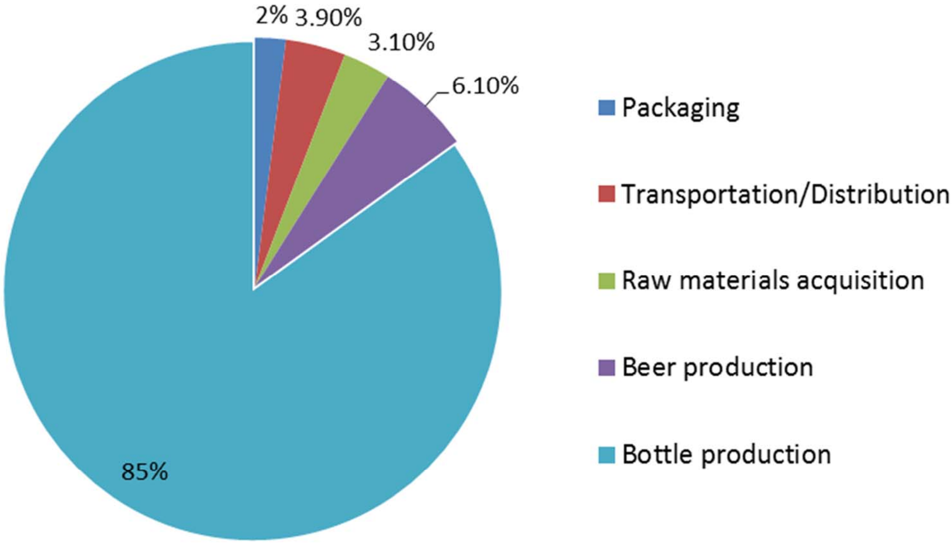
Water

Water is the main component of the beer, about 95% (w/w) of the product. The chemical characteristics of the water can influence not only the taste but also the brewing efficiency. Water chemical conditioning is achieved by the removal of unwanted ions and adding the required levels of desirable ions (Olajire 2012). Moreover water is necessary for various sub-processes like cleaning of equipment and infrastructure, cooling etc. In conclusion, for the production of one litre of beer, the water consumption in an efficient brewery should range from 4 to 7 litres (EC, 2006).

Energy

Breweries require both thermal and electrical energy in a ratio of 3:1. Thermal energy is consumed mainly in the brewhouse, pasteurisation, washing and cleaning of packaging and disinfection of equipment. In particular, for the production of 1 hectolitre of beer, an efficient brewery should consume 8-12 kWh of electricity and 150 MJ of thermal energy (Olajire, 2012). The energy use distribution in beer production is illustrated in Figure 7.3.

Figure 7.3 Distribution of energy use in the beer production sector



Source: Koroneos et al., (2005)

The specific energy use of a brewery is heavily influenced by the utility system and process design, but variations can arise due to the type of packaging, the temperature of the income brewing water and climatic variations (Olajire 2012). A well-run brewery would use from 8 kWh to 12 kWh of electricity and 150 MJ of fuel energy per hectolitre of beer produced.

Wastewater

The streams waste water generated in the brewery are characterised by large variations in their physicochemical parameters. In particular, the chemical characteristics and volumes of the waste water streams generated from the fermentation and filtering processes account for 3% of the total waste water generated, but 97% of the BOD (organic matter) load (EC, 2006). Other pollution parameters in waste water streams are suspended solids (discharge of by-products, diatomaceous earth, label pulp from the bottle cleaner), nitrogen (detergents malt and from additives), phosphorus (cleaning agents) and pH (variable depending on the use of acid for the cleaning process of equipment/infrastructure and returnable bottles).
Waste water treatment plants in breweries include primary (homogenisation, neutralisation) and secondary (anaerobic and/or aerobic sludge) treatment. However, in several cases, a combination of anaerobic and aerobic systems exists providing additional benefits such as the production of biogas. The Brewers of Europe (2012b) reported that approximately 23.6 million m^3 per year of biogas was produced in breweries in Europe in 2010.

By-products

The organic by-products like spent brewery grains and yeast surplus can be considered co-products as they can be used mainly for animal feed. However, due to their energetic value, they can also be considered suitable biomass either for combustion (or co-combustion) or as substrate for biogas production.

Waste

Spent diatomaceous earth, i.e. kieselguhr, used in the phase-out of beer filtration represents one of the biggest problems of waste management in the beer industry due to its volume and the difficulty to find suitable applications. These difficulties are based on the particular characteristics of the waste; limestone-inert matrix with a high organic solids content and a high moisture content.
Sewage sludge is another organic waste stream that could be relatively complicated to manage in certain cases. The simplest option is to use it for composting and production of fertiliser.

Air emissions

There are three main sources of air emissions: exhaust gases generated by fossil fuel combustion (for energy generation), dust from material intake and transport of raw materials (i.e. grains) and biogenic CO_2 generated during fermentation. The largest source of specific odour emissions is the evaporation from wort boiling.

Indirect aspects

The most relevant indirect environmental aspects are classified into upstream and downstream activities, and are listed below:

1. Upstream activities (The Brewers of Europe, 2012b)
   a. Primary production of barley and its transport: Agriculture and transport activities
   b. Usage of packaging materials: production of packaging

2. Downstream activities
   a. Packaging waste
   b. Transportation of packaged beer and retail

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7.4. Best environmental management practices

This chapter is aimed at giving guidance to beer manufacturers on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[30]. For the aspects addressed in this document, the tables mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of beer manufacturers on all aspects listed in the tables below.

Table 7.4: Most relevant direct environmental aspects for beer manufacturers and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Beer production	Energy consumption Water consumption Waste generation Waste water generation Air emissions	• Reference to BAT in FDM BREF • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3) • BEMP on reduction of diatomaceous earth sludge (Section 7.4.1) • BEMP on reduction of energy consumption in wort boiling (Section 7.4.2) • BEMP from batch to continuous production systems (Section 7.4.3) • BEMP on CO_2 recovery in beer production (Section 7.4.4)
Cleaning of equipment and installations	Energy consumption Water consumption Use of chemicals Wastewater generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)

[30] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
	Waste generation	
Packaging	Water consumption Energy consumption Use of materials (packaging) Waste water generation Packaging waste	• Reference to BAT in FDM BREF • BEMP on Improving or selecting packaging to minimise environmental impact (Chapter 3)
Water preparation	Water consumption Energy consumption Use of salt, acids, alkalis, additives Waste water generation Waste generation	• Reference to BAT in FDM BREF
Energy supply	Air emissions GHG emissions Fossil fuel consumption	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)
Auxiliary process	Fuel consumption Water consumption Energy consumption Use of chemicals	• Reference to BAT in FDM BREF

Table 7.5: Most relevant indirect environmental aspects for beer manufacturers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions…	• BEMP on sustainable supply chain management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x,	• BEMP on transport and logistics (Chapter 3)

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
	particulate matter etc.)	
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

7.4.1. Cross-flow rough beer filtration

Description

Beer clarification consists of filtration of rough beer to remove yeast cells (microbiological stabilisation) and retention of haze particles (protein-polyphenol complexes). In addition, this operation also improves beer's shelf life and appearance.

Standard filtration consists of the retention of solid particles (yeast cells, macro-colloids, suspended matter) during dead-end filtration with filter aids. The variety of compounds (chemical diversity, large size range) to be retained makes this operation one of the most difficult to control. In addition, this operation unit uses resources like water, energy and one-way filter aids (mainly diatomaceous earth also known by the name kieselguhr) and generates wastewater and solids.

Beer filtration by means of diatomaceous earth (DE) filters is the most common technology adopted by beer industries. The conventional dead-end filtration with filter-aids (kieselguhr) has been the standard industrial practice for more than 100 years and will be increasingly scrutinised from economic, environmental and technical standpoints in the coming century (Knirsch et al. 1997; Hrycyk 1997).

Kieselguhr filters use a form of silica composed of the siliceous shells of unicellular aquatic plants as a filter medium. Kieselguhr is still the preferred material. No other material gives quite the same filtration performance. Despite its efficiency and reliability, for the above-mentioned reasons, beer filtration with kieselguhr is becoming a problem for the brewing industry.

From an environmental point of view, the diatomaceous earth is recovered from open-pit mines and constitutes a natural and finite resource. After use, recovery, recycling and disposal of kieselguhr (after filtration) are a major difficulty due to its polluting effect. At the end of the separation process, the diatomaceous earth sludge (containing water and organic substances - high in suspended solid (SS) and BOD/COD) has more than tripled in weight.

Disposal of kieselguhr is often an environmental problem (landfill disposal) and can be an issue in some countries like Germany where spent kieselguhr is considered a "chemical waste" or classified in a strict class of waste which is extremely expensive to dispose of. From an economic standpoint, the diatomaceous earth consumption and sludge disposal generate the main costs of the filtration process.

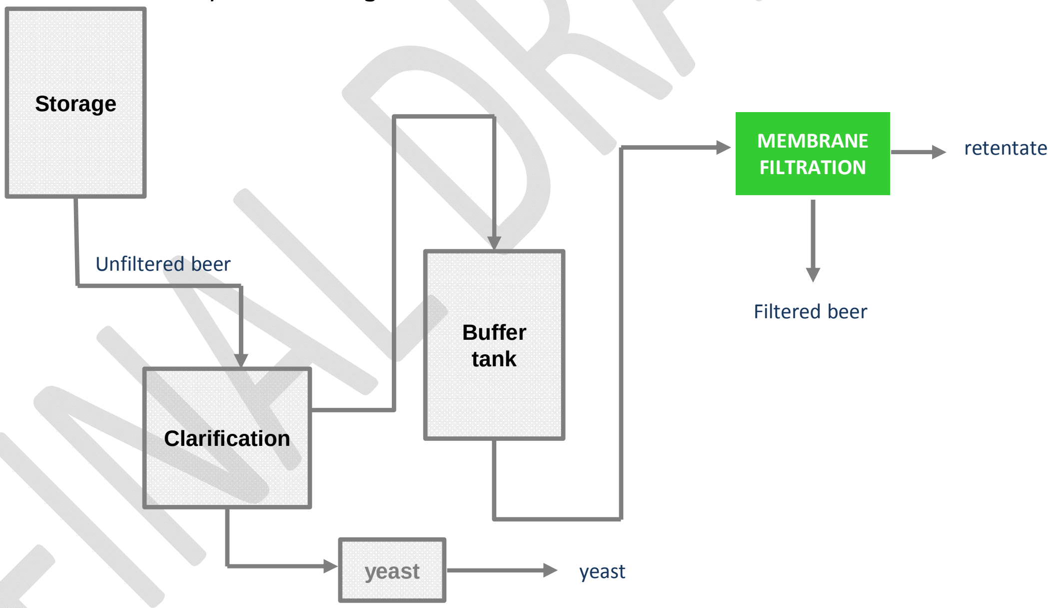
From a health perspective, the conventional dead-end filtration with filter aids consumes a large quantity of diatomaceous earth (1-2 g/l of clarified beer) and carries serious environmental, sanitary and economic implications (Fischer, 1992). Kieselguhr is regarded as a carcinogen when inhaled; in particular, flux-calcined white powders (heated in the presence of caustic soda) contain high levels of crystalline quartz (crystoballite) which is known to cause serious lung diseases.

This technique description focuses on the industrial application, because all the barriers to successful commercial implementation of membrane filtration as an alternative to kieselguhr in breweries are being overcome.

Cross-flow filtration technology

In cross-flow filtration the feed flow is tangential to the surface of the membrane. The retentate is removed from the same side further downstream, whereas the permeate flow is tracked on the other side. A proportion of the material which is smaller than the membrane pore size passes through the membrane as permeate or filtrate; everything else is retained on the feed side of the membrane as retentate.
As filtration progresses, the fouling on the membrane and in the membrane pores builds up and the flow rate is kept at a constant value by increasing pressure. In dead-end filtration, fouling continues to build up, ultimately resulting in the complete blockage of the membrane.
Compared to dead-end filtration in which the liquid flows directly towards the filter under the influence of pressure, tangential flow filters are less susceptible to fouling due to the sweeping effects and high shear rates of the passing flow.

Figure 7.4: Membrane filtration system for rough beer clarification



Source: AINIA

The membranes are made of synthetic materials, such as polyethersulphone, with a pore size between 0.5 microns and 0.65 microns. Depending on the provider system the membrane filters are packaged in a variable number within operational units or modules. The capacity per skid can vary between 100 hl/h and 200 hl/h. The nominal capacity of the commercial units can reach up to 900 hl/h.
Depending on the type of membrane and the existence of previous centrifugation the filtration flow rate can vary from 0.5 hl/m^2 to 0.8 hl/m^2 per hour with a cross-flow rate of around 1.2 m/s. The design of the system in modules or blocks is positioned in sequence for cleaning, thus allowing continuous operation. The system includes a retentate tank where the solids removed from the beer are collected.

A system pressure of about 3 bar gives a maximum trans-membrane pressure of 1.2 bar. Some filters reach an average run length of 20 hours because of small and short backflushes in order to remove surface blockages (yeast, proteins etc.) and reduce the trans-membrane pressure and allow CIP.

When a certain transmembrane pressure has been reached and the filtration performance starts to deteriorate, the system is emptied by means of CO_2. Then a cleaning process with caustic solution, an oxidiser and water takes place. In some systems, a final acid step is used. Following CIP, the modules are disinfected at a temperature of around 80 °C.

Some systems include a high-performance centrifugation step before filtration by membranes (clarification step shown in Figure 7.4). In this case, the unfiltered beer containing fine and coarse solids is fed into the centrifuge to remove as much solid material as possible. The pre-clarified beer still containing fine solids is fed into the membrane filtration system and passes through hollow fibre filter modules. This system has a single-pass cross-flow filtration and retentate flow is not needed. Internal cooling is usually executed in both systems.

Achieved environmental benefit

The environmental benefits associated with the use of cross-filtration membrane systems for beer filtration are the following:

- Prevention or reduction of the strain on natural resource such as the diatomaceous earth.
- Prevention of waste generation by the production of kieselguhr sludge. This waste has high humidity and organic load and is therefore not easy to manage. By eliminating the diatomaceous earth, disposal issues are no longer a concern for the brewery.
- Prevention of waste water pollutant loading (mainly suspended solids and COD) due to the dragging of diatomaceous earth during cleaning.

Appropriate environmental indicators

The amount of kieselguhr used in beer filtration is a good indicator for evaluating the main environmental benefits of the cross-filtration membrane systems proposed. Decreasing figures of this indicator mean more cross-flow filtration utilisation and less kieselguhr consumption.

Cross-media effects

- *Membrane replacement costs*

Commercially available membranes have different lservice lifetimes. More robust membranes need to be developed to increase reliability, with a higher guaranteed membrane life because its replacement cost is relevant to balance the general costs of cross-flow filtration.

- *Chemicals used for membrane cleaning*

Despite the reduced chemical consumption for membrane cleaning, the use of only simple technical-grade chemicals (caustic, oxidisers and acids) instead of the chlorine used for conventional filtration, is also another environmental factor to consider in this technology.

- *Retentate disposal*

When generating filtration retentate, the wastewater must be treated in the waste water treatment plant. Some of the available technologies do not generate this retentate but they do generate a waste stream in a more concentrated stream via the centrifuge.

Operational data

A 480-hl/hour continuous processing line for beer finishing treatment by cross-flow filtration was installed in 2006 at the Heineken brewery in Madrid, Spain.

The plant contains 18 modules per skid. The membrane type is polyethersulphone. This process is based on a specific cleaning procedure which combines several soak flushes and CIP cleaning based on a caustic step, strong oxidative step (three hours in duration) and finally an acid step. The water consumption rate is 0.38 hectolitres of water per hectolitre of filtered beer (water consumption for the DE pre-coat filter is 0.33 hectolitre of water per hctolitre of filtered beer). After cross-flow filtration, the filtered beer is stabilised by means of a PVPP filter (Heineken, 2013).

Another example that meets the specifications mentioned above under 'Description' is the 400-hl/hour continuous processing line for beer finishing treatment, installed at the Spendrups Brewery in Graengesberg, Sweden.

The line incorporates a beer clarification system consisting of a centrifuge, which removes yeast and other coarse matter from the rough beer before its clarification completed by a membrane filter. In this case, the latter comprises three modular blocks, each with 28 polyethersulphone membrane filter modules, with a membrane pore size rating of 0.65 microns and a filter surface area of 12 m^2 per module (336 m^2 per block). Filtration is carried out continuously, but only two of the three blocks are in use at any time, while the other is being cleaned or is standing by to be restarted when the next one is shut down for cleaning.

After clarification, the beer is stabilised by means of colloidal stabilising apparatus (in which the beer is run through "cassettes" containing fixed beds of regenerable PVPP) (Wendler et al., 2013).

Applicability

Cross-flow is technically possible for mainstream beer filtration and has been successfully applied in some installations. Diverse opinions exist regarding its global application for all kinds of beers.

This technique is applicable to new breweries and existing plants, which need to increase their capacity with new filtration operation units. For existing plants, the financial justification for changing conventional filtration (precoat filtration) for new cross-flow filtration must be proven.

Economics

Operating costs for cross-flow filtration technology include the cost of energy consumption, the cost of cleaning and regeneration of filtration membranes, the costs linked to the amount of beer losses and the waste water disposal costs.

The use of an optimised cleaning process (reduced water consumption, gentle chemicals against membranes) can extend the filtration run time and reduce the operating costs.

The robustness and reliability of the membranes, the guarantees and costs are reflected through the number of cleaning cycles guaranteed per module and the cost per module. The costs due to membrane replacement represent 27% of the total operating costs for the first example presented in the Operational data section. A guaranteed membrane life is currently between one and two years.

A cost comparison between the membrane and conventional processes is given in Table 7.6.

Table 7.6: Comparison of process costs for rough beer filtration (membrane filtration vs. kieselguhr dead-end filtration).

operation	Membrane process	Conventional process
Rough beer filtration	Cross-flow filtration, EUR 0.44/hl	Dead-end filtration with kieselguhr, EUR 0.43/hl

Source: Adapted from Fillaudeau et al., (2006)

The investment required for the technique will vary from plant to plant. More simplified skid designs and CIP units (with simple dosing of chemicals) and optimised operation for decreasing beer losses result in a lower investment being required.

Driving force for implementation

The main driving forces are the reduction of the amount of waste produced (kieselguhr) and the elimination of disposal costs. The disposal routes of kieselguhr sludge are into agriculture and recycling with an average cost of EUR 170 per tonne. Disposal costs vary widely from one brewery to another with a positive income of EUR 7.5 per tonne up to a maximum charge of EUR 1,100 per tonne of kieselguhr purchased (Fillaudeau et al., 2006).

The fact that DE handling is not hazardous to health means less health and safety risk management

Lower effluent pollutant loadings due to kieselguhr entering the drains results in better wastewater plant control operation and less sludge production.

Membranes allow a high level of automation, less labour and less environmental risk management. The operation of membrane filtration is simple and straightforward, with very short stop-start times.

Reference organisations

According to Pentair, there are 50 plants which cross-flow filtration Pentair technology currently in operation in almost every region of the world. Frontrunners in Europe are the Oettinger Group in Germany and Heineken in several countries.

For the technology described in this best practice, personal communication about cross-flow filtration technology was sent by Pentair. Other information was obtained from the Pall Food & Beverage, GEA Westfalia Separators, Alfa Laval and Sartorius official websites.

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7.4.2. Reducing energy consumption in wort boiling

Description

The brewing process is energy-intensive, especially in the brewhouse where mashing and wort boiling are the main heat-consuming processes (Table 7.7). Breweries with conventional systems for process heat have consumption figures between 36 kWh/hl and 40 kWh/hl while it is reported that the Best Available Technique (BAT) provides a minimum benchmark of 24 kWh/hl (Scheller et al., 2008).

Table 7.7: Energy demand in brewhouse at 7.5% of total evaporation (Scheller et al., 2008)

	Energy use (kWh/hl)	Energy use in brewhouse (%)
Mashing 52/78°C	2.21	19.8
Heating 78/99°C	3.38	30.2
Boiling	5.03	45
CIP	0.28	2.5
Hot service water	2.28	2.5

During the mashing process the malted barley is mashed with hot water for a period to allow the enzymes to break down starch and proteins. Once the wort is separated from the brewers grain by filtration, it is boiled for 1 - 1.5 hours in the wort kettle with hops or hop extracts. The rate of wort evaporation during boiling is 5 - 8 % of the casting volume per hour (EC, 2006).

The boiling stage has particular importance for the beer quality because in this operation the wort is sterilised, the malt enzymes are inactivated, the hops are added to the wort and the undesirable aromas and flavouring compounds are evaporated.

Traditional wort boiling requires high total evaporation (8-12%) to produce enough turbulence in the boil for a homogeneous wort heat transfer and guarantee the stripping of undesirable volatile substances. Two compatible strategies are described: a) recovering heat from boiling vapour condensate and b) reducing total evaporation in boiling. Both techniques can be implemented at the same installation.

Wort pre-heating with heat recovered from the wort vapour condensing

The heat recovery can result in the production of hot water for cleaning operations, flushing brew kettles etc. (EC, 2006).

However, in recent years some brewing plants have been implementing "energy storage systems" for recovering vapour condensate, which is integrated in the heat supply system to preheat the wort before boiling. The wort can be heated from 72°C to approximately 90°C by means of the heat recovered from the vapour condensate (Buttrick 2006; Krones 2013a, 2013b; GEA 2013).

The system consists of several parts: the vapour condenser, "energy storage tank", wort pre-run tank and wort heater. The "energy storage tank" stores water with an internal temperature gradient, colder at the bottom and hotter at the top. The cold water from the bottom part (~77°C) is used to condense the vapour in the vapour condenser. This water heats up to approximately 97°C and is returned to the storage tank from where is used to pre-heat the wort stored in the pre-run tank from 72°C to approximately 90°C. Water is then re-circulated again to the vapour condenser. Alongside this, vapour condensates produced in the vapour condenser are stored in another tank to be used in ohter processes such as cleaning operations.

Table 7.8 shows the energy savings achieved during wort boiling implementing energy storage systems. The total energy and time needed for the first stage (heating the wort to boiling temperature) is reduced by 70%. The reduction in heating time results in an increase in the number of brews per day.

Table 7.8: Energy savings using energy storage systems: Evaporation rate of 4% (Krones, 2013b)

	Standard	With Energy storage system
Evaporation [%]	4	4
Temperature at start of heating [°C]	75	92*
Temperature at start of boiling [°C]	99	99
Energy for heating [kJ/hl]	10,176	2,968
Heating time [minutes]	48*	14**
Brews per day	10.8	14.5

* Downstream of lauter wort heater; ** Start of heating at lauter end

Techniques for reducing evaporation rate during wort boiling.

It is reported that each 1 % of evaporation during wort boiling corresponds to a specific energy loss of 0.67 kWh/hl. Therefore it is worth applying practices that reduce the total evaporation because of the high impact on total energy consumption in the boiling process.

The standard total evaporation for an acceptable wort quality is around 8–12% despite the fact that breweries use different set points regarding time and evaporation rate. The quality of wort is related to the maintenance of homogeneity during wort boiling, low thermal stress on wort particles and enough stripping of unpleasant flavour volatiles. New techniques allow evaporationto be reduced to values below 4% without jeopardising the wort quality.

Different technical approaches have been developed by manufacturers to reduce total evaporation based on either increasing the heat transfer homogeneity (lower temperature differences between the heating medium and the wort by effectively increasing the heating area) or promoting the stripping of volatiles (by promoting the formation of liquid/vapour bubbles).

In particular, the two-phase boiling system achieves reductions in total evaporation to values under 4%. The first phase corresponds to the thermal conversion, in which wort naturally flows through the internal boiler and the boiler is pressurised very slightly to overcome the low pumping height for circulation. Only very little evaporation occurs in this phase and so, its duration can be selected irrespective of the required evaporation. In the second phase, an intensive evaporation of flavours takes place. The two phases (boiling with high homogeneity and stripping) are achieved with the same boiler equipment and in separated kettle and stripping equipment (Buttrick 2006; GEA-Huppmann 2013; Ziemann 2013). A reduction in total evaporation to values under 4% can be also achieved by means of a low rate evaporation boiling stage followed by an additional stripping step. Stripping is caused by flash evaporation due to a drastic drop in pressure in the liquid phase (Krones 2013c; Ziemann 2013).

Dynamic low-pressure boiling

Similar evaporation figures can be achieved using the dynamic low-pressure boiling technique. This technique involves heating wort at a pressure of 150 mbar, equivalent to a boiling temperature of 103°C. When this pressure is reached, it is rapidly reduced to 50mbar and the temperature drops back to 101°C. This takes place several times during each boil and the effect produces a flash evaporation, with the formation of foam and bubbles within the wort kettle, which strips unwanted volatiles and aids coagulation of hot break particles. In order to accommodate the flash evaporation, the kettle volume needs to be 30% greater than for a standard system and the wort is circulated 20–30 times per hour (Buttrick 2006).

The two-phase system and dynamic low-pressure boiling system can be combined in the same equipment. In this case, the second phase is conducted/considered as dynamic low-pressure boiling improving the stripping of undesirable aromas due to an intense formation of steam bubbles in all the wort in the kettle. This combined system allows the removal of undesirable aromas with very low total evaporation rates (3-4%) (GEA 2007).

Achieved environmental benefit

The main environmental benefit achieved with heat recovery and reduction in the wort evaporation systems is the reduction of thermal energy consumption. As this operation accounts for most of the energy requirement in the brewing processes, their implementation has a significant impact on the total energy consumption in the brewing plant. The installation of a vapour condenser and plate heat exchanger to recover heat from the wort vapour can reduce by 70% the energy needed to preheat the wort from 74 to 95°C during the transfer from the tank to the wort kettle.

The energy saving in wort boiling reaches 0.67 kWh/hl. In particular, the energy saving with dynamic low-pressure boiling at a total evaporation rate of 4.5% is approximately 19% lower compared with atmospheric boiling at 7.5% total evaporation. The equivalent reduction of CO_2 emissions would be 0.43 kg CO_2/hl (Scheller 2008).

Therefore a reduction in the use of fossil fuels is achieved with an additional benefit of reducing the CO_2 emissions. Moreover, the condensation of wort vapour minimises odour emissions.

An additional positive environmental effect of the reduction in the evaporation rate is the reduction of the cleaning of the kettle. During each brew a fouling layer is created in the wort side of the kettle which acts as a barrier to heat transfer. This layer has to be eliminated by means of periodic cleaning after a number of brews. The reduction in the evaporation rate reduces the formation of fouling so that less water, energy and cleaning products are required for cleaning. Typical installations require a cleaning operation after processing 16 brews. The number of brews between cleans can increase up to 32 in the case of kettles with external wort boilers where low pressure steam is used (O'Rourke, 2002).

The energy store (wort pre-heating) results in 68-80% energy savings by using recovered boil energy. It is reported that a minimum evaporation level of 3.6% is necessary to recover enough heat for wort pre-heating. Where evaporation exceeds this figure, excess recovered energy may be used for CIP or water heating (Hancock, 2014).

In particular, the following energy reduction levels can be compared dor the use if wort preheating (Hancock, 2014):

a) with no wort preheating: heating 1000 hl wort from 75°C to 100°C requires 10000 MJ

b) with wort preheating: heating 1000 hl wort from 92°C to 100°C requires 3200 MJ

Therefore, the achieved savings are 6800 MJ[31] or 68%.

According to Hancock, (2014) it is reported that a 1% reduction in evaporation results in energy savings of 2 to 4% of brewhouse energy consumption as well as emission reduction.

Appropriate environmental indicator

The total evaporation rate (%) in wort boiling is the core indicator and it varies idepending on wether a single phase or two-phase system is used. The consumption of energy, normally expressed in MJ/hl of beer produced, can be an alternative indicator.

The energy consumption in wort pre-heating (MJ/hl) is an indicator of heat recovery from wort vapour. Number of brews before a new cleaning of the boiling system could also be considered an indicator for quantifying the reduction of cleaning operations of the boiling systems due to a reduction of fouling.

[31] For steam: 6800 kJ/ 2133 kJ/kg = 3,188 kg/brew

Cross-media effects

The reduction of total evaporation in wort boiling reduces the energy recovery for wort pre-heating. This lower energy recovery could be compensated with another low temperature heat source, such as solar thermal heat.

A reduction of the boiling time can entails extra wort recirculation requirements to increase the homogeneity of boiling. The additional power consumption of extra pumping should be considered. However, in appropriately designed installations, this problem can be minimised by using the natural circulation of the thermo-syphon effect. The boiler has to be primed during the preboil stage using a small circulation pump. Once boiling is achieved, the circulation pump can be by-passed and the wort circulated due to the density change between the wort entering the boiler at 98°C and the wort and vapour exiting from the boiler at around 105°C (O'Rourke, 2002).

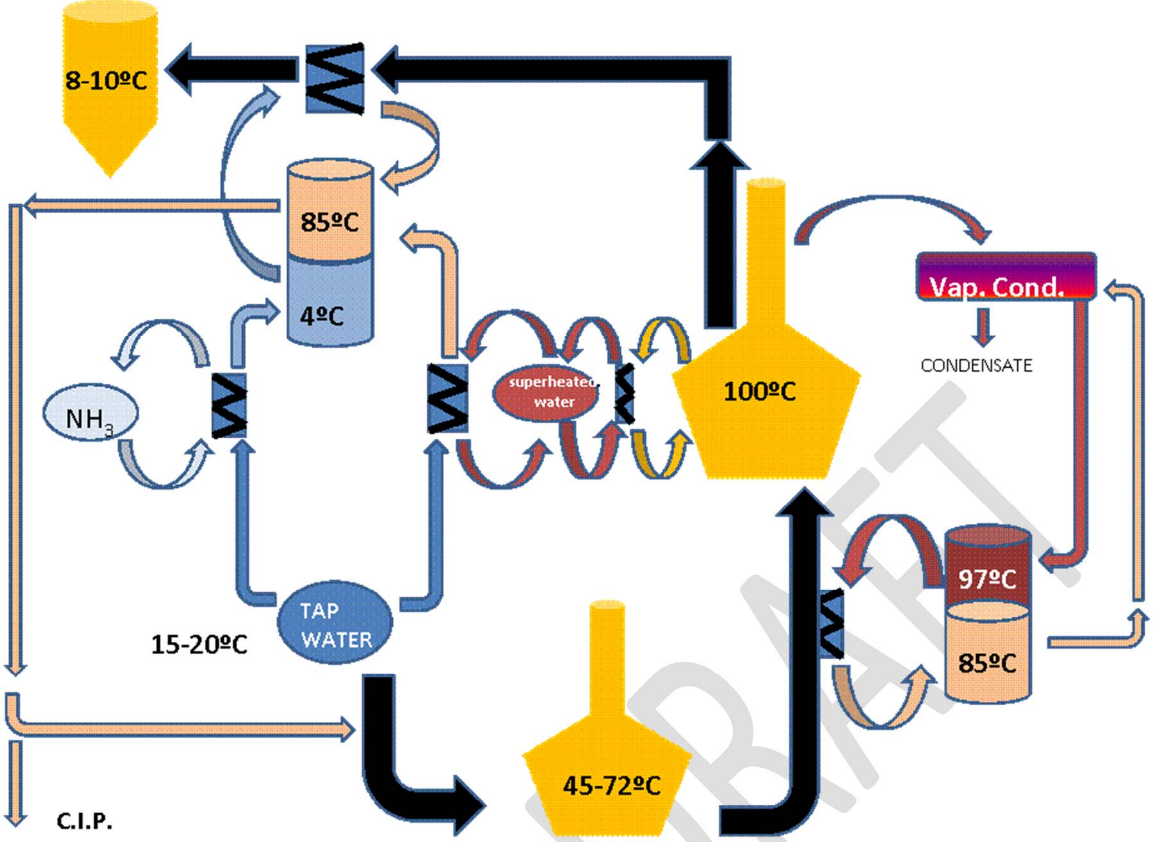
Operational data

Some relevant operational data regarding the implementation of this technique are presented below in the next paragraphs.

The Mahou-San Miguel plant in Alovera, Guadalajara, Spain has a total surface area of 430,000 m2 and a production capacity of 7 million hectolitres of beer per year. The plant has 11 packaging lines (5 for returnable packages and 6 for non-returnable packaging).

In 2007, the brewhouse consumed 60% of the total thermal energy of the plant, which was 219 kWh/t. In 2012, the wort vapour recovery system was installed (Figure 7.5, Table 7.9) and the total consumption of thermal energy was reduced by 25% reaching the value of 164 kWh/t. Likewise CO_2 emissions were reduced from 45 kg/t to 34 kg/t (Mahou-San Miguel, 2013).

Figure 7.5: Wort vapour recovery in the Alovera plant



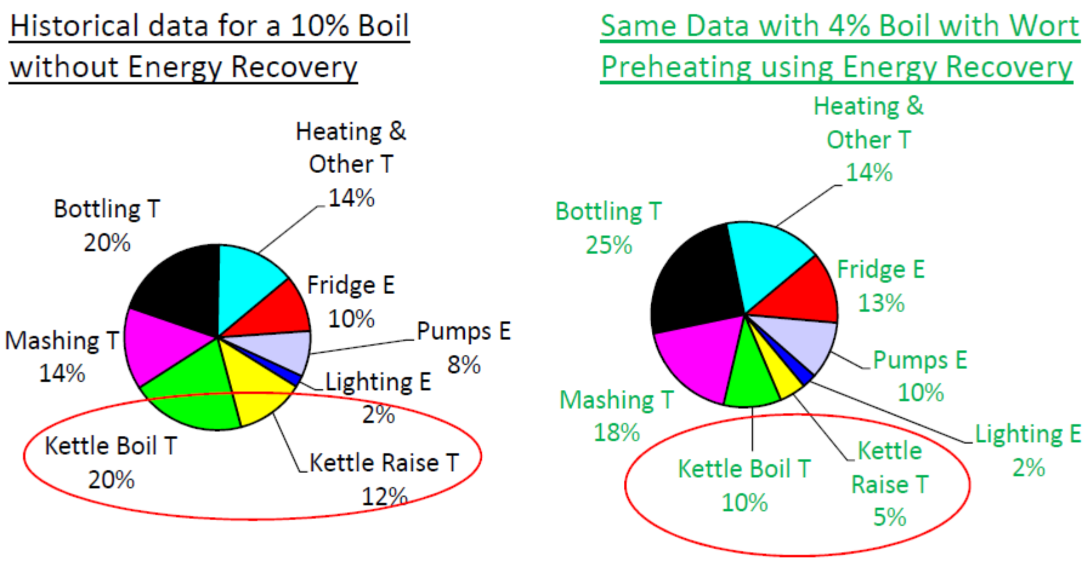
Source: (Mahou-San Miguel, 2013 pers. comm.)

Table 7.9: Figures of recovery system installed in the Alovera plant (Mahou-San Miguel, 2013)

	Unit	*Value*
Annual energy saving	GJ/year	111,600
CO_2 emission saved	t CO_2/year	6,000

As explained in the Description section, wort boiling is one of the major energy users in the brewing process. Figure 7.6 presents the energy use in a brewery for all the different production stages (Hancock, 2014).

Figure 7.6: Wort boiling without energy recovery and with wort pre-heating using energy recovery (Hancock, 2014)



Applicability

Energy storage systema are applicable for any brewing plant, provided that there are no space restrictions for installing the tanks (storage, wort pre-run) and the condenser.
Energy-saving methods based on the reduction of evaporation rate are applicable for any new brewing plant. Different technological alternatives exist for different plant sizes.
For existing plants, an economic study should be compiled in order to assess the opportunity to change the wort boiling installation and the most suitable alternatives. However, the economic study should also include an assessment of other relevant parameters besides energy efficiency such as process cycle times, easiness of cleaning and maintaining quality profiles.
Evaporation reduction is easily applicable in existing wort kettles although it must be mentioned that depending on the recipe, it is possible that the reduced evaporation may influence the beer's characteristics (Hancock, 2014).

Economics

The energy storage system involves the installation of a condenser, a hot water storage tank and heat exchanger for taking the wort from approximately 75°C after the wort separator to 95°C. Large energy savings are possible, especially if the energy recovered from the vapour condenser is used for preheating wort going to the copper vessel.
Data from Mahou-San Miguel in Alovera show an investment of around EUR 1800000 with a yearly saving in energy of EUR 825000.

Driving forces for implementation

Brewing is an energy-intensive activity, so brewers are very interested in finding innovative solutions to reduce energy consumption. Wort heating and boiling is one of the most relevant stages in energy

consumption, so the improvement of energy efficiency is a challenge for brewing companies. Economic savings are the main driving force to install the systems proposed.
Another driving force is the reduction of direct CO_2 emissions (fuel combustion for thermal energy) and therefore the reduction of carbon footprint linked to produced beer.

Reference organisations

Table 7.10: Reference organisations for the implementation of wort pre-heating and reduction of evaporation

Company	Country	Technique
Heineken Madrid plant	Spain	Wort vapour recovery system Reduction of the evaporation rate with two-phase wort boiling from 6.2 % to 4.5 %. This technique has reduced the thermal energy rate to 1.5 MJ/hl beer. (Heineken 2013)
Heineken Seville plant	Spain	Wort vapour recovery system Two-phase wort boiling Dynamic low-pressure boiling (testing) (Heineken 2013)
Heineken Vialonga plant	Portugal	Reduction of the evaporation rate from 4 % to 2.5 % (Heineken sustainability report 2012)
Heineken The Wijlre plant	The Netherlands	Achieved an evaporation rate of 2.5 %, down from 4.5 %. (Heineken sustainability report 2012)
Mahou-San Miguel Alovera plant	Spain	Wort vapour recovery system. Total consumption of thermal energy was reduced by 25 %, (Mahou-San Miguel 2013 pers. comm)

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7.4.3. Moving from batch to continuous beer production systems

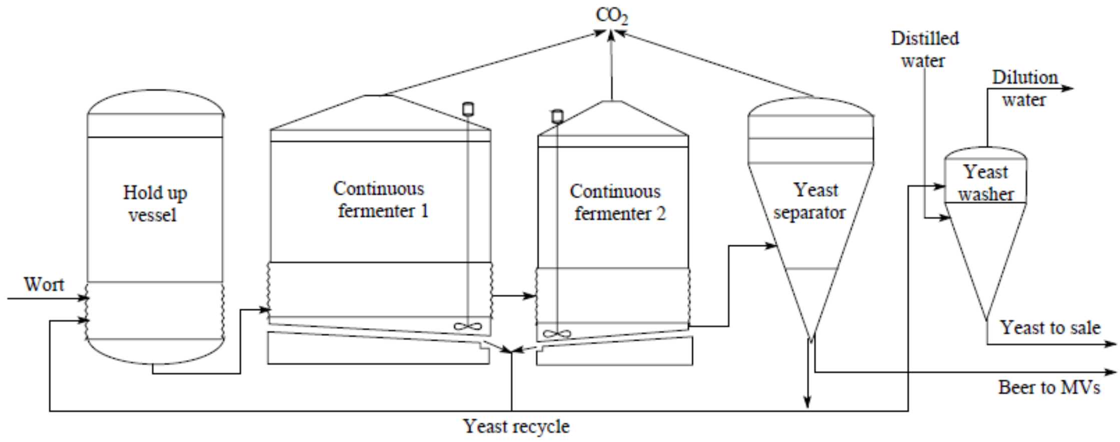
Description

The reduction of energy and water consumption in breweries can be achieved by moving from batch to continuous beer production systems. The continuous fermentation system consists of three stirred tanks and a fourth unstirred one where the beer is separated from the yeast. The system uses a flocculent yeast strain, which is precipitated and collected at the end of the fermentation. From the last (fourth) tank, the clarified beer flows to a warm maturation tank where the flavour is refined by yeast action. The total residence time is approximately from 40 to 120 hours, depending on production requirements. The whole process is illustrated in Figure 7.7.

The first vessel (hold-up vessel or HUV) is used to stimulate yeast growth and to ensure a steady flow of yeast and beer from later on in the fermentation process. The introduction of yeast into wort is stressful for the yeast because of the high nutrient levels. However, by mixing the wort with partially fermented beer, the concentration of nutrients is reduced and thus the fermentation starts faster. The residence time of the beer/wort mixture in the first vessel is about three to four hours.

In the first of the two fermenter vessels, the partially fermented beer is recycled back into the first hold-up vessel. The residence time is approximately 30 hours or more, depending on the production demands. In the second continuous fermenter vessel, a fine-tuning process is carried out, known as fine-tuning of the finished fermented beer. The duration of this stage is approximately 12 hours or even more. This is followed by the yeast separator, which is an unstirred vessel with a conical base. The beer flows into the vessel and most of the yeast settles at the bottom of the cone and is eventually piped back to the beginning of the fermentation system where it is mixed with the incoming wort. During the process, more yeast is produced than is required by the brewery process. Afterwards, the surplus yeast is washed/cleaned to recover as much beer as possible and the yeast can be sold.

Figure 7.7: The continuous fermentation plant



In the maturation vessel, the beer is stored for two days in cold storage.

Continuous wort boiling is implemented under pressure where the wort passes through various heat exchangers and the pressure is reduced to atmospheric through a series of flash-off vessels. The wort residence time can be reduced to a few minutes and the system can be run at any evaporation time relatively independently of the prime energy input (Brilliant Beer Company, 2004). This process has the advantages of reducing the energy requirements, easier integration of the system, full use of energy to preheat the wort, variable evaporation rates and high energy savings. On the other hand, the main disadvantage is the possibility of slightly changing the quality of the final product and potential microbial infection if the wort is stored cold.

Continuous wort boiling is an efficient way of reducing the energy demands. In particular, the energy used for boiling is used for heating up the incoming wort in a multistage process. Initially, the wort feeds into a holding vessel where hop additions can be made. Afterwards, the wort runs through an appropriate heat exchanger where it is heated to approximately 135oC. This temperature is kept constant for 1.5 to 2 minutes in holding tubes. Therefore the wort is held constant at 135oC by regulating the flow rate at the inlet to the first of two adjoining separators. When the wort is flowing into the separator, the pressure is decreased up to a certain value and thus the wort is boiled and evaporated. The wort from the separator runs through a booster pump to one of three whirlpool casting vessels (which should be sized to be approximately equivalent to the capacity of one hour of throughput from the boiler).

An effective evaporation rate of approximately 7% is required to remove the undesired aroma components. Continuous wort boiling allows the steam demand of the brewhouse to be maintained at a constant level, thus avoiding the peaks resulting from batch heating or boiling of the wort. Heat recovery is very efficient, requiring only prime energy input to compensate for the difference between the wort inlet and outlet temperatures and minor heat losses from the heat exchangers (O'Rourke, 2002).

Achieved environmental benefits

The energy use, the water use, the steam consumption and the amount of waste generated are significantly less compared with the batch brew process. In particular, it has been reported that approximately 30-35% of energy savings are achieved by moving from batch to continuous production systems.

The CO_2 which is produced during the fermentation process is collected from the top of the fermenting vessels and thus it is not systematically released to the atmosphere. CO_2 recovery is therefore possible and it may be used for other processes (e.g. purified and compressed for later use in the brewery itself).

Appropriate environmental indicators

Reduction of energy consumption (MJ/hl of beer produced) achieved thanks to moving from batch to continuous production is a suitable indicator.

In addition, the reduction in water consumption (hl/hl of beer produced) achieved due to changing from batch to continuous production is also a suitable indicator.

Cross-media effects

More equipment is employed in a continuous process than in batch processes, increasing the environmental footprint. However, this is compensated by the reduced energy and water consumption.

Operational data

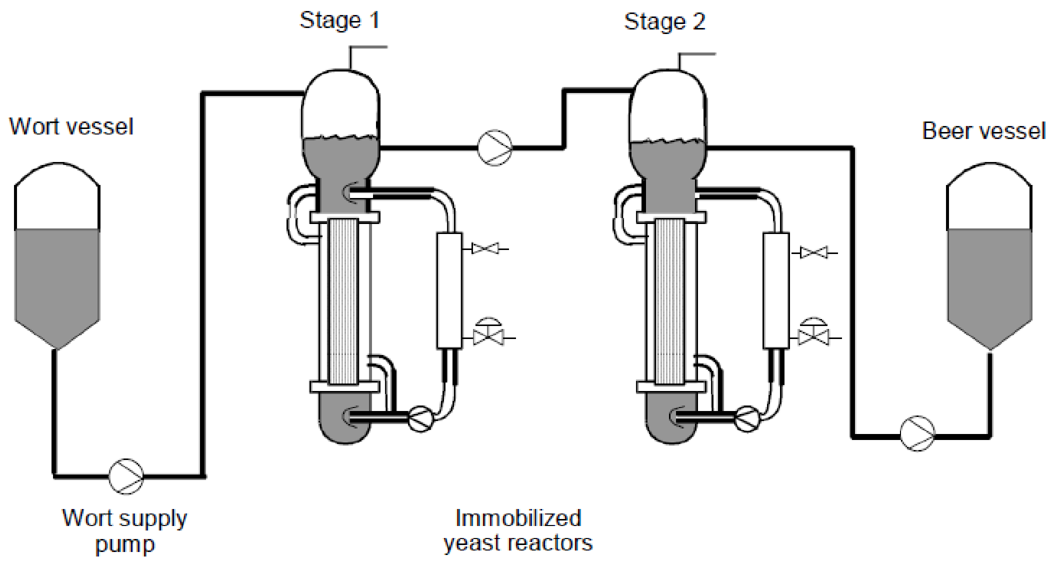
The operational data for Meurabrew (a continuous brewhouse) are presented in Table 7.11. The capacity of their brewhouse is approximately 200hectolitres/hour of cold wort. The beer recipes range from 100% malt brews to brews with 40% other materials.

Table 7.11: Brewhouse with continuous wort boiling and a capacity of 3 million hL at 12 brews/day (Larry Nelson, 2009)

Parameters	Continuous brewhouse
Capacity	200 hl/h of cold wort at 20°P
Pumps	Mash: 180 hl/h – 5.5 kW Wort: 225 hl/h – 4 kW
Utilities	Steam peak flow: 3 t/h Water peak flow: 220 hl/h Electricity installed: 250 kW Electricity peak: 200 kW Peak cooling power: 2,200 kW

In the case of the Meura Delta system, two similar bioreactors were used in series (Figure 7.8). The wort is continuously fed into the first bioreactor where controlled aeration is allowed. In parallel, an appropriate pump circulates the fermenting beer and facilitates the cooling process via an external heat exchanger. The beer from the top of the first bioreactor is pumped to the top of the second bioreactor. Afterwards, the green beer is pumped into a suitable vessel where the final treatment is taking place. The residence time is approximately 22 hours per bioreactor (Virkajarvi, 2001).

Figure 7.8: The Meura Delta system for increased beer production (Virkajarvi, 2001)



Applicability

Continuous wort boiling is difficult to manage with several different wort streams and a number of brewers still have reservations about the quality impacts of switching to continuous brewing. For example, the continuous production systems are noted to have an impact on the taste of the beer (Brányik et al., 2008). Despite being applicable to all size of breweries, the technique might only be feasible for medium- to large-scale brewing operations.

Some key aspects that should be taken into account when moving from batch to continuous wort boiling there are (Brilliant Beer Company, 2004):

- If the wort is stored at temperatures higher than 85°C, then there are hazards associated with oxidation resulting in the pick-up of colour and flavour changes, which may have a potential impact on customers.
- If the wort is stored at temperatures below 35°C, then microbiological infection is a potential hazard.

Economics

The labour and capital costs are reduced because all the steps for the fermentation process are simplified.

Driving forces for implementation

In principle, the continuous processes are more energetically efficient, easier to control and consequently lead to a lower production cost. The main driving forces for implementation are listed below:

- Reduced peak consumption of utilities
- Reduced energy and extract losses
- Reduced waste disposal
- Limited space requirements
- Easy process control

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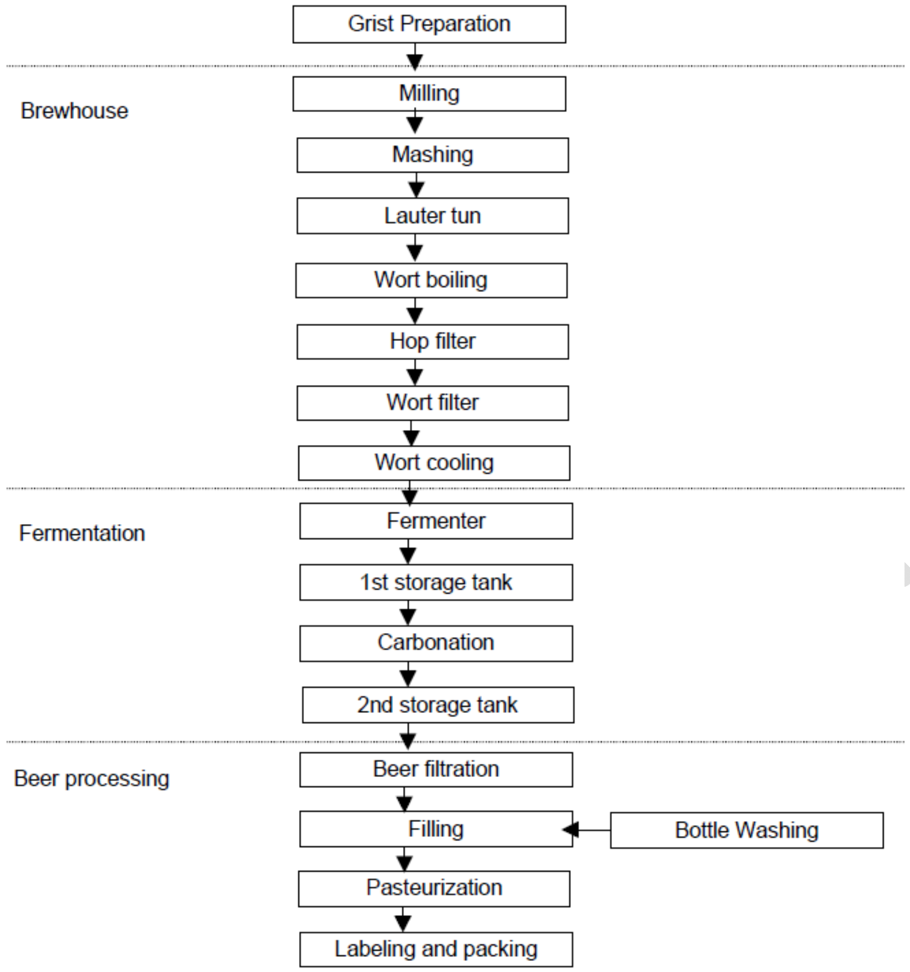
7.4.4. CO_2 recovery in beer production

Description

The main processes of beer production are illustrated in Figure 7.9.

Figure 7.9: Overview of the main processes of the beer manufacturing (Galitsky et al., 2003)



During the fermentation process, the yeast feeds on the wort which results in the production of carbon dioxide (CO_2) and alcohol. The CO_2 produced can be recovered from the top of the fermentation tanks/vessels, the maturation vessels and the bright beer tanks. CO_2 is then scrubbed, purified and compressed for storage. It can later be used in a number of brewery processes, e.g. carbonation and bottling.

The CO_2 generated during the fermentation process contains impurities, hydrogen sulphide, oxygen and dimethyl sulphide. These compounds must be removed due to their negative effect on the taste, odour and shelf life of the final products/beer.

The next step after the collection of CO_2 is therefore its cleaning. A number of processes can be put in place, e.g. liquefaction and then vaporisation. This means that a high amount of energy is needed for this operation.

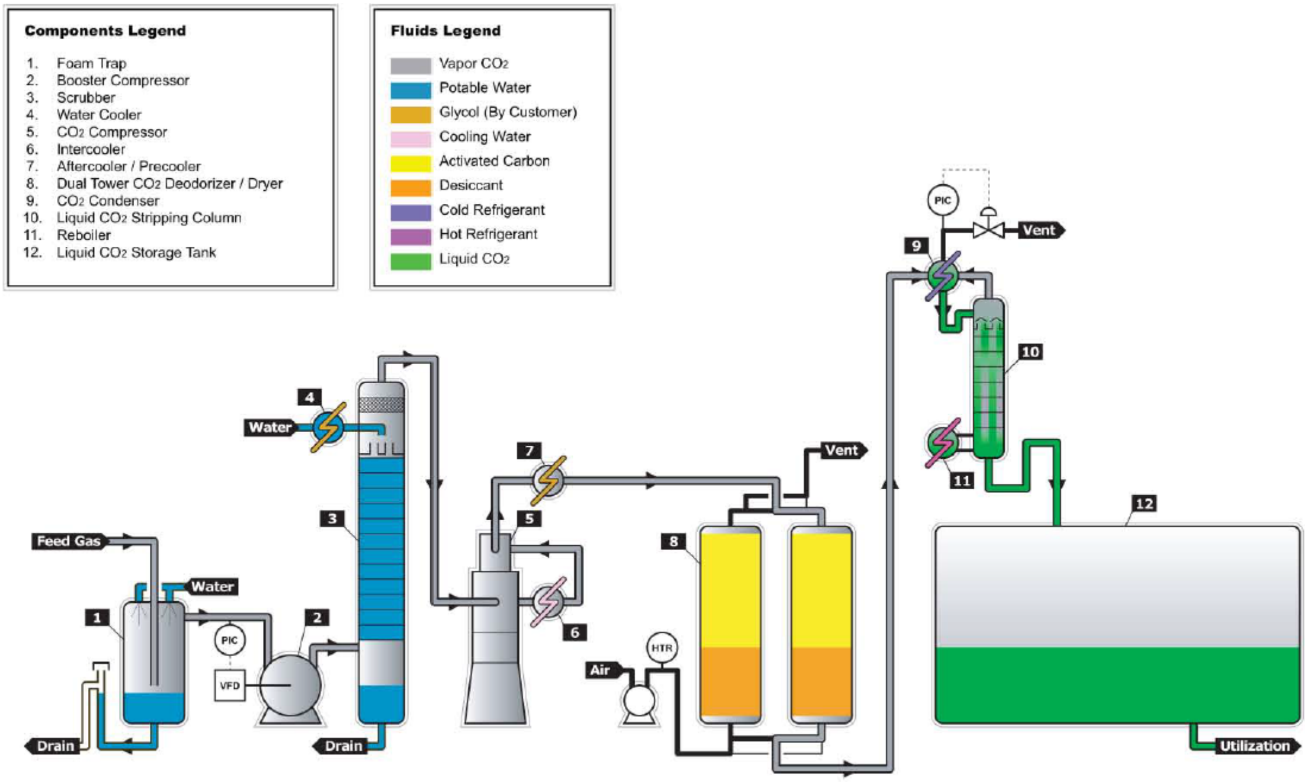
A brief outline of a CO_2 recovery system would include the following processes:

- Foam trap (separator): removes the foam carry-over occasional generated from fermentation
- CO_2 booster compressor: maintains the fermenter pressure and provides positive pressure for purification and compression
- CO_2 scrubber: provides bulk removal of water-soluble impurities in an efficient manner using potable water as the scrubbing medium
- CO_2 compressor: elevates the gas pressure to allow for efficient purification, dehydration and liquefaction

- CO_2 aftercooler/precooler: reduces the temperature of the gas, condenses the gaseous CO_2 and remove the humidity in the gas
- CO_2 dryer: removes impurities and water vapour
- CO_2 liquefaction: conversion of CO_2 gas to a liquid form by use of refrigeration
- Liquid CO_2 tank (storage tank): stores the liquid CO_2

A typical CO_2 recovery system from a brewery fermentation process is illustrated in Figure 7.10

Figure 7.10: Overview of the CO_2 recovery system from the fermentation process in a brewery



During beer fermentation, about 4 kg CO_2 are produced per hecytolitre of beer. Of these 4 kg, about 2 kg can be recovered thanks to currently available CO_2 recovery systems. Usually, a brewery requires about 2 kg/hl of CO_2 which means that almost the whole CO_2 demand can be covered by CO_2 recovery (Kunze, 2007).

Achieved environmental benefits

Implementing this technique reduces the amount of CO_2 purchased, decrasing the environmental footprint of the final product. This is because, industrial production of CO_2 to be added into drinks requires a high energy input.

Appropriate environmental indicators

An appropriate environmental indicator can be the amount of CO_2 recovered per hl of beer produced (kg CO_2/hl). In addition, the amount of CO_2 recovered hourly in the brewery could also be a suitable environmental indicator

Cross-media effects

Implementing this process requires energy (heat and electricity) and the installation of additional equipment, increasing the environmental footprint of the process.

Operational data

State-of-the-art CO_2 recovery systems can collect up to 2 - 2.5 kg CO_2/hL of cooled wort (CW) out of about 4.2 kg CO_2/hL CW released during fermentation. The input purity of CO_2 thereby decreases from 99.5 % to 95 % (Buchhauser et al., 2008).
The typical generation of CO_2 in the fermentation process ranges from 3 kg/hl to4 kg/hL and a typical scrubber requires 2 kg of water per kg of CO_2. In principle, it should mentioned that a large brewery can be self-sufficient for CO_2 if the CO_2 recovery process from the fermentation process is well-designed.

Case study - Molson Coors

Molson Coors is a brewery, which is located in the United Kingdom with a capacity of 2,000 kg CO_2/h. During fermentation, nearly equal amounts of alcohol and CO_2 are generated. The CO_2 production is approximately 2.5 kg CO_2 per hectolitre of beer recovered from original wort of 12 degrees Plato. Assuming a beer of 13 degrees Plato, this results in 2.9 to 3 kg of CO_2. During production, only half of the generated CO_2 is needed (1,000 kg CO_2/h) and the remaining CO_2 is cooled down in a separate cooling system (Pentair, 2012).

Applicability

Virtually all breweries use CO_2 in some form in their processes, typically for purging and bottling. If not recovered from the brewing process itself beverage-grade or at least food-grade CO_2 has to be sourced externally at a cost. The technique is therefore of potential interest to all brewers.
In theory, the technique can be sized to adapt to all scales of beer production. In practice however, micro-scale breweries might find it unattractive to recover their own CO_2.
The reusable CO_2 has to meet certain standards to be reused in the final product, most importantly in terms of residual oxygen concentration, as oxygen in the final products reduces the product shelf life and harms its organoleptic qualities. Therefore the CO_2 purity must be checked before its use in final products; to achieve this, the necessary inlet purity for the CO_2 treatment is approximately from 95 % to 99.7%. This reduces the scope of potentially recoverable CO_2 to only about 50 % of the released CO_2 from fermentation. In fact, it is difficult to separate the initial high concentrations of N_2 and O_2 from the CO_2 (CO_2 recovery normally begins 24 hours after the start of fermentation to ensure that the incoming fermentation gas has a minimum CO_2 concentration of 99.5 % vol).

Economics

CO_2 is required at the end of the manufacturing process in order to achieve the fizzy effect in the final product. Therefore on-site generation, by recovering it, reduces the operational costs of the breweries.

Driving forces for implementation

The main driving forces are reduction of operational costs (reduction of CO_2 purchased) and improved market visibility thanks to promoting an innovative product.

Reference organisations

Molson Coors Brewing Company, Göss and Calsberg Denmark are brewing companies that implement the CO_2 recovery system.

Reference literature

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8. PRODUCTION OF MEAT AND POULTRY MEAT PRODUCTS

8.1. Introduction

Production of meat and poultry meat products accounted for 20% of the total turnover of the food and beverage industry and 15% of value added in the sector in 2010 (Food and Drink Europe, 2012). Germany leads the production of meat and poultry meat products followed by France, Spain and Italy (Table 8.1).

Table 8.1 Main meat products and poultry meat products producers in the EU, in 2010 (tonnes)

Type of products	Germany	Spain	France	Italy
Poultry meat[1]	1 376 969	1 140 590	1 782 675	1 367 369
Pork meat	5 488 370	3 368 920	2 190 970	1 673 000
Bovine meat	1 205 000	606 591	1 530 070	1 068 900
Ovine & caprine meat	38 856	141 831	130 683	54 343
Other meat[2]	108 607	79 900	54 739	273 283
Total	8 217 802	5 337 832	5 689 137	4 436 895

[1] Including duck, turkey and/or chicken meat
[2] Including horse, game and/or rabbit meat
Source: FAOSTAT, 2013

The EU exports of meat and poultry meat products increased by 24% in the first semester of 2012 compared to the first semester of 2011, reaching EUR 5.4 billion. At the same time, imports have also increased by 12% in the first semester of 2012 achieving EUR 3.7billion (FoodDrinkEurope, 2012).

In terms of companies' size, 98.6 % of meat product companies are SMEs, whilst only 1.4 % are large companies (FoodDrinkEurope, 2012).

The meat products and poultry meat products industry is a complex sector including different groups/types of processed meat (Table 8.2).

Table 8.2: Meat and poultry products from whole or non-whole pieces

Meat products from whole pieces	
Type of product	*Definitions*
Cooked meat	Once the parts with better features are selected, they are deboned and cut into pieces. The brine is then injected with multi-needle injectors into the deboned pieces, which undergo a massage to facilitate the even distribution of the brine. Afterwards they are introduced into the moulds where they are cooked, and finally, cooled. This category includes products such as ham, pork shoulder, beef, etc.
Cured meat	Curing is the treatment in which muscle meat is mixed with common salt and sodium nitrite. It is mainly applied in the manufacture of larger pieces of meat selected for cured meat specialities and to achieve a pink-red colour and the typical flavour and taste in processed meat products. This category includes products such as raw-cured beef, cured ham and pork shoulder.
Meat products from non-whole pieces	
Fresh processed meat products	Mixtures of meat consisting of finely pulverised, minced or sliced muscle meat with varying quantities of animal fat attached to the muscle or added separately. This category includes products such as hamburgers, fried sausages, kebabs and chicken nuggets.
Raw-cooked sausages	The product components (raw muscle meat, fat and non-meat ingredients) are firstly minced and mixed. The resulting viscous mix/batter is cooked before portioning in order to obtain the typical firm-elastic texture for ready-to-eat raw-cooked sausages. This category includes products such as frankfurters, mortadella, bologna, meat loaf, liver sausage, blood sausage, corned beef, chicken and turkey cold cuts and sausages.
Raw-cured sausages	Raw-cured sausages receive their characteristic properties (tangy flavour, in most cases chewy texture, intense curing colour, etc.) through fermented processes and certain physical and chemical conditions which prevent the formation of pathogenic microorganisms in raw meat mixtures. Typical raw-cured sausages consist of coarse mixtures of lean meats and fatty tissues combined with salts, nitrite (curing agent), sugars and spices as non-meat ingredients. This category includes products such as salami-type sausages, spicy sausages, spicy pork sausages, etc.

In particular this study considers fresh, cooked and cured meat, distinguishing products processed as whole pieces (ham, shoulder, loin, etc.) from those that are processed after a mincing step (sausages, salami, chorizo, etc.).
It should be noted that dried meat is not included because this kind of products is popular in Africa, Asia and America but not very common in Europe (Heinz and Hautzinger, 2010).

8.2. Description of the production process of the meat products and poultry meat products

Table 8.3 depicts the main meat products production stages.

Table 8.3: Main meat products production stages (Heinz and Hautzinger, 2010)

STAGE	DESCRIPTION
Cutting/ Trimming	It involves removing surface skin, subcutaneous fat and other elements to give a final presentation according to the particular quality specifications.
Mincing/Ingredient application	Mincing the raw meat then mixing and kneading it with additives, fats or spices depending on the characteristics of each type of sausage.
Stuffing/Canning	The meat mass is introduced into casings or flexible packaging.
Brine injection	The brine is introduced into the meat pieces by multi-needle injectors. In this operation the meat moves along a conveyor belt while being penetrated by a needle system which moves up and down alternately.
Shaping/Packaging	The meat pieces are packaged in "final containers" or other containers and undergo heat treatment.
Cooking/Smoking	The thermal process takes place at temperatures around 80°C, whose purpose is to fully coagulate the protein and to achieve a bactericidal effect on the pathogenic flora. It is performed by immersing the product in hot water, steam ovens, dry air furnaces, etc.
Chilling	It consists of a rapid cooling. The most widely used systems are baths, cold showers and cold rooms with moving air.
Stoving/Fermentation	In order to accelerate microbial growth and fermentation reactions, the meat is heat-treated. This fermentation step typically takes between 24 and 48 hours.
Salting/pickling	This consists of an application of nitrite-nitrate and other additives into a salt matrix. This process can be performed manually by rubbing salt on thelean ham being cured, or mechanically. Hams are salted in dry salt chambers at 1-5°C and high humidity (around 80%) for a certain period of time depending on the weight of the ham.
Washing/Brushing	This phase employs special washing machines that remove excess salt stuck to the surface of the ham.
Drying/maturation	Meat parts are exposed to a temperature of around 10-12°C, which is then gradually raised. The length of this process depends on the final weight expected and on the characteristics of the meat product treated. It can take from 12 days to 26 months.
Pasteurisation/Sterilisation	It is a thermal process which reduces the content of pathogens. After the pasteurisation stage, treated products are rapidly cooled and hermetically sealed for food security purposes.

8.3. Main environmental aspects and pressures

The environmental aspects of the production of meat and poultry meat products can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects of the production of meat and poultry meat products are presented in Table 8.4.

Table 8.4: Main direct environmental aspects and pressures related to the meat and poultry meat industry

Main direct environmental aspects	Main environmental pressures	
Thawing	Water consumption Energy consumption	Waste water generation
Cutting/portioning/trimming/ grinding	Energy consumption	Waste water generation Solid waste generation
Cooking/smoking	Water consumption Energy consumption	Waste water generation
Dehydration/fermentation/salting/curing/brining	Energy consumption	Waste water generation Solid waste generation
Washing/brushing	Water consumption	Waste water and solid waste generation
Drying/maturation	Energy consumption	-
Packaging	Energy consumption Use of material (packaging)	Solid waste generation
Pasteurisation/sterilisation	Energy consumption Water consumption	Air emissions
Cooling	Energy consumption Water consumption	
Freezing	Energy consumption Water consumption	
Cleaning and disinfection	Energy consumption Water consumption Use of detergents/disinfectants	Waste water generation Solid waste generation
Energy supply	Energy consumption (fuel and electricity)	Air emissions GHG emissions

Overall, the most relevant impacts are:

- ✓ *Energy consumption,* both in terms of thermal energy and electricity.
- ✓ *Water consumption, u*sed i) as an ingredient, ii) for cleaning, iii) for un freezing of raw materials and iv) for cooling cooked products.
- ✓ *Waste water*, which contains a significant organic load, characterised by a high salt content and organic constituents including mainly blood, fat, protein, sugars, spices, additives, detergents and disinfectants. Skin and tissue fragments can also be found. Table 7.5 illustrates the main characteristics of waste water from the meat production industry.
- ✓ *Solid waste* consists mainly of by-products generated during the meat and poultry meat processing. These wastes include non-conforming products and meat scraps remaining on the processing equipment (e.g. bone, fat, leftover choppings). Other solid wastes such as packaging wastes (e.g. glass, cardboard, plastics, metal) can also be found.

Table 8.5 and Table 8.6 illustrate examples of the consumption of water and energy for specific meat products (EC, 2006).

Table 8.5: Main environmental impacts arising from the production of salami and sausages: water and energy consumption.

Product	**Unit**	**Salami**	**Salami**	**Various sausages**
Country		**DK**	**DK**	**NO**
Water	m^3/t	7.5	5.3	10
Electricity	kWh/t	-	1000	1300
Heat	kWh/t	1240	900	450

Source: EC, 2006

Table 8.6: Main environmental impacts arising from the production of cooked and cured ham: water and energy consumption and wastewater charge.

ENVIRONMENTAL IMPACTS	**TYPE OF PRODUCT**	
	COOKED HAM	**CURED HAM**
Water	4-18 m^3/t	2-20 m^3/t
Energy	2000-4000[1] kWh/t	2000-4000[1] kWh/t
Wastewater	20-25 kg COD/t	20-25 kg COD/t
Solid waste	35-50 kg/t	35-50 kg/t

Source: Adapted from European Commission, 2006.

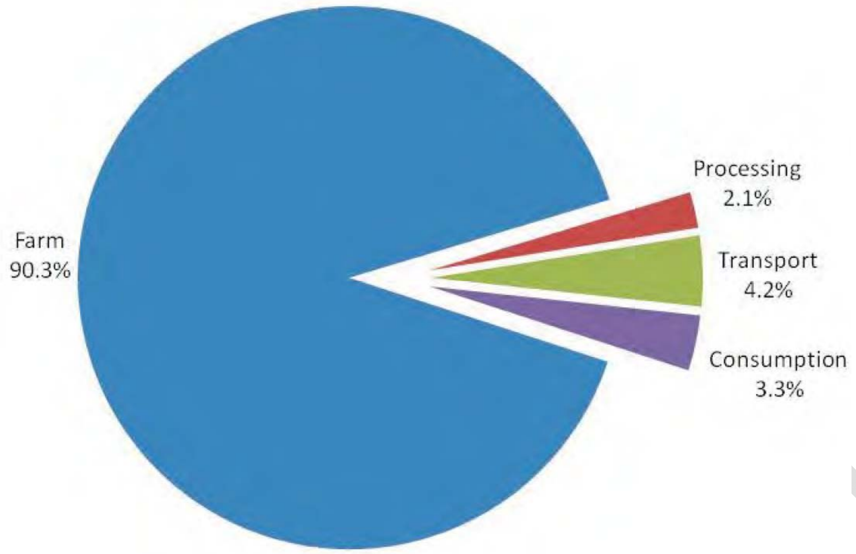
Indirect aspects

The meat processing stage is only a small part of the GHG footprint of meat and poultry meat products (Lieffering et al., 2012).

One particular example of the main environmental aspects of the production of beef products is illustrated in Figures 8.1 and 8.2. The total GHG footprint was calculated at 2.2 kg CO_2eq for a 100g portion of beef where 90.3% accounts for the on-farm stage, 2.1% for meat processing, 4.2% for transportation and 3.3% for the consumption stage. Moreover in Figure 8.2 it can be noticed that meat processing has a small impact (about 3%) on the overall carbon footprint of these products. The most carbon intensive phase is the on-farm stage (80%) followed by consumption (12%) and transport (5%) (Lieffering et al., 2012).

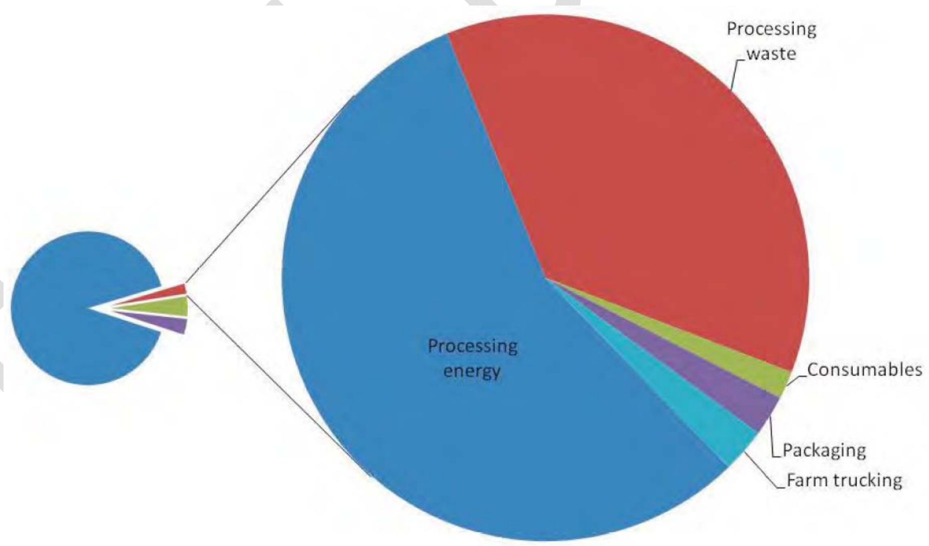
[1] Thermal: 1300-1400 m^3 methane/t.; Electricity: 150-180 kWh/t.

Figure 8.1: Allocation of environmental impacts of beef products along their value chain.



Source: Lieffering et al., 2012.

Figure 8.2: Allocation of environmental impacts of the meat processing stage for the production of beef products.



Source: Lieffering et al., 2012.

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8.4. Best environmental management practices

This chapter is aimed at giving guidance to meat and poultry meat products manufacturers on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[32]. For the aspects addressed in this document, the table mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an

[32] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of meat and poultry meat products manufacturers on all aspects listed in the tables below.

Table 8.7: Most relevant direct environmental aspects for meat and poultry meat products manufacturers and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Meat and poultry meat products processing	Water consumption Energy consumption Waste water generation Solid waste generation	• Reference to BAT in FDM BREF • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Packaging	Energy consumption Use of materials (packaging) Solid waste generation	• Reference to BAT in FDM BREF • BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Pasteurisation/Sterilisation	Energy consumption Water consumption Air emissions	• Reference to BAT in FDM BREF • BEMP on high pressure processing (Section 8.4.1)
Cooling/Freezing	Energy consumption Water consumption	• BEMP on improving freezing and refrigeration (Chapter 3)
Cleaning and disinfection	Energy consumption Water consumption Use of detergents, disinfectants Waste water generation Solid waste generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Energy supply	Energy consumption (fuel and electricity) Air emissions GHG emissions	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

Table 8.8: Most relevant indirect environmental aspects for meat and poultry meat products manufacturers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on Sustainable Supply Chain Management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x, particulate mtter etc.)	• BEMP on Transport and Logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

8.4.1. High pressure processing for decontamination of meat

Description

The decontamination of meat is a required process, which improves the safety of the food and reduces the number of undesirable microorganisms. Nowadays, thermal techniques involve the traditional and most commonly used method to achieve microbial stability and safety in the production of meat products (Torres and Velazquez, 2004; Purroy, 2013 pers. comm).

Two types of thermal treatment can be distinguished for meat and poultry meat products (Heinz and Hautzinger, 2007):

- Pasteurisation: heat treatment at temperatures below 100°C, mostly in the range of 60 to 85°C. Pasteurised products still contain a certain amount of viable microorganisms, which are more heat-resistant. The pasteurisation treatment is carried out by steam or heated water. Boilers are used to produce the steam as well as the heated water and they are usually placed in separate facilities. Two types of boilers can be used: shell and water-tube boilers. The choice of one or another is influenced by the steam pressure and quantity requirements. In these facilities, hot water tanks can also be found (Spanish Ministry of Agriculture, Food and the Environment, 2005).

- Sterilisation: Heat treatment at temperatures above 100°C. Sterilised products are completely free of viable microorganisms. At this temperature, the products are placed in glass jars, tin or aluminium cans or similar. These products, which have an extended shelf life, do not require refrigeration. The sterilisation treatment is carried out by autoclaves or retorts in which high temperatures are generated either by direct steam injection or by combined steam and water heating. This thermal process is performed under pressure which may vary according to the temperature (Heinz and Hautzinger, 2007).

Both treatments are completely effective, economical and readily available, although in many cases they have undesirable effects on food quality that a food processor must understand to be able to minimise (Torres and Velazquez, 2004).

In general terms, the pasteurisation stage is carried out in cooked and cured products. In the case of cooked products, once the product is packaged, cooked and chilled, the first packaging is usually removed and the product repackaged in another one. In this way, between the removal of the first packaging and the repackaging the product is exposed to external contamination, and as consequence, pasteurisation treatment is necessary. In the case of cured products, the pasteurisation stage is carried out due to the food safety requirements for exports to countries with more restrictive regulations (Grébol, 2010).

Once the pasteurisation has been carried out, the product undergoes subsequent chilling in refrigeration chambers or in cold water baths or showers (Spanish Ministry of Agriculture, Food and the Environment, 2005).

In the case of sterilisation, the process is carried out in raw cooked products. In these products, after the stuffing and the subsequent cooking or smoking, the product is packaged and subsequently sterilised. Otherwise, the cooking stage (in pasteurised as well as sterilised products) is currently carried out by hot water or steam ovens (Spanish Ministry of Agriculture, Food and the Environment, 2005).

Taking this approach into account, pasteurisation and sterilisation processes are really important from the point of view of energy and water consumption (Spanish Ministry of Agriculture, Food and the Environment, 2005, Azti tecnalia, 2013; European Bank for reconstruction and development, 2009). As a consequence, new measures have been developed to reduce those aspects.

One of these techniques consists of the use of high pressure for pasteurising and cooking processes. The combination of high pressure with heat is also taken into account.

High Hydrostatic Pressure (HHP) is a non-thermal or minimal processing technique (Nunes and Grebol, 2011), also known as Ultra High Pressure (UHP) or High Pressure Processing (HPP) in which the packaged food is subjected to water pressures from 200 to 600 MPa(Purroy et al., 2012). The process is generally carried out at temperatures between 5°C and 30°C (Hiperbaric, 2013).

A HPP machine has the following parts:

- Vessel: it is the cylindrical component in which the food is introduced and subjected to high pressures.
- Yoke: it is the frame of a high-pressure machine, which supports all the tensions generated during the process. It is a key component for the safety and reliability of the process.
- Baskets: they are cylindrical product carriers filled with the food product to be high pressure processed, then automatically introduced into the chamber and unloaded from the vessel once processed.
- Intensifiers: there are components that allow the pumping of high-pressure water into the vessel. They are sophisticated, pressure multiplier components that are powered by a hydraulic pump and piston and plunger systems which are able to pump up to very high pressures of 6000 bar and beyond.

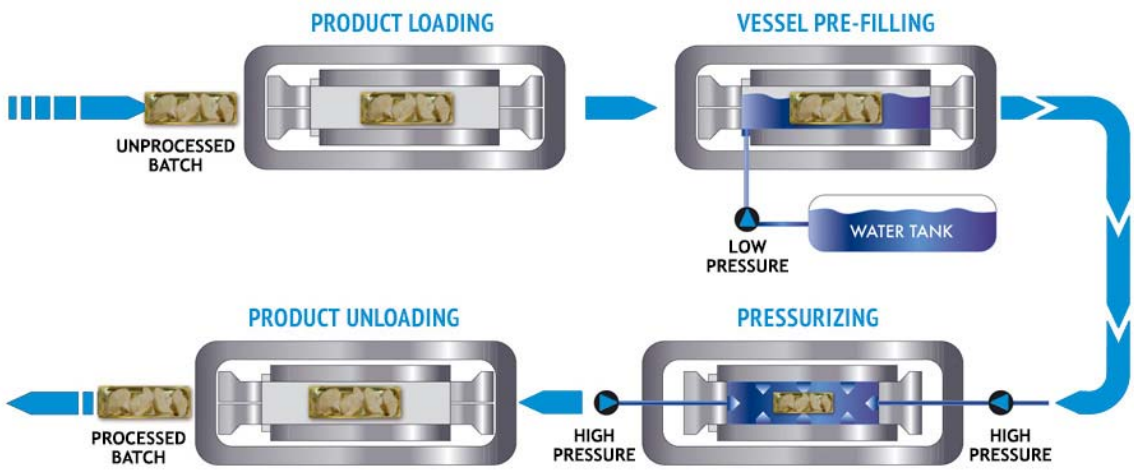
The applied pressure acts uniformly and instantly all around the product whatever its size and dimensions (Nunes and Grebol, 2011; Murchie et al., 2005; Torres and Velazquez, 2005). This pressure is isostatically transmitted (Pascal's law and Le Chatellier principle) inside the vessel (Aymerich et al., 2007). This results in a shorter process time in comparison with thermal treatment (Purroy et al, 2012).

Currently, two kinds of high-pressure equipment can be found in the industry, vertical and horizontal (Leadley et al., 2008), with the latter the most commonly used (around 97.5%) (Purroy et al., 2012).

In the case of horizontal equipment the product is loaded into plastic baskets and then pushed inside the vessel. Afterwards, the plugs hermetically close the vessel. Then the vessel is filled with low-pressure water with the plugs closed and when it is full, the intensifiers start to pump high-pressure water up to the desired pressure. When the holding time is over, water is discharged in a few seconds by opening the release valves. Finally, the vessel returns to the first step and is loaded again. The new product in the basket will then push out the processed product and a new cycle can start (Figure 8.3) (Purroy et al., 2012).

Thus, a cycle includes filling the high pressure vessel with food product, which must be packaged. The package must be more flexible than the product inside, resistant and waterproof (Azti tecnalia, 2013).. A complete cycle usually requires around 3-4 minutes (holding time excluded).

Figure 8.3: Diagram of operation of a HPP unit (Hiperbaric, 2013).



Key HPP equipment technologies are the pressure vessels and the high hydrostatic pressure generating pumps or pressure intensifiers. (Torres and Velazquez, 2004).

The microbial inactivation achieved with the technology depends mainly on two factors: the pressure applied and the process duration. Thus, the higher the pressure applied and the longer the holding time, the more microbial inactivation (Black et al., 2011).

Most of the pathogenic microorganisms (vegetative cells) can be inactivated through high pressures. This inactivation is caused by the break-up of the cell walls and by the disruption of the vital functions of the cells (Murchie et al., 2005; Torres and Velazquez, 2005) due to the denaturalisation of proteins and DNA. High Pressure Processing may induce some colour changes (depending on the pressure level) due to the state of oxidation of Fe in some pigments. For instance, in native myoglobin and haemoglobin, Fe^{2+} is changed under preassure to Fe^{3+} and the pigment changes colour. Similarly, in some matrices like raw salmon, the pigment is not affected, but the colour fades by protein denaturation and the consumer's visual perception may change.

High pressures can be used in different ways with potential energy consumption savings:

- By replacing thermal pasteurisation: conventional thermal pasteurisation is replaced by using high pressures in the case of re-pasteurization of cooked meat products.
- By reducing the cooking stage: as one of the objectives of the cooking stage is the decontamination of products, many companies usually increase this stage in order to increase the disinfection power during the cooking stage, although they continue to carry out the thermal pasteurisation. Thus, a great amount of energy is consumed. By using high pressures, the cooking stage can be reduced since the complete pasteurisation is carried out during the HPP pasteurisation stage. However, it should be mentioned that the reduction of the thermal energy consumption may not be greater than the required HHP re-processing energy.

Semi-continuous operation systems can also be used to improve the efficiency of the process. By coupling a number (usually two) of pressure systems, most of the energy stored in a pressurised vessel can be used to pressurise the second vessel, improving productivity and saving energy and process time (Hernando-Sáiz et al., 2008; Van der Berg et al., 2001).

High pressures can also be applied together with temperature, which become necessary to inactivate spore-forming bacteria. The so-called High Pressure Thermal Sterilisation (HPTS) technique involves the use of initial temperatures between 60°C and 90°C at pressures of up to 630 MPa (Barbosa-Cánovas and Juliano, 2008). HPTS combines the synergistic effects of elevated temperatures (90-121°C, under pressure) and pressures to realize a quick and sufficient inactivation of the microorganisms as well as spores, so the final product is free of viable microorganisms.

In the HPTS process, the increase in temperature is not due to heat transfer but to adiabatic heating by compression. As the pressure transfer is homogeneous and instantaneous, the increase in the product temperature due to pressure is also homogeneous and instantaneous, independent of the size and shape of the product (Wilson and Baker, 2000; Ramírez et al., 2009). In the same way, after the pressure is released, immediate decompression makes the temperature in the product also immediately decrease. This effect permits the time of processing to be reduced cosniderably, maximising process efficiency (Toepfl et al., 2006) and reducing energy costs and heat damage in the product.

Summarising, this technique contributes to the reduction of energy consumption and to the following features:

- Development of new products: it allows the development of new "pasteurised" products that could not be developed with thermal treatments due to their sensitivity to heat (e.g. foie).
- Development of low-additive products (salt, nitrates/nitrites, etc.), achieving raw materials savings.
- Applying this technique, the shelf life is increased. Furthermore this technique is not only used for decontamination but it also contributes to the maximisation of the interaction of the ingredients.

Achieved environmental benefit

In general terms, alternative technologies may lead to environmental impact reduction in comparison to traditional thermal processes (Pardo and Zufia, 2012).

HPP equipment are very efficient systems, with a low energy input (Hogan, Kelly and Sun, 2005). The required level of pressure is usually generated with the use of intensifiers that use electricity. Once the required pressure is reached (usually, in a few minutes), it can be maintained with no additional energy input (Murchie et al., 2005). Moreover, pressure processing uses cold (or room temperature) water as transmission fluid, so no additional energy is needed to generate steam or hot water, and used water can be recycled (with no loss due to evaporation). Finally, once the pressure cycle is complete, the pressure release takes place in less than one minute without any additional energy being required, which is another advantage relative to thermal treatment which often involves additional energy to rapidly decrease the product temperature (Lavilla, 2014 pers. comm.). High pressure energy consumption is shown in Table 8.9.

Table 8.9: High pressure energy consumption per cycle and per hour (Purroy, 2014)

	Vessel (s) volume (l)			
	55	135	300	420
Energy consumption per cycle (kW)	2.05	5.57	11.3	15.86
Energy consumption per hour (kW)	20	46	90	140

(1) Standard pasteurisation cycle conditions: 6,000 bar and 3 minutes cycles.
(2) Number of cycles which are carried out by the machine per hour (in standard conditions).

Real energy savings are produced when high-pressure treatment is used to replace the conventional thermal cooking stage (Purroy, 2014 pers. comm.; Bajovic et al., 2012; Lickert et al., 2010). For instance, this process is well known in the production of liver sausage. The liver sausage production process requires two thermal treatments (in the first one, before grinding, cured pork meat is cooked to 72˚C; in the second, after stuffing, at 75-80˚C), which may be replaced by two high-pressure treatments at 600 MPa for 2-5 minutes at room temperature (Bajovic et al., 2012). In addition, after the second HPP treatment the product is only stored, therefore the cooling operation is eliminated (Adapted from Bajovic et al., 2012).

Potential energy savings may also arise when high pressure treatment replaces conventional thermal post-pasteurisation. While the energy consumption of a a high-pressure treatment can be easily determined since the pressure is transmitted uniformly and instantly all around the product whatever its size and dimensions, heat treatment depends on the size and shape of the product owing to the diffusion of heat around the product, therefore its quantification is very complicated.

The energy consumption needed for increasing the temperature in meat products from 4 to 70°C using conventional treatments is about 250 kJ/kg product. Depending on the design of the equipment and the energy losses, this figure may reach 300-450 kJ/kg product. By using the electrical resistance of products (ohmic heating) heat application is carried out directly, achieving a uniform temperature. Thus, energy consumption is in the range of 280-350 kJ/kg. High-pressure treatment energy consumption is less than other treatments (200-280 kJ/kg) (Toepfl, 2014)[33].

Energy consumption savings may also be achieved by using High Pressure Thermal Sterilisation (HPTS). According to Toepfl et al. (2006), the specific energy input required for sterilisation of cans can be reduced from 300 to 270 kJ/kg.

Water savings might be achieved if high pressure treatment replaces conventional heat water batch or steam treatment. In this case the potential savings depend on many factors such as the size of the batch or the frequency with which water is replaced. Therefore, a more exhaustive study is required.

Additionally, by using high pressures, the conservatives and chemical additives, which are used to increase the shelf life of the processed products can be reduced (Azti tecnalia, 2013) or even eliminated (Comercial logística de Calamocha, 2015; Jung, Tonello and De Lamballerie, 2011). Thanks to this increase, a great amount of waste can be reduced (Hiperbaric, 2013).

[33] Study carried out by comprising conventional and novel disinfection methods with a production of 1,000 kg/h. The study shows potential energy savings although they depend on many factors such as packaging (size, type, etc.) as well as process objective (disinfection, denaturing, etc.) (Toepfl, 2014).

Appropriate environmental indicators

The appropriate environmental indicator is the energy efficiency in the preparation of meat products expressed as:

- kWh/ cycle of processed product or as kJ/kg of product.

The energy consumption should be measured by the organisation through direct (electricity meter) or indirect measures (electricity bills).

Cross-media effects

Water recirculation within the high pressure process requires energy (e.g. filtration, de-pressurisation), therefore the corresponding emissions to air are the main environmental cross-media effect.

Operational data

A wide range of configurations can be found in the industry depending on the productivity of the facilities. Several years ago this was the limiting factor, since only low productivity equipment was available (Purroy et al., 2012). However, equipment from 55 litres to 420 liters may currently be found on the market. The main operational data of high-pressure processing equipment are summarized in Table 8.10.

Table 8.10: Main operational data of high pressure equipment according to its capacity (Purroy, 2013 pers. comm.)

Vessel(s) volume	Litres	55	120	135	300	420
CYCLE						
Vessel filling ratio	%	50	50	55	55	60
Total cycle duration	min	6.13	6.48	6.78	7.12	6.67
EQUIPMENT						
Number of intensifiers (45 kW)		1	2	2	4	8
OPERATING DURATION						
Daily operating duration	hours	16	16	16	16	16
COSTS AND COMSUMPTIONS						
Energy cost	kWh/h	20	47	45	95	143
PRODUCTION						
Number of cycles / hour		9.8	9.3	8.9	8.4	9.0
Hourly production	kg	269	556	657	1,390	2,268

Table 8.11: Pressure and time values for High Pressure Processing of several food products (Comaposada, 2014 pers. comm.)

	PRESSURE [MPa]	TIME [min] *	COMMENTS
Raw meat	400 - 600	1 - 3	Only for food service (raw colour changes to grey/brown, but there are no differences in colour after cooking)

Cooked meat products	400 - 600	1 - 6	No sensorial changes, even at 600 MPa
Fermented/dried products	600	3 - 10	Longer treatment for lower water activity products
Shell fish	300 - 350	1 - 3	To inactivate Vibrio and marine viruses
Crustaceans	300 - 350	1 - 3	For easy extraction of fish from shell plus inactivation of main pathogens
Fish	400 - 600	1 - 6	Not for raw tuna (same pigment as meat). Not for raw salmon (pigment is not affected, but colour fades by protein denaturation). For raw white fish, texture is varyingly affected, depending on fish species and pressure intensity/time. For cooked fish, no sensorial changes, even at 600 MPa

* = residence time at the maximum pressure

Regarding the recirculated filtered water, 15% of used water reenters the machine in every cycle. When the cycle has finished (after depressurizing from 6000 bar to 0 bar) it goes through several pressure valves where it is warmed up to 35-40°C by means of friction. Therefore, water recirculation requires energy, while an alternative could be to use it for other purposes within the production plant (e.g. cleaning operations).
Companies that do not re-use the water from the depressurisation process are losing considerable amounts of it, as can be appreciated in the table below (Purroy, 2013 pers. comm.).

Table 8.12: Water consumption of high pressure systems (Purroy, 2013 pers. comm.)

	55 l	120 l	135 l	300 l	420 l
Consumption water/cycle (litres)	8.2	18	20.25	45	63
Consumption water/hour(litres) (*)	73.8	162	182.25	405	567
(*) Taking into account a continuous pressure of 6,000 bar with 3 minutes at constant pressure and therefore 9 cycles/hour.					

Applicability
In meat products, the operating pressure in most cases (~90%) is 6,000 bar.
The processing time usually ranges from 3 to 9 minutes, depending on the water activity (e.g. higher values of water activity, allows less operating time), the inactivation kinetics of the microorganism that should be inactivated, the initial amount of microorganism and the shelf life extension to be achieved. For instance, some indicative data show that, the operating time for ham is approximately three minutes for ham and nine minutes for dried cured ham treated with low water activity.
When a moderate level of pressure is applied, a reduction in the growth rate and reproduction of microorganisms is observed. A higher level of pressure causes inactivation.
Thus, HPP equipment can be used in order to comply with the Community legislation on food safety. Although the traditional treatments guarantee the safety of the processed products, they could negatively affect their nutritional and sensory qualities (Nunes and Grebol, 2011).

HPP represents a considerable advantage because microorganism inactivation is achieved, preserving nutritional value, smell, appearance and fresh taste (Nunes and Grebol, 2011). Thus, the quality is higher in comparison with thermal treatments. In addition, HPP achieves an increase in the shelf life of minimally processed products and products that are susceptible to thermal treatment such as foie, low-fat and low-salt products, which cannot be treated with heat. In products which can be treated with heat, while the shelf-life is maintained, the quality increases (Lavilla, 2014 pers. comm.).

Table 8.13: Shelf life extension in different meat products

Product	Shelf-life extension	Other benefits or adverse effects
Marinated beef loin (raw)	13-15 days	Some greying of meat
Cooked sliced ham	Up to 66 days (depending on HPP level)	None
Blood sausage	28 days	None
Pre-cooked sliced chicken	21 days	None
Cooked meat products free of nitrites: ham, sausages and bacon	4 weeks	None

Source: (adapted from CSIRO ANIMAL, FOOD AND HEALTH TECH, 2012; Lavilla, 2014 pers. comm.)

As far as the capacity is concerned, commercial equipment with a capacity of 10-300 litres are available and can be purchased from different suppliers (Aymerich et al., 2007). Nowadays equipment with a capacity of 420 litres and 520 litres are also available (Hiperbaric, 2013).
It should be mentioned that the high investment cost (purchase of the equipment) limits the use of this techniques to big companies, although, when rental of the service of High Pressure Processing is available, small companies may also use this technique.

High pressures can be used in a large variety of products:

- Cured and cooked products and raw-cured products: these products, which may be affected by heat, are exported to other countries with more restrictive safety food regulations such as the USA, Japan, Canada or Australia (Grebol, 2010).
- Cooked products: HPP avoids over-cooking, producing energy savings and improvements in the productivity. These products can be subjected to high pressures in different ways (Purroy, 2013 pers. comm):
    - By replacing the cooking stage: This is the case of the filet americain or the leberwurst sausage.
    - By replacing thermal pasteurisation in both whole and sliced products.
    - By reducing the cooking stage.
- Fresh products: carpaccio or fresh foie gras are usually treated with high pressures in order to develop a safer product. In addition, improvements in the flavour and structure are achieved (Zwanenberg food group, 2013).
- Raw-cooked products: for products which undergo a sterilisation process and are packaged in cans.

Economics

Calculations of the operation costs depends on the type of machine as far its capacity, pressure applied and operation time are concerned (Table 8.14).

The investment needed for a HPP machine is in the range of EUR 500 000-2 000 000 depending on the volume of the vessel (Purroy et al., 2012). Although the initial investment is high, the processing cost has been estimated at EUR 0.14/kg of product treated at 600 MPa, including investment and operation costs (Aymerich et al., 2007).

Table 8.14: Economic model for 600 MPa operating machines (Purroy, 2013 pers. comm.)

EQUIPMENT						
Vessel(s) volume	litres	55	120	135	300	420
COSTS AND COMSUMPTIONS						
Investment cost	EUR thousand	540	790	990	1,420	1,950
Depreciation period	year	5	5	5	5	5
TREATMENT COST PER LITRE OR KG						
Depreciation charge	EUR	0.090	0.063	0.067	0.046	0.038
Wear of parts	EUR	0.055	0.042	0.046	0.030	0.024
Energy	EUR	0.007	0.008	0.006	0.006	0.006
Total	EUR	0.151	0.113	0.119	0.082	0.068
TREATMENT COST PER CYCLE						
Depreciation charge	EUR	2.46	3.81	4.99	7.53	9.67
Wear of parts	EUR	1.50	2.50	3.40	5.00	6.00
Energy	EUR	0.18	0.46	0.46	1.02	1.43
Total	EUR	4.15	6.77	8.85	13.54	17.10

(*) Investment cost includes: Equipment, loading/unloading basket systems, installation and start-up

Driving force for implementation

Companies implementing HPP can improve its image thanks to a higher product quality and the achievable microbial risk reduction potential (Azti tecnalia, 2013).

Furthermore, companies can reduce energy and reduce the process time in some meat and poultry meat products (Purroy, 2013 pers. comm.). In addition, conservatives and chemical additives may be eliminated or reduced significantly (Comercial logística de Calamocha, 2015) increasing the shelf life of the products.

High Pressure Processing allows icompanies' to increase their turnover in two ways (Grebol, 2010):

- By developing new products (such as omega 3, low-salt or natural products with no additives).
- By exporting to other countries with more restrictive safety food regulations (such as the USA, Japan, Canada or Australia).

Reference organisations

There are more than 170 HPP machines all over the world (Nunes and Grebol, 2011), and two manufacturers at industrial level (Leadley et al., 2008). Nowadays, this technique is well established in the meat and poultry meat sub-sector. Espuña was the pioneer in implementing High Pressure Processing. In 1998 the company installed HPP equipment for sliced cured products such as ham which is exported to

countries with more restrictive food safety regulations. Nowadays, the company has two pieces of high pressure equipment of 6000 and 4500 bar (Espuña, 2015).
Campofrio has been employing the technology since 2002. It started implementing High Pressure processing for cured ham for Listeria Free exports to the USA. In 2003 the company installed equipment for sliced ham, turkey and chicken, increasing its shelf life to eight weeks and using less additives.
In 2008 more equipment was installed in order to launch marinated chicken and turkey with six week shelf life onto the market(Adapted from Hiperbaric, 2013).
The company Hormel has been treating dry cured ham since 2001. Nowadays it treats a wide range of products including ham, turkey and beef. Treated products have longer shelf life and zero preservatives (Adapted from Hiperbaric, 2013).

Table 8.15: Companies worldwide that have High Pressure Processing installed (Hiperbaric, 2013).

Itohan	Japan
Ferrarini	Italy
Golden Valley Farms	Canada
Columbus Salumeria	US
Jamcal	Spain
Freybe	Germany
Foster Farms	US
Cooper Farms	US
Maple Leaf	Canada
Martiko	Spain
Moira Mac's	Australia
MRM	Spain
Casa Italia	Italy
Espuña	Spain
Quantum Foods	US
Rovagnati	Italy
Safe Pac	US
Tyson Foods	US
Deli24	United Kigdom
Zwanenberg	Holland
Campofrio	Spain
Creta Farms	Greece
Cooper Farms	US
Mondelez Int	US
Abraham	Germany
Santa Maria Foods	Italy
Viau	Canada
Angst	Switzerland

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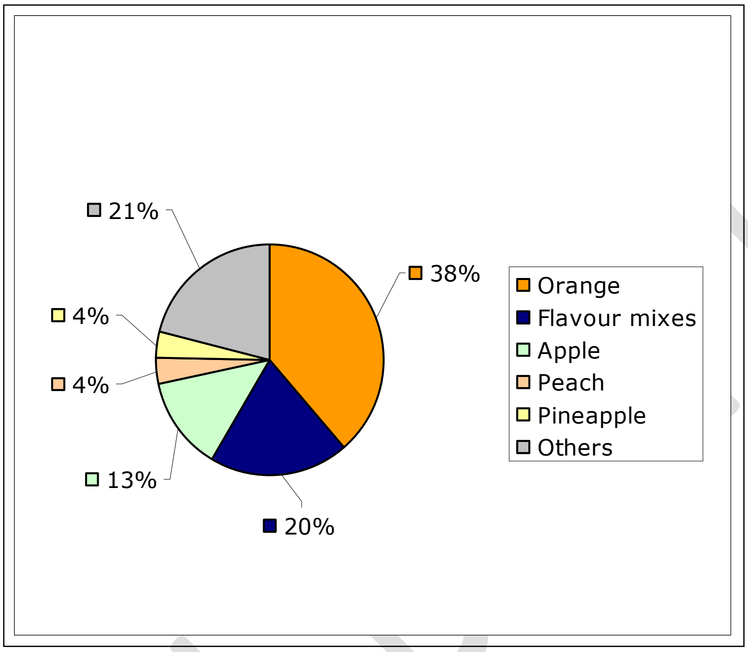
9. MANUFACTURE OF FRUIT JUICE

9.1. Introduction

Figure 9.1 illustrates the main flavours of fruit juice in the EU. The figure shows that oranges and apples are the most important fruits for producing juice and nectars. For instance, orange juice and apple juice represent 38 % and 13 % respectively of the total juice production in EU (AIJN, 2012).

Figure 9.1 EU fruit juice and nectars by flavours



Source: AIJN (2012)

Orange juice

EU orange production is concentrated in the Mediterranean region. Oranges are the second largest EU fruit crop after apples, with more than 80 % of the EU's total production of oranges coming from Spain and Italy. The remaining 20 % is distributed among other Member States, mainly Cyprus, Greece and Portugal (USDA, 2012).

The European citrus sector is orientated towards the fresh produce market. Margins are better for fresh fruit consumption for both domestic and export demand. In the market year 2011/2012 (November-October), total EU imports of orange juice were valued at USD 1.594 billion with exports worth USD 145 million. Brazil is the main supplier of orange juice to the EU with around 85% of the total imports of orange juice to the EU market (USDA, 2012).

Orange juice products can be classified as follows (AIJN, 2010):

- **Freshly squeezed**: Juice from freshly squeezed oranges, unpasteurised, chilled and with a shelf life of a few days.
- **Not from concentrate** (NFC): Juices that are directly pressed or squeezed and then pasteurised. They can be either chilled or ambient stored.
- **From concentrate** (FC): Juice that has had water removed prior to transportation, with the product reconstituted to 100% juice from concentrate during the production process. Typically, FC juice is sold through ambient distribution, although chilled FC products are also available.

Chilled juices, pasteurised or unpasteurised, are sold through a chilled supply chain, either due to product requirements or due to chosen trade positioning. Ambient juices, FC or NFC, are heat-treated and do not require a chilled retail chain. Ambient juice can have a shelf life of up to 18 months.
Orange juice is produced in the three following types of facilities in the EU (AIJN, 2012):

a) Installations that squeeze orange juice directly from fresh oranges (extraction) and sell the product as bulk juice, chilled or concentrated. These companies are mainly located in the Mediterranean EU countries, near orange fruit production areas.
b) Installations that produce and package orange juice from imported juice or concentrate. Spain remains an important NFC source, but it ranks well behind Brazil, whose total imports in 2012 approached 700 000 tonnes/year. The main gateways to the European industry are Belgium and the Netherlands (90% of total volume imported)
c) Installations which squeeze orange juice directly from fresh oranges (extraction) and package it in retail formats. These companies are mainly located in the Mediterranean EU countries, near orange fruit production areas (Spain, Italy).

Two main activities can be developed in the orange juice facilities: a) the production of juice from fresh oranges (extraction) and b) the production of juice from imported juice or concentrate.

Direct orange juice extraction is carried out mainly in the Mediterranean countries where facilities perform the following stages: washing, squeezing, filtration/centrifugation, pasteurisation, concentration, refrigeration, freezing and packaging. Some of these facilities supply bulk juice or concentrate to third companies which use this juice as raw material.

Apple juice

The EU is the second largest apple producer worldwide with about 10 million tonnes in 2013/2014, after China. Within the EU, Poland, Italy and France are the biggest producers (Agrochart, 2013). In terms of apple juice concentrate Poland is the leading producer country. In particular, in 2011, Poland exported within the EU approximately 145 000 tonnes of the 263 000 tonnes of apple juice concentrate it produced. In addition, the EU also imported apple juice from China (about 115 000 tonnes in 2010) which is the biggest importer (Ennser, 2011.

9.2. Description of the fruit juice production process

Orange juice

The oranges are washed and sorted before being fed to the extractors (juicing machines). As the juice contains a high proportion of pulp, the extent to which it is removed depends on the objective. Pulp can be removed in subsequent process stages: finishers to remove the coarser fruit cells and hydro-cyclones and separators for the finer pulps.

The quantity of juice obtained varies; it depends on the quality and the characteristics of the citrus fruit. In general, orange juice represents approximately 35-45% of the processed orange fruit and orange waste (peel, seeds and pith) represents approximately 55–65%. Other minor fractions obtained during extraction are limonene and essential oils.

Juice is de-aerated, pasteurised/sterilized and cooled before being sent to buffer tank storage. A part of the removed pulp can be added again before pasteurisation. Therefore juice can be:

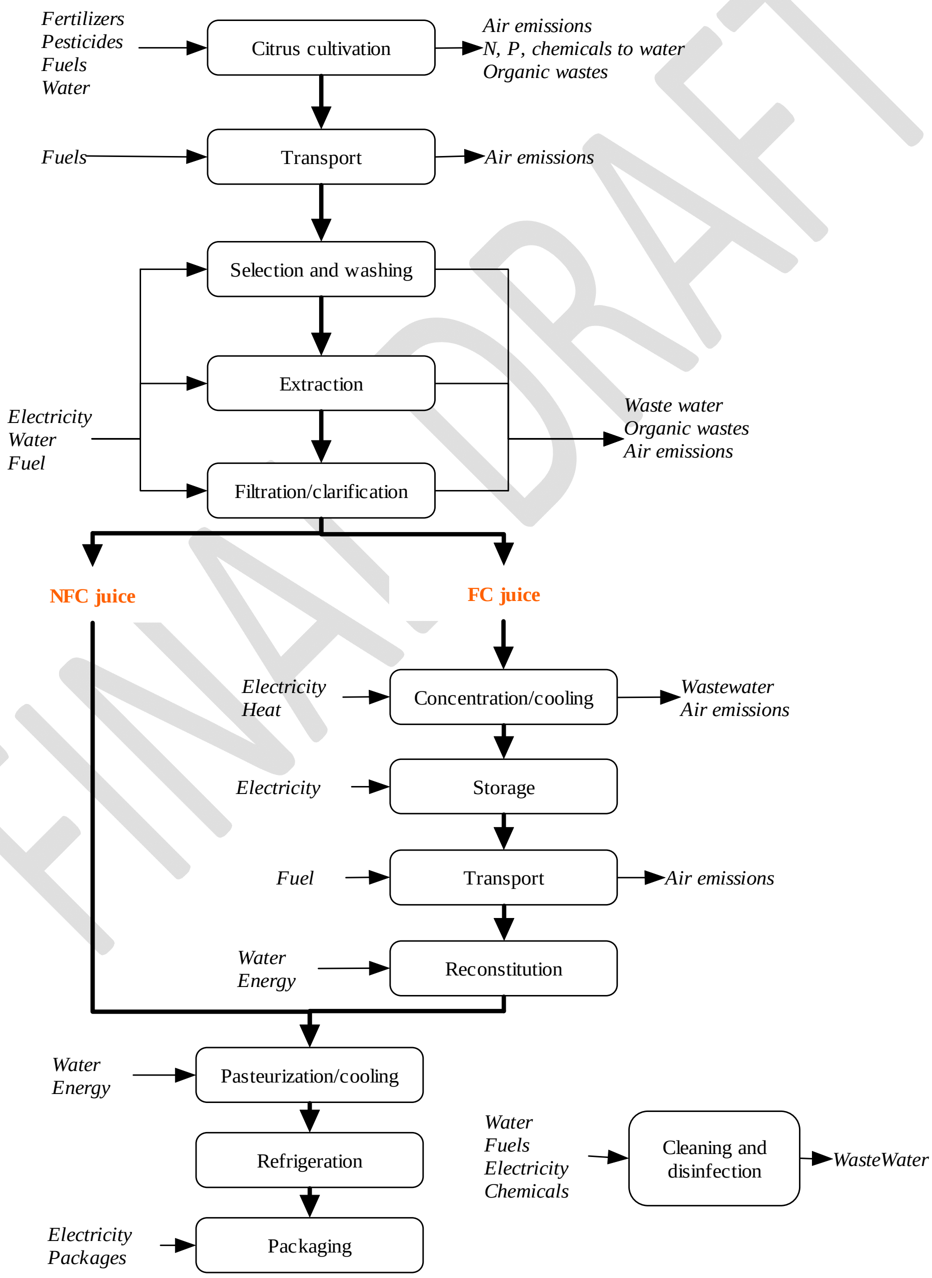
1. Sent to the filling lines to be packaged in situ.
2. Stored (cold or frozen) to be subsequently exported in drums or tanks to other third orange juice facilities.
3. Concentrated.

Concentration is performed in evaporators in which the water fraction is drawn out of the juice until the original volume is reduced to approximately one fifth. A particular proportion of water is then added to the concentrate in the country of consumption and it is marketed as citrus juices, nectars or citrus drinks.

A flowchart of the whole process is shown in Figure 9.2, including the main input and output mass streams, the cultivation and transport stages.

Figure 9.2: Flowchart for orange juice production including cultivation and transport.

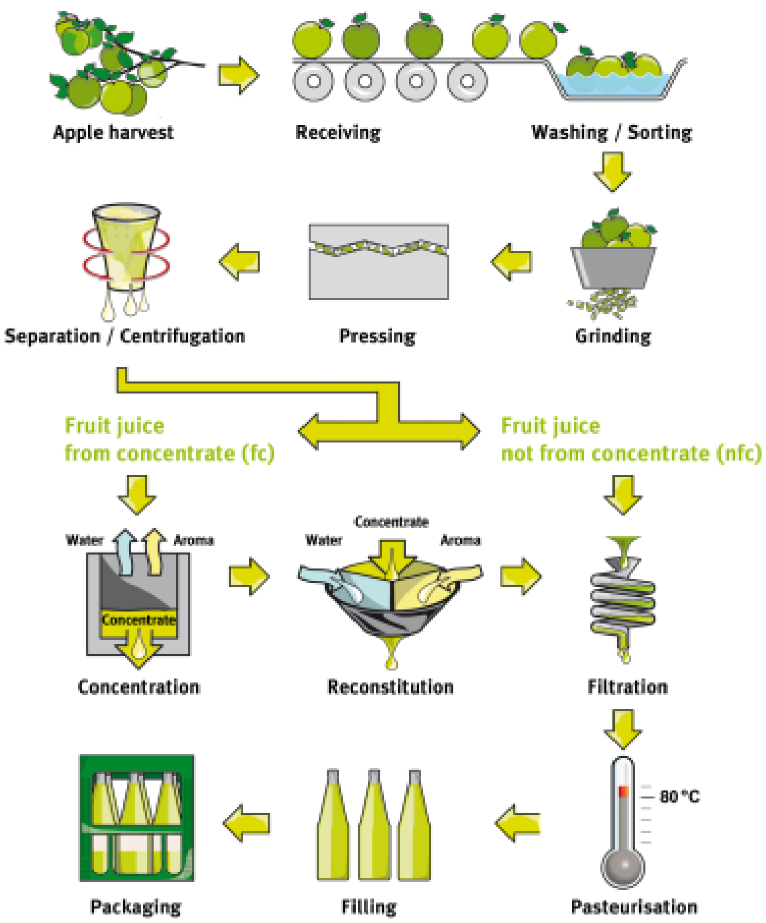
Source: AINIA



Apple juice

The apples are inspected before processing and are then washed and sorted to properly remove rotten and damaged fruit. The damaged and mouldy apples are culled or trimmed to remove the damaged parts. It has been reported that some molds may contribute to high levels of patulin, a toxic substance. Afterwards, the apples are rinsed with water, brushed/scrubbed and washed with an approved sanitiser prior to pressing. In the next stage, the apples are crushed and pressed to extract juice and are eventually separated centrifugally. The Juice produced is then classified either as fruit juice from concentrate or fruit juice not from concentrate. The next step is the preparation of the flavour of the final product (apple juice) by adding the concentrate water and aromas. Finally, the juice has to be filtered and eventually bottled (Figure 9.3).
It should be mentioned that cider is refrigerated as quickly as possible after pressing, to less than 5oC, preferably closer to 0^{o}C. in order to keep the best quality. This is accomplished by a refrigerated holding tank prior to bottling, or immediately bottling the cider and placing it under refrigeration.

Figure 9.3 Flowchart for apple juice production
Source: AIJN, 2012



9.3. Main environmental aspects and pressures

Direct aspects

The main direct environmental aspects and pressures of fruit juice production are shown in Table 9.1.

Table 9.1: Main direct environmental aspects and pressures in fruit juice production

Main direct environmental aspects	Main environmental pressures	
	INPUTS	**OUTPUTS**
Juice/concentrate production	Water consumption Enzyme use Energy consumption (electricity and heat)	Wastewater generation Organic wastes generation (peels, rejected fruits), Odour (concentration)
Transport of juice/concentrate	Energy consumption (fuel)	Air emissions (i.e. CO_2, NO_x, SO_x)
Packaging	Water consumption (rinse) Energy consumption (electricity) Use of materials (packaging)	Waste water generation Waste generation (packaging)
Sanitation of equipment and installations	Water consumption Energy consumption (heat) Use of chemicals (acid, alkali, detergents and disinfectants)	Waste water generation
Energy supply	Energy consumption (fuel and electricity)	Air emissions GHG emissions

Source: AINIA

Overall, the most relevant are:

- Water consumption and waste water generation
- Energy consumption
- Organic by-products/waste
- Air emissions

<u>Water consumption and wastewater generation</u>

Water consumption and the corresponding generation of waste water are the main environmental impacts of fruit juice industries. Water is consumed in the following process stages: fruit washing/transport, fruit juice reconstitution, packaging rinse, heating and cooling operations, cleaning and disinfection of equipment and installations etc.

The effluent varies according to the different processes carried out at each plant. However, most of the companies that produce orange and/or apple juice from imported juice or concentrate also manufacture other fruit juices or fruit products such as pineapple or grape.

Several researchers have investigated the parameters of the wastewater in the orange juice industry. In Spain, the average waste water volume of the orange juice processing industry ranges from 4 m^3 to 9.5 m^3 per tonne of raw material, and in general primary and secondary treatments are often used to break down the high organic content of the waste water stream by aerobic and/or anaerobic fermentation processes (MMA, 2006).

Regarding apple juice concentrate production, the waste water generated totals about 124 800 mg/l. The waste waters stream can be treated either aerobically or anaerobically (Ozbas et al., 2006).

Energy consumption

The main thermal and electrical energy consumption takes place in the stages of pasteurisation, concentration, cleaning, grating, crushing, screw finishing in the holding tank (storage), refrigeration (if applicable) and packaging. For instance, Waheed et al., (2008) analysed the energy performance of an orange juice company and their inventory is summarised in Table 9.2. They found that 19 % of the total energy used was electrical and the remaining 81% was thermal.

Table 9.2 Energy consumption of an orange juice company

Stage	Electrical energy (MJ)	Thermal energy (MJ)
Sorting	-	
Cleaning	64.43	
Grating	90.20	
Crusher	309.26	
Screw finisher	90.20	
Holding tank	128.86	
Pasteurisation	259.20	9,059.40
Packaging	6.00	

Source: Waheed et al., (2008)

Organic by-products/waste

Waste peel accounts for approximately 55-65% of the raw product depending on the fruit and the local conditions. Fresh or silage waste peel can be used as animal feed in neighbouring farms or can be treated anaerobically (e.g. in adjacent anaerobic digestion plants). Therefore in order to be used as animal feed, the peel should be dried and pelletised. However, it should be noted that the drying process of citrus peels has a significant environmental impact due to the energy required, leachates management and the air emissions generated. An alternative feasible option for treating the citrus waste is to use it as substrate for biogas production. In addition, the sludge produced in waste water treatment plants can also be treated as described above (as citrus waste, either for producing animal feed, or as a substrate for biogas production).
In general, the characteristics of organic waste from fruit juice processing are presented in Table 9.3.

Table 9.3: Characteristics of organic waste from fruit juice processing; typical proximate analysis is also illustrated below (Allobergenova, 2006; Tchobanoglous, 1993)

Organic residue	N content (%)	Water content (%)	C:N
Fruit waste	0.9-2.6	62-88	20-49

	Proximate analysis by waste				Energy content (MJ/kg)		
Type of waste	Moisture	Volatile matter	Fixed carbon	Non-combustible	As collected	Dry	Dry ash free
Fruit waste	78.7	16.6	4.0	0.7	0.004	0.0186	0.0193

Air emissions

The main air emissions are generated form the use of fossil fuels for the generation of thermal and/or electrical energy. In addition, methane and odour emissions (due to the "uncontrolled" fermentation) can result from the bad management of the solid organic waste produced.

Indirect aspects

The most relevant indirect environmental aspects are classified into upstream and downstream activities. In upstream activities primary production of fruit and its transport (agricultural and transport activities) and use of packaging materials are the most relevant indirect environmental aspects.
In downstream activities, the generation of waste (packaging and food) and the transportation of packaged fruit juice and retail are the most relevant indirect aspects.

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9.4. Best environmental management practices

This chapter is aimed at giving guidance to fruit juice processors on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[34]. For the aspects addressed in this document, the table mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of fruit juice processors on all aspects listed in the tables below.

Table 9.4: Most relevant direct environmental aspects for fruit juice processors and how these are addressed

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
Juice/concentrate production	Water consumption Energy consumption Waste water generation Waste generation	• Reference to BAT in FDM BREF • BEMP on energy production from anaerobic digestion (Section 9.4.1) • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Transport of juice/concentrate	Energy consumption Air emissions	• BEMP on improving transport and distribution operations (Chapter 3)
Packaging	Water consumption Energy consumption Use of materials (packaging) Waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Cleaning of equipment and installations	Water consumption Energy consumption Waste water generation	• BEMP on environmentally friendly cleaning operations (Chapter 3)
Energy supply	Fossil fuel consumption Air emissions GHG emissions	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of

[34] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
		renewable energy in manufacturing processes (Chapter 3)
Auxiliary processes	Fuels consumption Electricity consumption Water consumption Use of chemicals Air emissions: exhaust gases Waste water treatment Waste generation	• Reference to BAT in FDM BREF

Table 9.5: Most relevant indirect environmental aspects for fruit juice processors and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on Sustainable Supply Chain Management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NOx, particulate matter etc.)	• BEMP on transport and logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

9.4.1. Value-added use of fruit residues

Description

The fruit processing industries are concentrated mainly in southern Europe, most of them are small and/or medium size and they generate a considerable amount of fruit residues. For example, citrus processing industries generate a large amount of orange peels for example, which makes up approximately 45-65% of the original citrus fruit weight. CRES (2014) demonstrated that the average annually processed amount of citrus fruits is approximately 2,500 kt. Hence, assuming that 50% of the production process becomes waste then the amount of organic residues is approximately 1,250 kt.

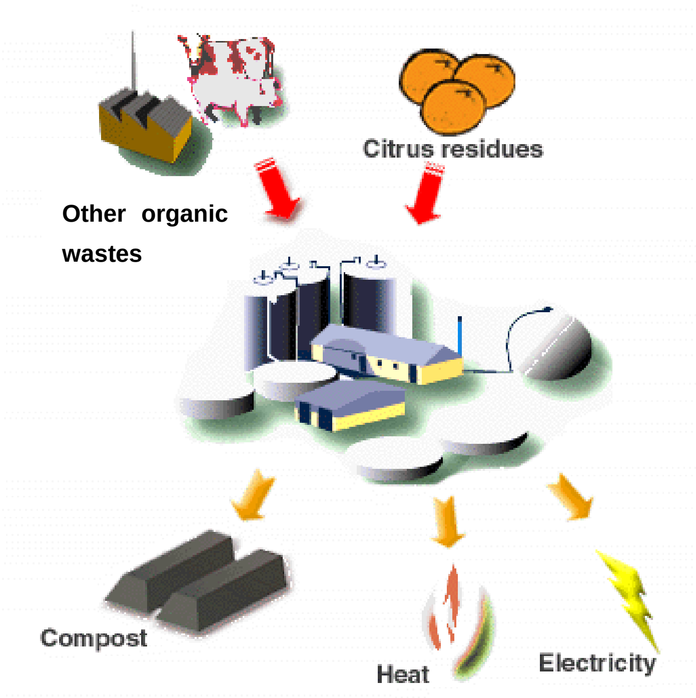
Manufacturers of fruit juice can dispose of their fruit residues in a number of ways, attempting to follow the order of priority cascade which includes:

- The recovery of valuable products which is an activity that has only recently started to be developed, e.g., production of pectin (from citrus and peach residues), fine chemicals (beta-carotenoids from carrot residues) and multifunctional food ingredients (from carrot, orange and apple residues) that can be used in bakery products, composting, etc (Petruccioli et al., 2011).
- The use of the fruit residues as animal feed: this option depends on the availability and requirements of local livestock or any animal feed producer.
- The use of the fruit residues as anaerobic digestion co-substrate: the event that there is already an existing anaerobic digestion (AD) plant nearby, the fruit juice producer can agree to provide the plant with the fruit residues, to be used as co-substrate. Alternatively, agreements with other nearby organisations producing organic waste, which could be processed in an AD plant, can lead to the construction of a new AD system.

Obviously, the availability of local options significantly affects the process(es) chosen.

The use of fruit residues for animal feed is a well-established practice while this BEMP describes in more detail the potential benefits of the use of fruit residues as co-substrate for biogas production in agro-industrial biogas plants or in anaerobic digesters dedicated to treating sludge from wastewater treatment plants (WWTP). This concept, taking into consideration the example of orange juice production, is illustrated in Figure 9.4 and below.

Figure 9.4: Citrus residues as co-substrate for biogas production (CRES, 2014)



The most common option for making use of orange residue is as animal feed. However, the high moisture content of fresh citrus waste results in high transportation costs, while the high biodegradability levels limit their use as fresh feed in the surrounding areas. Therefore the orange residue can be processed anaerobically (as a co-substrate) in order to generate electricity, heat and compost (Figure 9.4).

Anaerobic co-digestion is a technically feasible option to make use of orange residues, for producing renewable energy. Orange peel shows high methane potential, high anaerobic biodegradability and kinetics degradation. Ruiz et al., (2011) showed a maximum orange peel specific biogas production of 1,100 L/kg TS (total solids). Complete orange degradation is achieved after 11 days. Muscolo (2011) demonstrated that 1 m^3 of citrus pulp weighs approximately 0.4 tonnes and has a potential biogas yield of 147 m^3. Therefore, assuming that the methane percentage in the biogas ranges from 50 to 80%, the heating value ranges from 4,500 to 6,500 kcal/m^3 as well. Ruiz-Fuertes et al.., (2007) mentioned that the orange pulp's potential for biogas formulation is approximately 700-750 Nl biogas/kg VS (volatile solids) with a methane content of 52%.

Anaerobic digestion technology offers a high flexibility for treating different forms of citrus residues (e.g. peels and pulp) and in different states of decomposition. The main advantages of AD include the limited production of biological sludge, the low nutrient requirement and the high efficiency of methane production; which can be used as an energy source for on-site heating and electricity generation (Nallathambi, 2009).

Despite the good characteristics of citrus residues as co-substrate for biogas production, they contain D-limonene, unless it was previously extracted using one of the now well-known technologies for its recovery e.g. FMC (Citrech, 2015). D-limonene is an essential oil that is a well-known antimicrobial agent but the co-digestion of citrus residues with other organic waste prevents the possible inhibition caused by the limonene. The maximum percentage of citrus residues to keep methane production high and stable is a topic that should be defined in each blending of co-substrates (Martin et al., 2010).

The most common strategy for orange juice companies is to create synergies or reach agreements with local waste managers, other orange juice companies, farms or urban WWTPs with anaerobic digesters or biogas plants capable of treating citrus residues in co-digestion with the bio-waste they usually treat (sewage sludge, manure, other substrates). Co-digestion consists of using complementary organic substrates, mainly waste with no-cost (or limited options for further use), as co-substrates to significantly increase the biogas productivity in their facilities and thus obtain more income from the energy produced. The use of citrus residues has given good results in co-digestion in either WWTPs with AD systems or agro-industrial biogas plants (Martin et al. 2010; Martin et al., 2013). The production of economically valuable biogas boosts the agreements between orange juice companies producing orange peel and waste managers.

Silvestre et al. (2010) studied sewage sludge anaerobic digestion with orange peel (12% of volatile solids input) and other organic wastes in a semi-continuous anaerobic system. The biogas production from sewage sludge and orange residues increased 286% compared with the biogas production using only sewage sludge. Additionally, the organic matter removal efficiencies increased from 50% (sewage sludge anaerobic digestion) to 68% (sewage sludge co-digestion).

Despite the fact that orange peels provide a significant biomethane potential, low pH, low micronutrients content and high content of essential oils (if not previously extracted), they cannot be used as the only feedstock (mono-substrate) in an AD plant. Therefore, co-digestion is highly recommended for achieving stable processes. Table 9.6 shows an example of a more balanced composition of 1:3 feeding mixtures with cattle manure.

Table 9.6: Characteristics of orange residues and 1:3 feed mixture with cattle manure used by the GSR AD plant* (Ruiz-Fuertes M.B et al., 2007)

Parameter	Orange residue:Cattle manure (1:3 dry basis)
Total solids (TS) (%)	11.2
Volatile solids (VS) (%ST)	88.0
Anaerobic biodegradability	Very good
C/N ratio	35.0
Biomethane potential (L biogas/kg VS)	370.0
pH	7.0
Alkalinity	High
Micronutrients	Good
Essential oils (5)	<0.5

*As mentioned in the text above, orange waste is not suitable as mono-substrate for AD, it is recommended it be used as co-substrate.

Other studies also support the need to co-digest citrus residues with other organic wastes, in order to stabilise the AD process. For instance, the Probiogas project found that the maximum percentage of citric residues to be added to manure for AD is 10 %, due to the fact that in the industrial trials the residues had two to four times more limonene than in the lab studies. Moreover, in the same study, it was found that the results for biogas production from AD are better when the citrus residues are added without trituration, which makes their handling easier at industrial level (Probiogas project, 2010)

Achieved environmental benefits

The appropriate management of fruit residues, trying to follow the order of priority mentioned above, allows firstly the achievement of 'hidden' environmental benefits. In fact, extracted components can be used to substitute ‘virgin’ components which otherwise, through their own production, transportation and so

on, would have been responsible for further environmental impacts. The same would apply for using the fruit residues as animal feed, since this would avoid producing other feed from other natural resources.
Finally, the use of fruit residues as co-substrate for biogas production contributes to the reduction of the environmental impacts caused by inappropriate management. In particular, landfilling significant amounts of fruit residues may cause the release of uncontrolled leachates, which will eventually result in the pollution of groundwater sources.
Moreover, the anaerobic digestion process generates biogas which can then be employed for the generation of renewable electricity and heat. Therefore, the use of biogas as a renewable source of energy prevents the consumption of non-renewable resources, such as fossil fuels and the corresponding CO_2 emissions.

Appropriate environmental indicators

The most appropriate environmental performance indicator is:

- Fruit residue explotation rate (%): total amount of fruit residues used as animal feed or co-substrate in AD plants.

Cross-media effects

The environmental impact of fruit residues transportation from the fruit juice facility to livestock or to the biogas plant (fuel consumption and exhaust gases) is the main cross-media effect of this technique. However, these impacts are common to all alternatives which imply the treatment of wastes in external installations (feed preparation, composting) or disposal in landfill.

Operational data

In order to anaerobically process the orange residues as co-substrate, the chemical composition is required. Table 9.7 illustrates the most important chemical characteristics of different orange residue categories.

Table 9.7: Chemical characteristics of the orange residue categories (Ruiz and Flotats, 2014)

Characteristic	Citrus pulp		Dried citrus pulp	Citrus pulp silage	Orange residue	Orange peel	
Water content (%)	10.8	82.5	11.7	79.0	79.02	74.8	72.5
pH		3.93			4.30		
S (% dry matter)	0.11	0.13	0.07	0.02			
Sugar (%)	22.8	20.3			15.00	46.649	
Protein (% dry matter)	6.4	8.29	7.37	7.3	6.53	8.015	5.45
References	De Blas et al., (2010)	Calsamiglia et al., (2004)	Bampidis and Robinson (2006)		Mahmood et al., (1998)	Kammoun Bejar et al., (2012)	Morton (1987)

The use of orange residues generated in juice companies to produce biogas in co-digestion with sewage sludge has been successfully implemented at full scale in the WWTP of EPSAR in Alzira in Spain. This particular plant has a capacity of 82,000 inhabitants or 1,500 m^3/h (EPSAR, 2013).

The WWTP has two anaerobic digesters with a capacity of 2,110 m^3, which treat all the sewage sludge generated in the plant. The digesters have a treatment capacity of 5.000 kg SS/d and 150 m^3/d with a residence time of 20-25 days. The sewage sludge has approximately 3.5% total solids at the entrance of the anaerobic digester. The calculated productivity of biogas using only sewage sludge is 0.9-1 Nm^3/kg organic matter removed.

The orange residues received from local juice companies are ground in a pneumatic press to a maximum size of 8 mm in order to avoid orange solids causing a hydraulic blockage in the sludge pipes, tanks and pumps. Once ground, the orange residue is added to the sewage sludge at a proportion of 2-5% in a mixture tank from which the anaerobic digester is fed.

One important aspect of this technique is the intermediate storage of the orange residues. In particular, due to the fact that the orange residues generated vary seasonally the intermediate storage should be well managed, e.g. building of a tank. Otherwise, the plant can be operated in batches in order to address the seasonal variation.

Applicability

The different options for using fruit residues outlined in this BEMP largely depend on the local conditions e.g. availability of nearby AD plant and willingness to cooperate. The agreement between the fruit juice plant and the AD plant will depend on several factors such as the availability and price of other local organic wastes, the transportation distance, the profitability of electricity produced from biogas, etc.

Regarding technical aspects, the presence of essential oils in orange residues and consequently in the AD reactor should also be taken into account in the actual operation of the plant. As mentioned earlier, despite the good characteristics of citrus residues as co-substrate for biogas production, they contain D-limonene, an essential oil that is a well-known antimicrobial agent. The co-digestion with other organic waste prevents the inhibition caused by limonene. The maximum percentage of citrus residue to keep methane production high and stable is a topic that should be defined in each blending of co-substrates (Martin et al., 2010).

Economics

The economic feasibility of the agreement between parties (e.g. orange juice plant and waste manager) will depend mainly on the economics. The main costs are related to the transport of the fruit residues to the livestock or biogas plant (distance) and the market price allocated to the fruit residues, which can depend on the cost of other available organic wastes with similar characteristics. The profits obtained by biogas plants using fruit residues are related to increased biogas production thanks to the anaerobic process being kept stable (depending on local conditions).

Driving force for implementation

The main driving forces for managing the fruit residues appropriately are the environmental benefits and the potential economic benefits achievable thanks to the potential market value of the:

- useful products which can be extracted.
- fruit residues used as feed or co-substrate for AD.

Reference organisations

Granja San Ramón" (GSR). Cattle farm for milk production, biogas and organic fertilisers production. The company is located in Valencia, Spain.

The public organisation responsible for the wastewater treatment in the Comunidad Valenciana (EPSAR) uses citrus waste as co-substrate for anaerobic digestion sludge, in order to improve electricity generation. The WWTP is sited in Alzira (Spain)

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10. CHEESE MAKING OPERATIONS

10.1. Introduction

Production of dairy products was the fourth most important sub-sector in turnover in the food and beverage industry in 2009 (Food Drink Europe, 2011). Annual milk production in the EU-27 was over 148 million tonnes in 2010 (European Dairy Association, 2012).

According to the technical and health regulations of milk and dairy products, cheese is the product which is obtained by the enzymatic coagulation of milk and dairy products, with the separation of the parts of water, lactose and mineral salts, with or without subsequent ripening (Madrid Vicente, 1999).

The EU is the largest worldwide cheese producer with an annual cheese production of almost 9 million tonnes in 2010. Germany (23% of the EU-27 total), France (21%) and Italy (13%) were the main producers in 2010 (Eurostat, 2011).

The EU has also a high cheese consumption per capita, (17.3 kg in 2011). The main consumers in the EU-27 were France (26.3 kg per capita), followed by Germany and Luxembourg (both with 24.2 kg per capita) (CDIC, 2014).

Cheese making is a relevant sector from an economic point of view. Export and import values and quantities are presented in the table below. Germany, Holland and France were the main exporters; while Germany, Italy and United Kingdom were the main importers (FAOSTAT, 2014).

Table 10.1: Export and import values and quantities

Variable	EU-27 export quantities (tonnes)	EU-27 export values (USD thousand)	EU-27 import quantities (tonnes)	EU-27 import values (USD thousand)
Cheese, sheep's milk	61 518	420 134	54 421	398 143
Cheese, skimmed cow's milk	1 355	6 326	2 160	12 115
Cheese, full fat cow's milk	3 780 253	20 768 332	3 191 142	16 627 929

Source: Adapted from FAOSTAT, 2014.

There are considerable variations among the cheeses production processes. Depending on the consistency of the cheese, measured as HSMG (moisture content of the fat-free cheese), there are four groups of cheese. Taking this into account, the most common European cheeses are shown in Table 10.2.

Table 10.2: Most common types of cheese

TYPES OF CHEESE		DEFINITION (% HSMG)	EXAMPLES
Cheese made with cow's milk	Hard	49-56	Cheddar
	Semi-hard	54-63	Gouda, edam, emmental

TYPES OF CHEESE		DEFINITION (% HSMG)	EXAMPLES
	Soft	>67	Fresh cheeses, camembert
Cheese made with sheep's milk	Hard	49-56	Feta, manchego
	Semi-hard	54-63	Blue cheeses
	Soft	>67	Serra

Source: Adapted from mundoquesos, 2014.

The scope of this study includes those cheeses made from cow's or sheep's milk, which represent around 90% of the total cheese production (CAR/PL, 2002[1]). Cheeses made from buffalo's or goat's milk were not studied because their use is not widespread in Europe.

10.2. Description of the cheese production process

The milk, when arriving at the cheese production site, is usually stored for one or two days before undergoing treatment that includes filtering, clarification and standardisation operations (Ministry of Environment & Ministry of Agriculture, Fisheries and Food, Government of Spain, 2004).

Depending on the type of cheese produced, some operations may or may not be required (i.e. in Spain, cheeses with an ageing or ripening period of less than 60 days cannot be commercialised unless the raw milk is previously pasteurised). Cheese is produced by adding coagulants and heating the milk which allows the precipitation of the casein curd. The subsequent stages and their duration are different depending on the type of cheese produced (i.e. pressing is carried out in some types of cheese, as well as ripening). Finally, the cheese is packaged (Ministry of Environment & Ministry of Agriculture, Fisheries and Food, Government of Spain, 2004). The main stages of the cheese production process are shown in Figure 10.1 and Table 10.3.

[1] Data from Mediterranean countries (EU-27 data not available).

Figure 10.1: Main cheeses production stages. *Source: Adapted from Madrid Vicente, 1999.*

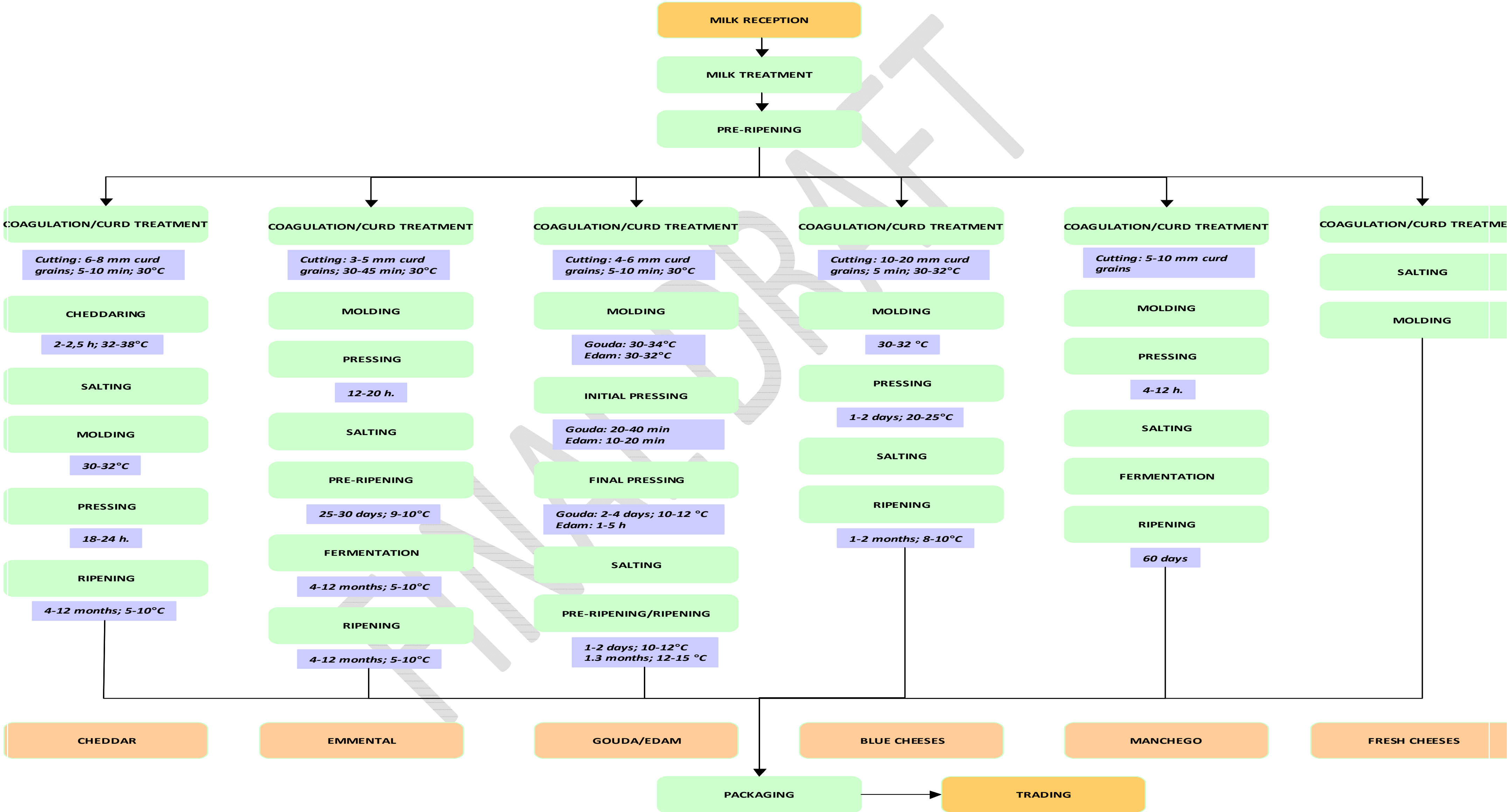

Table 10.3: Main stages of cheese production

STAGE	DESCRIPTION
Milk reception	The milk is received and unloaded in the installation.
Storage	After sieving, the milk is stored at a controlled temperature in tanks with different capacities.
Milk treatment	Milk treatment usually includes centrifugation and pasteurisation.
Pre-ripening	In this process, lactobacillus are added in order to transform the lactose into lactic acid, thus facilitating the coagulation process.
Coagulation, curd treatment and drainage	Coagulation is the basis of cheese production. The milk is coagulated by adding a coagulant*, obtaining casein curd (solid part of the milk) and whey (liquid part). The process is carried out in appropriate containers which are heated. When the milk is coagulated, the curd grains are recovered and the whey is discharged.
Moulding and pressing	The cheese acquires the structure that allows its preservation in the following operations. Additional whey drainage is also achieved. With the moulding operation the cheese acquires the shape and size required for the type of cheese produced.
Salting	It consists of the addition of sodium chloride with the goal of completing the drainage and preventing the appearance of microorganisms.
Ripening	In this process, cheese acquires its own texture, aroma and appearance.
Storage and packaging	Storage and packaging protect and preserve the cheese from odours, humidity loss, etc.

*In the past, coagulants used were of animal origin (specifically beef). Nowadays, coagulants are mainly of vegetal or bacterial origin.

Source: Adapted from Madrid Vicente, 1999.

10.3. Main environmental aspects and pressures

The environmental aspects of the production of cheese can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects and pressures of cheese production are presented in Table 10.4.

Table 10.4: Main direct environmental aspects and related pressures in cheese production

Most relevant direct environmental aspects		Main environmental pressures	
		INPUTS	OUTPUTS
TREATMENT	MILK RECEPTION	Energy consumption	-
	STORAGE	Energy consumption	-

Most relevant direct environmental aspects		Main environmental pressures	
		INPUTS	OUTPUTS
	MILK TREATMENT	Energy consumption	Air emissions
	PRE-RIPENING	Energy consumption	Air emissions
COAGULATION AND MOULDING	COAGULATION, CURD TREATMENT AND DRAINAGE	Energy consumption Water consumption Waste generation	Waste water generation Air emissions
	PRESSING AND MOULDING	Energy consumption	Waste water generation
SALTING AND CURING	SALTING	Energy consumption	Waste water generation
		Use of Salt	
		Water consumption	
PACKAGING	RIPENING AND STORAGE	Energy consumption Water consumption	-
	PACKAGING	Energy consumption Use of material (packaging)	Waste generation (e.g. plastics, paper, etc.)
CLEANING OF EQUIPMENT AND INSTALLATIONS	-	Water consumption Energy consumption Use of chemicals	Waste water generation Waste generation
ENERGY SUPPLY	-	Energy consumption	Air emissions GHG emissions

Source: Adapted from Madrid Vicente, 1999.

Overall, the most relevant environmental impacts are:

- *By-products generation*, mainly whey from coagulation, curd treatment and drainage, as well as pressing processes.
- *Waste water generation,* mainly whey from coagulation, curd treatment, drainage and pressing, and brines from the salting stage. In addition, it is important in cleaning and disinfection operations.
- *Energy consumption*, both in terms of thermal energy (pasteurisation as well as cleaning and disinfection operations) and electricity (refrigeration).
- *Water consumption*, mainly used in cleaning and disinfection operations.

The amounts of water and energy required and waste water generated in the production of cheese products are presented in Table 10.5.

Table 10.5: Main consumptions and waste water generation in cheese production

ENVIRONMENTAL ASPECTS		AMOUNT
Energy	Thermal	0.15-4.6 MJ/l processed milk
	Electricity	0.08-2.9 MJ/l processed milk
Waste water generation		2-4 l/l processed milk
Water consumption		1-60 l/l processed milk

Source: European Commission, 2006 ; CAR/PL, 2002.

Indirect aspects

The most relevant indirect aspects of cheese production is the production of milk (agricultural phase). In addition, other indirect environmental aspects are the transport and distribution of milk and finished products, the choice of packaging and the retail of the finished products.

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10.4. Best environmental management practices

This chapter is aimed at giving guidance to cheese producers on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[35]. For the aspects addressed in this document, the tables mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of cheese producers on all aspects listed in the tables below.

Table 10.6: Most relevant direct environmental aspects for cheese producers and how these are addressed

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
Milk treatment	Energy consumption Air emissions	• Reference to BAT in FDM BREF • BEMP on improving freezing and refrigeration (Chapter 3)

[35] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
Coagulation, moulding, salting and curing	Energy consumption Waste generation Waste water generation Air emissions	• Reference to BAT in FDM BREF • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3) • BEMP on recovery of whey (Section 10.4.1)
Packaging	Energy consumption Water consumption Use of materials (packaging) Waste generation	• Reference to BAT in FDM BREF • BEMP on Improving or selecting packaging to minimise environmental Impact (Chapter 3)
Cleaning of equipment and installations	Water consumption Energy consumption Use of chemicals Waste water generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Energy supply	Fossil fuel consumption Air emissions GHG emissions	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

Table 10.7: Most relevant indirect environmental aspects for cheese producers and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on Sustainable Supply Chain Management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NOx, particulate matter etc.)	• BEMP on transport and logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

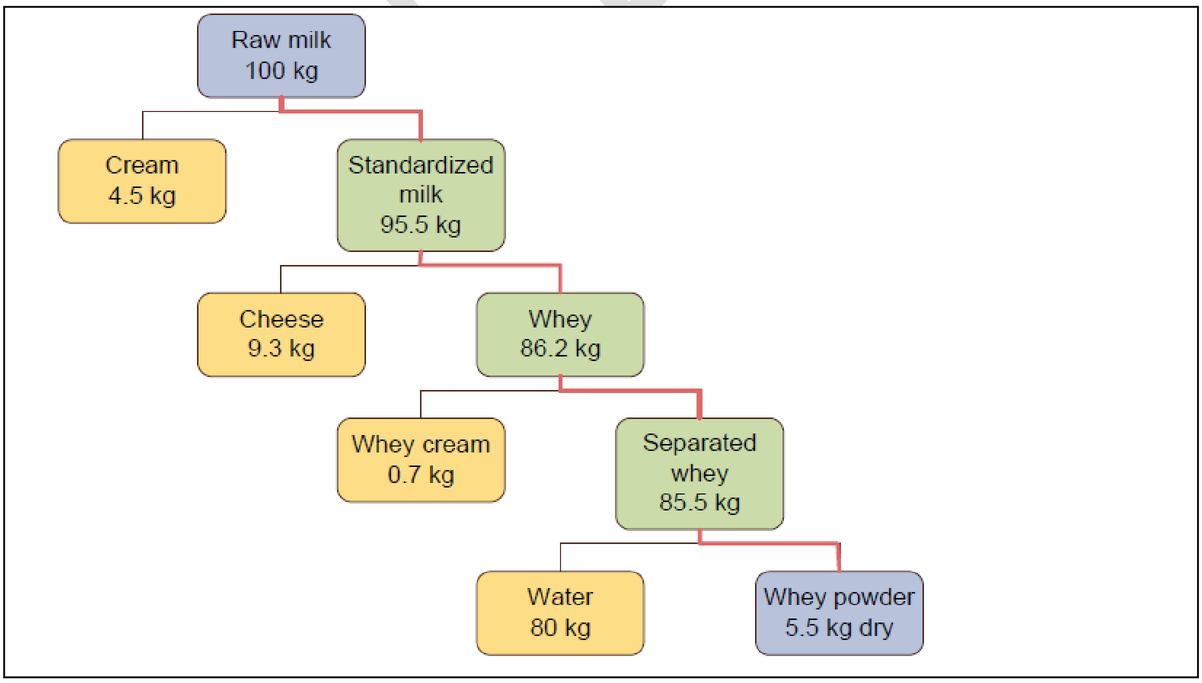
10.4.1. Recovery of whey

Description

Introduction

In the manufacture of most cheeses, typically less than 10% by weight of the original raw milk is used to make the cheese, leaving behind substantial quantities of a liquid known as 'whey' (Figure 10.2). The whey is largely comprised of water (more than 90% by weight) although it also contains valuable nutrients, especially serum proteins and lactose.

Figure 10.2: Milk and whey distribution



Source: Smith (2014)

The significance of whey, its use and disposal practices lies in three main factors:

1. Up to 55% of milk's total nutrients are retained in whey during cheese processing. This includes lactose, minerals, vitamins and 20% of milk proteins (Banaszewska, 2014).

2. Whey is a highly polluting substance due to its high BOD content, reported to be approximately 175 times higher than the average sewage effluent (Smithers, 2008). The disposal of whey can cause an excess in oxygen consumption, eutrophication and toxicity (Prazeres, 2012).
3. Large amounts of whey are produced annually. It is estimated that worldwide production of whey is around 180 to 190 million tonnes per year (Baldasso, 2011). According to Eurostat, 67 million tonnes of milk were processed to obtain 9 million tonnes of cheese in the EU-27 in 2011 (Marquer, 2013). For every litre of milk used in cheese production, approximately 85 to 95% results in whey (Guimarães, 2010). Therefore, it can be estimated that perhaps 60 million tonnes of whey were produced in the European Union alone.

Given its excellent nutritional properties, whey can be used in a number of food applications. However, according to the European 'WheyLayer' project, which seeks to develop new bioplastics from whey, half of the whey produced annually in Europe is left unprocessed and is simply flushed into municipal drains (King, 2014). Anecdotal evidence suggests that it is the smaller and medium-sized cheese-makers in particular that tend to do this. This practice not only wastes valuable nutrients but can also be expensive. Local sewage treatment companies and environmental protection agencies require that the effluent from factories, including dairies, meets stringent limits on dissolved organic content. These limits are costly for cheese-makers to achieve if whey is included in their waste water and often dairies have to install their own on-site water treatment equipment, in order to 'pre-clean' the effluent (FACE network, 2014), or pay higher rates to the waste water companies. These rates vary significantly with locality.

This BEMP describes how frontrunners, especially among small and medium-sized cheese producers, avoid these financial and environmental impacts by recovering the whey for use themselves, or by others, in new applications.

For the purposes of this report, the following definitions of company size are used, as suggested by ACTALIA, the research and technology institute for the French dairy sector:

- **Large**: industrial producers, processing 40 million litres of milk per year, with a highly automated process.
- **Medium**: small industrial or larger artisanal producers, processing 2 to 40 million litres of milk per year, often with an automated process.
- **Small**: artisanal and/or farmer producers, processing less than 2 million litres of milk per year using a traditional, manual process.

The preferable option is to concentrate, filter and/or evaporate the whey to produce whey powder, whey protein concentrate (WPC), lactose and other by-products. By doing this, the nutritional value of the whey is fully exploited; and the market for such whey-derived products is large and growing. Where this option is not feasible, however, perhaps due to low production volumes, the manufacture of whey products intended for human consumption such as whey cheeses or whey drinks should be considered; these latter applications, though, suffer from low market demand and may exploit only a small proportion of the whey's constituents. This BEMP also briefly explores other options, which can be implemented when the previous two are not feasible, such as feeding the whey to animals, using it as a fertiliser or processing it in an anaerobic digestion plant to generate energy.

Production of whey powder and isolation of components

As discussed, whey contains a number of valuable components, especially a variety of proteins (e.g. β-lactoglobulin, α-lactalbumin, lactoferrin, lactoperoxidase) and the sugar lactose. Other constituents include fats (i.e. phospholipids), non-protein nitrogen (e.g. urea, ammonia) and minerals (e.g. calcium phosphate) (Smith, 2014). Whey powder, simply a dried version of whey is used as an ingredient in a variety of processed food products. However whey's value is maximised when the individual constituents, particularly the protein and lactose, are isolated or fractionated from the liquid whey. The proteins in particular are highly versatile and can be used in products from baby milk powders and ice cream to fortified yogurt and bodybuilding supplements as well as as an egg substitute in baked goods. The whey-derived lactose meanwhile is often polymerised and used for applications such as bioplastics and foams.

Production of whey cheeses and drinks

The production of 'whey cheeses' such as ricotta (Italy), or 'brown cheeses', e.g. brunost (Scandinavia) or sérac (France) is a method of extracting some value from the protein contained in whey. However, it may not exploit the full value of the protein as a source of human nutrition while continuing to incur sewage treatment costs. For instance, in ricotta production, a significant proportion of the protein is lost in effluent, although some producers supplement the whey with small quantities of raw milk, the casein content of which helps to extract more of the protein (Wisconsin Center for Dairy Research, 2014 pers. comm.).

In some parts of Europe, cheese-makers will produce 'whey drinks' to meet local demand. These beverages are created by first removing any residual fat from the whey by skimming, pasteurising, adding flavourings and packaging it (Wisconsin Center for Dairy Research, 2014 pers. comm.). The most successful whey drink is made by the Swiss company **Rivella** with annual domestic sales of approximately 80 megalitres (Rivella, nd.), although a proportion of the nutrients in this product are removed during manufacture so, again, this does not fully exploit the whey's true potential. By contrast, **Wei4All**, produced by a microbusiness in Holland, does use the full nutritional content of whey (Wei4All, 2014 pers. comm.). The product can be made of both 'acid' and 'sweet' whey (see below) and from most kinds of cheese-making; however, no preservative such as saltpetre (potassium nitrate) can be present in the whey.

It should be clarified that the whey drinks discussed in this report are those derived directly from the whey with minimal processing. Another class of whey beverages to be considered are those made with whey protein concentrate (WPC) as a key ingredient. Sometimes called 'protein drinks', these were originally targeted at body-builders but are becoming more universally popular (Walker, 2013). Due to the high costs of producing WPC discussed below, small and medium-sized cheese-makers are very unlikely to be in a position to manufacture this type of product.

Other options

Traditionally, smaller cheese-makers have either fed their whey to livestock (e.g. pigs, goats, sheep), either their own or those of other farmers, or have spread their whey directly onto the land as a fertiliser. This practice is still very common and may be a viable option in certain circumstances, however, it is unlikely to attract a revenue and fails to directly exploit the true value of the whey as a source of human nutrition. A perhaps more promising avenue is processing the whey in an anaerobic digestion plant to release a 'biogas' for use as a fuel, as well as a 'digestate' used as a fertiliser or soil conditioner. As well as the production of methane, whey can also be used to make other fuels such as alcohol (Smith, 2014). This end use may be most appropriate application for the so-called 'acid whey' produced in the manufacture of certain cheeses, yoghurts and other dairy products (see below). The French technologies firm Utilities Performance, in conjunction with a Japanese company, is among those currently trialling a biogas system which runs on acid whey (Utilities Performance, 2014 pers. comm.).

Achieved environmental benefits

The production of whey powder offers the greatest environmental benefit of all the options for recovering whey in that large quantities of polluting effluent are avoided. This in turn reduces the substantial chemical, water and energy inputs which would have been required to treat the whey (either by the manufacturer or the waste water treatment company). Whey powder also offers hidden environmental benefits in that the nutrients can be used to substitute 'virgin' ingredients in a wide variety of food products and which themselves would have been responsible for environmental impacts through their growing, transportation and so on.

Membrane processes result in high contaminant removal, with COD reductions of between 74% and 98%. In addition, these result in protein and lactose recovery in the ranges of 87-100% and 89-100% respectively. Limiting factors in the use of these technologies are the by-products generated during the process: concentrates, membrane fouling and the pollutant permeate production (Prazeres, 2012).

The production of whey drinks could offer comparable benefits assuming these drinks contain all the whey's nutrients and have not had some removed during production. Indeed, whey drinks theoretically offer the greatest benefit because the energy-intensive heating and filtration processes needed for whey powder production are avoided. However, the tiny market for whey drinks means that these are not a realistic option to 'solve the whey problem'. The environmental benefit of producing whey cheeses, versus discharging the whey to thr drains, is also considerable and the market is strong for certain products, although, as noted above, in some cases only a small proportion of the nutrients are exploited and an effluent still results.

The use of whey as feedstock in biogas production (through anaerobic digestion) offers the advantage of generating renewable energy. COD reductions of 36% to 99% can be achieved; at the same time the gas resulting from the digestion contains between 53% and 79% methane (Prazeres, 2012).

The environmental benefits of the other options are likely to be substantially lower and are not further discussed here.

Appropriate environmental indicators

The most appropriate indicator for this BEMP would be the percentage (weight) of dry matter recovered in whey for use in products intended for human consumption per weight of total whey generated.

Cross-media effects

The production of whey powder can be highly energy intensive due to the evaporating and filtering of the whey; detailed analysis on a case by case basis may be necessary to understand whether these impacts potentially outweigh the benefits of recycling the whey versus disposal to drains (or alternatives such as feeding to animals). To minimise the energy demand, the evaporation is carried out in a vacuum (Wisconsin Center for Dairy Research, 2014 pers. comm.). In addition, transportation of the whey concentrate in liquid form has a significant environmental impact in terms of greenhouse gas emissions due to the water content when compared with competing dry ingredients such as corn (Wisconsin Center for Dairy Research, 2014 pers. comm.). Some dairies, including relatively small ones, have invested in equipment to concentrate the whey (from 5% to 15% solids content) in order to reduce these impacts (Wisconsin Center for Dairy Research, 2014 pers. comm.).

Certain whey cheeses also require considerable amounts of energy to produce. For instance, the Scandinavian brunost is produced by simmering the whey until almost dry to leave a viscous caramelised product whose texture resembles that of peanut butter (Wisconsin Center for Dairy Research, 2014 pers. comm.).

Cross-media effects are significant for some of the other less recommended uses of whey. For instance, as with any fertiliser, whey spread on the land may run off fields into watercourses – especially when improperly applied or when the ground is frozen - and with its naturally very high BOD, it may impact negatively on aquatic biota.

Operational data

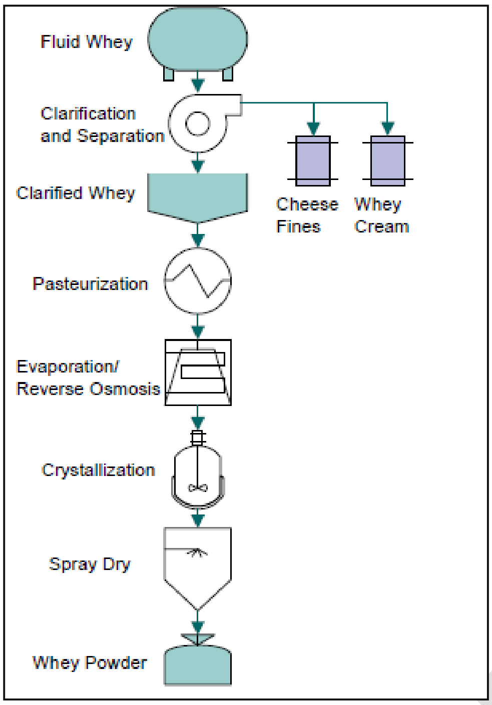
Production of whey powder, whey protein concentrate and lactose

Whey powder is essentially a dried version of whey containing a naturally-occurring blend of proteins, sugars and minerals. Large cheese manufacturers can use their own facilities for the production of whey powder since they produce considerable amount of whey. Small and medium-cheese producers can instead either deliver their whey to big producers in order to use their whey powder production facilities can decide to share the same facility as or nearby small and medium cheese producers for the production of whey powder. Several small and medium-sized cheese manufacturers can invest in a plant which is able to treat their cumulative production of whey. This has already proven successful in France, where seven cheese makers decided to build a facility able to treat 52 million litres of whey per year (ACTALIA, 2014).

The whey is passed through an evaporation and reverse osmosis process and then spray-dried to produce a powder. Unlike the liquid whey, the powder can be stored indefinitely and offers lower shipping costs.
Figure 10.3 summarises the main steps in the production of whey powder.

As discussed, to maximise the value of the whey, the main constituents need to be separated out. These are found in very low concentrations; for instance, protein constitutes just 0.8% by weight of raw whey. Therefore, a number of processes are used to isolate and concentrate the protein, lactose and other substances. The main product from whey is whey protein concentrate (WPC), a variety of products with protein contents varying upwards from 34%. The percentage figure given here refers to the proportion of the dissolved solids that is constituted by protein and thus can be applied to either liquid or powdered WPC.

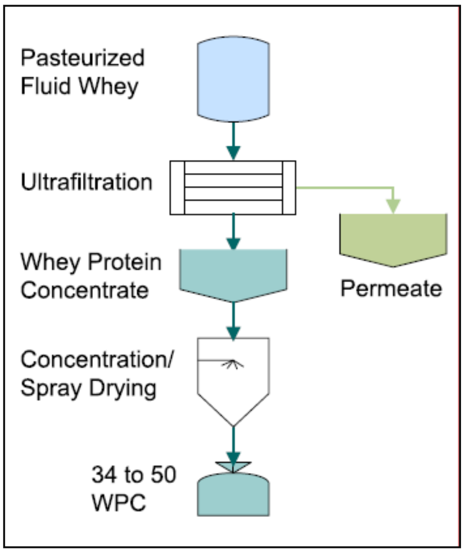
Figure 10.3: Production of whey powder



Source: Smith (2014)

The usual first step is filtering the whey in order to concentrate the protein. 'Ultrafiltration', as it is called, is performed using specially designed membranes which allow water, lactose and minerals, but not the protein, to pass out (as 'permeate') under pressure. The removal of minerals – sometimes called 'ash' or 'milk salts' - is important as any later heating processes will precipitate calcium phosphate furring pipes and severely reducing the performance of evaporation and other equipment. Simple ultrafiltration will create a WPC with a protein concentration varying from 34 to 50% of the dissolved solids which has a market value. This liquid can then be dried using a spray dryer (Figure 10.4).

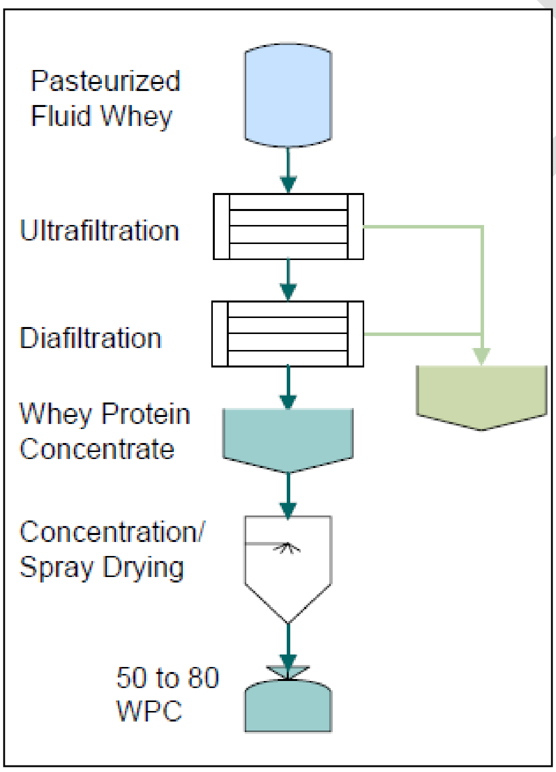
Figure 10.4: Production of whey protein concentrate (34-50 %WPC)



Source: Smith (2014)

For a more concentrated WPC, up to 80%, more of the minerals and lactose must be removed. The 80% WPC is highly viscous and water needs to be added to facilitate the ultrafiltration process, a step called 'diafiltration' (Figure 10.5). Due to the high protein content it is dried directly.

Figure 10.5: Production of whey protein concentrate (50 -80% WPC)



Source: Smith (2014)

As with whey powder, WPC is also spray-dried to prolong its shelf life and for ease of shipping. Yet further processes can be performed on WPC to create a product with close to 100% protein, known as protein 'isolate' and to separate out the individual proteins.

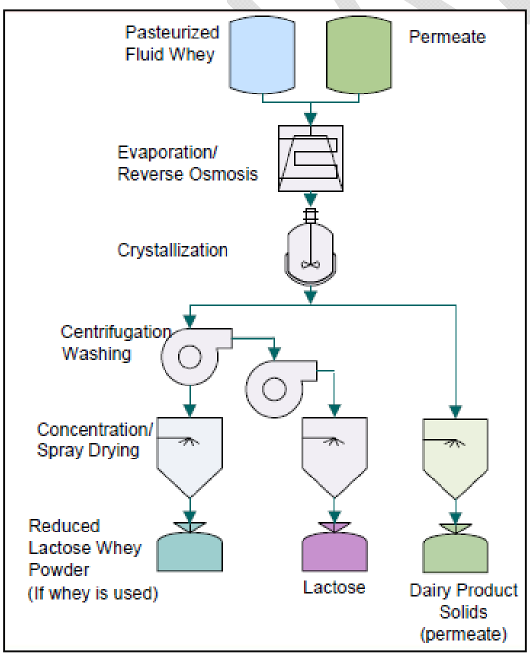
The ultrafiltration of 100 kg of normal sweet whey (with 6% solids) discharges (Niro, nd.):

- aproximately 20 kg of 35% WPC liquid (with 10% solids, increased to 45% solids with evaporation before spray drying)
- aproximately 8 kg of 60% WPC liquid (15% solids, increased to 42% solids with evaporation before spray drying)
- aproximately 3 kg of 80% WPC liquid (28-30% solids).

The lactose within the permeate is itself isolated by flushing with added water across another set of reverse osmosis membranes followed by crystallisation and centrifugation. The lactose can also be directly recovered from whey using the same processes (Figure 10.6).

Some larger frontrunner manufacturers will reuse the waste water recovered from the whey (through evaporation and filtration) within their own facility. The most advanced filtering systems can sufficiently 'polish' the water to drinking water standards; for example, **Müller Wiseman Dairies** in the UK has demonstrated that the water extracted from whey can be filtered sufficiently to be reused in the process (Arla Foods, 2014 pers. comm). However, the rules in many jurisdictions require whey water to be kept out of contact with foodstuffs. This does not preclude its use for other purposes such as in boilers or for cleaning processes, and, in the USA, a small number of dairies are locally permitted to use the whey water for this purpose (Wisconsin Center for Dairy Research, 2014 pers. comm.).

Figure 10.6: Production of lactose



Source: Smith (2014)

Production of whey cheese

There are two classes of products generally known as 'whey cheeses' which are produced in different ways.

Whey cheeses, such as ricotta, are produced as follows (Sveriges Gårdsmejerister, 2014):

- The whey is heated up gradually without boiling it
- At 40°C - salt may be added, which improves the efficiency of protein recovery (but this salt can preclude the feeding of waste whey to animals or for landspreading)
- At 70°C - milk may be added, again to improve protein recovery. (This temperature needs to be reached before the milk is added to ensure the rennet in the added milk is inactivated, otherwise this could result in 'true' cheese being inadvertently produced)
- At 85-90°C - a mild acid such as acetic or citric acid is added to lower the pH of the whey, causing the albumin protein within the whey to coagulate and form curds. These curds can be skimmed off and are, essentially, the finished product

'Brown cheeses', such as Scandinavian brunost, are produced as follows (Sveriges Gårdsmejerister, 2014 pers. comm.):

- The whey is heated, typically using a steam vat (although traditional makers may heat the whey in a cast iron kettle). The simmering process allows the lactose within the whey to caramelise.
- At the start of the process, the albumin protein in the whey may coagulate and rise to the surface. Some brunost-makers will skim off this protein to eat (effectively as a form of ricotta), but generally it is left in the whey
- When the right texture is achieved the whey is allowed to cool while being stirred continuously until the temperature reaches 40°C, at which point the end product is allowed to cool completely.
- Towards the end of the process, some producers will add some milk or cream to change the texture of the end product, to give it a rounder taste
- Using a modern, efficient steam vat, within one hour of heating, 100 litres of whey (from cow's milk) can reach the necessary texture, producing a residue of about 8 kg or 9 kg of whey cheese. To produce the same amount of whey cheese from goat's milk (which is lower in protein and fat than cow's milk), about 20% more whey would be required.

Production of whey drinks

As noted above, whey drinks are produced very simply by skimming and pasteurising the whey, and perhaps adding some flavourings.

Applicability

Although the production of whey powder maximises the value of the material, significant investment may be required which can only be justified when threshold volumes of production are met. This barrier is discussed in the 'Economics' section below. Another constraint is that the type of whey normally used to make whey powder is known as sweet whey. This material is recovered relatively early on in the fermentation process and is typically generated in the production of cheeses such as cheddar or mozzarella. However, the manufacture of certain products such as cream cheese and cottage cheese (actually curds rather than 'true' cheese) requires that the whey is drawn off significantly later in the process; by this point, bacterial action has lowered the pH of the whey (by converting lactose in the whey to lactic acid) and has also begun to brown the sugars (Wisconsin Center for Dairy Research, 2014 pers. comm.). Producers of whey protein concentrate and other whey-derived products tend to avoid acid whey because (Smith, 2014):

- it has a lower lactose content (due to conversion to lactic acid);
- it causes evaporator problems due to greater calcium;
- the permeate has an undesirable brown colour, and;
- sweet whey is readily available.

Acid whey is therefore still largely fed to animals, spread on the land or, in more recent years, used as a feedstock for anaerobic digestion plants (Arla Foods, 2014 pers. comm.).

It is worth noting that in the USA, projects are now underway to develop new specialised membranes able to 'sweeten' the acid whey by removing some of the acid (Wisconsin Center for Dairy Research, 2014 pers. comm.). Much of the research is being conducted on the acidic whey produced in the making of Greek-style yogurt but any findings should be applicable to whey from cheese-making.

For other whey products, market factors are critical. The markets for certain whey cheeses are already long established, for instance, the Italian ricotta, French sérac and the brunost of Scandinavia. However, new entrants with new cheese products may find it difficult to interest consumers in new and unfamiliar products without significant investments of time and money in marketing campaigns. Also, the production of the established whey cheese products is often geographically constrained in the consumer's mind. Even traditional whey cheeses offer limited scope since they are usually produced from the milk of certain animal species only. In Scandinavia, goat's milk alone is used to make brunost, with the whey from sheep's or cow's milk usually fed by the cheese-maker back to the animal providing it, or to pigs (FACE network, 2014).

Despite these difficulties, the option to make whey cheeses has a key benefit for smaller producers in that large economies of scale or substantial investment in new equipment are not needed. This is evidenced by the fact that cheeses such as brunost are manufactured in very small dairies (FACE network, 2014). With other end uses, such as the evaporation of whey to make powder, this may not be the case.

Consumer demand for whey drinks is generally more limited. Although **Rivella** is popular in Switzerland and parts of Italy and Germany, it has so far failed to break into other markets, notably North America. **Wei4All**, a whey drinks microbusiness based in the Netherlands, reports that marketing the drink domestically is a challenge due to lack of consumer awareness of the product and its nutritional benefits (Wei4All, 2014 pers. comm.). Wei4All sells only about 2,500 litres per year.

Applicability issues are important for the less recommended whey recovery options. For instance, feeding whey to animals or spreading on land may not be feasible for cheese-makers based in non-rural locations (Barbers Farmhouse Cheesemakers, 2014 pers. comm.). In addition, landspreading of whey may be prohibited in specific regions due to the risks of ru-noff.

Economics

Regardless of the end use, recovering and recycling the whey offers significant cost savings because disposal to the drains can be expensive (Wisconsin Center for Dairy Research, 2014 pers. comm.). Furthermore, given the large and growing worldwide demand for whey powder, WPC and other by-products, this option offers frontrunners the greatest financial opportunity. The trading prices for whey powder have risen markedly in the last 10 years, from an EU wholesale price of EUR 400/tonne in 2004 to approximately EUR 1000/tonne in July 2014 (Figure 10.7)
Part of the reason for this rising price is thought to be an increasing demand from China for whey powder used in infant feed (Wisconsin Center for Dairy Research, 2014 pers. comm.).

Figure 10.7: EU wholesale prices for whey powder, EUR/tonne

Source: DairyCo website. Available at: http://www.dairyco.org.uk [Accessed 12 September 2014]

While standard whey powder sells for approximately EUR 1000/tonne, whey protein concentrate (WPC) attracts higher prices. For instance, at the time of writing, WPC with a 34% protein content sold for USD 1.55/lb (around EUR2,638/tonne), and for yet more concentrated WPC - and for 100% protein 'isolate' - the prices climb higher still. Similarly, the permeate (containing lactose and minerals) attracts a modest USD 0.40/lb (about EUR680/tonne) but the price for extracted lactose (which is highly volatile depending on prevailing demand) was at the time of writing, approximately USD 0.50/lb (about EUR 1191/tonne[36]). Although lactose has found use as a precursor to biopolymers, the demand is low due to its high cost relative to competing materials derived from corn starch. Further processing to make WPC and lactose adds more value but substantial additional investment is needed, perhaps more than EUR 1 million, in machinery (Wisconsin Center for Dairy Research, 2014 pers. comm.) and so it will be beyond the scope of most SMEs.

Currently, anecdotal evidence indicates that in Europe at least, smaller cheese-makers tend not to exploit these opportunities. According to dairy experts in Italy and the Netherlands, SMEs are unable to produce whey powder due to the perceived need for large quantities and the costs of transport; instead these companies spread the whey on the land or feed it to animals such as pigs. The Dutch interviewee was aware of only one cheese-maker in their country that was making whey powder, and this firm was processing approximately 10,000 litres of milk per day, or approximately 4 million litres annually, putting it in the 'medium' category according to the size definitions presented in the Introduction to this report (Wei4All, 2014 pers. comm.). In Italy, however, large cheese manufacturers processing at least 50 000 litres of milk per day produce whey powders and concentrates (CNR - Istituto di Scienze delle Produzioni Alimentari, 2014 pers. comm.).

This finding is surprising because the production volume threshold at which it becomes cost-effective to recover whey for use in whey powder, either by the manufacturer themselves or for passing on to other larger manufacturers, is reportedly low. For instance, according to one American dairy expert, "as soon as you can fill a tanker, it's worth it" (Wisconsin Center for Dairy Research, 2014 pers. comm.). However, this information may not be applicable to companies operating in Europe. The threshold quoted by this American expert is approximately "10,000 lbs of whey per day" which equates to 5000 litres per day or 1.8 million litres per year. This is therefore applicable even to small artisanal cheese-makers, and in the USA at least, even for the smallest producers who cannot meet this threshold, options remain to pool the whey with others in the area, for instance through cooperatives. According to the same American expert, small cheese-makers may get paid for their whey, although the amount will vary widely.

Although the threshold at which it makes financial sense to recover the whey is low, substantial investment in equipment is needed to process the recovered whey into powder and ingredients for human consumption. For instance, a single evaporator machine may cost GBP 500 000 (about. EUR 600 000), reverse osmosis membrane equipment may cost GBP 250 000 (about EUR 300 000) and a large whey drying operation may cost up to GBP 10 million (about EUR 12 million) (Barbers Farmhouse Cheesemakers, 2014 pers. comm.). Thus, this next step in the whey powder supply chain may only be feasible for the larger cheese-makers. The threshold at which it becomes worth making such investments will vary with factors such as prevailing market prices. However, one leading UK cheese-maker suggests that when more than 2000 tonnes per year of cheese is being produced at a site (roughly equivalent to 20 million litres of raw milk being processed per year – or a 'medium' sized cheese-maker in the definitions above) - then it becomes a viable proposition; indeed, according to this UK interviewee, a 'whey strategy' is 'essential'. Should on site generation of whey fall below this threshold, those who have invested in the equipment will seek to source additional whey from other smaller local cheese-makers (Barbers Farmhouse Cheesemakers, 2014 pers. comm.).

[36] Conversions from USD/lb to euros/tonne performed using Google on 12 September 2014.

The alternative uses for whey discussed above (e.g. drinks, cheeses) may generate a modest revenue in some niche products with limited markets. However, as mentioned, the production of whey cheese is not thought the best way to exploit the full value of the protein content of whey given that a sizeable proportion of the protein is still lost in by-products, and that additional milk is sometimes needed to maximise the proportion of protein recovered (e.g. in ricotta production) (Wisconsin Center for Dairy Research, 2014 pers. comm.). But the use of whey for alternative products means the liquid does not have to be disposed of or treated further before disposal. According to an expert in Italy, disposal costs amount to EUR 10 000 per month for a dairy company processing 100,000 litres per day. Thus, significant monetary savings can be achieved by reducing the need to dispose of whey (CNR - Istituto di Scienze delle Produzioni Alimentari, 2014).

Uses such as passing the whey to farmers to feed animals or for landspreading typically attract no revenue, but these fates at least avoid the disposal costs. The use of whey as a feedstock in biogas production or the production of alcohol (fuel) may yield a revenue depending on local renewable energy incentive schemes or subsidies and whether the energy generated is sold on; in some cases, however, the energy may instead be used internally by the dairy itself. It should be noted that fuels such as methane and alcohol derived from whey are less competitive in the biofuels marketplace than those made from other raw materials such as corn (Smith, 2014).

Driving force for implementation

The key driver for recovering the whey and using it in any of the ways described above is to avoid the steep costs associated with disposal of the whey to the drains. For the frontrunners, the additional motivating factor is to maximise the value from the whey by producing highly marketable products, such as whey powder.

Reference organisations

Whey powder production: The following companies are frontrunners in maximising the economic value of their whey, and minimising the environmental impacts (especially those associated with sewage treatment), by evaporating, filtering and fractioning their whey into desirable protein- or lactose-based precursor ingredients for re-use in the production of new food products:

- Arla Foods (Sweden, Denmark, UK)
- Barber's (UK)
- DMK Deutsches Milchkontor GmbH (Germany)
- FrieslandCampina (Netherlands)
- Groupe Lactalis (France)
- Kerry Group (Ireland)
- Müller Wiseman Dairies (UK)

Whey cheeses: No specific frontrunners in the production of these products have been identified, although leaders in the field are likely to be found in Italy (for ricotta) and Scandinavia (for brunost and other 'brown cheeses').

Whey drinks: Rivella (Switzerland) is a frontrunner in exploiting whey for producing a popular beverage. Wei4All (Netherlands) is a frontrunner as the whey drink produced by this SME uses 100% of the nutritional content of the whey.

Biogas generation: A number of cheesemakers are frontrunners in producing a biogas from whey which can be used to generate energy. These include Abbaye de Tamié in the Savoy region of France and BV Dairy (in the UK)

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11. MANUFACTURE OF BREAD, BISCUITS AND CAKES

11.1. Introduction

In general terms, baking is a process that follows the basic principle of cooking by dry heat. This process involves heating dough in an oven to produce the shape and colour of the crust and to set the internal structure. From this basic process, a wide variety of products such as bread, biscuits and cakes with different shapes, colours, flavours and sizes can be produced (Fellows et al., 1995).

The manufacture of bread, biscuits and cakes (MBBC) industry is an important economic sector in the European Union. The European consumption of bread, biscuits and cakes was about 39 million tonnes in 2010 (Federation of Bakers, 2014). Among cereals, the most important one used for flour production in Europe is wheat. In addition, corn and rye flours are also employed.

The most important subsector within the MBBC industry is bread, which accounts for 79% of the total baked goods consumption (GIRA, 2013). Data on bread consumption diverge sharply in EU countries, although the average consumption is 50 kg of bread per person per year (Federation of Bakers, 2014). Meanwhile, within the biscuits subsector, the EU-27 consumption in 2011 was 7.8 kg of biscuits per person per year (Caobisco, 2013).

The MBBC industry has a high degree of representativeness within the food industry, mainly due to the economic relevance of the products. As shown in Table 11.1, the MBBC industry, including both NACE codes 10.71 and 10.72, accounts for over 12% of the total turnover of the EU food industry (NACE 10). The number of enterprises in this subsector was around 148,000 in 2010, accounting for a significant share (56%) of the number of enterprises within the food industry. This is due to the fact that these enterprises may range from large industrial groups to small neighbourhood bakeries. Thus, the MBBC is also an important sector in terms of employment (35%) (Eurostat, 2010).

Table 11.1: Sectoral breakdown of key indicators in the EU-27, for MBBC products (2010) (NACE 10.7.1&2).

Sub-sector	Number of enterprises		Number of persons employed		Turnover		Value added at factor cost	
	thousand	(%)	thousand	(%)	(EURmillion)	(%)	(EUR million)	(%)
Manufacture of bread, fresh pastry goods and cakes (NACE 10.71)	142.1	53.8	1300.9	31.7	78 047	9.6	31900	19.1
Manufacture of rusks, biscuits, preserved pastry goods and cakes (NACE 10.72)	5.8	2.2	135.2	3.3	21320	2.6	6360	3.8
Manufacture of food products (NACE 10)	264.1	100	4105.3	100	813,590	100	166872	100

Source: (Eurostat, 2010).

Manufacturing of bread and pastries has recently incorporated new technological changes that have profoundly altered the production strategies. Freezing the products before baking has allowed the marketing of new intermediate products, such as frozen dough (non-fermented) and part-baked products (frozen, refrigerated or ambient temperature) (Gil, 2010). This emerging area of industry has shown continuous growth within the EU each year, transforming the bread market and increasing baking in supermarkets (The Federation of Bakers, 2014). For instance, part-baked products represent about 40-50% of bread consumption in Spain (Fundesa, 2013).

The MBBC includes a wide variety of products such as pastry, biscuits, cakes, bread and rusks. Considering that in 2011 industrial supply represented 66% of the EU-27 total bakery consumption (GIRA, 2013), only products made by industrial processes have been considered in this document. In addition, only bread (which accounts for the main consumption) and biscuits and cakes (which represent the second) have been included (GIRA, 2013).

Flour and yeast are the main raw materials needed to produce bread, biscuits and cakes. Flour provides the major functional ingredients (starches and proteins), which give strength and structure to the baked products. Yeast acts on natural sugars in the flour by producing carbon dioxide gas that raises the dough (Fellows et al., 1995).

There are a large variety of products manufactured within this industry which may be classified according to different parameters and characteristics such as the commercial typology, scale and size of production, types of flour, formulation and composition, softness and elasticity and additives such as preservatives, dyes, thickeners and surface-active agents, (Barbiroli, 1994). This is the reason why a common classification available for the whole of Europe is not possible, so every country identifies its products according to their national legislation. The typologies of the main types of products recognised for throughout Europe are defined below.

Bread is made by combining flour, water, salt and yeast with or without other ingredients. Commercial production may also involve the addition of preservatives and additives to improve its characteristics (European Commission, 2006). The main types of industrial bread are common bread e.g. baguette or ciabatta and special bread, made with additives that enrich its flavour e.g. sliced bread, fruit bread or whole grain bread (Gil, 2010). Intermediate baked bread (i.e. part-baked bread) can also be produced when the baking is interrupted and the dough is frozen or conserved by other means. Moreover, different types of frozen dough are also available on the market (Gil, 2010).

Biscuits are made of wheat flour, fat and sugar. Moreover, when decorated, other ingredients may be added, such as dried or fresh fruit, cream, custard, etc. Biscuits are usually defined as cereal-based and they are baked to a moisture content of less than 5 %. Biscuits are classified based on (Manley, 2001):

- texture and hardness.
- method of forming the dough: fermented, developed, laminated, cut, moulded, extruded, deposited, wire cut, coextruded.
- the enrichment of the recipe with fat and sugar.

A classification based on the secondary processing is also possible, in relation to the addition of a chocolate, jam, or cream filling.

In general, cakes are made of sugar, eggs, milk, fats, flavours and soft wheat flour; however the boundaries between biscuits and cakes are difficult to define. It is possible to divide cakes between shortening-based cakes and sponge cakes (Gulum, 2008).

11.2. Description of the bread, biscuit and cake production processes.

Bread production (Figure 11.1) begins by mixing the main ingredients to form dough. After bulk fermentation triggered by yeasts, other additives are added, depending on the final product. Later, the dough is divided into individual loaf-sized pieces and then it is moulded. Afterwards, the dough is introduced into a chamber for a few hours to finalise the rising. Finally, the pieces are ready for baking or part-baking and then, after cooling, the bread is frozen or directly packaged, ready for distribution (European Commission, 2006; Gil, 2010).

The methods used for **biscuits** production at each stage vary considerably depending on the final product type (Figure 11.2). Most of these products weigh less than 100 g and typically the unit weight is only 15–16 g, (Cauvain and Young, 2006). During manufacturing, raw materials are usually automatically transferred into dough mixers. Then, the ingredients are blended. The division of the dough into pieces varies depending on the type (rotary moulding, wire cutting, etc.). Afterwards, the biscuits are baked, usually in tunnel ovens. Once baked, the biscuits are cooled and packed or transferred to a secondary process (e.g. layering of cream fillings). Cooling is typically done by conveying the biscuits around the installation for a set time period (European Commission, 2006). After the cooling it is possible for some products to be coated and sprinkled before the wrapping and final packaging (Caobisco, 2013).

Cakes are usually mixed using continuous mixing systems (European Commission, 2006). The production lines involves a mixer, a continuous dough feed, and moulding and/or portioning into tin moulds. Once baked, the cakes are released from their moulds, cooled and then, after the product injection (if required), transferred to the packaging machines (Figure 11.3).

Figure 11.1: Main bread production stages

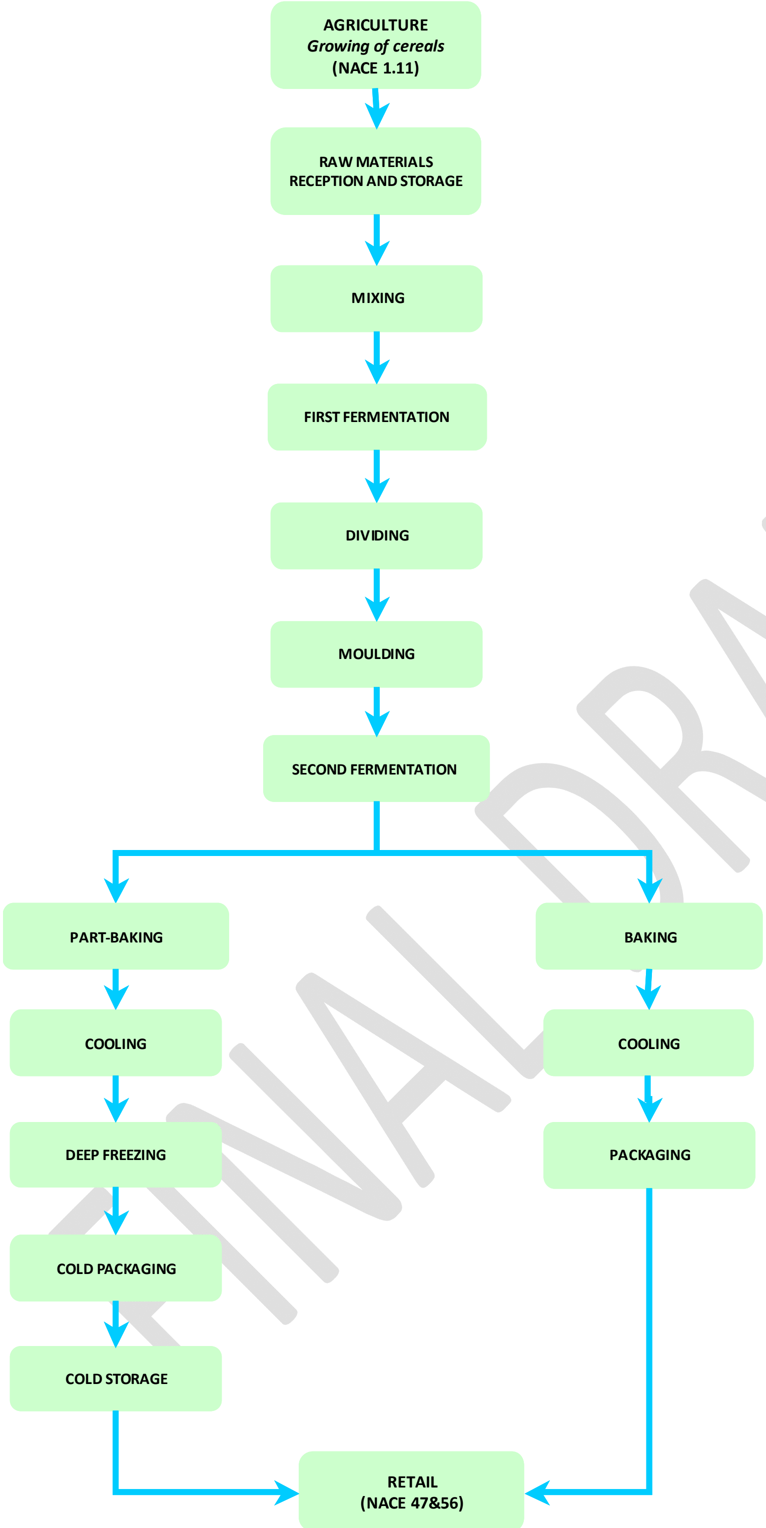


Figure 11.2: Main biscuit production stages.

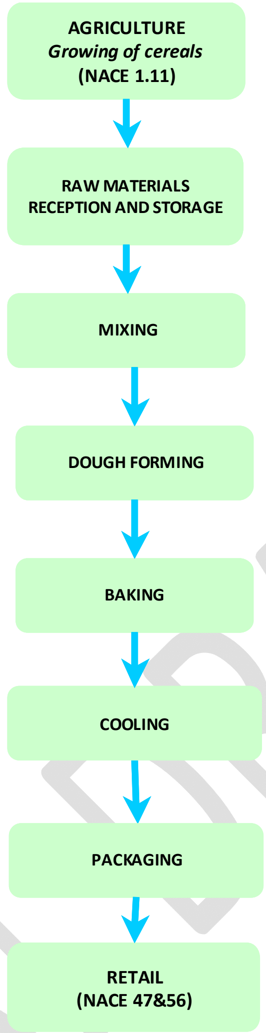
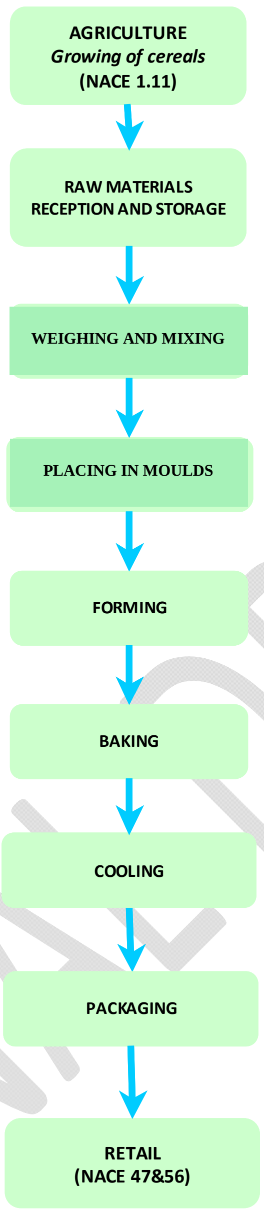


Figure 11.3: Main cake production stages



11.3. Main environmental aspects and pressures

The environmental aspects of the production of bread, biscuits and cakes can be classified as direct or indirect.

Direct aspects

The main direct environmental aspects and pressures of each phase of the manufacture of bread, biscuits and cakes are shown in Table 11.2.

Table 11.2 Main direct environmental aspects and pressures of MBBC industry stages.

Main direct environmental aspects	Main environmental pressures	
	INPUTS	OUTPUTS
MIXING	Water consumption Energy consumption	Waste generation
FIRST FERMENTATION[37]	-	Air emissions (CO_2)
FORMING/MOULDING	Energy consumption	Organic solid waste generation
SECOND FERMENTATION[38]	Energy consumption	Air emissions (VOCs, CO_2)
BAKING	Energy consumption	Air emissions (mainly CO_2)
COOLING	Energy consumption	-
FREEZING	Energy consumption	-
PACKAGING	Energy consumption Use of packaging (e.g. cardboard, plastics, metal)	Solid waste generation (e.g. cardboard, plastics, metal)
CLEANING OF EQUIPMENT AND INSTALLATIONS	Water consumption Use of chemicals Energy consumption	Waste water generation Solid waste generation
ENERGY SUPPLY	Fuel consumption	Air emission GHG emissions

Overall, the most relevant impacts are:

- *Energy consumption:* thermal energy is used for baking and steam production. In addition, electricity is used during several production stages.
- *Water consumption*, it is used both as an ingredient and also for others purposes (e.g. cleaning operations).
- *Waste water,* generated during cleaning/disinfection of the facilities.

[37] *Not relevant for biscuits production.*

[38] *Only applicable for bread production.*

- *Air emissions*, mainly produced during fermentation (CO_2, VOCs produced by yeast metabolism) (EBRD, 2009). In addition, air emissions are also produced during baking due to the combustion of fossil fuels.
- *Solid waste,* due to inorganic (linked to packaging stage) and organic waste (wasted dough).

Indirect aspects

The most relevant indirect environmental aspect for the manufacture of bread, biscuits and cakes is the primary production of ingredients, mainly from agriculture. Other indirect environmental aspects are transport and distribution of ingredients and finished products, production of packaging, retail of finished products and waste generated at consumer level or at retail level (unsold bread).

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11.4. Best environmental management practices

This chapter is aimed at giving guidance to manufacturers of bread, biscuits and cakes on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other available reference documents such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[39]. For the aspects addressed in this document, the tables mention the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of manufacturers of bread, biscuits and cakes on all aspects listed in the tables below.

Table 11.3: Most relevant direct environmental aspects for manufacturers of bread, biscuits and cakes and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Mixing, fermentation and forming/moulding	Water consumption Energy consumption Waste generation Air emissions (CO_2, VOCs)	• Reference to BAT in FDM BREF • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3)
Baking	Energy consumption Air emissions Waste generation	• Reference to BAT in FDM BREF • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3) • BEMP on minimising energy consumption for baking (Section 11.4.2)
Cooling/freezing	Energy consumption	• BEMP on improving freezing and refrigeration (Chapter 3)
Cleaning of equipment and installations	Energy consumption Water consumption Use of chemicals Waste water generation Waste generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Packaging	Water consumption Energy consumption	• Reference to BAT in FDM BREF • BEMP on improving or

[39] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Most relevant direct environmental aspects	Related main environmental pressures	BEMPs
	Use of packaging Waste water generation Packaging waste	selecting packaging to minimise environmental impact (Chapter 3)
Energy supply	Air emissions GHG emissions Fossil fuel consumption	• Reference to BAT on energy efficiency in FDM BREF • BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

Table 11.4: Most relevant indirect environmental aspects for manufacturers of bread, biscuits and cakes and how these are addressed

Most relevant indirect environmental aspects	Related main environmental pressures	BEMPs
Supply chain management	GHG emissions, energy consumption, water consumption, air emissions etc.	• BEMP on sustainable supply chain management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture –crop and animal production SRD
Packaging	GHG emissions, energy consumption, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy consumption, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x, particulate matter etc.)	• BEMP on Transport and Logistics (Chapter 3)
Retail	Energy consumption, food waste generation	• Reference to Retail Trade SRD • BEMP on un-sold bread and pastry waste reduction schemes (Section 11.4.1)
Food preparation by consumers	Energy consumption, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

11.4.1. Unsold bread and pastry waste reduction schemes

Description

Bakery products are always fresh and available during typical shopping hours. A recent survey in Austria showed that approximately 66% of people bought bread every second day and 78% rated freshness as the most important characteristic of the bread. Therefore, that results in some cases in wastage of up to 25% of the prepared bakery products, with an average of about 10% in Austria (Schneider and Scherhaufer, 2009; Schneider, 2011).

In Austria in 2008, it was reported that 70 kt of bread was thrown away and considered waste. An increasing trend in shop wastage (related to bread) was reported by 35% of outlets, while a decrease was reported by for 18% of outlets. Bakery owners claimed that the bread waste is caused by the supermarkets where the return rates of bread range from 15 to 25%. On average, it may be estimated that Austrian supermarkets return approximately 20% of the baked goods delivered every day (Bernhard, 2009).

Waste bread can be generated in different places of the value chain. In particular, one part of the waste bread is generated at the manufacturing site (in bakeries) and the remaining part is generated in the sales outlets and/or in the supermarkets (retail market). The main waste bread generators are listed below (Scherhaufer and Schneider, 2011):

- Bakeries: bread production plant.
- Sales outlets: shops where bakeries sell their bread.
- Retail market: supermarkets which buy the bread from bakeries

Bakeries in Austria and Germany decided to take measures against bread and pastry waste. One of the options chosen for reducing bread wastage was to raise the awareness of the consumers and to train hotel and restaurant managers how to store edible bread for some days and/or to suggest other uses for old bread. Moreover, special shops have been established in which only unsold goods from the day before are sold at remarkably lower prices. In those bakeries the décor is different and the afternoon display baskets for rolls are smaller in order to create the illusion of being full although there are only a few rolls left. In addition, the staff are trained in the strategic placing of goods on the shelves in order to create a pleasing impression even if no new products are left (Bernhard, 2009).

Another possibility for reducing bread wastage is to establish appropriate bread returning schemes. In Germany there are some cases where the unsold bread from the outlets returns to the bakery where it was produced. In the morning, the fresh bread is delivered to the outlets, while the same truck returns to the bakery carrying all the unsold bread and bakery products from the previous day. Afterwards, the collected products are stored in the bakery and can later be processed for producing bread crumbs and dumplings or they can be collected by licensed companies (e.g. charities or social organisations if they are still suitable for human consumption, or waste management companies). Another option is that the collected bread can be used for other purposes, e.g. animal feed. Depending on the use foreseen for the returned bread, appropriate handling, transport and storage must be ensured to meet hygiene requirements.

Figure 11.4 illustrates the aforementioned bread returning operational concept; dashed arrows illustrate the unsold bread collected and solid arrows show the fresh bread delivered.

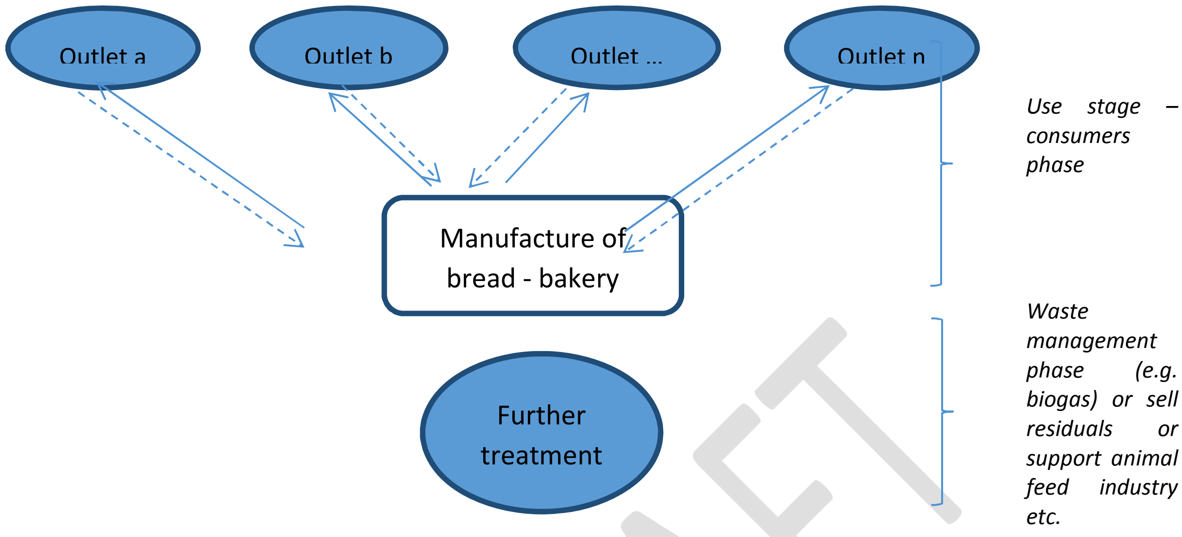


Figure 11.4: Overview of the bread returning scheme in Germany

The small bakeries (i.e. the ones which sell their products directly) can instead distribute the unsold bakery products directly to charities or for processing of bread crumbs and dumplings (if hygiene is ensured and they are still edible), or for animal feed (only those products that are suitable for animal feed). Some specific products (e.g. rolls or bread with ingredients from animal proteins or fillings containing meat) can instead be disposed as organic waste for further treatment (e.g. biogas production) and are not allowed to be fed to animals. Figure 11.5 illustrates an overview of prevention, recycling and disposal options for waste bread in Austria (Scherhaufer and Schneider, 2011).

In Austria 87% of the waste bread is used for animal feed, approximately 4% is treated in biogas plants, and 3% is re-used within the production process and given to social organisations (Scherhaufer and Schneider, 2011).

Figure 11.5: Overview of different prevention, recycling and disposal options for waste bread in Austria (Scherhaufer and Schneider, 2011)

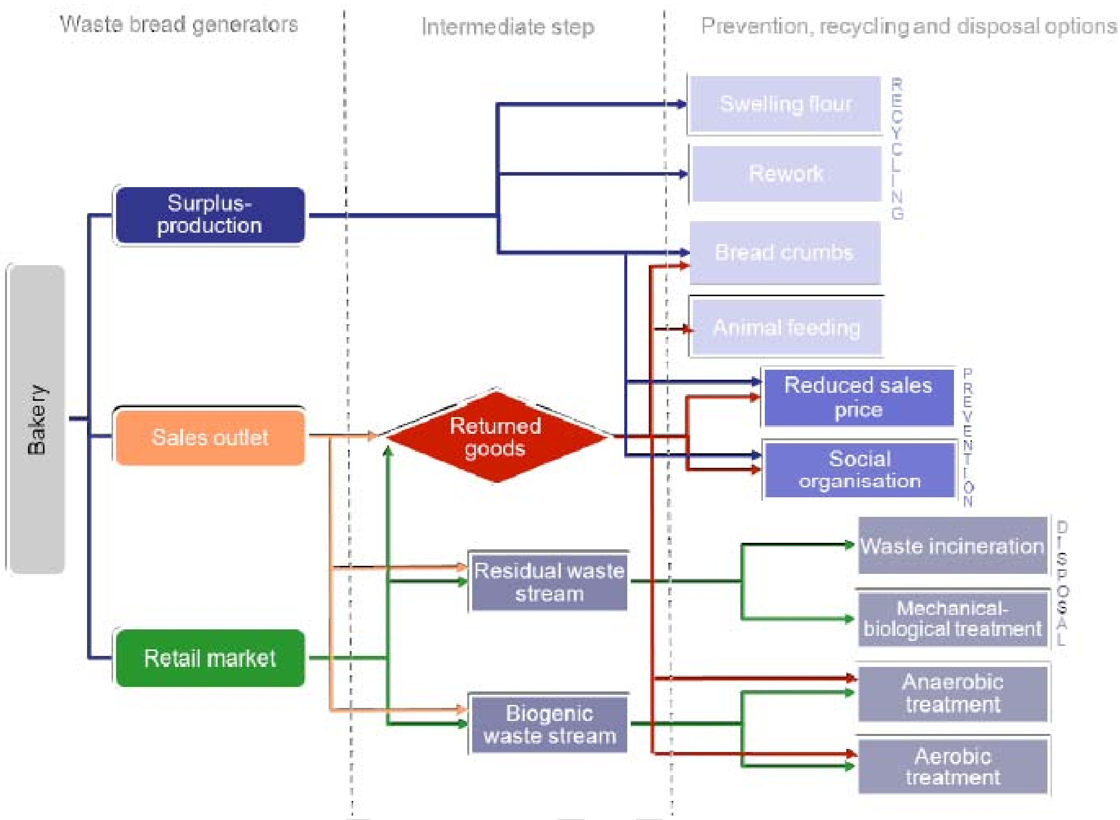
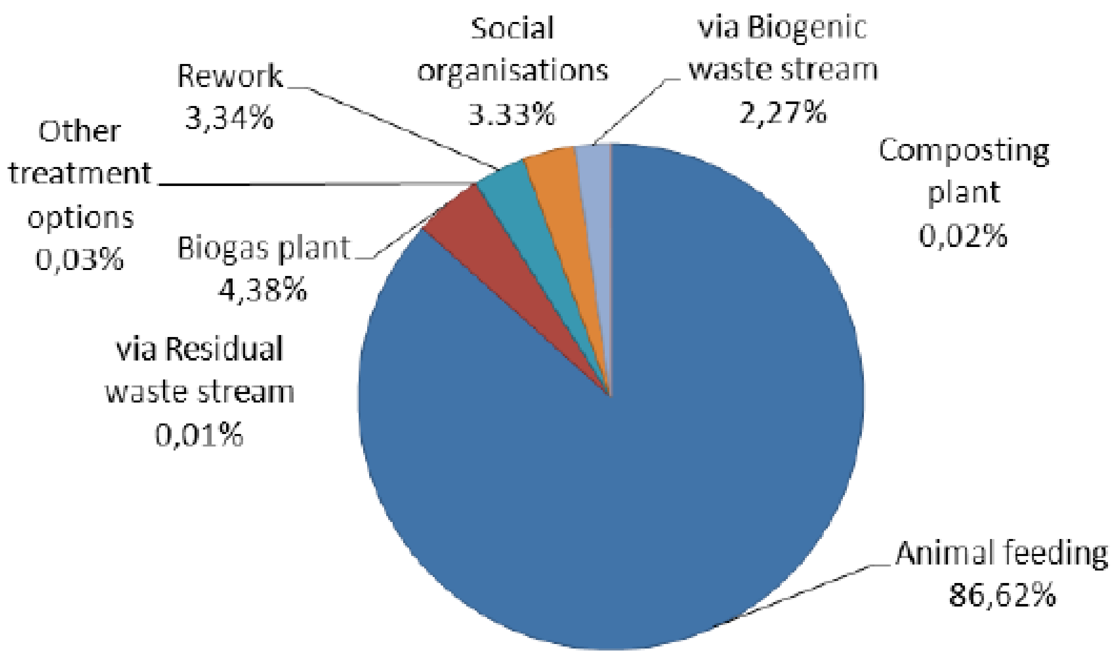


Figure 11.6: Share of waste bread per treatment and disposal option in Austria in companies representing approximately 22% of the Austrian production volume (Scherhaufer and Schneider, 2011)



Achieved environmental benefits

Given the fact that in Austria 70 kt of bread waste is generated and assuming an annual per capita consumption of about 70 kg, one million people could be fed with the wasted bread (or the equivalent amount of the ingredients used) or an eighth of the total number of inhabitants. Apart from the above social benefits, environmental benefits can also achieved since 70 kt of waste are prevented (Bernhard, 2009).

According to Sainsbury's (2013), all bread and bakery waste is returned daily to the depots of Sainsbury's (retailer company in UK), and afterwards it is sent to feed processors where it is turned into animal feed to support the farming industry. It was reported that Sainsbury's achieved 100% conversion of its bread waste into animal feed. The aforementioned activities resulted in the prevention of 13 000 tonnes of waste bread going for further treatment (either anaerobic digestion or landfilling). The above figures equate to around 40 loaves unsold a day or 2.4 % of the in-store bread sold daily (Sainsbury, 2013).

Appropriate environmental indicators

The bread returning schemes are described by:

- Return rates (%) of unsold bread from bakeries participating in the returning scheme
- Number of truck routes for deliveries and collections of the unsold bread (truck capacity should also be mentioned).
- Participation (%) of outlets in existing returning schemes for a given area.
- Segregation of non-compatible ingredients (e.g. products and/or ingredients of animal origin, highly perishable products (e.g. salad)).
- Percentage of unsold bread converted to other uses to avoid food waste generation.

Cross-media effects

The establishment of bread and pastry returning schemes requires the transportation of the unsold products back to the bakery. This does not lead to additional transport-related environmental impacts, since the bread should be transported to other facilities for appropriate disposal anyway.

Overproduction may be encouraged if alternative low end uses for unsold bread and pastries are put in place. However, if possible this should be avoided and bakeries should first accurately tailor their production to the demand for products.

Operational data

The example of a bread returning scheme in Germany is described.

The returned bakery products are properly separated into fractions according to their further use/treatment. For instance, the goods unsuitable for feed stuff, e.g. salads, meat products, are separated from the other waste streams; and the production dough waste is usually baked and added to the returned goods. Only waste that is not recyclable as feed stuff, not baked dough remains, or food leftovers containing meat is recycled further, e.g. in a biogas reactor or composting.

The outlets that are owned by the bakeries do have higher return rates than outlets on a franchising contract. This is due to the fact that their own outlets are forced to accept bread from overproduction (due to batch size). Outlets located in the entrance areas of supermarkets usually have higher return rates (e.g. 1% higher than average) since they are contractually obliged to offer a wide range of products until they close. On average, the return rates are approximately 15%. However, it should be noted that the return rates differs slightly among the various product groups as is depicted in Figure 11.7 (illustrated data from 2013). Likewise, Figure 11.8 illustrates the return rates of unsold bread for a bakery located in southern Germany with one production site and a significant number of outlets (the average return rate for the period January 2013 to May 2014 was 17.4 %).

In conclusion, it should be mentioned that the figures presented (Figures 11.7 and 11.8) show that the returning schemes work properly and efficiently although more effort should be made to reduce the amount of the unsold bread from the outlets, bakeries etc.

Figure 11.7: Return rates of various different bread types for a bakery in central Germany and a significant number of outlets; reference year 2013

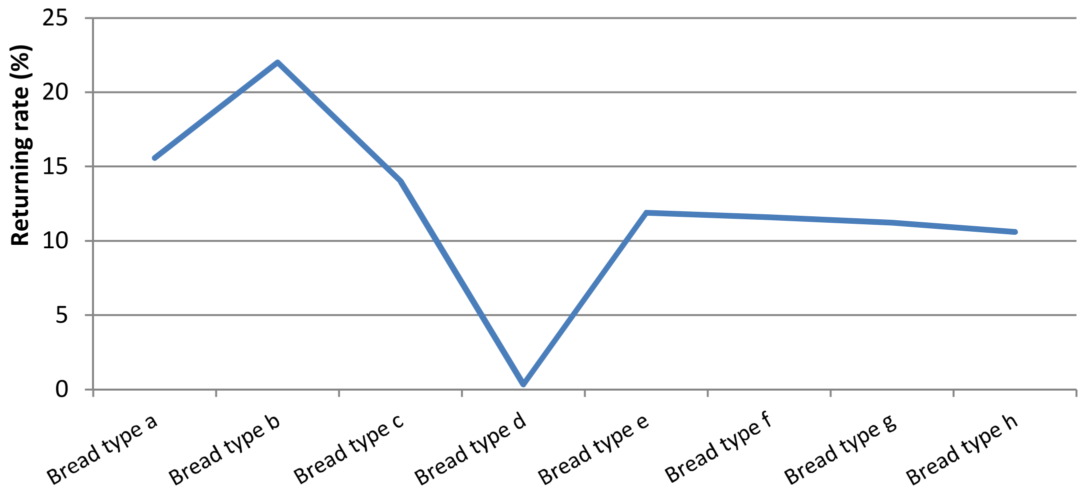
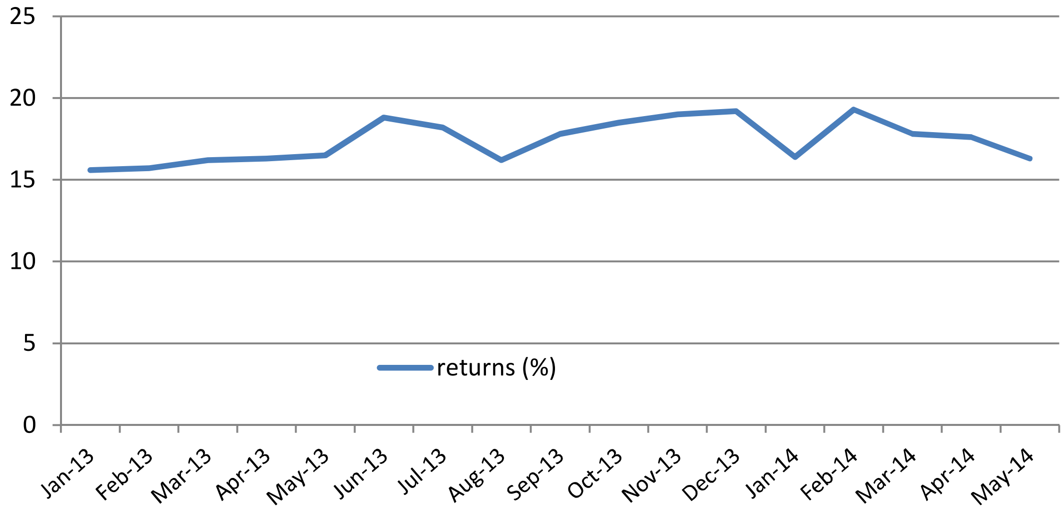


Figure 11.8: Return rates (%) for the period January 2013 – May 2014 for a bakery located in southern Germany with one production site and a significant number of outlets



Applicability

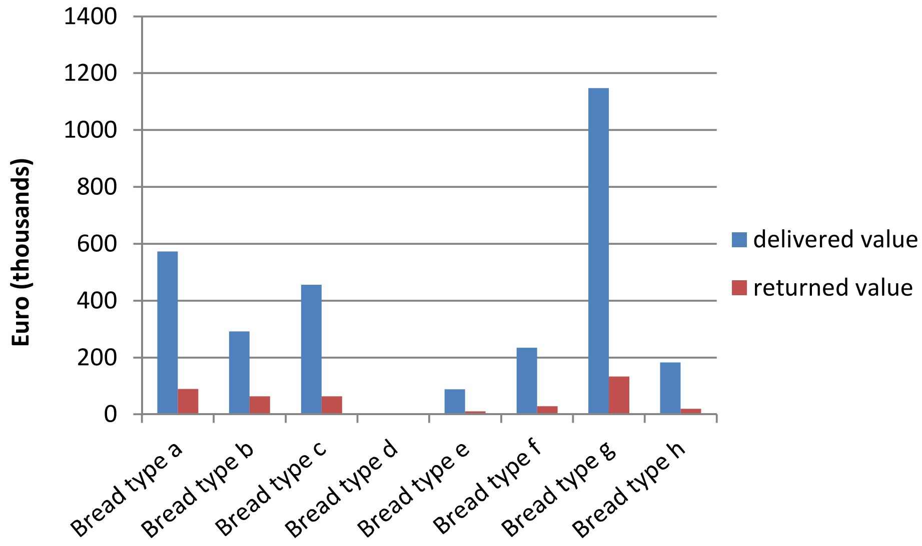
To ensure the efficiency of the returning schemes, relatively strict management and supervisory instruments should be applied in the participating bakeries and/or outlets. Therefore, the prerequisites that should be met are listed below:

- The returned amounts need to be large enough to fill the transport containers at least within two days (short delivery intervals to prevent spoilage). The outlets have to make sure that there is a high standard of segregation of by-products and ingredients that are incompatible (i.e. which would prevent further use for feed stuff, e.g. products of animal origin like meat and dairy products/ingredients).

Economics

The bakeries in Germany that participate in these bread returning schemes have to contract a licensed waste management company and to pay the formulated waste fee, which varies according to the amount, the number of the waste fractions (related to the waste segregation), distances etc. Moreover, amounts of bread the delivered and returned have different economic values since each bakery product has its own production costs. Figure 11.9 illustrates the economic values of the delivered and returned bread for a bakery located in northern Germany with two production sites and a significant number of outlets for the year 2013. The results from an Austrian project (where 43 bakeries participated) showed that on average 9.5% of the bread offered for sale by bakeries could not be sold. However it was clarified that if the supermarkets send the unsold bread back to the bakery, a significant economic loss in its value is noticeable for the bakery. Initially the first measure that was taken was to optimise the ordering activities within the headquarters and the branches as well as of the external customers. By implementing such activities, it was reported that an Austrian bakery saved more than EUR 400000 in 2008 (Bernhard, 2009; Schneider and Lebersorger, 2011).

Figure 11.9: Delivered and returned values of eight different bread types for one bakery in northern Germany with two production sites and a significant number of outlets; reference year 2013



Driving force for implementation

The driving forces for implementation are:

1. The minimisation of the generation bakery products waste.
2. The optimisation of further treatment of bakery products waste.

Reference organisations

The Austrian Bakery Association implemented surveys and developed measures for preventing the generation of bakery products waste.

Data collected by Umweltgutachterbüro Dr. Sulzer from three German companies with five production sites and a total of some 450 outlets (companies wish to remain anonymous).

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11.4.2. Minimising energy consumption for baking

Description

The energy consumption is the main environmental issue in the baking industry as the transition from dough to baked product requires large amounts of energy. The energy demand for baking can range from 3.7 MJ/kg to 7 MJ/kg (Purlis, 2012), accounting for 26 % to 78% of the total energy consumption of a bakery (Stanley et al., 2008; Khatir et al., 2013; Therkelsen et al., 2014).

This BEMP deals with minimising the energy consumption for baking by either operating existing ovens in the most energy-efficient way or by selecting the most efficient oven to cater for the specific baking needs.

The ovens used for baking bread, biscuits and cakes mainly consist of four elements (all of which have an influence on the energy efficiency of the oven):

- Heat generation system: where fuel (or electricity) is converted into heat.
- Baking chamber: where the physicochemical changes to the dough are produced.
- Chimney: which allows gases to be vented out (i.e. flue-gas from the heat generation system and gases released by the dough during baking).
- Insulating frame: which limits the heat losses from the baking chamber and prevents damage to the oven.

A wide variety of ovens are used. They are characterised by:

- The heat generation system: ovens can be powered by fuels (i.e. natural gas, propane, liquefied petroleum gases, biomass) or electricity (Stanley et at., 2006). The most common heat generation systems are burners. The use of burners involves a combustion process where fuel is burned (mixed with air and the heat transferred to the baking chamber) (Gas Natural Fenosa, 2014). In artisan bakeries and small outlets, the ovens are usually powered by electricity instead (Garcia, 2014).

- The way in which heat is transferred and distributed: the ovens can use convection, radiation or conduction (Manhiça et al., 2012; Sakin et al., 2009).

- The operation mode: the ovens can operate by batch or in continuous mode.

- The charging system: see Table 11.5.

Table 11.5: The most representative ovens and characteristics according to their charging systems.

CHARGING SYSTEM	*ADVANTAGES*	*DISADVANTAGES*	*SUITABLE FOR*
Rack ovens (rotative)	• Versatile. • The air flow is sufficiently uniform. • Rotating carriage. • Large amount of steam production. • High degree of flexibility.	• High space requirements.	• Bakeries with production capacity below 5.000 - 6.000 kg product per day. • Ovens used for baking at the point of sale: small ovens with low capacity (discontinuous – batch systems)
Multi-deck ovens	• Lower space requirements.	• The height or thickness of the baked products is limited.	
Tunnels	• Good performance. • Process automation. • Can be combined with other food processing equipment to form a production line.	• Only suitable for large production of same-size pieces. • High investment and operating costs.	• Production higher than 6.000 kg product per day. • Industrial bakeries / installations (continuous systems).

Source: IDAE, 1998; Alvarez de Diego and H_2O renovables, 2013

Besides the different oven designs and features, the main parameters that determine an oven's energy consumption are listed in Table 11.6.

Table 11.6: Parameters that determine an oven's energy consumption.

PARAMETER	*DESCRIPTION*
FUEL	• Fuel type • Thermophysical properties and composition • Input temperature
FLUE GASES	• Output temperature • Measurements of oxygen (O_2) and carbon monoxide (CO) content. • Combustion efficiency
PRODUCT FOR BAKING	• Product type: products have different process energy requirements • Heat capacity • Input temperature • Input humidity • Output temperature

PARAMETER	*DESCRIPTION*
EXTERIOR OVEN FEATURES	• Height, length, diameter, width • Emissivity of the oven surface • Oven surface temperature • Ambient temperature surrounding the oven • Oven placement

Source: Energpyme, 2013; Pino, 2004.

An important key parameter of the baking process influences many of the parameters listed in Table 11.6: the baking temperature. Indeed, the heat losses from the oven are a main source of energy inefficiency and depend, among other factors, on: the temperature of the external surface of the oven, the temperature of the ambient air surrounding the oven, the air flow near the oven surface (Khatir et al., 2013; Le-bail et al., 2010; Ploteau et al., 2012; Therkelsen et al., 2014).
The baking temperature depends not only on the product to be produced, but also on the scale of production. Indeed, products are often baked at temperatures between 230°C and 270°C for around 25 minutes where baking is carried out at the point of sale; whereas, at industrial scale baking temperatures are lower and residence times are higher (around 60 minutes) (Paton et al., 2013; Williamson and Wilson, 2008; Walker, 2005; Ploteau et al., 2012).
The first step for minimising the energy consumption for baking is to ensure that existing ovens are operated in the most energy efficient way. In the following table, the most important measures for improving the energy efficiency without oven substitution are reported.

Table 11.7: Main measures for improving the energy efficiency of existing ovens.

MEASURE	*DESCRIPTION*
Switch off the oven if the time between consecutive baking batches is long	Ovens with good insulation retain much of the heat produced during the last baking; 10 minutes is enough to reach optimum cooking temperature again.
Reduce operations between consecutive baking batches	Reduction of preheating periods and times for which the oven remains empty.
Regular cleaning of furnaces	This improves heat transfer and energy efficiency.
Optimisation of the use of the oven	A reduction of the daily baking times can be achieved by optimising the baking (e.g. oven at full load, bake all the batches consecutively).
Increase inspections and preventive maintenance of furnaces	Inspection allows the oven to be checked to ensure it works at the best efficiency and potential.
Burner maintenance	The system must operate with very low excess air, optimum combustion and low cold air infiltration.

MEASURE	*DESCRIPTION*
Oven insulation improvement	Oven performance can be improved by using more or better insulating material (low thermal conductivity), with a low coefficient of expansion at different temperatures, resistance to water absorption and combustion. Oven insulation can be improved in existing ovens.
Heat recovery from the oven's output products	Recovered waste heat can be used in different ways, including recirculating directly in the oven or in other bakery processes (e.g. proofing stage).
Repairing air leaks	Air leaks can be a major source of heat losses to the environment surrounding the oven. Moreover they can cause temperature imbalances, which decrease the quality of the final product.
Use of renewable energy	Changing only the fuel (e.g. biomass) can lead to a reduction in CO_2 emissions, but burners and the fuel feed system would often need to be changed too.

Source: Enerpyme, 2014; Therkelsen et al., 2014; Pino, 2004

When a company decides to replace its oven or install a new one, it is important to consider a number of key factors to ensure that the most suitable and energy efficient system is selected: production requirements, energy sources, space constraints, temperature requirements, operation mode, and heat transfer mode (See Table 11.8).

Table 11.8: Main factors that should be taken into account for selecting a new system.

FACTOR	*DESCRIPTION*	*MAIN POSSIBILITIES*	*ADDITIONAL INFORMATION*
Energy source	The heat generation system of an oven can be powered by electricity and/or fuels.	Electricity	Electric ovens allow an accurate temperature control and they can work in a wide range of temperatures. The associated environmental impact depends on the energy source used to generate the electricity.
		Fuel	Burning fuels requires a chimney or a vent to remove the exhaust gases. The main fuels used are: • Biomass (from an environmental point of view, combustion of renewable biomass is considered neutral in terms of CO_2 emissions). • Natural gas. • Liquefied petroleum gases. • Propane. • Diesel.

FACTOR	*DESCRIPTION*	*MAIN POSSIBILITIES*	*ADDITIONAL INFORMATION*
Operation mode	Ovens can operate in batch or continuous mode	Batch ovens	Recommended for small loads, for applications where production volumes change substantially, or when a high degree of flexibility is required. In small bakeries, batch ovens are the most commonly used. The main types of batch oven are: bench-top ovens, cabinet ovens and walk-in and truck-in ovens.
		Continuous ovens	Where a large quantity of similar products are processed. Continuous ovens usually have greater efficiency than batch ovens and, from the energy point of view, they are usually more efficient. The most commonly used continuous ovens in bakeries are tunnel ovens.
Chamber sizing	Chamber size depends on the number of pieces per batch and on the number of batches required to meet production requirements. If the interior space is too small, the performance of the baking is low while if it is too large, space, time and energy are wasted.	Benchtop/ countertop ovens	These ovens are used for small batch loads or when there are space constraints that do not allow bigger ovens. Sizes range from 28 L to 764 L.
		Cabinet ovens	These ovens are floor-mounted and are designed for easy loading and unloading. They are very efficient. Sizes ranges from 113 L to 2718 L.
		Walk-in and truck-in ovens	These ovens are suitable for large batches. They allow product loading either by forklift or manually.

FACTOR	DESCRIPTION	MAIN POSSIBILITIES	ADDITIONAL INFORMATION
Temperature requirements	Temperature is one of the most important parameters in the baking stage. The following pfactors should be taken into account:: • Minimum/maximum temperature. • Heat-up/cool-down requirements. • Temperature uniformity requirements.		Bakery products are usually baked between 230 °C and 270°C.
Airflow type	The most common way in which heat is transferred and distributed in the baking chamber is by convection. This is because bread loaves and individual cakes often have better results when baked in convection ovens. Convection can be: • natural • forced: ▪ by circulation ▪ by recirculation	Natural convection	This is the easiest and less expensive way: heated air rises and once it is cooled by transferring heat to the product, it returns to the heat source. It is mainly applied when chamber temperature uniformity is not essential.
		Forced circulation	This system incorporates a fan to create an airflow that improves the temperature uniformity of the chamber and speeds up the heat transfer. It requires proper spacing of parts to ensure optimal airflow between them.
		Recirculation	It is recommended for applications involving tray-loaded products that require precise temperature uniformity. The fan produces recirculation between the heat generation system and the baking chamber leading to a fast and uniform heat transfer, even when the product is densely loaded.

FACTOR	*DESCRIPTION*	*MAIN POSSIBILITIES*	*ADDITIONAL INFORMATION*
Design and quality	A good oven design and a selection of high quality materials allow: • Better temperature uniformity in the chamber. • Reduction of heat losses. • Simplification of maintenance operations.		
Charging system	The charging system conditions the production capacity of the system.	Rack ovens (rotative)	Rack ovens operate in batch mode. Production capacity below 5000 - 6000 kg of product per day. Oven with high space requirements.
		Multi-deck ovens	Multi-deck ovens operate in batch mode. Production capacity below 5.000 - 6.000 kg of product per day. These ovens have lower space requirements than rack ovens.
		Tunnels	These ovens operate in continuous mode. Production capacity higher than 6.000 kg of product per day.

Source: Adapted from Despatch Industries, 2013; FSW, 2014.

Achieved environmental benefits
The main environmental benefits are a reduction in energy consumption and the related reduction in CO_2 and other air emissions (e.g. particles).

Energy savings can vary depending on the type and number of measures implemented. For the measures to improve the efficiency of existing ovens, Table 11.9 provide an indication of the energy savings that can be achieved.

Table 11.9.-Energy savings achieved by implementing the proposed measures in existing ovens.

MEASURE	*SAVINGS IN TOTAL ENERGY CONSUMPTION OF THE FACILITY (%) (*)*
Switch off the oven if the time between consecutive baking batches is long	7.5
Reduce operations between consecutive baking batches	Up to 8.5
Regular cleaning of furnaces	Up to 3.5
Optimisation of the use of the oven	Up to 11
Increase inspections and preventive maintenance of furnaces	Up to 4
Burner maintenance	Up to 2.7
Oven insulation improvement	Up to 7
Heat recovery from the oven's output products	N/A
Pipes thermal insulation	Up to 7
Repairing air leaks	N/A
Use of renewable energy	Between 25 and 75**

Source: Enerpyme, 2014; Therkelsen et al., 2014; Pino, 2004
N/A: Data not available
* Data calculated on the basis of a rotary oven with four batches/day
**Stanley et al., 2008; Khatir et al., 2013; Therkelsen et al., 2014

Appropriate environmental indicators
The appropriate environmental indicator is the energy consumption in the baking process i.e. kWh per:

- tonne of baked product, or

- tonne of input flour used, or
- m^2 of baking area (oven surface)

Energy savings should be monitored by comparison of current data and data consumption records from before the implementation of the proposed measures.

Cross-media effects

There are no environmental cross-media effects associated to the implementation of these measures.

Operational data

As previously shown, a wide range of oven configurations are commercially available.

Applicability

The measures proposed in this BEMP are applicable for new and existing bakery facilities and outlets.

Economics

Implementation costs may vary depending on the nature and number of measures implemented. Substitution of ovens is generally more expensive than measures to improve the energy efficiency, but high energy savings can also lead to short pay back periods for oven replacements.

In Table 11.10, the investment costs linked to the improvement of the energy efficiency of existing systems are classified as follows:

- Zero costs (Zero)
- Low investment costs (Low)
- Relatively high cost (High)

Table 11.10: Investment costs of the proposed measures.

MEASURE	INVESTMENT REQUIRED	PAYBACK PERIOD
Switch off the oven if the time between consecutive baking batches is long	Zero	Immediate
Reduce operations between consecutive baking batches	Zero	Immediate
Regular cleaning of furnaces	Zero	Immediate
Optimisation of the use of the oven	Zero	Immediate
Increase inspections and preventive maintenance of furnaces	Low	5 - 8 months
Burner maintenance	Periodic control system: EUR 2200 (approx.)	0,3 - 1 year

Oven insulation improvement	Low	Less than a year
Heat recovery from the oven's output products	High	2 - 4 years
Repairing air leaks	Low	Less than a year

Source: Enerpyme, 2014; Therkelsen et al., 2014.

Driving force for implementation

Improved energy efficiency leads to cost reductions, increased competitiveness of the company and in improved market image.

Reference organisations

The bakery Hornipan Rangel, S.L. (Alvarez de Diego and H_2O renovables, 2013) has successfully implemented renewable energy sources (biomass) in their baking process.

There are several examples of bakeries that have successfully implemented heat recovery systems, using the recovered waste heat in their proofing chambers (Therkelsen et al., 2014).

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12. MANUFACTURE OF WINE

12.1. Introduction

Wine is the beverage resulting exclusively from the partial or complete alcoholic fermentation of fresh grapes, whether crushed or not, or of grape must. Its alcohol content shall not be less than 8.5% vol., or 7% vol in the case of specific climate or soil conditions, vine variety, special qualitative factors or traditions specific to certain vineyards (OIV, 2014a).

The global annual wine production amounted to 271 million hectolitres in 2014 (OIV, 2014b). The main worldwide wine producers are illustrated in Table 12.1.

Table 12.1: Worldwide wine production from 2010 to 2014 (excluding juice and musts)(1). (OIV, 2014b)

1000 hl	2010	2011	2012	2013	2014	2014/2013	2014/2013	Ranking
France	44,381	50,757	41,548	42,004	46,151	4147	10%	1
Italy	48,525	42,772	45,616	52,429	44,424	-8005	-15%	2
Spain	35,353	33,397	31,123	45,650	37,000	-8650	-19%	3
United States (2)	20,890	19,140	21,740	23,500	*22,500*	-1000	-4%	4
Argentina	16,250	15,473	11,780	14,984	15,200	216	1%	5
Australia	11,420	11,180	12,260	12,310	12,560	250	2%	6
China (3)	13000	13200	13810	11780	*11780*	0	0%	7
South Africa	9,327	9,725	10,568	10,980	11,420	440	4%	8
Chile	8844	10464	12554	12,846	10,029	-2817	-22%	9
Germany	6,906	9,132	9,012	8,409	9,725	1316	16%	10
Portugal	7,148	5,622	6,327	6,238	5886	-352	-6%	11
Romania	3,287	4,058	3,311	5,113	4,093	-1020	-20%	12
New Zealand	1,900	2,350	1,940	2,480	3,200	720	29%	13
Greece	2,950	2,750	3,115	3,343	2,900	-443	-13%	14
Brazil	2,459	3,460	2,967	2,710	2810	100	4%	15
Hungary	1,762	2,750	1,776	2,666	2,734	68	3%	16
Austria	1,737	2,814	2,125	2,392	2,250	-142	-6%	17
Bulgaria	1,224	1,237	1,442	1,755	1,229	-526	-30%	18
Switzerland	1,030	1,120	1,000	840	900	60	7%	19
Croatia	1,433	1,409	1,293	1,249	874	-375	-30%	20
OIV World Total(4)	**264,372**	**267,243**	**256,222**	**287,600**	**270,864**	-16736	-6%	

(1): Countries for which information has been provided with a wine production of more than 1 mhl
(2): OIV estimate (USDA basis)
(3): Report for the year 2013, 2014 figures not yet available
(4) Range used for 2014 world production: 266.2 mhl to 275.5 mhl

Europe accounts for 62.3% of global wine production, whilst America, Asia, Oceania and Africa account for 20%, 6.9%, 4.5%, 5.9% and 5% respectively (OIV, 2013).

In the EU, the wine sector was comprised of about 10,000 companies in 2009, which account for 43.3 % of the beverage manufacturing sector. Moreover, it is the third beverage subsector in terms of number of people employed (100,300 employees) and turnover (around EUR 25.8 million) (OIV, 2012).

Wines can be classified in two main categories: still and sparkling wines, including the subcategories; quality sparkling wine, quality aromatic sparkling wine, aerated sparkling wine, semi-sparkling wine and aerated semi-sparkling wine. These two main wine categories represent 99.46% of the wine traded in the EU. Additionally, fortified wines are another category representing only a small share of EU wine production (TS PEF, 2015).

12.2. Description of the wine production process

There are numerous variations of the winemaking process, mainly due to the type of wine to be produced and the winery itself. Firstly, the collected grapes are weighed and then all the unwanted vegetal material (mainly stems and talks) are removed. Afterwards, the grapes are broken to liberate the juice without squashing the seeds. The mixture that includes juice, pulp, skins, and seeds is called must. The main stages of the wine production process are shown in Table 12.2.

Table 12.2: Main wine production stages (OIV, 2014a; TRINOR, 2003)

STAGE	DESCRIPTION
Stemming/Stalking	Action of separating the grapes from stalks or stems.
Crushing	Operation that consists of breaking the skin of the grapes and crushing them to liberate the must.
Pressing	Operation consisting of pressing the harvested grapes or the pomace in order to extract both the liquid part and the must, either for the preparation of grape juice or for fermentation in the absence of grape solids or to separate the press wine from the pomace after fermentation in the presence of grape solids.
Fermentation	Transformation of the sugars in the must into ethyl alcohol using yeasts. It usually takes place in stainless steel tanks. Temperature control is very important during fermentation, so cooling and/or heating may be required. In this step, important organoleptic properties of the wine are produced.
Settle	Separation of the varyingly clear liquid from the solid matter suspended in the must.
Decanting/Racking	Operation involving the transfer of wine from one wine container to another allowing the separation of solid deposits from the liquid.
Malolactic Fermentation	Secondary fermentation where the tart malic acid is transformed into lactic acid. Many, but not all red wines go through this stage.
Fining	Clarification of wine by the addition of substances that precipitate particles in suspension to remove anything that may be making the wine cloudy.
Filtration	Physical process consisting of passing the wine through appropriate filters that retain particles in suspension.
Stabilisation	Operations intended to achieve the physicochemical and microbiological stabilisation of wine by avoiding the precipitation of salts and metals, as well as limiting and/or preventing the growth of yeast and technologically unwanted bacteria.
Storage/Aging	Stage where the wine is stored after clarification and where further malolactic fermentation can take place.
Bottling	Operation involving the transfer of wine from the wine storage containers to the bottles/final packaging.

There are two main winemaking processes (Figure 12.1):

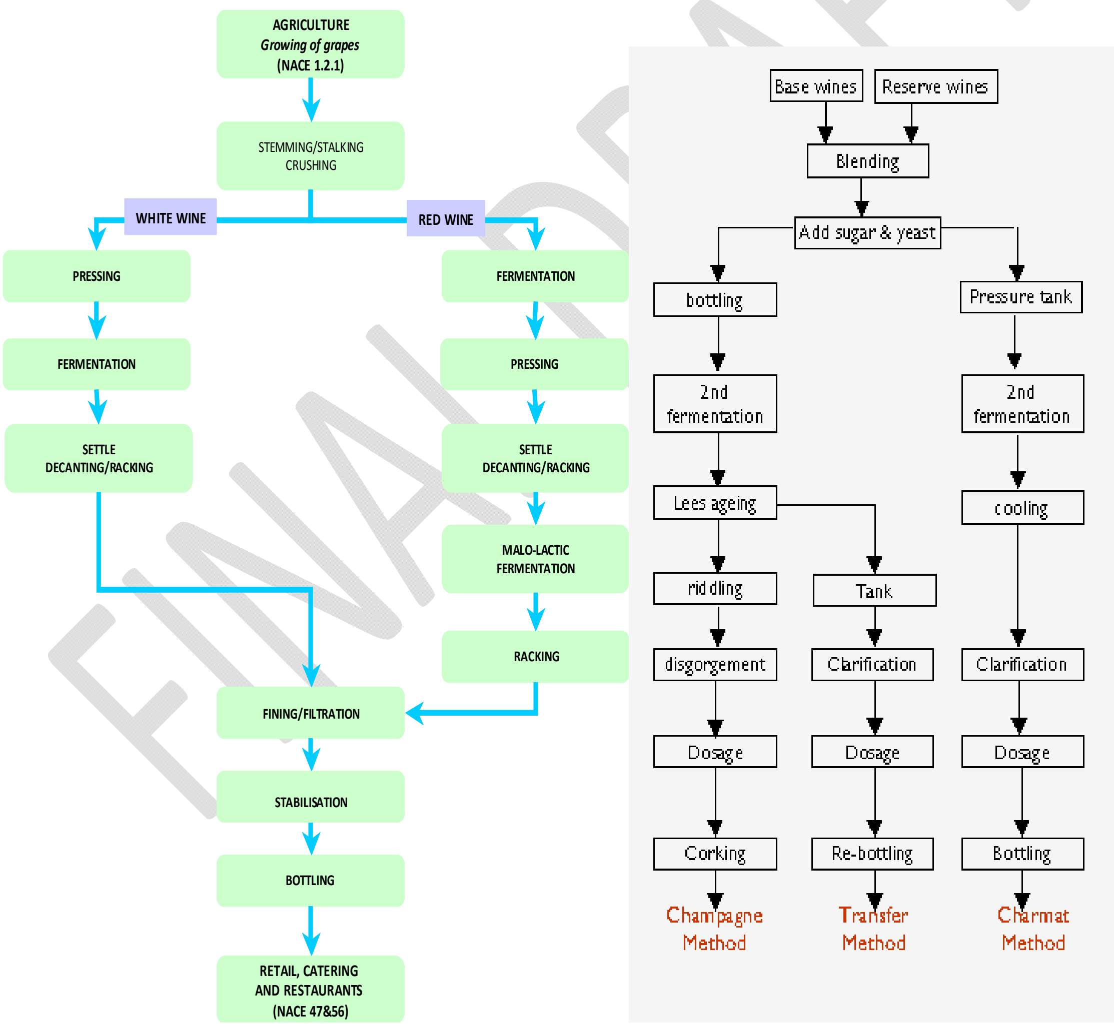
- “white vinification”: the must is transferred directly to the pressing stage (prior to fermentation);
- "red vinification": the must goes directly to the fermentation stage.

In some cases, a secondary fermentation takes place, called malolactic fermentation. This reaction converts malic acid into lactic acid, reducing the acidity of the wine. Most red wines (and some white wines) go through this stage.

Once fermentation is finished, the main goal is to clear the produced wine. Different techniques are used to remove the dead yeasts and suspended solids (also called lees). These techniques can include sedimentation of the solids, racking (transfer of the clear wine from one tank to another after solids sedimentation), fining (addition of substances that precipitate particles in suspension) and filtration.

The next step is the storage and/or aging of the produced wine. The wine can be stored in large tanks or in smaller wooden barrels (usually oak). This storage requires climate control. Afterwards, the finished wine is finally bottled, labelled and corked (Galitsky et al., 2005; Toscano et al., 2013).

Figure 12.1: Main wine (a) and sparkling wine (b) production processes (Adapted from SUSTAVINO, 2010)



(a) (b)

12.3. Main environmental aspects and pressures

This section describes the main environmental aspects for companies producing wine.

Direct aspects

The main direct environmental aspects and pressures are shown in the Table 12.3.

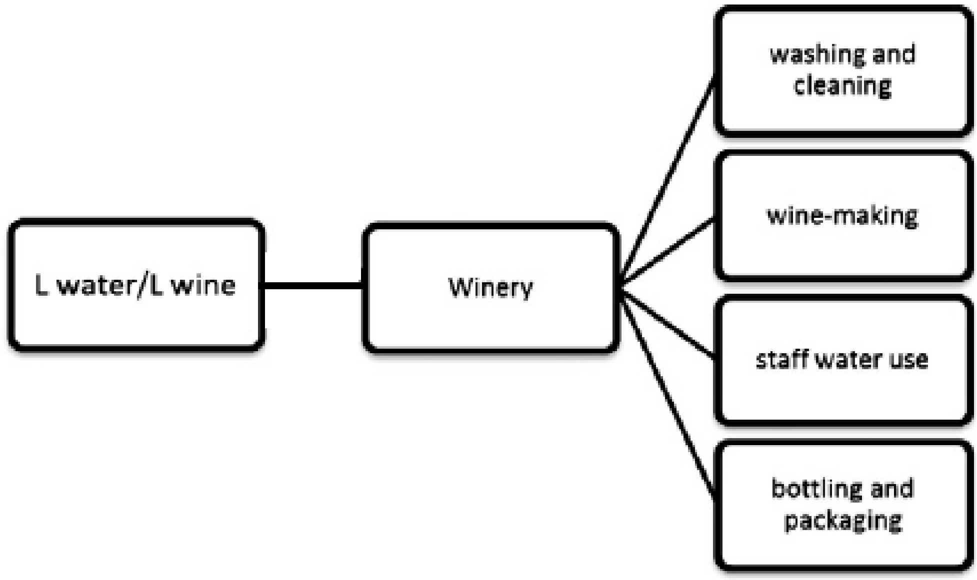
Table 12.3: Main environmental aspects and pressures in the different stages of wine production

Main direct environmental aspects	Main environmental pressures	
	INPUTS	OUTPUTS
Stemming/Stalking		Wastewater generation Organic matter, mainly stems and stalks from the grapes
Crushing		Waste water generation
Pressing	Water use Energy use	Waste water generation Pomace: residue from pressing (skins, seeds and stems of the grapes, as well as yeast)
Fermentation		Waste water generation
Settle Decanting/Racking		Waste water generation Lees: sediments resulting from the fermentation of wine (yeast remnants, colloidal matter, and other remains).
Malolactic fermentation		Waste water generation
Fining/Filtration	Water use Energy use	Organic matter Used filter plates and diatomaceous earth
Stabilisation		Tartrates Waste water generation
Bottling		Waste water generation Waste from bottling/packaging

Overall, the most relevant environmental impacts (SUSTAVINO, 2010; WINEC, 2012) are:

- Water use, not only for cleaning and sanitation, but also for other purposes e.g. cooling (Figure 12.2).
- Waste water generation, mainly due to the large amount of wastewater with high organic matter content generated in a short period of time.
- Solid waste:
  - solid organic waste, mainly due to the large amount produced during a short period of the year.
  - other solid waste, namely the inorganic waste produced during bottling/packaging.
- Energy use, both in terms of thermal energy and electricity, mainly for the refrigeration process.

Figure 12.2: Water use in the wine manufacturing process (Lamastra et al., 2014)



Indirect aspects

The most relevant indirect environmental aspect for wine manufacturers is agriculture, i.e. the primary production of the grapes. This aspect must be considered direct by those wine producers that own and operate their own vineyards but, in that case, they would also belong to the agricultural sector and appropriate guidance on agricultural practices is provided in the Sectoral Reference Document on Best Environmental Management Practice for the Agriculture - Crop and Animal Production Sector[40].

Other upstream and downstream activities with relevant environmental impacts are:

- production of packaging (mainly glass bottles);
- transport and logistics operations of final products;
- retail of the final products;
- use by consumers (including storage and refrigeration by consumers and generation of packaging waste by consumers).

Table 12.4 illustrates the total climate impact of wine production per litre in a number of LCA studies reviewed by Saxe (2010). Although the overall result for the impact of wine on the climate ranges from 1.1 kg to 5.3 kg CO_2eq/l (Table 12.4), the review demonstrates the relevance of the viticultural (agricultural) phase, of the production of wine bottles and of the transport/distribution of the finished products which all have a greater impact on climate than the wine making operations themselves, confirming the importance of the indirect environmental aspects for this industry.

[40] http://susproc.jrc.ec.europa.eu/activities/emas/agri.html

Table 12.4: Total climate impact of wine production per litre (Saxe 2010)

Production steps	**CO_2eq (g) per litre**					
	Point (2008)	Gazulla et al., (2010)	Aranda et al., (2005)	Fullana et al., (2005)	Cichelli et al., (2010)	Benedetto (2010)
Vineyard/viticulture	957	671	273	656	160	942
Winery/wine making	483	53	252	28		
Production of barrels/bottles	1933	521	485	431	940	1246
Transport/distribution	1828	214	892		260	
Disposal/recycling	55			9		
Total	5260	1459	1902	1124	1360	2188

Production of wine packaging

The materials used for wine packaging are: glass bottles, Tetra Packs, PET bottles and bag-in-box (Euromonitor International, 2013). Glass bottles are the most commonly used material worldwide followed by Tetra Packs. It has been estimated that 17% of the total greenhouse gas emissions of wine production are related to the production of packaging (Garnett, 2007).

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12.4. Best environmental management practices

This section is aimed at giving guidance to wineries on how to improve the environmental performance for each of their most relevant environmental aspects identified in the previous section. The following two tables (Table 12.5 and Table 12.6) present how the most relevant environmental aspects and the related main environmental pressures are addressed, either in this document or in other reference documents available such as the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF)[41]. For the aspects addressed in this document, Table 12.5 and Table 12.6 list the best environmental management practices (BEMPs) identified to address them. Moreover, there is also an overarching BEMP on performing an environmental sustainability assessment of products and/or operations (Chapter 3), which can help improve the environmental performance of wineries on all aspects listed in the tables below.

Table 12.5: Most relevant direct environmental aspects for wine producers and how these are addressed

Most relevant direct environmental aspects	**Related main environmental pressures**	**BEMPs**
Wine making processes	Energy use Water use Waste generation Wastewater generation	• Reference to BAT in FDM BREF • BEMP on deploying energy management and energy efficiency throughout all operations (Chapter 3) • BEMP on avoiding food waste in food and beverage manufacturing (Chapter 3) • BEMP on reducing water use, organic waste generation and energy use in the winery (12.4.1)
Cleaning of equipment and installations	Energy use Water use Use of chemicals Wastewater generation Waste generation	• Reference to BAT in FDM BREF • BEMP on environmentally friendly cleaning operations (Chapter 3)
Bottling (Packaging)	Energy use Water use Use of material (packaging) Wastewater generation Packaging waste	• Reference to BAT in FDM BREF • BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Energy supply	Air emissions GHG emissions Fossil fuel consumption	• BEMP on integration of renewable energy in manufacturing processes (Chapter 3)

[41] For more information on the content of the Best Available Techniques Reference Documents and a full explanation of terms and acronyms, refer to the European Integrated Pollution Prevention and Control Bureau website: http://eippcb.jrc.ec.europa.eu/

Table 12.6: Most relevant indirect environmental aspects for wine producers and how these are addressed

Most relevant indirect environmental aspects	**Related main environmental pressures**	**BEMPs**
Supply chain management	GHG emissions, energy use, water consumption, air emissions etc.	• BEMP on sustainable supply chain management (Chapter 3)
Agriculture	GHG emissions, biodiversity, air emissions, eutrophication, water consumption	• BEMP on sustainable supply chain management (Chapter 3) • Reference to the Agriculture – crop and animal production SRD
Packaging	GHG emissions, energy use, resource depletion (material use)	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)
Transport and logistics	Energy use, GHG emissions, air emissions (CO_2, CO, SO_2, NO_x, particulate matter, etc.)	• BEMP on transport and logistics (Chapter 3)
Retail	Energy use, food waste generation	• Reference to Retail Trade SRD
Wine storage and consumption by consumers	Energy use, food waste generation	• BEMP on improving or selecting packaging to minimise environmental impact (Chapter 3)

12.4.1. Reducing water use, organic waste generation and energy use in the winery

Description

The overall environmental concerns that wine producers face are rather complex and likely to vary in scope and scale according to their specific activities and geographic location (Christ and Burritt, 2013). This BEMP outlines, for a number of relevant environmental pressures or aspects, the most common actions that can help wine producers minimise their environmental impact.

Water use

Water use is a key input for wineries, which use water not only for cleaning and sanitation (to keep clean and to avoid contamination and spoilage) but also for other purposes (e.g. cooling the fermentation cellars and tanks). It is estimated that wineries use around 2,000-3,000 litres of water to process one tonne of grapes, however, data regarding the quantity of water used are scarce and heavily dependent on the size of the winery (Gabzdylova et al., 2009; Kumar et al., 2009).

The most important water consumption in wineries is due to cleaning operations and maintenance of the facility and machinery[42]. The wastewater produced during these processes is characterised by a high content of wine, lees, tartrates and fining agents, as well as remaining cleaning and disinfectant products.

In order to reduce the water use in wineries, cleaning operations can be improved[43]. Moreover, wine producers can install equipment with high water efficiency (low flow, water recirculation, water reuse) for all processes with substantial water use (e.g. cooling, temperature control). In addition, water use reduction in wineries can be achieved by (WINEC, 2012; Conradie et al., 2013):

- Installation and monitoring of water meters at various sections of the winery.
- Use of brushes and squeegees (dry sweeping of floors before washing).
- Stopping water flow during breaks, e.g. installing nozzles on water pipes.
- Use of low-volume/high-pressure washers or use of equipment for mixing a water jet and a compressed air stream, which reduces water consumption by 50-75% compared to a low-pressure system. The use of low-volume/high-pressure washers may have several disadvantages regarding the maintenance of the tanks and of the equipment used (FAO, 1985; WINEC, 2012).
- Ozone tank cleaning of barrels (see Section 3.5).
- Organising water awareness training for the staff working in the winery.

Organic waste

It is important that wineries firstly apply measures to minimise the generation of organic waste and secondly, for the waste still generated, treat it appropriately. Initially, winery managers should understand where organic residues are generated (in which processes) and encourage the related data collection.

In general, the main organic residue fractions generated in the wineries are:

- grape pomace, which is the grape material (mainly skin, pulp and seeds) that is left over from crushing and pressing;
- grape stalk, which is the skeleton of the grape bunch and consists of lignified tissues;
- lees, which is the material that accumulates in the bottom of grape juice or wine fermentation tanks;
- filtered solids, which are caught by filter pads, especially from vacuum filters which are used for filtering the must;
- waste water sludge, consisting mainly of microbial cells and grade residues.

One of the main environmental concerns related to the management of residues from wineries is the generation of large amounts during a short period of time (normally three months). For instance, 281 000 tonnes of grape stalks; 787 000 tonnes of grape pomace; 337 000 tonnes of wine lees and 24 million m^3 of waste water were generated in Spain from August to October in 2005 according to Bustamante et al., (2008). These residues have a low pH and electrical conductivity, whilst their net wet calorific value is approximately 16.4 MJ/kg (van Eyk and Ashman, 2010).

[42] In the case of cooling plants using water or mixed water/air, there is also significant consumption due to evaporation in cooling towers.

[43] More information about environmentally friendly cleaning operations is provided in Section 3.5

The best management options for organic residues produced in the wineries are:

- distillation for alcohol production (e.g. Italian grappa), for the grape pomace,
- as fuel in CHCP plants[44] (especially ligno-cellulosic biomass),
- as substrate for composting (displacing synthetic fertilisers or as soil mulch under the vines).

Energy use

Wine production uses large amounts of energy. For instance, Christ and Burritt (2013) report a consumption of 2,618 GJ of energy for the processing of one tonne of grapes into the finished product while Smyth and Russell (2009) report 1,555 GJ/tonne (excluding bottle making and final product transport).

The energy used in wineries is mainly electricity. The stages where most electricity is consumed are those that include temperature control and/or refrigeration (e.g. stabilisation, fermentation). The rest of the electricity is mainly used for the production of compressed air, for pumping and bottling line motors and for other miscellaneous uses (e.g. lighting, office equipment, space heating) (Galitsky et al., 2005).

A detailed share of the electricity use of a winery is presented in Table 12.7.

Table 12.7: Typical proportion of electricity use in a winery (SAWI, 2013)

Technology	Related processes/activities	Energy use
Refrigeration and tank storage	Must chilling Cold stabilisation Refrigeration Wine storage	50-70% electricity
Pumping	Wine transfer Cleaning Waste water treatment	10-20% electricity
Compressed air	Tank presses Cleaning	5-10% electricity
Hot water and steam	Cleaning and sterilisation	5-10% electricity
Heating, ventilation and air conditioning	Barrel stores Warehouses offices	5-15% electricity
Lighting	Warehouses Barrel stores Processing shed and plant room Offices Security and floodlights	5-10% electricity

As for thermal energy, mainly in the form of hot water or steam, its main uses are for cleaning and heating purposes (e.g. heating of tanks for malolactic fermentation, and preheating wine before bottling or after cold stabilisation, or thermovinification - a method used for dealing with botrytis infection problems on grapes) (Galitsky et al., 2005).

44 More details on the use of pruning residues for energy generation are provided in Section 3.9.

Since wineries use large amounts of energy, improving energy efficiency is very important to improve their environmental performance[45]. The processes offering the most potential for energy efficiency improvements are temperature control, refrigeration, cold stabilisation and lighting. This potential can be realised not only by choosing energy-efficient equipment whenever there is a need for replacement or expansion, but also by ensuring the proper sizing of the equipment used, according to the process needs (e.g. valves, pumps). Moreover, other measures which do not involve the purchase of new equipment can be implemented to optimise the energy efficiency of the existing production processes, such as increasing the insulation of pipes, cooling lines etc. or regularly inspecting the heating/cooling pipes in the tanks in order to prevent and/or repair leaks or damage to their insulation.

Regarding cooling operations in the winery, the whole system should be well maintained and, in particular, suitable cooling temperatures should be selected. In addition, it must be ensured that the cooling supply piping duct and the tanks are sufficiently insulated in order to eliminate potential energy losses. In parallel, variable speed refrigerant compressors can be installed in order to reduce energy consumption. The diameter of the pipe duct is calculated according to several parameters e.g. economy of the whole installation, required velocity of the flow. In particular, the oversized diameter of the pipes may lead to energy savings but must be balanced with other costs for pump systems components.

As for lighting, energy consumption can be reduced by maximising the use of daylight and choosing the most energy-efficient lighting technologies. The installation of skylights in the manufacturing sites and the use of high-efficiency light bulbs (e.g. LED) in the cellar (including proper and suitable motion detectors) result in significant energy savings. The installation of motion detectors can result in energy savings of between 10 and 20% depending on the winery (Galitsky et al., 2005).

Energy savings can also arise from reducing the need for pumping. This can be achieved by designing the building to exploit gravity systems. The reception of the grapes can be at the highest point of the building whereas the bottling phase together with the (temporary) storage room can be at the lowest level. In this case the use of pumps is minimised.

Energy efficiency in the winery can also be improved by optimising the drying stage. The main aim of the drying stage is to achieve a significant reduction in the water content of the grapes and a modification of their physicochemical and aromatic characteristics.
The Unione Italiana Vini has recently created a self-evaluation matrix (scoring from 1 to 4) for wineries to assess their sustainability in a number of different areas (e.g. cleaning of grapes, fermentation stage) (TERGEO, 2015). According to this matrix (Table 12.8), in the case of grape drying, the frontrunner organisations use non-conditioned stores, a drying process based on the utilisation of suitable exchanges between the outside and inside environment, and the drying process is carried-out outside or directly on the grapevine (Unione Italiana Vini, 2014).

[45] General aspects of energy efficient production processes are presented in Section 3.8

Table 12.8: Best practice for grape drying where sustainability increases from 1 to 4 (Unione Italiana Vini, 2014)

	4th level	3rd level	2nd level	1st level
Grape drying system	Use of non-conditioned stores; drying process based on utilisation of suitable exchanges between outside and inside environment; drying process carried out outside or directly on grapevine	Use of conditioned and insulated stores (thermo-conditioned and humidity-controlled stores)	Use of conditioned stores but not insulated; drying process based on utilisation of suitable exchanges between outside and inside environment	Use of conditioned stores but not insulated

Finally, an important aspect for reducing the energy use in wineries is the appropriate design of the cellar (rooms where the bottled wine or barrels with wine are placed for wine aging) in order to minimise its cooling needs. The following measures can maximise the energy savings:

1. Selection of a suitable orientation to avoid high sun exposure (avoid SE orientation).
2. locate the aging room, the cellar and the bottling room in the basement of the winery in order to reduce sun exposure.
3. Selection and use of proper construction materials like cement blocks or other suitable materials with low U-value (thermal transmittance).
4. Use of green roofs or reflective paint/materials on the roof of the winery.

When implementing the measures above adequately, only fans or other appliances/systems for ventilation are needed in the aging/storage room. The selection of energy-efficient equipment, the precise definition of its capacity and the use of reflective paint/materials on the roof of the winery contribute to the reduction of approximately 15-20% (depending on the local climate characteristics and the building envelope) of the cooling requirements of aging and storing as well as office buildings (Galitsky et al., 2005).

Achieved environmental benefits

The measures described in this BEMP allow the use of energy and water in the winery to be reduced (consequently saving natural resources and reducing GHG emissions). The sustainable management of organic waste leads to a reduction of GHG emissions, thanks to the production of renewable energy or to the displacement of the production of fertilisers (and the related use of natural resources and GHG emissions).

Appropriate environmental indicators

The proposed indicators are listed below. It should be clearly mentioned that high energy load occurs during the harvest time, which varies depending on the geographical location and the local weather conditions (e.g. as an average, the harvest period can be considered from August to November). The appropriate environmental indicators for this BEMP are:

- Total water used (L or m^3) per L of wine produced. The volume of water used can also be measured at the process level.

- Organic residues generated either in mass or volume per litre of wine produced. The organic waste generation can also be measured per stream of waste.

- Organic waste generated (residues not employed for any of the uses mentioned above) either in mass or volume per litre of wine produced per month/year

- Energy use
  - Thermal energy used – kWh/L of wine produced: can be calculated on an annual basis or only for the duration of the harvesting season
  - Electricity used – kWh/L of wine produced: can be calculated on an annual basis or only for the duration of the harvesting season

Cross media effects

There are no reported cross media effects for the implementation of the aforementioned measures to save water and energy and reduce organic waste generation. However, there is a negative impact due to the disposal of existing systems when upgrading to new and more efficient ones. This impact may outweigh any increased efficiency offered by new equipment if premature disposal occurs or if the end-of-life treatment of the equipment is not managed properly. Determining the point at which it offers a net environmental benefit to switch to new equipment is not straightforward although, in general, the older the equipment being replaced the more likely it is that the replacement makes good environmental sense. It is always advisable to choose the most environmentally friendly and efficient equipment when a replacement is needed (e.g. due to broken equipment or new technology requirements).

Applicability

The presented measures are fully applicable in new wineries or wineries undergoing major refurbishment or expansion, taking them into consideration from the design stage. For existing wineries, the applicability depends on the specific production processes already in place.

Economics

The direct economic benefits from savings on the energy and water bills and from the waste management costs differ significantly from case to case. There are also a number of indirect benefits. An example is that improving the environmental reputation of a company can benefit sales thanks to an increased number of customers.

Driving forces for implementation

The main driving forces for the implementation of measures to reduce energy and water use as well as waste generation are their contribution to a reduction in production costs and the improvement of the quality of the final product (bottled wine). This is particularly the case for the proper selection of the materials used for the construction of the winery and the appropriate location of the aging room, which lead to an improved final product.

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13. CONCLUSIONS

This document identifies the most important environmental aspects, direct or indirect, relevant to the organisations or companies belonging to the Food and Beverage Manufacturing Sector. The report presents the Best Environmental Management Practices for dealing with these identified aspects, including also sector-specific environmental indicators which allow the tracking of sustainability improvements. The following table lists all the BEMPs presented in the document, including some details on their applicability, the environmental performance indicators applicable for each of them and, finally, also the benchmarks of excellence which were agreed by the Technical Working Group for this sector. As mentioned in the Preface of this document, the benchmarks of excellence represent the highest environmental standards that have been achieved by companies implementing each related BEMP; however, they are not targets for all organisations to reach but rather a measure of what can be achieved (under stated conditions) that companies can use to set priorities for action in the framework of continuous improvement of environmental performance.

Table 13.1: BEMPs presented in this document with their related environmental performance indicators and benchmarks of excellence

Overall food and beverage manufacturing sector			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
1) Performing an environmental sustainability assessment of products and/or operations (Section 3.2)	This BEMP is largely applicable but a number of challenges need to be considered (i.e. depending on the complexity of the products, cost, time or expertise constraints and manufacturer's influence in the supply chain)	• Company-wide environmental sustainability assessment covering all operations (Y/N) • Environmental sustainability assessment for all new products (Y/N)	• % of total sites or products assessed using a recognised assessment protocol • Number of sites or products assessed using a recognised assessment protocol
2) Sustainable supply chain management (Section 3.3)	This BEMP can be applied when 'green' choices and suitable sustainable ingredients are available. A number of situations exist where manufacturers may be unable to influence the performance of their suppliers.	N/A	• % of suppliers engaged in sustainability programs • % of ingredients or products (e.g. packaging) sourced via green procurement • % of ingredients or products (e.g. packaging) meeting company's specific sustainability criteria or complying with existing sustainability standards • % of suppliers with environmental management systems in place
3) Improving or selecting packaging to minimise environmental impact (Section 3.4)	This BEMP is largely applicable. Refillables, reusable and returnable transit packaging work best in simple and localised supply chains. A main constraint for lightweighting packaging can be consumer perception.	• Use an eco-design tool when designing packaging to identify options with a low environmental impact (Y/N)	• Packaging related CO_2eq per unit weight of product manufactured • Volume/weight packaging per unit weight of product manufactured. • % of packaging which is recyclable • % recycled material content in packaging • Weight of packaging per unit product • Average density of product category in kg (net) product per litre of (gross/packaged) product.

4) Environmentally friendly cleaning operations (Section 3.5)	Any changes to cleaning regimes or techniques must ensure that all relevant standards continue to be met. For smaller manufacturers, substantial investment in the latest, most sophisticated technology may not be warranted by the relatively small financial savings available to them.	N/A	• Cleaning-related energy (kJ) per unit of production • Cleaning-related water use (m^3) per unit of production • Waste water generation (m^3) per unit of production • Waste water generation (m^3) per clean • Water consumption volume (m^3) per day • Mass (kg) or volume (m^3) of cleaning product (e.g. caustic soda) used per unit of production • Share (%) of chemical-free cleaning-agents • Share of cleaning-agents (%) with recognised environmental certification (e.g. EU ecolabel)
5) Improving transport and distribution operations (Section 3.6)	This BEMP is applicable to all food and beverage manufacturers managing their transport and distribution operations. Measures requiring relevant financial investments and agreements (e.g. shifting to less polluting transport modes) may be difficult for small companies	• For 100 % T&L operations (including 3PL), the following indicators are reported: % of transport by different modes; kg CO_2eq per m^3/pallet etc. delivered. • For in-house T&L operations, the following indicators are reported: truck load factor (% weight or volume capacity); kg CO_2eq per tkm. • Temperature-controlled warehouse insulation is optimised (Y/N) • HGV average fuel consumption $\leq$ 30 L/100 km	• kg CO_2eq emitted during transport per: t, m^3, pallet, or case (according to relevance) or kg CO_2eq per net amount of product delivered • Total energy consumption of warehouse (kWh/m^2/yr) normalised by relevant unit of throughput (e.g. kg net product). • L/100 km (vehicle fuel consumption) or mpg; or: kg CO_2eq /t·km. • % of truck empty runs • % of deliveries carried out through back-hauling

6) Improving freezing and refrigeration (Section 3.7)	It may be difficult to monitor specific energy consumption for freezing and refrigeration if electricity metering is on a site-wide basis. The use of environmentally friendly refrigerants may require adaptation of the refrigeration systems and circuits.	• Use 100% natural refrigerants in all sites (Y/N)	• % use of natural refrigeration systems • Coefficient of performance (COP) • Coefficient of service performance (COSP) • Energy efficiency ratio (EER) • Energy demand (KWh) for refrigeration per unit product / per cooled area
7) Deploying energy management and energy efficiency throughout all operations ((Section 3.8)	Energy efficiency solutions can be deployed in all facilities, from incremental to in-depth refurbishments.	• Put in place a comprehensive energy management system (EnMS) such as ISO 50001, which can be part of an environmental management system like EMAS (Y/N) • Deploy regular energy auditing and monitoring to identify the main drivers of energy consumption. (Y/N) • Implement appropriate energy efficiency solutions for all processes in a facility. (Y/N) • Exploit synergies in heat/cold/ steam demand across processes, within the facility and neighbouring ones. (Y/N)	• Overall energy use per unit, weight or volume of output product (e.g. annual kWh / tonne output product) • Overall energy use per facility space (kWh / m2 of productive facility) • Net energy use per unit, weight or volume of output product (e.g. annual kWh / tonne output product) i.e. total minus recovered and renewable energy • Energy use for specific processes (kWh per process) • Deployment of heat exchangers to recover hot / cold streams (Y/N) • Insulation of all steam pipes (Y/N)

8) Integrating renewable energy in the manufacturing processes (Section 3.9)	Renewable heat systems are applicable in new and existing food and beverage productions sites with a relevant heat demand. However, the technical feasibility shall be analysed in each particular case. For new plants, the integration of renewables can be part of the overall energy concept.	• Implement on-site or nearby renewable energy generation for specific suitable manufacturing processes. (Y/N) • Process technologies are adapted to better match the supply of heat from renewables. (Y/N)	• % of production energy demand (heat and electricity) met by renewable energy sources • % of production energy demand (heat and electricity) met by on-site or nearby renewable energy sources
9) Avoiding food waste in food and beverage manufacturing (Section 3.10)	Measures to avoid food waste are always applicable.	N/A	• Overall Equipment Effectiveness (OEE) • Tonnes of food waste generated ((sent for recycling, recovery and disposal, including food waste used as a source of energy or fertilising material) per tonne of finished products
10). Link to the Reference Document on Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF) ((Section 3.11)	This BEMP is applicable when relevant BAT and emerging techniques are presented in the FDM BREF	• Achieve a level of environmental performance which is within the best 10% of each of the BAT-AE(P)L ranges defined in the FDM BREF.	• Relevant BAT are implemented (Y/N) • Relevant emerging techniques are implemented (Y/N).
Processing of coffee			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
11) Reduction of energy consumption through the use of green coffee preheating in batch coffee roasting (Section 4.4.1)	The pre-heating system can be installed in any new batch roaster but this operation may require considerable space and/or reinforcement of the building structure. Retrofitting an old roaster instead is very difficult.	• A green coffee pre-heating system is in-place.(Y/N)	• % of heating energy reduction in coffee roasting thanks to the introduction of green coffee pre-heating • Heating energy used in roasting operations in KWh/ tonne of green coffee. • Specific CO_2 emission measured as kg CO_2eq/tonne roasted coffee and calculated with electricity and fuel consumption (e.g. propane, methane) in roasting operations.

Manufacture of olive oil			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
12) Minimising water consumption in olive oil separation (Section 5.4.1)	Reducing the amount of water used can affect the quality of the olive oil. The quantity of water used should be kept to the minimum amount required to achieve the desired final composition.	• 50 litres (5%) of water per 1,000 litres of oil manufactured	• Water use in olive oil separation (litres) per weight (tonnes) of olives processed or per unit volume (litres) of olive oil manufactured
13) Reduced washing of olives upon reception (Section 5.4.2)	This BEMP is applicable to all oil mills. However, farmers' cooperation is essential.	• For olives collected clean, 0 litres of water to wash olives upon reception	• L (of water used to wash the olives upon reception) / t (amount of olives processed).
Manufacture of soft drinks			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
14) Use of blowers in the drying stage of bottles/packaging (Section 6.4.1)	Blowers can be installed in all facilities when replacing compressed air systems for drying bottles/cans	N/A	• Energy consumption (kWh) for blowing/drying per litre of product
Manufacture of beer			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
15) Cross-flow rough beer filtration (Section 7.4.1)	This BEMP is applicable to new breweries and existing plants which need to increase their capacity with new filtration operation units.	• 0 kg of kieselguhr used in beer filtration	• Amount (kg) of kieselguhr used in beer filtration per hl of beer produced

16) Reducing energy consumption in wort boiling (Section 7.4.2)	Applicability should be assessed case by case, based on the space available and the brewing process.	• Install a wort pre-heating system with recovered heat from wort vapour condensing. • Evaporation rate during wort boiling is < 4%	• Evaporation rate (%) in wort boiling (different in case of one-phase or two-phase) • Energy consumption per hL of beer produced (MJ/hL) • Energy consumption in wort pre-heating (MJ/hl) • Number of brews before cleaning the boiling system again
17) Moving from batch to continuous beer production systems (Section 7.4.3)	The BEMP might only be applicable to medium- to large-scale brewing operations and may have an impact on the taste of the final product.	N/A	• Energy consumption (MJ) in production process per hl of beer produced • Water consumption (hL) in production process per hl of beer produced
18) CO_2 recovery in beer production (Section 7.4.4)	Micro-scale breweries might find it unattractive to recover their own CO_2. Moreover, it is important that the quality of the recovered CO_2 meets the necessary standards for its reutilisation	• Implement a system recovering 50% of the CO_2 generated during fermentation	• Amount of CO_2 recovered per hL of beer produced • Capacity of CO_2 recovered hourly in the brewery could also be a suitable environmental indicator
Production of meat and poultry meat products			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
19) High pressure processing for decontamination of meat (Section 8.4.1)	There are some products which are not usually treated with HPP. Small companies may not have the financial capacity to buy the equipment but can look into renting the service	• Use of high pressure processing (owned or outsourced) to treat suitable meat products (cooked products, cured and cooked products and raw-cured etc.)	• kWh/ cycle of processed product or as kJ/kg of product.
Manufacture of fruit juice			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**

20) Value-added use of fruit residues (Section 9.4.1)	Availability of local AD plants is an essential requirement. Additionally, the willingness of the owners of the AD plant to cooperate is also essential.	• 100% of fruit residues are used for the recovery of valuable products (e.g. pectin, essential oils) and/or as animal feed and/or as co-substrate for anaerobic digestion.	• Fruit residue explotation rate (%): total amount of fruit residues used as animal feed or co-substrate in AD plants.
Cheese making operations			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
21) Recovery of whey (Section 10.4.1)	Significant investment may be required which can only be justified when threshold volumes of production are met and the products manufactured meet the market demand.	• Recover whey and further treat it in order to obtain other products for human consumption based on market demand. Employ excess whey instead for animal feed and/or AD biogas production. (Y/N)	• % (weight) of dry matter recovered in whey for use in products intended for human consumption per weight of whey generated.
Manufacture of bread biscuits and cakes			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
22) Unsold bread and pastry waste reduction schemes (Section 11.4.1)	This BEMP is applicable when strict management and supervisory instruments are put in place in the participating bakeries and/or outlets.	• For bakeries: 100% retail outlet participation in appropriate collection schemes for the unsold bread and other pastry products	• Return rates (%) of unsold bread from bakeries participating in the returning scheme • Number of truck routes for deliveries and collections of the unsold bread (truck capacity should also be mentioned) • Participation (%) of outlets in existing returning schemes for a given area • Segregation of non-compatible ingredients (e.g. products and/or ingredients of animal origin, highly perishable products (e.g. salad)) • % of unsold bread converted to other uses to avoid food waste generation
23) Minimising energy consumption for baking (Section 11.4.2)	This BEMP is applicable for new and existing bakery facilities and stores	N/A	Energy consumption in the baking process i.e. kWh per: • t of baked product, or • t of input flour used, or • m^2 of baking area (oven surface)

Manufacture of wine			
BEMPs	**Applicability**	**Benchmarks of excellence**	**Environmental performance indicators**
24) Reducing water use, organic waste generation and energy use in the winery (Section 12.4.1)	The BEMP is fully applicable in new wineries or wineries undergoing major refurbishment or expansion. For existing wineries, the applicability depends on the specific production processes already in place.	N/A	• Total water used (L or m^3) per L of wine produced. Water used can also be measured at process level. • Organic waste generation either mass or volume per litre of wine produced per month/year • Energy use o Thermal energy used – kWh/L of wine produced: can be calculated annually or during the harvesting season o Electricity used – kWh/L of wine produced: can be calculated annually or during the harvesting season