
Code of good practice for the beef processing industry

Title: Code of Good Practice for the Beef Processing Industry

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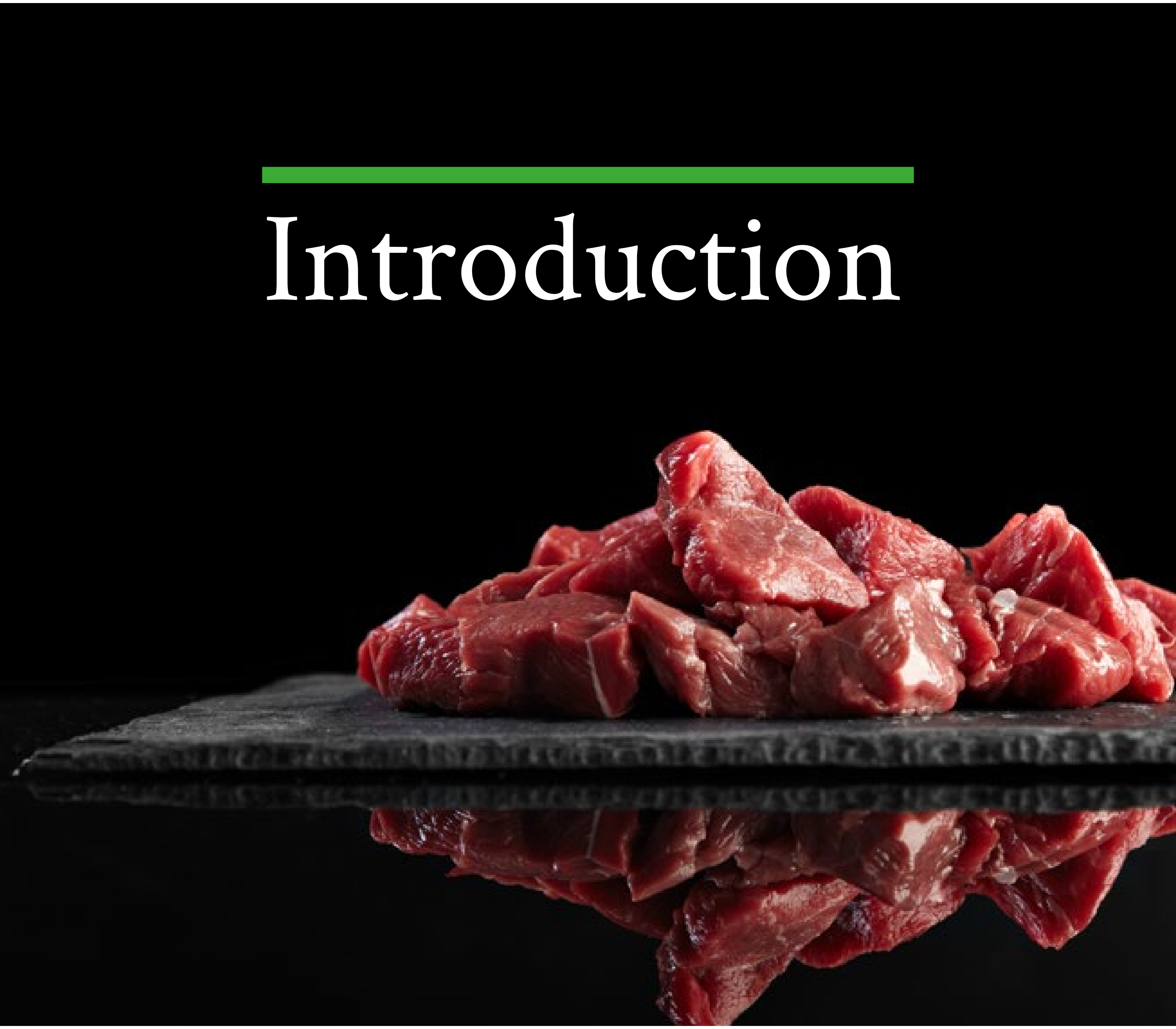
# Introduction



Spain, as a member state of the European Union and a signatory of the United Nations Framework Convention on Climate Change and its Kyoto Protocol, is obligated to implement the various environmental regulations agreed upon both internationally and at the European level. These regulations are achieving very positive results within the EU.

The Spanish beef sector, through PROVACUNO, has long pursued its "2050 Carbon Neutral Strategy", a strategy which unites all stakeholders in the value chain in **a commitment to progressively reduce GHG emissions in the coming years. This reduction goes hand in hand with improvements in the efficiency and effectiveness of all processes, from production to processing.**

**PROVACUNO** expresses its commitment and alignment with international objectives to reduce Greenhouse Gas (GHG) emissions. It emphasizes the involvement of **the entire beef value chain** in this endeavor, taking a proactive role in reducing emissions and promoting environmental sustainability. This includes supporting research and technological development, with the goal of applying the results to both the livestock sector and the meat processing industry.

Following its planned sustainability strategy, and after developing a code of good practices for the production sector, **PROVACUNO** aims to continue its work by creating a document for the processing industry. This document will guide operators in **improving key environmental indicators at each stage of the process.**

These indicators are directly related to:

- Efficient water use

- Minimizing the discharge of liquids with high organic content

- Optimizing energy for refrigeration and water heating

- Wastewater and sewage sludge management

- Management of ABP in general and SRM in particular.

The implementation of environmental sustainability policies reflects a growing societal demand for responsible industrial practices, particularly in the areas of pollution prevention, animal welfare, and biodiversity. Community institutions have embraced this demand, as seen in initiatives such as the Green Deal, the Farm to Fork Strategy, and the publication of best available practices for various sectors. Spain has approved initiatives like the Climate Change and Energy Transition Law, the Waste and Contaminated Soil Law, the circular economy strategy, and updated regulations on integrated pollution prevention.

In the short and medium term, this strategy will generate cost savings. Access to natural resources (water, energy, fuel, raw materials) is becoming increasingly limited, leading to significant cost increases. **Often, basic actions within companies can achieve substantial improvements in environmental management.**

The **CODE OF GOOD PRACTICE** breaks down the basic operations of slaughterhouses and cutting plants, highlighting the phases that require the most energy or generate the greatest environmental impact. Monitoring these consumption levels within the industry allows for the establishment of work standards and the identification of potential deviations and issues.

The recommendations on improving energy efficiency contained in this document are based on the SCOoPE project. This collaborative venture brought together cooperatives, universities, and agri-food research centers to explore ways to reduce energy consumption and develop collaborative energy management systems.

Reducing energy consumption must be achieved without sacrificing production capacity, while at the same time maintaining the best possible socioeconomic and environmental conditions. To achieve these objectives, the project promotes **the adoption of specific and transversal innovative technologies and techniques** which have proven effective in other industrial sectors, but which are not commonly implemented in the agri-food sector.

**Around 37% of the total energy savings achieved during the SCOoPE lifespan has been obtained through investments related to renewable energy systems. The remaining 63% comes from investments related to energy efficiency.**

# 1 Slaughterhouses and Cutting Plants

# Slaughterhouses and Cutting Plants

The objective of cattle slaughterhouses and cutting plants is to hygienically obtain meat suitable for human consumption through various cuts derived from beef carcasses. This hygienic process adheres to the highest food safety standards and requires strict veterinary oversight.

Throughout the process, proper control of animal by-products is essential to eliminate any potential risk to consumers and the environment. Facilities must be adequately designed and employ the most efficient techniques to minimize energy consumption and environmental impact.

The beef processing industry involves two primary operations: slaughtering animals in slaughterhouses, and butchering carcasses in cutting plants.

The final products from a slaughterhouse fall into two main categories:

**Carcasses or half carcasses and viscera suitable for human consumption.**

The carcass refers to the entire body of the slaughtered animal after bleeding, evisceration and skinning, with the head and feet removed.

**Animal by-products (ABP) not intended for human consumption.**

These include hides, bile, bone, fat, hooves, and claws. These have significant potential for recovery in the agro-industrial industry, such as in the manufacture of fertilizers, pharmaceutical products, or biofuels. Other ABPs are classified by their risk level as Category 1 by Regulation (EC) 1069/2009 and must be destroyed. This Specified Risk Material is specifically handled to prevent transmissible spongiform encephalopathies.

Cutting room

Vacuum packing cuts of beef

Meat is chilled until it is processed. Cutting and filleting of fresh meat typically occurs in a dedicated white room. Half carcasses are cut into pieces and trimmings, which are then marketed fresh or used as intermediate products for prepared meats and meat product manufacturers. Prepared cuts can be vacuum-packed, packaged using modified atmosphere packaging (MAP), etc., and then labeled. After packaging, the meat is stored in a cold room until it is shipped. (See the Cutting Plant Flow Diagram in Appendix II and the Prepared Meat Product Flow Diagram in Appendix III).

Throughout these operations, it is crucial to consider the main aspects of each that may have the greatest environmental impact or require the most energy.
A more detailed description can be found in Appendix I.

Vacuum packing cuts of beef

## Key considerations in the production chain include:

**Humane animal transportation:** Transporting animals in a way that respects animal welfare and minimizes the risk of injury (which also has environmental benefits by reducing waste).

**Proper vehicle hygiene:** Thoroughly cleaning and disinfecting trucks to enable selective collection of solid waste and wastewater.

**Minimizing suffering:** Adhering to the appropriate time between stunning and bleeding to minimize animal suffering.

**Proper blood collection and storage:** Correctly collecting and storing blood is crucial due to its potential as a pollutant. Proper handling increases its potential for recovery and use. Discharging blood directly into the treatment plant should be avoided, as it increases wastewater treatment needs, violates legislation, and raises energy costs.

**Clean evisceration techniques:** Using clean evisceration techniques helps prevent carcass contamination and reduces washing requirements.

**Proper by-product separation:** Correctly separating and classifying by-products not intended for human consumption maximizes their potential for recovery.

**Water conservation:** Using small volumes of pressurized water for washing carcasses, or employing alternative methods like steam, hot water, or disinfectants.

**Slaughterhouse cleaning process control:** Monitoring water consumption, selecting appropriate cleaning and disinfection agents, and providing operator training.

**Solid waste management:** Properly collecting solid waste throughout the production process to minimize the polluting load of wastewater.

2

# Environmental Aspects in Slaughterhouses and Cutting Plants

Washdown facility for beef slaughterhouse transport vehicles

**The most significant environmental impacts of slaughterhouse operations are water consumption, the discharge of liquids with high organic content into water systems, waste generation, and energy consumption (particularly for water used in cooling and heating).**

The following table outlines the most relevant environmental aspects related to emissions and energy consumption in slaughterhouses.

## Table 1: Main Environmental Aspects in Slaughterhouses

### Source: BAT Reference for the Meat Sector.

| ASPECT | OPERATION | OBSERVATIONS |
|---|---|---|
| **Water consumption** | Washing carcasses and edible offal | |
| | Cleaning and disinfecting equipment, facilities, and vehicles | |
| **Thermal energy consumption** | Various washing procedures | |
| | Cleaning and disinfecting equipment, facilities, and vehicles | |
| **Electrical energy consumption** | Refrigeration/Freezing | |
| | Compressed air generation | |
| **Fuel consumption** | Heat generation | |
| **Atmospheric emissions** | Heat generation | Combustion gases: $CO_2$, NOx, SOx, CO, particles |
| | Cold generation | Refrigerant gases: $NH_3$, HFC |
| **Wastewater** | Reception and lairage | Droppings, slurry, straw bedding: COD (1), BOD (2), SS (3), N (4), P (5) |
| | Stunning | Urine, N, BOD |
| | Bleeding | Blood, BOD, SS, N |
| | Various washing procedures | Fat, gastric juices... |
| | Cleaning and disinfecting equipment, facilities, and vehicles | COD, BOD, fat, SS, N, P |
| **Waste generation** | Reception and lairage | Droppings and bedding |
| | Shank and horn removal | Legs and horns |
| | Evisceration | Non-edible organs |
| | Carcass splitting | Cutting remains |
| | Wastewater treatment | Sewage sludge |
| **Odors** | Reception and lairage | |
| | Waste collection, processing, and storage | |
| | Wastewater treatment | |

**(1) COD: Chemical Oxygen Demand**
**(2) BOD: Biochemical Oxygen Demand**
**(3) SS: Suspended Solids**
**(4) N: Nitrogen**
**(5) P: Phosphorous**

Appendix II provides a more in-depth analysis of the environmental aspects of slaughterhouses, as their environmental impact is significantly greater than that of cutting plants.

Extensive environmental legislation regulating the environmental impact of these activities exists at both the state and regional levels, and operators must comply with this legislation throughout the production process. Appendix VIII of this document summarizes environmental legislation at the European and state levels.

Key environmental considerations for a beef slaughterhouse include:

## Water Consumption

Water use is a significant environmental concern in beef slaughterhouses. The primary water demand comes from cleaning and disinfecting equipment, facilities, and vehicles. Water is also essential throughout the production process, used for washing animals in lairage, cleaning carcasses and offal, and rinsing at various stages of slaughter and dressing. Water use increases significantly when the facility also processes by-products like tripe.

The volume of water used depends on several factors, including the size and age of the plant, the level of automation, and the specific cleaning and disinfection techniques employed.

Cleaning water and boiler circuits often require treatment to reduce water hardness and conductivity, including decalcification, deionization, or activated carbon filtration. These treatment processes can generate wastewater with high conductivity or extreme pH levels.

Offal washing-cleaning machine

**Excessive water use is an environmental and economic concern and places an additional burden on the Wastewater Treatment Plant (WWTP).**

## Energy Consumption

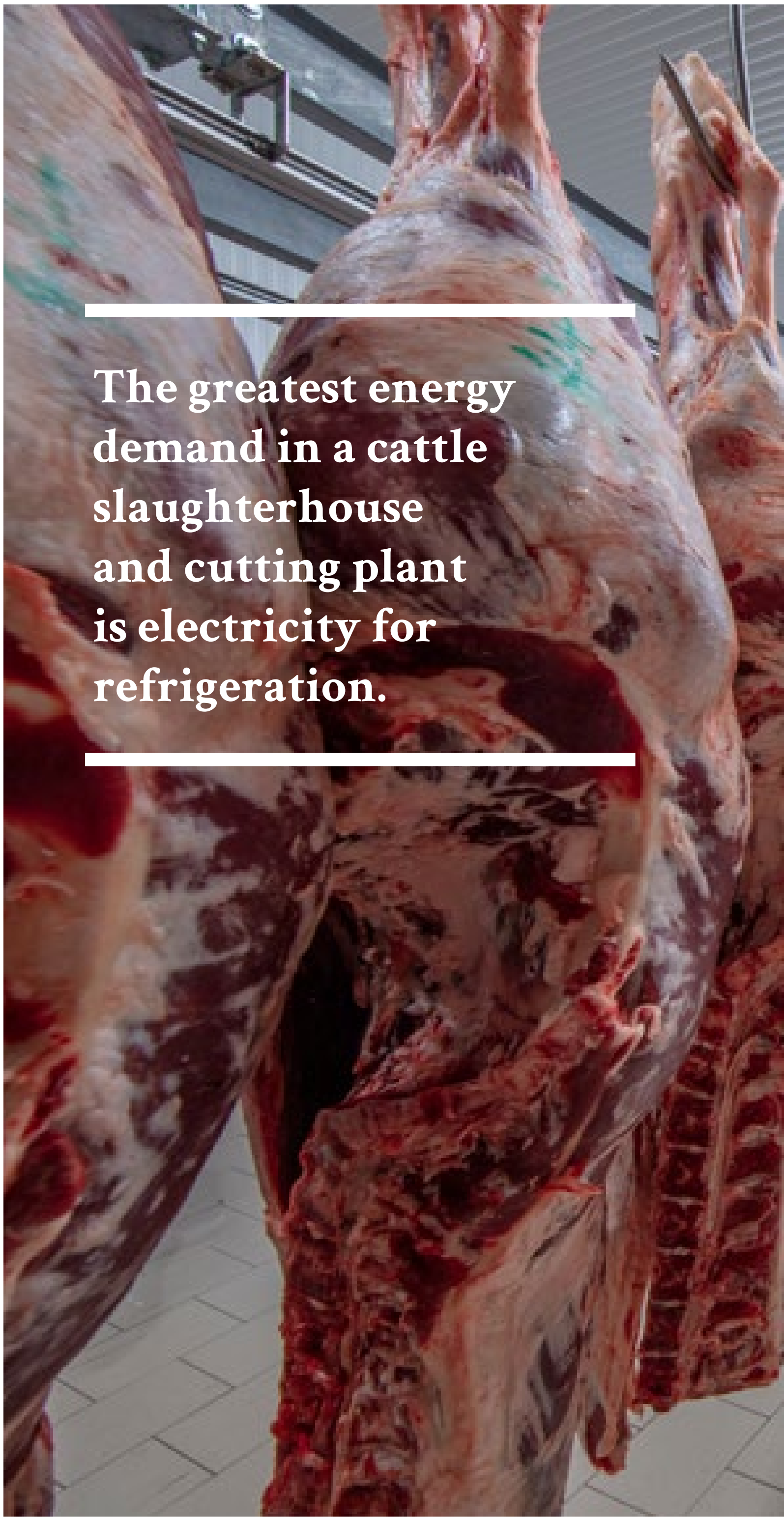
**Refrigeration systems represent a significant portion of energy use in slaughterhouses, accounting for 45-90% of electricity consumption during operation, and nearly 100% during non-production periods. These systems cool work areas, cold stores, and freezers.**

Cattle and sheep slaughterhouses generally require less hot water than pig slaughterhouses. While pig slaughterhouses may use up to 80% thermal energy for processes like heating scald tanks, raising steam, and singeing, cattle and lamb facilities typically require only 30-50%.

**Slaughterhouses rely heavily on electricity to power a range of critical functions, from refrigeration, compressed air, ventilation, and lighting, to the equipment used in slaughtering, deboning, and by-product processing.** Examples of electricity-powered equipment include saws, forklifts, conveyors, packaging machines, and electrical stimulation systems. Electricity also supports on-site rendering plants and wastewater treatment.

**Thermal energy is primarily used for cleaning and disinfecting equipment, work surfaces, and utensils, as well as for washing carcasses and offal, and processing by-products.**

**Heating water to 60°C for cleaning facilities and equipment accounts for the largest share of thermal energy use in beef slaughterhouses.**

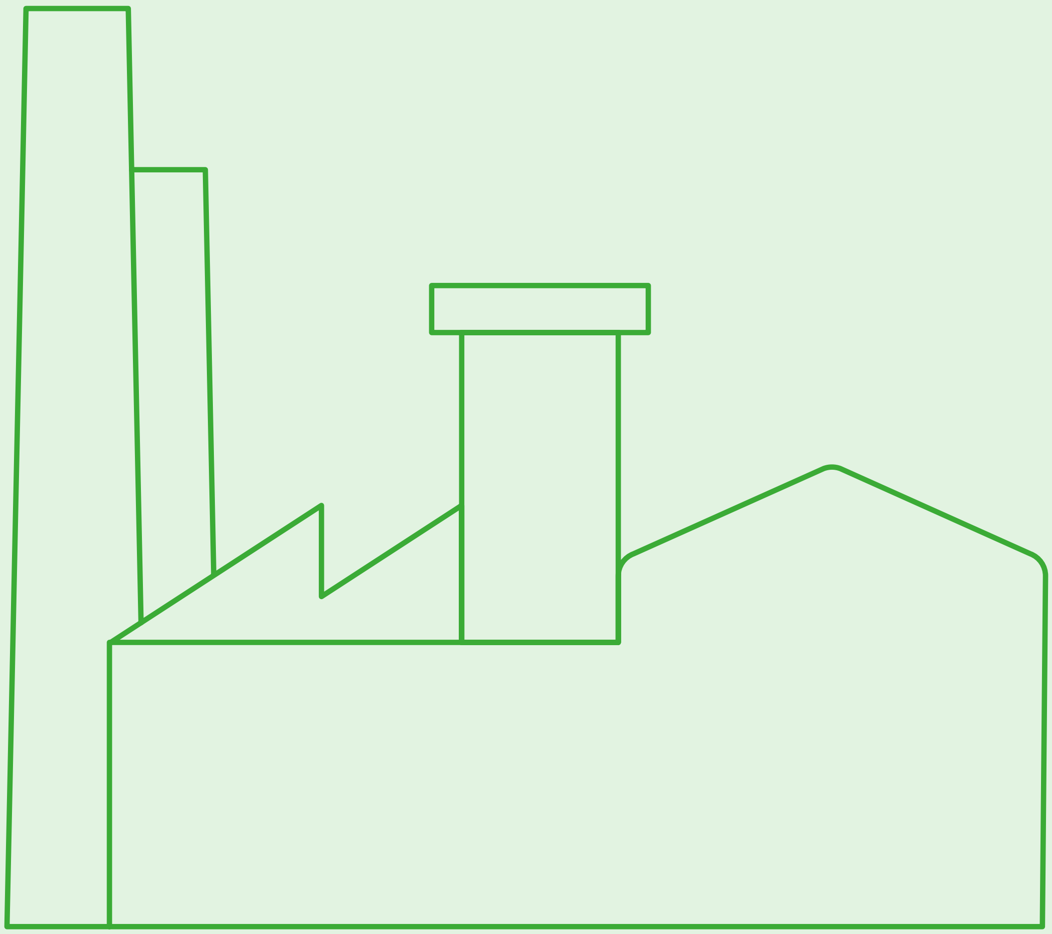



Pre-cooling/chilling room for beef carcasses

## Atmospheric Emissions

The primary source of air emissions in a slaughterhouse is the combustion gases produced by the boiler room. These gases include carbon dioxide ($CO_2$), nitrogen oxides (NOx), sulfur oxides (SOx), and carbon monoxide (CO). $CO_2$ emissions are directly related to the amount of thermal energy used.

Other less significant air emissions, typically diffuse in nature, include refrigerant gases from refrigeration systems, and methane, ammonia, and particulate matter from manure and slurry.



## Wastewater

The most critical environmental impact associated with slaughterhouses stems from water emissions, which are intrinsically tied to the industry's high-water consumption—a pressing environmental challenge.

Equipment and facility cleaning ranks as one of the largest sources of wastewater, both in volume and organic load.

**Blood has the highest Chemical Oxygen Demand (COD) concentration of all liquid slaughterhouse waste. Its pollution potential and the large quantities handled make it a significant environmental concern requiring evaluation and control.**

Typically, 80-95% of the water consumed at a slaughterhouse becomes wastewater, which is characterized by high concentrations of organic matter, suspended solids, oils, and fats, as well as a high degree of biodegradability.

The operations generating the greatest amounts of wastewater are shown in the following table:

## Table 2: Stages Generating Wastewater, and Their Associated Pollutants

### Source: Manual de buenas prácticas y sostenibilidad ambiental en el sector agroalimentario: Instalaciones para el sacrificio de animales.

| STAGE | MAJORITY COMPONENT | MAIN COMPONENT |
|---|---|---|
| **Lairage** | Manure and slurry carried in cleaning operations | $H\text{-}NH_3$ |
| **Bleeding** | Blood | COD, C/N ratio |
| **Evisceration** | Pieces of viscera, fat and blood | SST, MO, $PO_4^{3-}$, salts, and fats |
| **Carcass washing** | | Flow |
| **Cleaning of equipment and facilities** | Detergents and organic matter | Flow and BOD5 |
| **Refrigeration** | | Temp. and flow |

## Waste Generation

In addition to animal by-products, waste is also generated from sewage treatment, packaging, refrigeration system maintenance, cleaning, administrative tasks, etc.

These waste streams can be categorized as follows:

**Animal By-Products (ABP) not intended for human consumption. This category includes Specified Risk Material (SRM), blood, manure, and slurry.**

**Specified Risk Material** refers to the tissues and organs defined in Commission Regulation (EU) 2015/728, which amends the definition found in Annex V of Regulation (EC) No 999/2001 of the European Parliament and of the Council laying down rules for the prevention, control, and eradication of certain transmissible spongiform encephalopathies. This material must be managed in accordance with current legislation, which outlines procedures for collection, storage, handling, and disposal by slaughterhouses.

**Blood** may be considered a by-product depending on the hygienic conditions maintained during its collection, transport, and storage, as well as available external management options.

**Manure and slurry** are livestock excreta generated primarily during reception and lairage. Excreta is also present in the stomachs and intestines of animals at the time of slaughter. Segregated collection of manure facilitates its use as fertilizer. However, in practice, manure is often washed into the drainage system during cleaning, significantly increasing the pollutant load of the wastewater.

Sewage sludge

Hazardous waste

Other waste

On-site slaughterhouse waste collection station


Specific container for SRM disposal

## Odors

Odors generated by the storage and handling of blood, slurry, occupied lairage, and inedible offal storage are the most problematic. Other potential sources of odor include patio areas, unwashed by-product containers, and wastewater treatment plants (including the initial solids separation stage).

## Noise

The primary sources of noise and vibration pollution are animals during unloading and sorting procedures, vehicle movements, compressors, air conditioners, and fans.

# 3

# By-Product Management

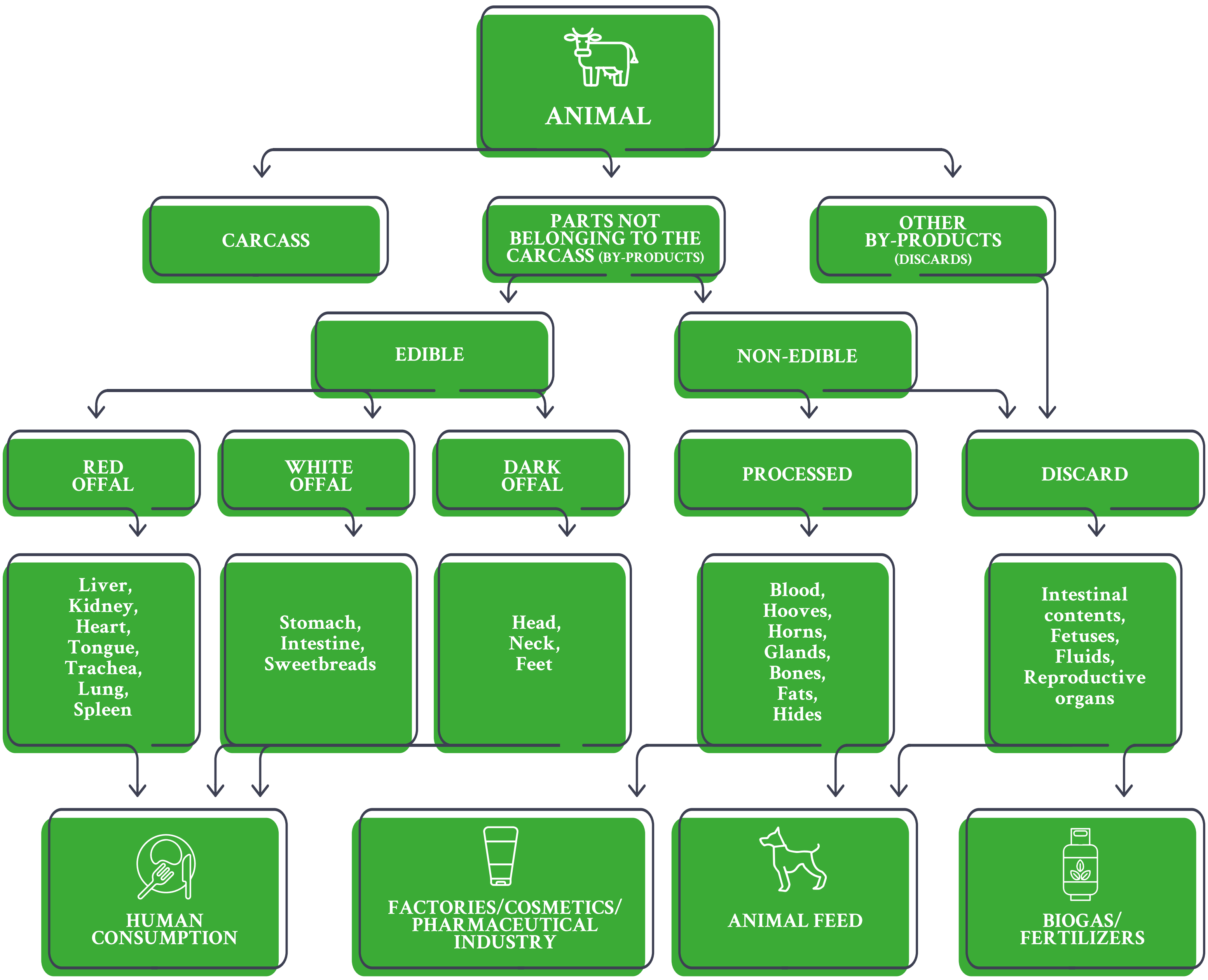
**Slaughterhouses generate a significant volume of by-products. These can be used directly as food, or further processed for agricultural and industrial applications.**

While animal by-products comprise approximately two-thirds of the animal after slaughter, their yield represents only about 10% to 15% of the live animal's value in developed countries.

The following figure shows a classification of by-products and their primary uses.

# Figure 1: By-Product Classification

Source: The Potential of Animal By-Products in Food Systems: Production, Prospects and Challenges.



In the meat industry, animal by-products from slaughterhouses are sometimes referred to as the "fifth quarter". This includes edible materials like tongues, edible offal, fats, and casings, as well as inedible materials like hides and skins. In the past, these by-products were a valuable source of revenue for slaughterhouses. However, due to BSE, the value of fifth quarter materials has decreased significantly in recent years. Many materials that were once used are now disposed of as waste [12, WS Atkins-EA, 2000, BREF].

Edible co-products, also known as food-grade products, are those suitable for and intended for human consumption. As such, **all processing steps, including collection, transport, processing, and delivery, are governed by Regulation (EU) 853/2004 on the hygiene of food of animal origin**. All edible co-products must be sourced from healthy animals that have undergone both ante-mortem and post-mortem inspections, and have been declared fit for human consumption.

Edible co-products can be obtained from slaughterhouses (e.g., blood) and cutting plants. Key examples of edible co-products include:

- Gelatin/collagen
- Blood products like plasma and hemoglobin
- Beef tallow fat

Tallow fats are primarily used as a food ingredient for human consumption, while blood products and gelatin serve as functional proteins. Food-grade products can also be used for purposes outside the food chain, such as animal feed and technical applications (e.g., fats in feed or soaps, blood products in feed, or gelatin in pharmaceuticals, glue, or wallpaper) [259, EFPRA-EAPA 2020, BREF]. **Slaughterhouse products like blood or animal fat can be categorized as either food-grade products, or animal by-products (non-food grade).**

The following table provides an overview of relevant animal by-products and the volumes generated per head of cattle.

## Table 3: By-Products Generated from Cattle

Source: 267, VDI 2020, BREF.

| TYPE OF BY-PRODUCT | Beef Cattle (Kg/animal) |
|---|---|
| **Blood (including blood for human consumption)** | 15-20 |
| **Stomach and stomach contents** | 55 |
| **Intestinal content** | 15 |
| **Hide** | 40 |
| **Shanks (incl. hooves) and horns** | 11 |
| **Internal fatty tissue** | 35 |
| **Internal organs** | 90 |

All food products can potentially be classified as ABP, but not all ABPs could have been used for human consumption.

The animal by-product industry handles raw materials that are either declared unfit for human consumption, or are fit for human consumption but are not intended for this purpose for commercial reasons.

The distinction between products intended for human consumption and those that are not depends on their intended market. This means that if a food product is not intended for human consumption and is instead sent to processing plants or used for animal feed, it is classified as ABP. This classification is irreversible.

The production of edible co-products from animal by-products is prohibited [259, EFPRA-EAPA 2020, BREF].


Regulation (EC) 1069/2009 and Regulation (EU) 142/2011 govern the permitted uses, disposal routes, and health rules for animal by-products (ABP) and derived products not intended for human consumption. The regulations ensure the safe handling and management of ABP from generation to final use, recovery, or destruction. This minimizes risks to human health, animal health, and the environment, with a particular focus on safeguarding the human and animal food chains.

In Spain, Royal Decree 1528/2012 sets out the conditions for applying EU regulations to ABP, and establishes the National Commission for Animal By-Products Not Intended for Human Consumption, responsible for monitoring and coordinating the implementation of ABP regulations.

ABP and derived products are classified into three categories (1, 2, and 3) based on their risk to public and animal health, as determined by risk assessments.

- Products excluded from human consumption under EU legislation (especially those that do not comply with food hygiene regulations or are unsafe for human consumption) are classified by law as ABP (Category 1, 2, or 3).
- Products of animal origin fit for human consumption but designated for purposes other than human consumption by an “irreversible” operator decision are automatically classified as Category 3 ABP under Regulation (EC) 1069/2009.

The regulation specifies different recovery or disposal options for ABP based on their classification.

## Table 4: Primary Uses of Category 1 ABP from Beef Cattle

| CATEGORY 1 |
| --- |
| Incineration or co-incineration with or without prior processing. |
| Processing, marking, and burial in an authorized landfill. |
| Use as fuel with or without prior processing. |
| Use in the manufacture of derived products as specified in Articles 33 (cosmetic products, active implantable medical devices, in vitro diagnostic medical devices, veterinary medicinal products, medicines), 34, and 36 of Regulation (EC) 1069/2009. |

## Table 5: Primary Uses of Category 2 ABP from Beef Cattle

| CATEGORY 2 |
| --- |
| Same uses as Category 1 by-products. |
| Manufacture of fertilizers/organic soil amendments after sterilization and marking. |
| Composting or biogas production after pressure sterilization and marking. |

## Table 6: Primary Uses of Category 3 ABP from Beef Cattle

| CATEGORY 3 |
| --- |
| Same uses as Category 1 and 2 by-products. |
| If the material has not undergone decomposition or degradation that poses an unacceptable risk to public health/animal health, it can be processed and used for: |
| Pet food, fur animal feed, and aquaculture feed, provided the raw material meets the requirements of Annex X of Regulation (EU) 142/2011. |
| Fertilizers and soil amendments, in accordance with Annex XI of Regulation (EU) 142/2011. |

# 4 Wastewater Treatment

Pre-treatment: Fine particle removal

Slaughterhouse wastewater contains a high concentration of organic pollutants. These originate from various sources, including blood loss during slaughter, scalding (in pig slaughterhouses), carcass washing, cleaning and disinfection of equipment and facilities, and manure removed during the cleaning of lairages and trucks. Tripe processing generates sewage with a particularly high organic load.

The attributes of wastewater vary based on several factors, including how well water consumption and waste management are optimized throughout the process.
This includes:

- Manure collection procedures in lairages and truck washing areas;

- Minimizing water use during slaughter and carcass processing to reduce the dragging of organic matter like fat and feces;

- Equipment and technology used in high-water-consumption operations (e.g., scalding by immersion or vertical spray in pig slaughterhouses);

- Cleaning methods and the chemicals used.

The most suitable wastewater treatment solution depends on thorough preliminary studies, which should assess flow rates, pollutant loads, and various design and sizing alternatives for treatment systems in large-scale operations.

Pre-treatment: Grit removal

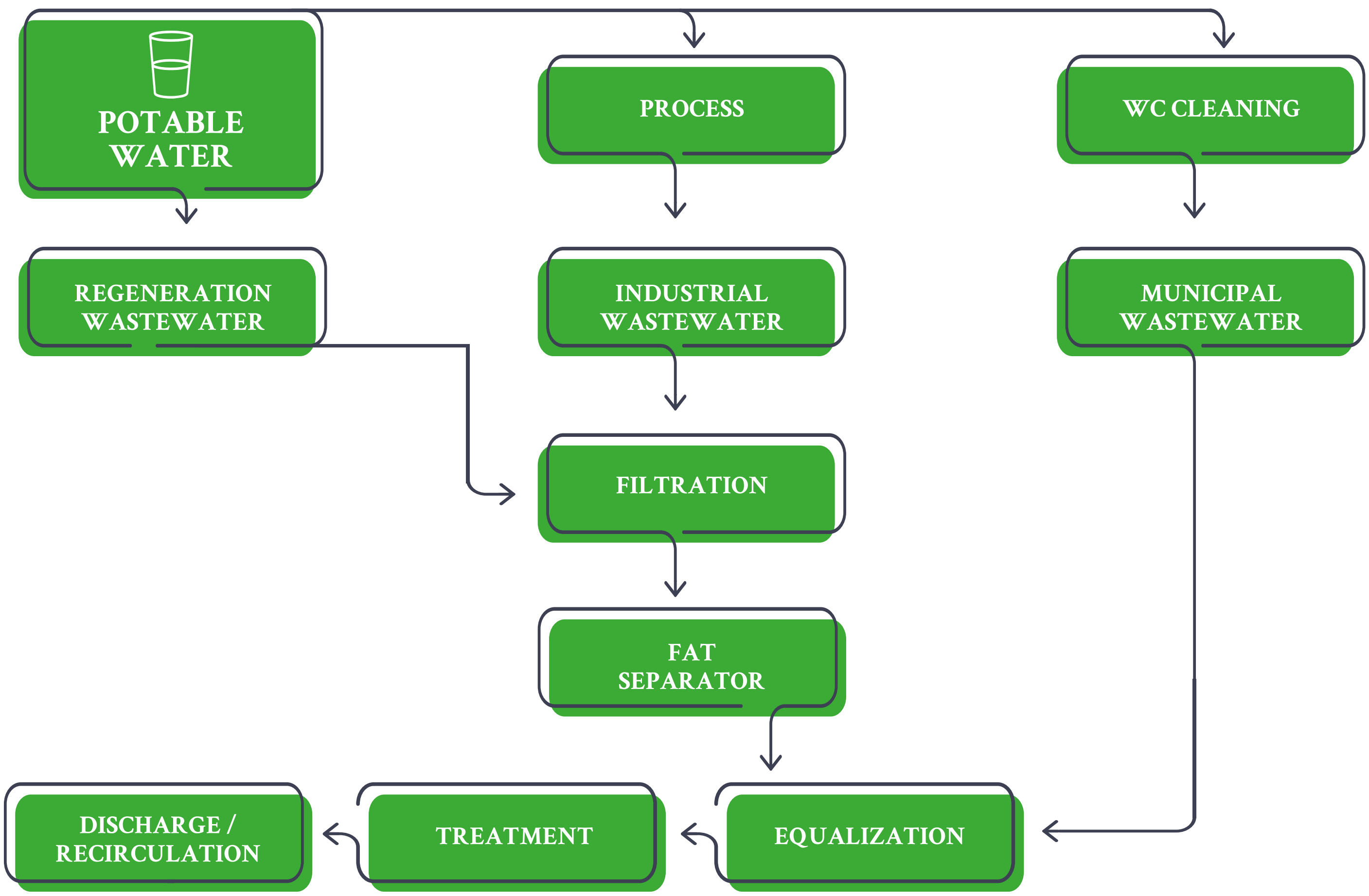
Industrial wastewater treatment technology should meet the following requirements:

- Simple maintenance requirements.
- Minimal implementation and operating costs, including energy consumption, electromechanical components, and chemical reagents.
- Simple sludge management.
- Robust systems. Ability to self-regulate flow and load.
- Environmental integration.

Discharge parameters are highly variable, with COD values ranging from 600 to 35,000 mg/L, and suspended solids ranging from 200 to 5,000 mg/L.

## Figure 2: Example of a Flow Diagram of Water Circulation in the Different Slaughterhouse Processes

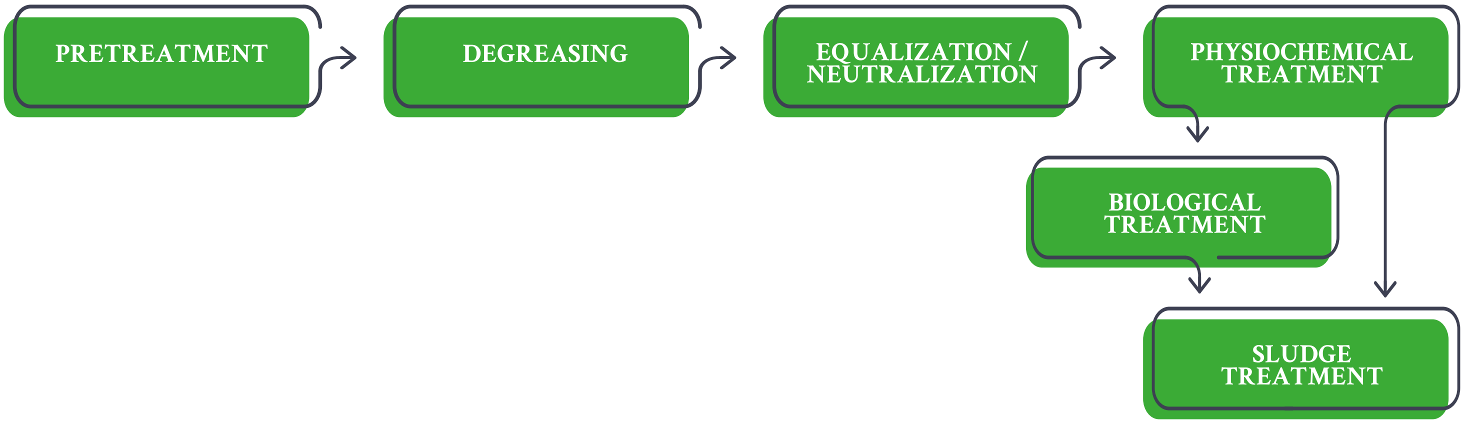
Source: Guía práctica para la depuración de aguas residuales en la industria alimentaria.




Basic treatment systems that adapt to the general characteristics of slaughterhouse wastewater can be considered. These can serve as a guide for each facility to develop the most suitable systems for its specific discharge.

Biological reactor treatment plant of a cattle slaughterhouse

## Figure 3: Basic Wastewater Treatment Operations in Slaughterhouses




The most common and advantageous wastewater treatments for the slaughterhouse sector are detailed in Appendix V: Specific Wastewater Treatments.

# 5 Sewage Sludge Management

Sludge treatment tank and dewatering system

**After wastewater has been purified—whether by physicochemical or biological means—the sludge generated during the purification stages must be treated and managed quickly to avoid foul odors. Various types of sludge treatment are available: thickening, stabilization, and dehydration.**

**Thickening:** The function of thickening is to reduce the volume of sludge by eliminating water and thus increasing solid concentration. This treatment increases the efficiency and optimizes the cost of subsequent processes. Several thickening processes are available. The choice of process and the availability of implementation space will influence the design and construction of the equipment. Gravity and flotation systems are the most frequently used.

**Stabilization:** Various sludge stabilization processes exist, grouped primarily into chemical and biological processes. The main objective is reducing organic matter to reduce pathogens and odors, and reduce or eliminate the putrefaction capacity of the organic matter.

**Conditioning:** Gelatinous sludge can hinder drying operations. In these cases, prior conditioning is performed to improve the sludge characteristics for dehydration. The most frequently used methods are chemical and thermal conditioning.

**Dewatering:** Dewatering is a physical operation (natural or mechanical) which reduces the moisture content and volume of the sludge. Its main objectives are to increase the dry matter content by 30-40%, improve handling and transport, and reduce costs by reducing the transported volume. The most common mechanical dewatering systems are centrifuges, filter presses, and belt filters, each with advantages depending on the sludge characteristics.

Wastewater sludge is classified as primary, secondary (biological), mixed, or tertiary (chemical or physicochemical), depending on the treatment stage from which it originates. The final destination of the sludge depends on its quality, which is determined by the type of industry and pollutants present. Sludge management must always comply with environmental regulations.

According to the 2008-2015 **National Sludge Plan**, Spain generates approximately 1.135 million tons of WWTP sludge yearly. **The majority of national sludge (82%) is recovered for agricultural use.** While landfill disposal has decreased to just 7%, energy recovery is on the rise, currently accounting for approximately 6% of sludge treatment. The remaining 5% undergoes various other treatments.

**Agricultural application remains the predominant disposal route for sludge generated by slaughterhouses and cutting rooms.**

Sludge can be recovered and reused for agricultural purposes, serving as a soil corrector and organic fertilizer, provided it undergoes adequate treatment. This can be done through:

## Agricultural Recovery Through Direct Application on The Land

This method facilitates soil fertilization and organic amendment by connecting sludge managers with farmers who utilize it as fertilizer. To ensure proper tracking and management, a National Sludge Registry has been established, containing comprehensive information about treatment facilities, managers, and application sites. However, the process of identifying, assessing, and registering suitable land with the relevant authorities presents a challenge.

## Agricultural Recovery After Composting

This biological stabilization method decomposes and stabilizes organic matter within the sludge under controlled, aerobic conditions. This process yields a stable, pathogen-free product suitable for use as an organic fertilizer. Benefits include a high-quality agricultural product and responsible management of wastewater treatment plant waste.

This method adheres to the regulations outlined in:

- Royal Decree 1310/1990, of 29 October, regulating the use of sewage sludge in the agricultural sector;
- Order AAA/1072/2013, of 7 June, governing sewage sludge use in agriculture;
- Gas line legislation.

**Biogas,** a fuel produced through the anaerobic digestion of wastewater and biological sludge, is primarily used for generating electricity and heat in engines or boilers.

When constructing biogas lines (including pipes, bolts, and instrumentation), strict adherence to safety legislation is critical to avoid ATEX zones (explosive atmospheres).

Biogas can potentially provide 50–100% of a facility's energy needs, serving the dual purpose of generating electricity and utilizing the engine's exhaust gases for heat. However, sludge must reach nearly 50% dryness to be combustible.

The economic viability of biogas production depends on factors such as industry size and type, and requires careful analysis of electricity production potential and market conditions. Initial implementation and operating costs can be significant. Additionally, biogas requires cleaning before use to minimize equipment corrosion and maintenance issues.

**Cogeneration, which maximizes energy recovery from anaerobic digestion, is economically viable when there is substantial biogas production.**

# 6

# The Future of Refrigerant Gases

The increasing global demand for refrigeration, particularly in developing nations experiencing rapid middle-class growth and warm climates, has led to a significant rise in atmospheric HFC emissions in recent years.

**Enacted on January 1, 2015, the F-Gas regulation (Regulation 517/2014) aims to progressively reduce emissions by controlling the use of fluorinated greenhouse gases. These gases will be phased out and replaced by alternatives with a lower global warming potential (GWP) before 2030.**

A national **tax on fluorinated gases** (article 5 of Law 16/2013), in effect since January 1, 2014, has further encouraged the search for alternative solutions.

The ideal refrigerant should possess the following characteristics:

- A freezing point below the operating temperature of the system;
- High density to enable the use of smaller liquid lines;
- A high latent heat of vaporization, maximizing heat absorption with minimal refrigerant;
- Non-flammable, non-toxic, and non-corrosive, with low electrical conductivity;
- Minimal specific volume to minimize the size of suction and compression lines.

Appendix VI, Refrigerant Gases, provides a comprehensive analysis of commonly used refrigerants and potential alternatives. Among the most widely adopted and efficient alternatives are **R-717 (Ammonia) and R-744 ($CO_2$).**

**As of 2020, regulations prohibit the installation of new systems using refrigerants with a Global Warming Potential (GWP) exceeding 2500. And, since 2022, refrigerants used in centralized direct expansion systems over 40kW must have a GWP below 150.**

# 7 Recommendations

Directive 96/61/EC was incorporated into Spanish law through Law 16/2002 of 1 July, on integrated pollution prevention and control. This law, later consolidated by Royal Legislative Decree 1/2016, aims to prevent and reduce pollution of air, water and soil through a preventative approach to environmental protection. To this effect, **the law established integrated environmental authorization as a new form of administrative intervention to replace and consolidate the various environmental authorizations previously required for implementing good practices.**

Article 3 of Title 1 defines "Best Available Techniques (BAT)" as the most effective and advanced stage in the development of industrial activities and operating methods. These techniques serve as the basis for emission limits and other permit conditions, designed to prevent or, when not feasible, minimize emissions and their impact on the environment and human health.

This section outlines recommended best practices for minimizing the meat industry's environmental impact. The recommendations prioritize water conservation, wastewater reduction, and energy efficiency. These sustainable practices benefit both the environment and businesses by lowering operational costs and optimizing processes. Further information on these recommendations can be found in several resources, including: the European Commission Joint Research Centre's BREF document (Best Available Techniques (BAT) Reference Document for Slaughterhouse, Animal By-Product and Edible Co-Product Industries), the BAT guide for the meat sector, and the Manual of Good Practices and Environmental Sustainability for the agrifood sector.

**Numerous best practices can be adopted by the meat industry. The most appropriate practices will vary depending on the specific circumstances of each company, including available resources and environmental challenges.**

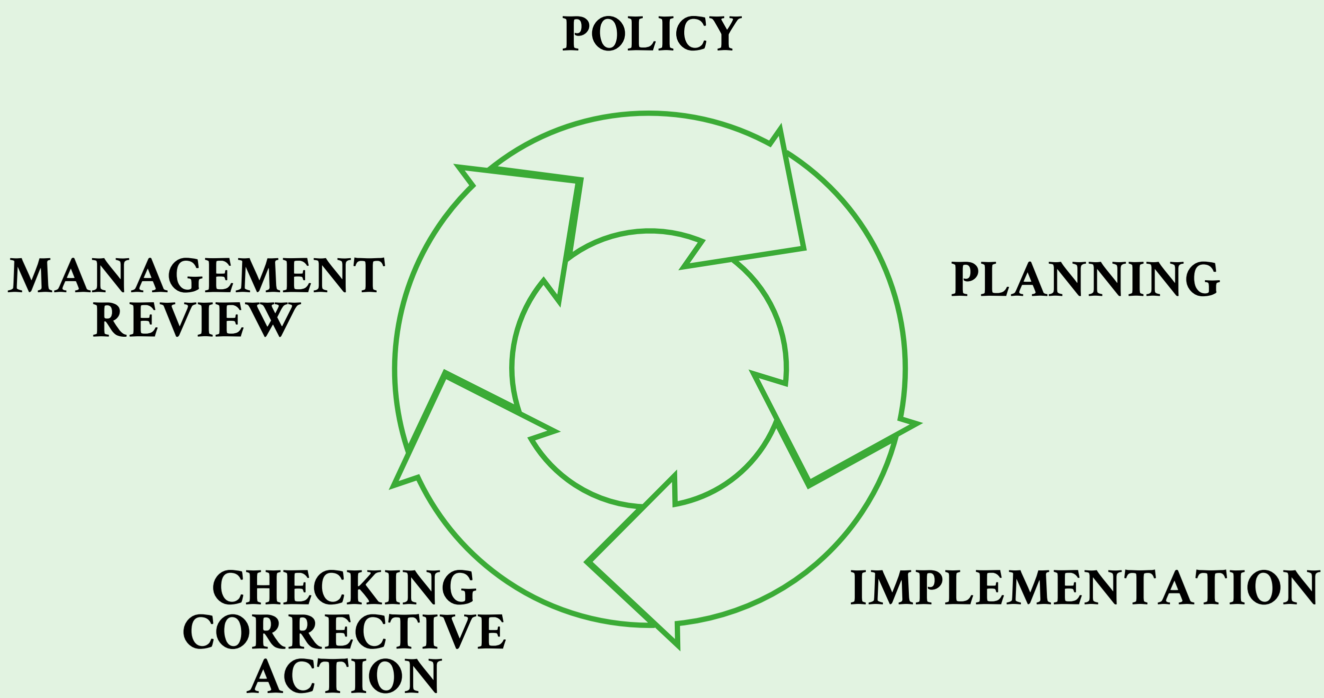
# Implementing an Environmental Management System

**An environmental management system (EMS) provides facility operators with a systematic and verifiable approach to addressing environmental issues.** For optimal effectiveness, an EMS should be an integral component of a facility's overall management and operational framework.

An EMS prioritizes a facility's environmental performance through clear operating procedures for all conditions and well-defined lines of responsibility. Effective EMSs are built on the principle of continuous improvement, recognizing that environmental management is an ongoing commitment, rather than a finite project. While various process designs exist, **most EMSs utilize the plan-do-check-act (PDCA) cycle**, a common framework widely used in business management. The PDCA cycle provides a dynamic and iterative model for continuous improvement, where the completion of one cycle leads directly into the next.

## Figure 4: Continuous Improvement Model for Environmental Management Systems

Source: BREF



An EMS can be based on a standardized framework or customized to suit specific needs. **Adhering to an internationally recognized standard like EN ISO 14001:2015** enhances the credibility of the EMS, particularly when validated through external verification. The European Union's Eco-Management and Audit Scheme (EMAS) under Regulation (EC) No 1221/2009 provides further credibility through public transparency (environmental statements) and a robust framework for ensuring compliance with environmental laws. However, non-standardized (customized) systems can be equally effective, provided they are properly designed and implemented.

An effective environmental management system (EMS) is characterized by the following:

- Strong commitment and leadership from all levels of management, including senior leadership, to drive successful implementation;
- A comprehensive analysis of the organization's context, including stakeholder needs and expectations, potential environmental and health risks associated with the facility, and all applicable legal requirements;
- Clearly defined environmental requirements;
- A robust environmental policy that prioritizes continuous improvement of the facility's environmental performance;
- **Clear objectives and performance indicators for key environmental aspects, with an emphasis on ensuring compliance with all applicable legal requirements;**
- A proactive approach to planning and implementing procedures and actions, including corrective and preventive measures, to achieve environmental objectives and mitigate risks;
- Clearly defined roles, responsibilities, and organizational structures related to environmental aspects and objectives, supported by adequate financial and human resources;
- Ensuring that personnel whose work impacts environmental performance possess the necessary competence and awareness through appropriate information and training programs;
- Effective internal and external communication strategies;

- Actively promoting employee engagement and participation in sound environmental management practices;
- A comprehensive management manual and documented procedures to control activities with significant environmental impact, along with meticulous record-keeping;
- Effective operational planning and process control;
- **Implementation of robust maintenance programs;**
- **Implementation of a comprehensive energy efficiency plan, including regular energy audits** (further details in section 8.4.5);
- Robust emergency preparedness and response protocols, including comprehensive measures to prevent and mitigate adverse environmental impacts;
- Integrating environmental considerations throughout the lifecycle of a new or updated facility, from design and construction to operation, maintenance and eventual decommissioning;
- **Implementing a comprehensive monitoring and measurement program, as needed (refer to the reference report on monitoring air and water emissions from IED installations for further guidance);**
- Regularly benchmarking environmental performance against industry best practices;
- **Conducting regular independent internal and external audits to assess environmental performance and ensure the EMS aligns with planned arrangements and is effectively implemented and maintained;**
- Thorough investigation of non-conformities, implementation of effective corrective actions, and ongoing review to prevent recurrence and identify potential similar issues;
- Regular review of the EMS by senior management to ensure its continued suitability, adequacy and effectiveness;
- Ongoing commitment to developing and implementing cleaner technologies and practices.

## Resulting environmental benefits:

An EMS promotes and supports continuous improvement of a facility's environmental performance. If a facility already demonstrates strong environmental performance, an EMS helps maintain that high standard.

Cleaning and disinfecting operations

# Water Consumption and Wastewater Generation

## Cleaning

Efficient water use starts with implementing good cleaning practices. Cleaning processes should consider water and energy consumption, as well as the use of cleaning products.

The following recommendations promote efficient cleaning practices:

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Monitor water consumption by area.** Installing smart meters helps monitor water consumption. Smart meters can alert users to potential issues or anomalies in the water supply, such as leaks, by identifying unusual spikes in consumption. Monitoring consumption also helps assess water usage across different production phases. | Better water control and reduced water consumption. |
| **Begin cleaning operations immediately after production processes conclude, while residue is still soft.** | Reduced water consumption. |
| **Remove as much solid waste as possible with dry cleaning methods before proceeding to wet cleaning.** | Lower overall usage and reduced organic matter residue, resulting in less wastewater and lower Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) levels. Increased potential for recovering and recycling valuable by-products. Reduced energy consumption for heating water. Reduced detergent use. |
| **Use cold water instead of hot water for pre-cleaning in areas where blood and meat juice are the primary by-products.** In areas with blood and meat juice, initial pre-cleaning can be performed with cold water. Hot water causes blood to coagulate and adhere to surfaces. Hot water should be reserved for areas with fatty residue. | Reduced energy consumption by eliminating the need to heat water for initial rinsing and subsequent cleaning, which is often required when materials adhere to surfaces. Reduced detergent use and detergent contamination in wastewater. |


Knife and glove washer

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Apply hot, pressurized water to the surface being cleaned.** Cleaning effectiveness doubles for every 10ºC increase in temperature. | Optimized cleaning with high-pressure hoses depending on water flow and pressure. High-pressure cleaning can reduce water consumption by up to 75%, thus reducing the volume of wastewater requiring treatment. This also reduces the energy required to heat cleaning water. |
| **Utilize hoses equipped with small-diameter nozzles and on/off valves.** | Reduced water and energy consumption. Reduced wastewater volume. |
| **After foaming and while residue is still soft, rinse surfaces with water at medium pressure.** | Reduced water consumption. |
| **Utilize presence detectors in intermittent washing processes.** | Reduced water consumption. |
| **Separate cooling water (used in cooling processes) from process and wash water, and recirculate the cooling water.** | Reduced water consumption. |
| **Eliminate unnecessary water outlets along the slaughter line.** | Reduced water consumption. |

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Utilize advanced cleaning systems for utensils and small equipment.** Using automatic cleaning equipment reduces water consumption and the use of cleaning/disinfection products compared to traditional methods. This is because automatic systems allow for higher pressure application and recirculation of cleaning solutions. Examples include washing tunnels, cabinet washers, and wash booths. | Reduced cleaning agent and detergent consumption. |
| **Select cleaning agents with a lower environmental impact.** | Reduced cleaning agent and detergent consumption.<br>Minimized risk of groundwater contamination in the surrounding area due to infiltration of contaminated runoff. |

## RECOMMENDED ACTIONS

**Peracetic acid is the most suitable replacement for hypochlorites due to lower organohalogenated compound production and high degradability.** Peracetic acid decomposes into harmless acetic acid, oxygen, and water. Peracetic acid-based products are also less corrosive to metals than hypochlorite, making them ideal for disinfecting metal surfaces. The primary human health hazard is direct exposure, as peracetic acid corrosive.

Although quaternary ammonium compounds are also effective disinfectants for domestic and professional use, there is limited reliable evidence regarding their toxicity. Minimize their use, as they can be harmful to the environment and human health.

**Ozone (O3)** in aqueous solution can destroy pathogen cell membranes by oxidizing phospholipids and lipoproteins, and rapidly decomposes into harmless oxygen. Ozone is effective against a wide range of microbes, including bacteria, yeasts, molds, viruses, and spores. **Using ozone-rich water in Clean-in-Place (CIP) and other cleaning processes offers advantages over traditional disinfectants: it leaves no residue and is applied cold. This reduces the water volume needed to rinse detergents and the associated energy consumption from water heating. Ozone can also be used in dry environments.**

**Using products with an EU Ecolabel demonstrates a voluntary commitment to environmental sustainability.** Independent experts evaluate EU Ecolabel products from raw materials to production, packaging, distribution, and disposal to ensure they meet criteria that reduce environmental impact. Detergents meeting European Ecolabel criteria are easily biodegradable and non-toxic to the environment.

Chemical product storage

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Monitor and record the consumption of cleaning agents.**<br><br>**Ensure proper storage of cleaning products.** | Reduced water and detergent consumption. |

## RECOMMENDED ACTIONS

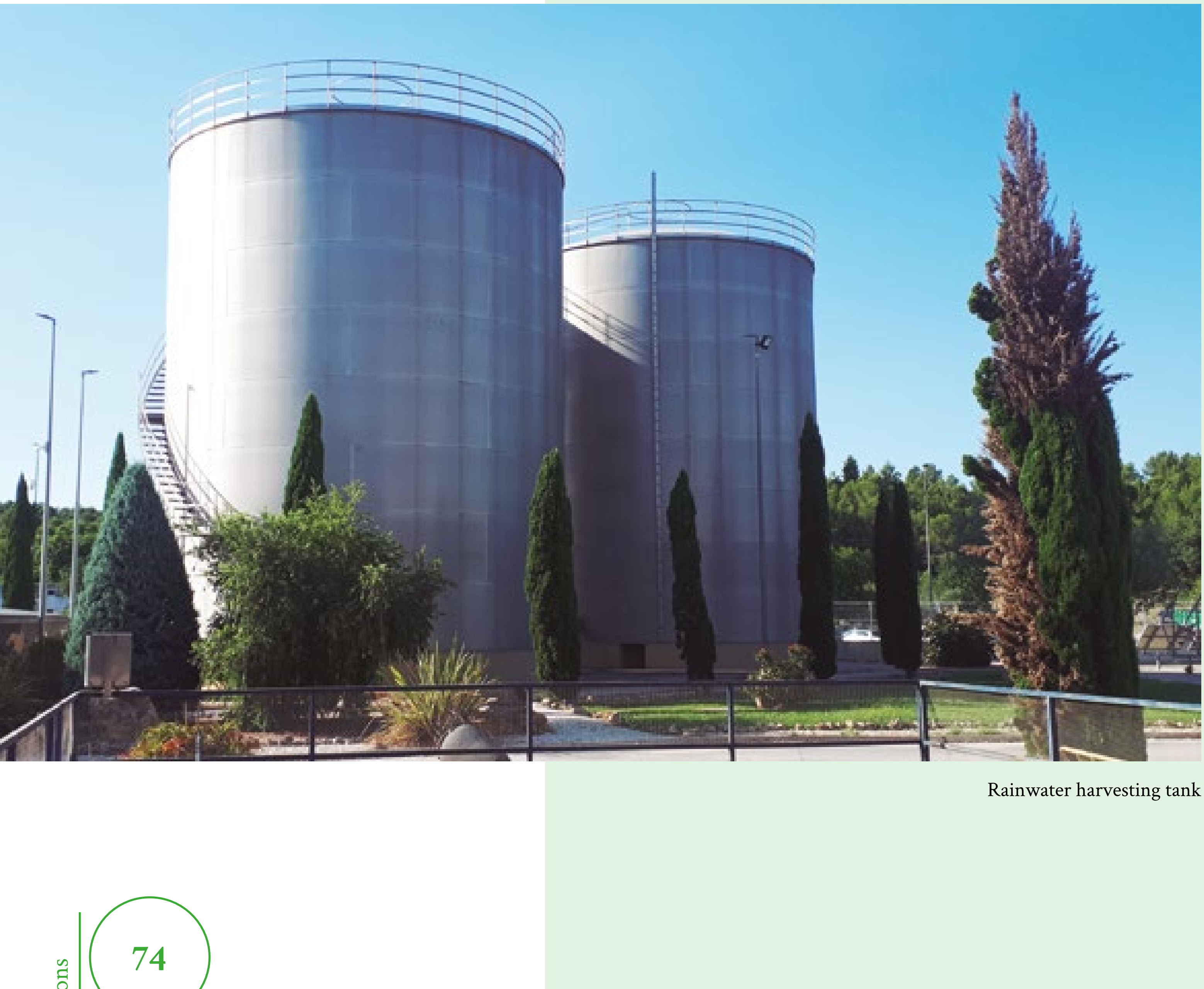
Use cleaning products in the quantities recommended by the manufacturer. Using higher doses than recommended does not guarantee better cleaning and increases the pollutant load of wastewater, in addition to wasting raw material.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Install hand and apron washing systems with automatic water cut-off.** | Reduced water and energy consumption. |

## RECOMMENDED ACTIONS

Water supply is controlled automatically by foot pedal or presence detectors.

Foot-operated handwashing station



Rainwater harvesting tank

## Reducing Wastewater Volume and Contamination

Implement the following practices to reduce wastewater volume and contamination:

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Establish a separate network for rainwater collection.** | Collecting rainwater in the wastewater network significantly increases the volume of water requiring treatment and unnecessarily treats clean rainwater. |

| RECOMMENDED ACTIONS |
| --- |
| Install a network of gutters on roofs to collect rainwater and divert it to a storage tank. This collected rainwater can then be used for purposes such as irrigation, washing, and facility cleaning.<br><br>Design the drainage system to separate wastewater into different categories: rainwater, cooling water, truck and stable cleaning water (where filtered manure can be used for biogas production and composting), and water from production processes. This separation is only feasible in new facilities due to the impact on pipeline design. |

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Prevent organic solids from entering wastewater.** | Reduced water consumption and wastewater pollution. |

## RECOMMENDED ACTIONS

Implement dry cleaning of machinery and floor waste before wet cleaning to reduce pollutants in wastewater. Throughout the process, prevent solid waste from entering wastewater. **Use trays and other utensils in waste generation areas. Prevent liquid product loss by ensuring machinery, channels, tables, and barriers are properly sealed.**

**During intermediate washes, separate large debris before washing using compressed air or vibration equipment without water.**

**Install manholes and separating grids in drains at the most polluting stages** (washing, cutting, etc.) to capture fats and organic fragments, reducing their concentration in wastewater. Ensure the design prevents clogging and allows for easy daily cleaning.

This measure can reduce water consumption by up to 25%, detergent consumption by up to 65%, and labor hours dedicated to cleaning. It also reduces COD, BOD, fats, suspended solids, and energy used for water heating.

Grating for collecting solid waste

Sticking and bleeding

Blood pump

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Optimize bleeding and blood collection processes.** | Liquid blood has a high pollutant load, with a Chemical Oxygen Demand (COD) of approximately 400 g/l and a Biological Oxygen Demand (BOD) of approximately 200 g/l. Therefore, blood containment is crucial for environmental control in slaughterhouses. Blood spills are among the most environmentally damaging accidents that can occur in a slaughterhouse. |

## RECOMMENDED ACTIONS

Blood has a high organic pollutant load, making proper collection, storage, and management critical from an environmental perspective. **A bleeding time of more than 7 minutes is recommended for cattle.**

Some slaughterhouses have installed additional blood collectors at other points in the process, such as the hind leg skinning platform.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Implement overflow protection for bulk storage tanks (e.g., those containing blood or tallow).** | Reduced risk of accidental overflows, which can cause significant environmental damage. For example, a blood overflow can massively increase wastewater COD and potentially overwhelm on-site or municipal treatment systems. |

## RECOMMENDED ACTIONS

Install level detection devices to automatically monitor liquid levels in tanks. These devices provide audible and visual warnings when tanks are nearing capacity and can automatically stop filling (e.g., by stopping the pump or diverting the flow) if no action is taken.

Secondary containment systems, such as bunds, can also be installed. Bunds are retaining walls around the tank, designed to hold at least 110% of the tank's volume. They must be structurally sound and impermeable to prevent leaks.


Blood storage tank

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Replace hydraulic transport of by-products with mechanical or pneumatic systems.** | Reduced water consumption and wastewater generation. |

## RECOMMENDED ACTIONS

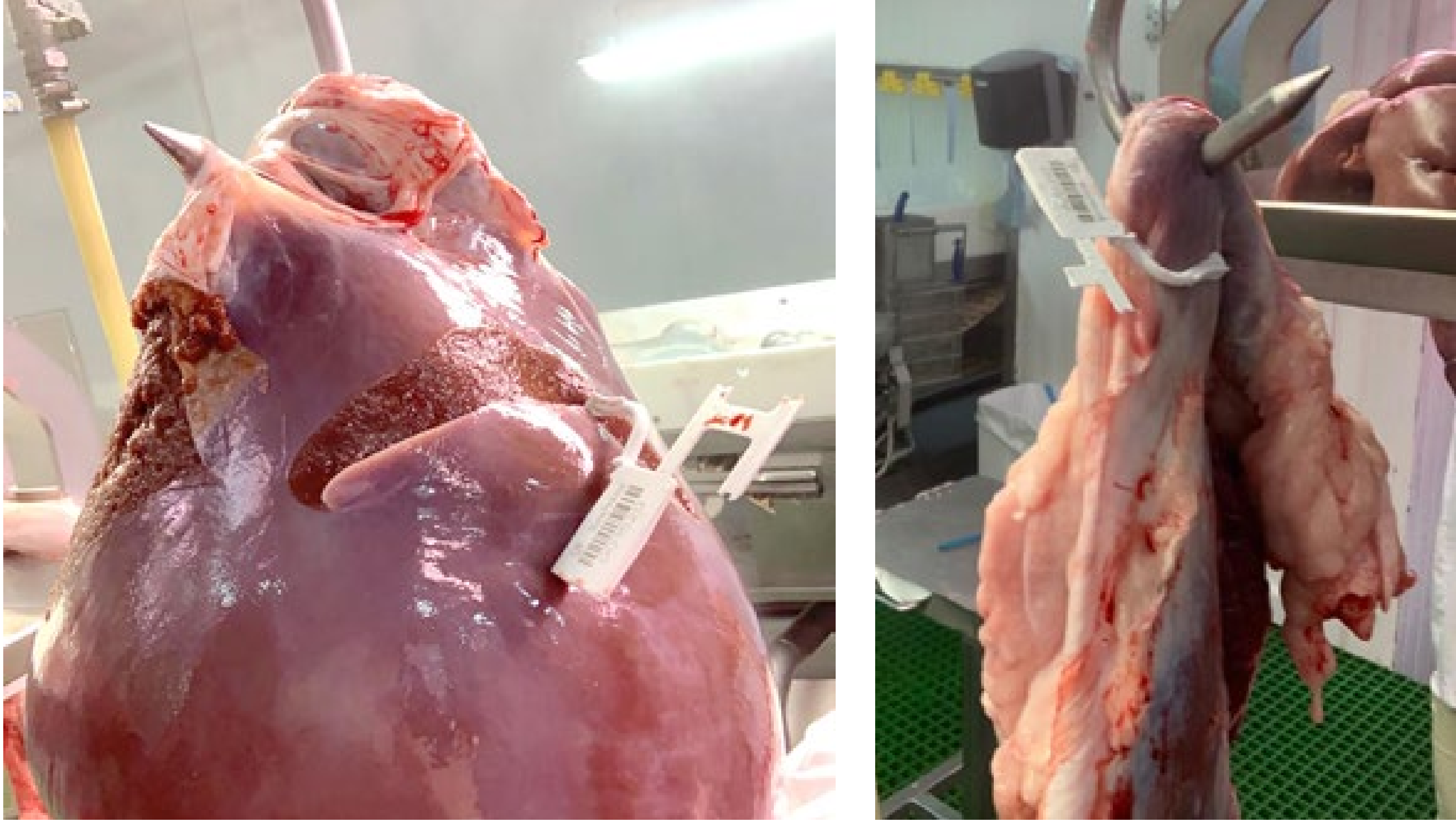
Replacing hydraulic transport systems (which use water) with dry systems (mechanical or pneumatic) to transport meat by-products within the facility prevents the generation of contaminated transport water. Hydraulic systems create wastewater with a high degree of organic contamination (blood, solids, fats, hair) due to the transfer of these materials from the by-products to the water. Dry transport systems also improve the sanitary conditions of by-products by reducing the risk of microbiological contamination from transport water and maintaining a lower moisture content.

Carcass washing

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Install presence detectors in line showers.** | Reduced water consumption and wastewater generation. |

## RECOMMENDED ACTIONS

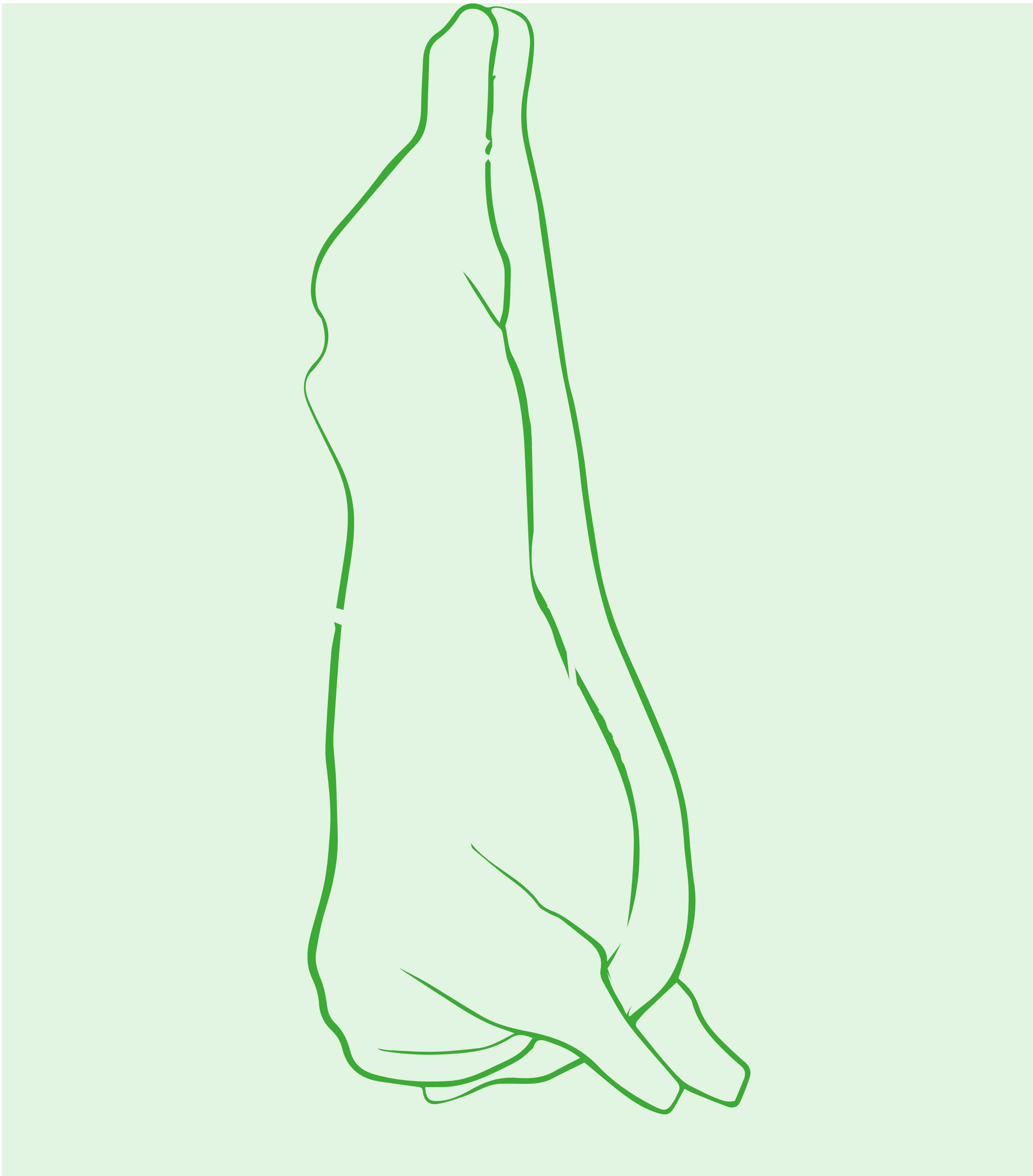
Install presence detectors in showers used for washing animals, carcasses, or cuts on continuous lines. The detectors activate solenoid valves, ensuring water is only dispensed when material is present. Different types of presence detectors can be used, including contact sensors, photoelectric cells, and ultrasonic detectors. Using efficient shower heads with spray nozzles further reduces water use.



Beef offal

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Avoid or minimize carcass rinsing by using clean evisceration techniques.** | Reduced water consumption and wastewater generation. |

| RECOMMENDED ACTIONS |
|---|
| Carcass washing in the evisceration area is generally unnecessary unless contamination from damaged viscera occurs. |



# Waste Management

Effective waste minimization and management are crucial. Consider the following recommendations to improve these aspects:

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Implement robust raw material stock control.** | Prevent waste generated by expiration. |
| **Control packaging and utilize bulk purchasing.** | Minimize waste. |
| **Implement selective collection of non-hazardous waste.** | Minimize waste. |
| **Improve the management of by-products and Animal By-Products (ABP).** | Reduce waste generation and recover ABP for other uses. |

## RECOMMENDED ACTIONS

**By-Product Recovery:** Some slaughterhouse waste can be recovered and used as by-products, generating additional revenue streams. One example is the blood resulting from livestock bleeding.

Proper blood collection during the bleeding stage allows for its use in various applications:

- Direct use in the meat industry without prior treatment.
- Use in food flours and the pharmaceutical industry after appropriate pre-treatment.

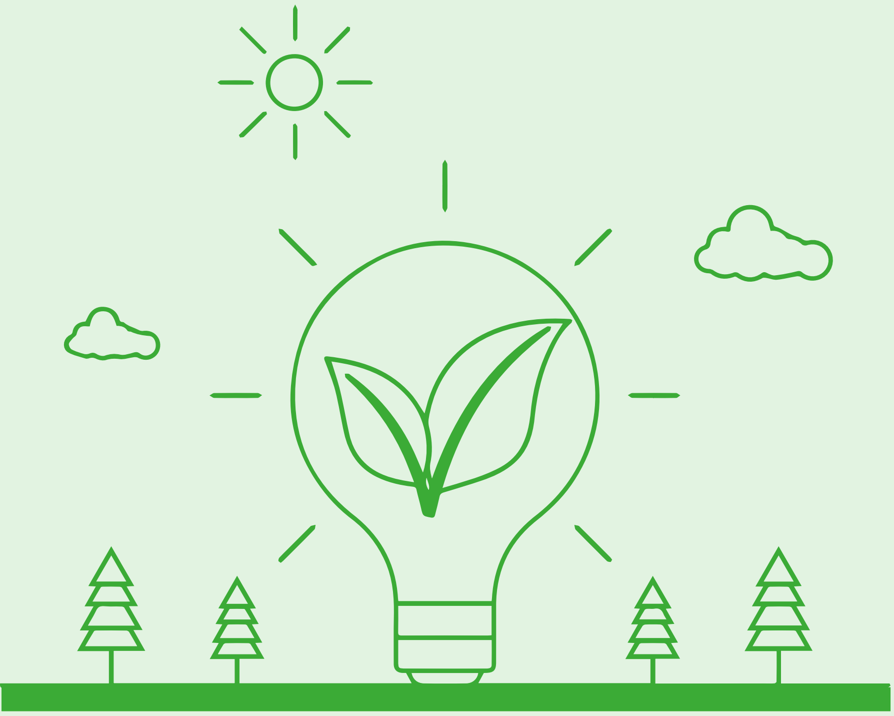
**The evisceration stage generates the majority of by-products, which, for commercial and/or social reasons, are often categorized as ABP despite their potential value.**

Prior selection and separation of these by-products enables recovery for diverse applications.

Potential uses include exploring new markets and extracting products for the chemical and pharmaceutical industries.

**While the head is generally considered SRM, cartilaginous materials like ears and snouts can be separated for the extraction of collagen, hyaluronic acid, and chondroitin sulfate.**

**Leg bones can be processed into bone meal for animal feed. They can also be used in composting tanks as part of the biomass used to produce biofuels and biogas through co-digestion and fermentation.**



# Electrical and Thermal Energy Consumption

**One of the most significant inefficiencies in the sector in the area of energy consumption is the improper sizing of equipment or process lines. This often leads to equipment running and consuming energy during inactive work periods. Thoroughly analyze the process under real-world conditions to match estimated production for each period with actual equipment capacity.**

The following factors are key to achieving greater energy efficiency: efficient motors and automation, energy management, refrigeration systems, compressors, boiler upgrades, pipe insulation, Combined Heat and Power (CHP) systems, and solar photovoltaic energy.

## Heat Generation Systems

Boilers are essential components in various industrial processes. Selecting the appropriate system is crucial for ensuring optimal energy efficiency and providing water or steam under the required conditions.

A boiler is a heat exchanger where energy is typically supplied by combustion or from the heat contained in a circulating gas.

This heat is transferred to a fluid, usually water, which may or may not vaporize depending on the design temperature and pressure. The heated fluid is then transported to consuming equipment where the energy is used. Boilers are classified as water-tube or fire-tube depending on the flow path of the combustion gases and water.

Slaughterhouses typically use low-power, low-pressure fire-tube boilers. Common fuels include diesel, natural gas, and propane. Fuel composition is critical for determining combustion characteristics and predicting potential emissions of harmful pollutants.

The sulfur content in most fuels results in the emission of sulfur oxides (SOx) during combustion. Sulfur dioxide combines with atmospheric particles or moisture to form sulfuric acid, contributing to acid rain, which harms forests and wildlife and acidifies surface water.

Natural gas and liquefied petroleum gases (propane and butane) are sulfur-free, while heating oil (Diesel C) has a regulated maximum sulfur content of 1,000 mg/kg (1%).

Common boiler defects that reduce energy efficiency and increase energy costs include:

- Insufficient combustion control;
- Inadequate feed water treatment;
- Increased system purging;
- Insufficient and unscheduled cleaning.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Upgrade boilers with new technology.** | Increased energy efficiency and reduced $CO_2$ emissions. |

## RECOMMENDED ACTIONS

Upgrading boilers with new technologies improves efficiency and provides environmental benefits. Modernizing combustion systems can significantly reduce emissions. Installing heat recovery systems allows for the transfer of heat from combustion gases to other fluids in the thermodynamic cycle, such as feed water or combustion air. **This heat recovery provides significant energy savings, resulting in a tangible reduction in fuel consumption and $CO_2$ emissions.**

## RECOMMENDED ACTIONS

○ **Biomass boilers:**

Heat can also be produced using renewable fuels such as solid biomass, saving energy and reducing $CO_2$ emissions. Biomass boilers can utilize industrial waste and agricultural by-products such as olive pits, cereal straw, almond shells, and wood chips. Furthermore, using biomass does not necessitate replacing the entire boiler; often, only the burner needs to be replaced.

Replacing burners that use fossil fuels (like natural gas or diesel) with biomass burners can be applied to boilers producing hot water or steam, as well as other burner applications such as industrial furnaces, boilers, and dryers. Replacing burners aims to reduce fossil fuel consumption and lower energy costs. Pollutant emissions are significantly lower compared to direct biomass combustion.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Implement heat recovery from exhaust gases.** | Increased energy efficiency. |

## RECOMMENDED ACTIONS

One common method for increasing efficiency is to use an economizer to heat the incoming water. Economizers utilize the heat from exhaust gases to preheat incoming water, increasing energy efficiency and reducing losses.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Implement boiler blowdown control measures.** These include pretreating water, maximizing condensate recovery, using automated blowdown control systems, and flashing blowdown at medium or low pressure. | Reduced water consumption and wastewater generation. |

## RECOMMENDED ACTIONS

Boiler blowdown limits the buildup of salts (e.g., chlorides, alkalis, and silicic acid) in the boiler water, keeping these parameters within prescribed limits. It also removes sludge deposits (e.g., calcium phosphates) and corrosion products (e.g., ferric oxides) from the boiler, maintaining water clarity. Wastewater is discharged from the boiler at high pressure and temperature, either intermittently or continuously. This results in energy loss due to the discharge of hot water. Therefore, minimizing blowdown is essential.

**Reducing blowdown volume by 10% at a steam pressure of 10 bar can achieve fuel savings of 2.1%.**

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Insulate pipes and valves throughout the facility. Insulate scalding tanks in pig slaughterhouses.** | Increased energy efficiency. |

## RECOMMENDED ACTIONS

Potential energy savings depends on factors such as pipe length and diameter (or surface area to be insulated), internal and external temperatures, and the conductivity and thickness of the insulating material. This measure can achieve significant energy savings at a low cost, reducing convection and radiation losses by over 90%.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Implement automatic hot water temperature control.** | Increased energy efficiency. |

## RECOMMENDED ACTIONS

Slaughterhouses have varying hot water temperature requirements. For example, sterilization requires water at 82°C, while cleaning requires a lower temperature of 60°C. Often, water continues to be heated to 82°C even after slaughter operations (requiring the higher temperature) are completed, resulting in unnecessary energy consumption.

**Automatically stopping water heating to 82°C once slaughter operations are finished can be achieved with minimal investment.**

Lower water temperatures facilitate the removal of fats from the drainage system, reducing wastewater contamination. However, this may require increased detergent use.

Individual knife sterilizing station

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Insulate knife sterilizers and consider alternative sterilization technologies.** | Increased energy efficiency. |

## RECOMMENDED ACTIONS

Uninsulated knife sterilizers with constantly running water consume approximately 2,000 liters of water per day. Insulating and covering the sterilizer reduces heat loss, decreasing the required water renewal frequency and hot water consumption. Using 20 mm thick insulation reduces heat loss by 80% compared to an uninsulated sterilizer without a lid.

Replacing water sterilizers with low-pressure steam sterilizers significantly reduces water and energy consumption, achieving an energy savings of 75%.

The food industry has introduced sterilizers based on alternative technologies, such as ozone and ultraviolet (UV) radiation.

Ozone sterilizers utilize the disinfectant and decontaminant properties of ozone. Ozone has high oxidizing power, effectively eliminating bacteria and viruses.

In UVC sterilizers, the lamp emits ultraviolet rays that act as a germicide by disrupting the microorganism's molecular structure, sterilizing it and preventing reproduction.

Tool sterilization tank

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Sterilize saws in cabinets equipped with hot water nozzles.** | Reduced water consumption. |

| RECOMMENDED ACTIONS |
| --- |
| Sterilize saws in cabinets with hot water nozzles (82°C) instead of using containers with constantly running water at the same temperature. |

## Industrial Refrigeration Systems

Industrial refrigeration facilities utilize various technologies to achieve a specific objective: cooling a defined space.

The design of these systems is primarily based on the following parameters:

- Operating temperature (evaporation and condensation temperatures);
- System capacity, typically measured in kilowatts (kW) and defined by the thermal load;
- Environmentally friendly refrigerants with a broad cooling effect;
- System operating costs.

The refrigeration cycle uses a set of components to absorb heat from the target environment and transfer it to the surroundings through the circulation of a refrigerant fluid, driven by external work.

Most cooling processes utilize mechanical compression refrigeration equipment. System performance depends on operating conditions,

Insulated refrigeration system

making it crucial to optimize these parameters for optimal efficiency.

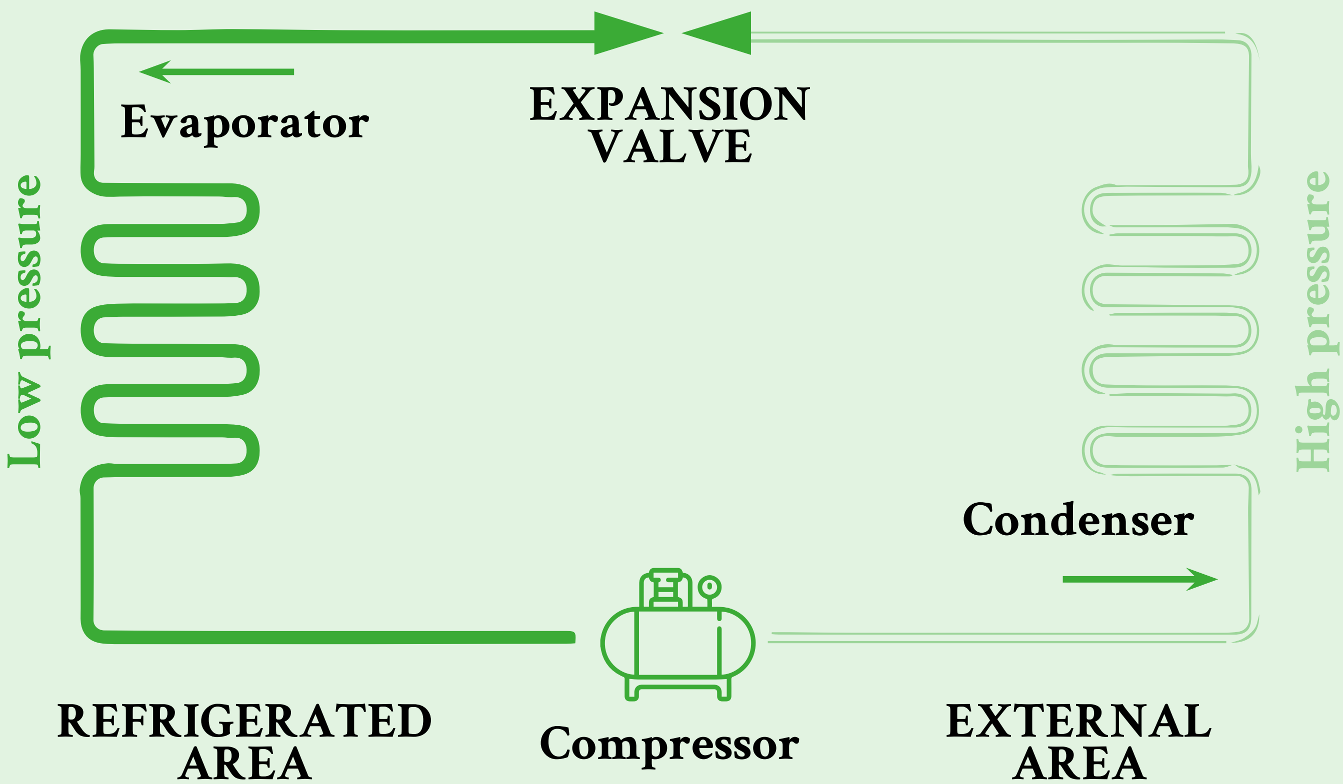
**Complementing these systems with free-cooling, waste energy (condensation heat), and variable speed configurations can further optimize energy consumption (e.g., in pumping) by adjusting equipment operation to real-time demand.**

**A simple refrigeration system consists of the following components: compressor, condenser, evaporator, expansion valve, and various auxiliary elements,** including: shut-off, isolation and check valves, filter driers, sight glasses, liquid receivers, oil separators, siphons, ejectors, etc.

The heat removal capacity of a refrigeration system is measured in watts (W). The heat extraction rate depends on the size and operating conditions of the system.

The system requires energy, usually in the form of electricity, to power the compressor motor, pumps,

Figure 5:
Refrigeration
Cycle



fans, etc. This energy input is also measured in watts. The system achieves optimal efficiency when minimum input power results in maximum heat extraction. The Coefficient of Performance (COP) describes a refrigeration system's efficiency.

COP = Cooling capacity (W) / Total energy input to the system (W).

**Common inefficiencies in cold generation facilities often stem from inadequate maintenance and a lack of control over parameters such as energy consumption relative to equipment power.**

Recommendations for improving refrigeration system efficiency:

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Implement a preventive maintenance program for all system components.** Implementing and monitoring a proper preventive maintenance program for industrial refrigeration systems significantly improves energy savings and extends equipment lifespan. This includes: cleaning equipment, controlling fluid levels, defrosting, adjusting control panels and automation systems, and regulating the installation. | Increased energy efficiency. |
| **Ensure proper insulation of the refrigeration system.** | Increased energy efficiency. |
| **If multiple refrigeration units are present, install them together.** | Increased energy efficiency. |
| **Utilize high-efficiency fans in the condenser and evaporator.** | Increased energy efficiency. |


Closed door of cooling/cold room

## Cold Store

Maintaining the cold chain is essential in slaughterhouses and cutting rooms. Breaches in the cold chain can compromise both product quality and food safety, as well as increase energy consumption.

Refrigeration and freezing chambers have high energy demands. Therefore, minimize cold loss by designing these facilities away from heat sources.

Recommendations for increasing energy efficiency in refrigeration chambers:

Inside the cold room

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Improve cold room insulation.** Consider the following aspects for cool room insulation:<br><br>Ensure wall panel thickness is at least 100 mm for temperatures above 0°C and 200 mm for temperatures below 0°C.<br><br>Insulate the cold room floor effectively using materials with minimal water absorption to prevent condensation. Install a vapor barrier to protect the insulation from moisture that can reduce its effectiveness. Protect the insulation with a covering to prevent accidental damage. | Increased energy efficiency. |
| **Install automatic, fast-opening doors.** | Increased energy efficiency. |
| **Optimize loading and unloading schedules to minimize the frequency of opening cold rooms.** | Increased energy efficiency. |
| **Use insulated containers for transferring products between the cold room and trucks.** | Increased energy efficiency. |
| **Install a conditioning anteroom to prevent the entry of untreated air.** | Increased energy efficiency. |

Refrigeration compressor

## Compressors

Refrigerant compression involves circulating a refrigerant fluid through a closed circuit, operating at two pressure levels (high and low). This process allows the fluid to absorb heat in one area and release it in another. System performance is measured by the Energy Efficiency Ratio (EER) or Coefficient of Performance (COP). **Compressors account for approximately 60-70% of the total energy consumption of a refrigeration system.** Distributing the load among multiple compressors is recommended except in low-power installations.

Auxiliary compressor equipment

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Install variable frequency drives (VFDs).** VFDs are recommended to optimize compressor operation at very low partial loads.<br><br>VFDs are a highly efficient method for regulating refrigeration compressor capacity to match variations in cooling demand. VFDs offer multiple benefits, including:<br><br>- Maintaining more stable temperatures and operating pressures, which reduces energy consumption;<br><br>- Eliminating frequent compressor starts and stops. | Increased energy efficiency. |
| **Utilize high-efficiency motors for compressors.** | Increased energy efficiency. |


Heat recovery system

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Recover heat from refrigeration compressors to provide low-grade heat for other applications (e.g., space heating and domestic hot water).** | Increased energy efficiency. |
| **Carefully consider the selection of accessories:**<br><br>Oil coolers, shut-off and check valves (primarily on the suction side, but also on the discharge side), and filters. Inefficient accessories can lead to a 10% power loss . | Increased energy efficiency. |

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Replace existing compressors with more efficient, variable-capacity models.** | Increased energy efficiency. |
| **Install multi-stage compressors** to generate different pressures, efficiently meeting cooling needs at various temperatures. | Increased energy efficiency. |
| **Implement centralized control for the compressor group.** | Increased energy efficiency. |

Heat recovery status screen


Evaporator

## Expansion Valves

The thermostatic expansion valve (TXV) is a flow control device installed at the evaporator inlet. It regulates refrigerant flow to ensure that only vapor exits the evaporator.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Install electronic expansion valves (EEVs).** EEVs are a product of continuous development toward more efficient components.<br><br>EEVs provide several advantages:<br><br>- Improved superheat control under varying load conditions;<br><br>- Faster response times;<br><br>- Increased evaporator cooling capacity.<br><br>**Because they lack a thermostatic charge, EEVs are compatible with various refrigerants.** | Increased energy efficiency. |

## Evaporators

Evaporators are heat exchangers that transfer heat from the space to be cooled to a refrigerant. Heat always flows from warmer objects to cooler objects. Evaporation occurs during the heat exchange process. Consider the following recommendations:

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Select the optimal number and location of evaporators based on the specific needs of the space.** | Increased energy efficiency. |
| **Prevent ice buildup on the evaporator by performing regular defrost cycles. Defrosting can be time-based or utilize smart defrost systems.** For time-based defrosting, review and adjust defrost intervals at least every three months. | Increased energy efficiency. |
| **Hot gas defrosting is an energy-efficient defrosting technique.** This technique involves diverting high-temperature refrigerant (gas or liquid) from the receiver to the evaporators. The hot gas is introduced into the evaporator, causing it to cool. When using hot gas defrosting in a system where the refrigeration unit only serves the evaporators, defrost a maximum of one-third of the evaporators simultaneously. This ensures sufficient hot gas availability for rapid and effective defrosting. | Increased energy efficiency. |
| **Ensure adequate air throw (the reach of the air stream from each evaporator) to effectively circulate air throughout the space.** | Increased energy efficiency. |

## Condensers

A condenser is a heat exchanger that condenses refrigerant vapor. It transfers heat from the refrigerant vapor (coming from the compressor) to a cooling medium. This causes the refrigerant to cool, condense, and transition from a vapor to a liquid state. The size and surface area of the condenser depend on the amount of refrigerant to be condensed. Various condenser types exist, including air-cooled, water-cooled, adiabatic, and evaporative condensers. While each type has advantages and disadvantages, **evaporative condensers are most effective in reducing electricity costs.**

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Recover heat from the condenser to meet low-temperature thermal demands.** | Increased energy efficiency. |

| RECOMMENDED ACTIONS |
|---|
| The refrigerant condensation temperature in a refrigeration cycle typically exceeds ambient temperature. The heat from the high-pressure side of the refrigeration system can be recovered (fully or partially) to heat a fluid for various applications. The temperature of this heated fluid (typically between 30 and 40°C) can be used to meet low-temperature heating needs, such as space heating, hot water preheating and preheating ventilation air during colder periods. |

### Floating Condensation and Evaporation Systems

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Implement floating condensation and evaporation systems.** | While effectiveness varies depending on the climate and system control capabilities, this measure can yield energy savings of 10-25% with minimal investment. |

## RECOMMENDED ACTIONS

Floating condensation and evaporation systems allow the condensation and evaporation temperatures of a refrigeration circuit to fluctuate freely. These temperatures are not fixed but instead dynamically adjust based on external temperatures and production demands.

This dynamic adjustment allows the system to adjust to outside changes, reducing the temperature difference between the condenser and evaporator at certain times and increasing efficiency and overall system performance.

Implementing floating condensation and evaporation requires a control system with electronic expansion valves (instead of thermostatic valves) and variable frequency drives (VFDs) on the compressor. This setup allows for more efficient adjustment of condensation and evaporation temperatures, ensuring the system meets demand while maintaining an appropriate temperature differential for effective heat exchange.

## Cold Energy Storage Systems

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Utilize cold storage systems.** | Increased energy efficiency. |

| RECOMMENDED ACTIONS |
|---|

Cold storage can be achieved through three primary methods: within the stored product itself, using sensible heat in liquids, or through ice accumulation.

- **Cold storage in the product:** In cold rooms, utilize a lower temperature setpoint during off-peak hours with lower electricity rates. This can involve lowering the temperature by three to four degrees.
- **Cold storage in liquids (sensible heat):** Utilize secondary fluids in indirect refrigeration systems to store cold energy. This primarily provides time for compressors to complete their off cycles.
- **Cold storage with ice:** Ice accumulation systems are beneficial in industrial refrigeration when cooling demands fluctuate significantly throughout the day, with periods of high and low demand. This method involves accumulating energy in the form of ice during off-peak hours and utilizing that stored energy during peak demand periods. The primary goal is to reduce investment in refrigeration equipment by decreasing the required installed capacity. Implementing ice storage can reduce refrigeration costs by up to 30% compared to conventional systems, but requires an initial feasibility study.

## Motors

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Replace old motors with new, high-efficiency models.** | Increased energy efficiency. |

### RECOMMENDED ACTIONS

**Refrigeration facility compressor motors consume 60-70% of the total energy used. Additionally, the lifetime energy cost of running a motor can be up to 100 times the motor's initial purchase price.** Therefore, replacing less efficient motors with more efficient models quickly pays for itself. It is recommended to use high-efficiency motors in the following cases:

- When repairing or replacing old motors;
- In new facilities;
- For motors operating over 4,000 hours per year;
- For motors running at maximum power and constant speed.

Compressor motor

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Install variable frequency drives (VFDs).** | This measure can reduce energy consumption in variable load processes by over 40%. |

## RECOMMENDED ACTIONS

Devices such as pumps, fans, elevators, and conveyor belts operate with variable loads. In these cases, it can be beneficial to adjust motor rotation speed using variable frequency drives to optimize power consumption.

Variable frequency drive

Lighting installation on beef slaughter line

## Horizontal Processes

### Energy Efficient Lighting

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Maximize the use of natural light.** | Increased energy efficiency. |

### RECOMMENDED ACTIONS

To maximize the use of natural light, consider the following design elements:

- Designate areas with the most natural light for workstations, and use darker areas for storage;
- Regularly clean windows, skylights and roof lights;
- Position workstations to take advantage of natural light;
- Use curtains with maximum transparency.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Design the lighting system to allow for easy partial illumination.** | Increased energy efficiency. |

## RECOMMENDED ACTIONS

To optimize energy consumption and lighting control, the lighting system should be designed to allow for easy partial illumination. This can be used to take advantage of natural light or to adjust the number of lights in use as needed.

**Implementing lighting controls reduces energy and maintenance costs while increasing system flexibility.**

These controls allow for selective switching and dimming of lights during different periods or types of activity. Several systems are available, including manual and timed switches, daylight sensors, occupancy sensors, and centralized lighting control systems.

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
|---|---|
| **Use LED lighting technology.** | Experts estimate energy savings of up to 92% compared to incandescent bulbs and 30% compared to fluorescent lights. |

## RECOMMENDED ACTIONS

The main advantages of LED technology include: fast on/off response time, long lifespan, durability, compact size, low heat output, reduced maintenance, and energy savings. The primary disadvantage is the cost of installation.

## Energy Efficiency in Compressed Air Systems

Compressed air systems are found in most industries, where they help to improve productivity by automating and accelerating production.

A compressed air system consists of a compressor station, where the air is properly prepared for use, and a distribution network that transports the compressed air to the point of consumption. The key element of a compressed air system is the compressor, which increases the air pressure for use in various applications.

Consider the following recommendations for improving the efficiency of these systems:

Pneumatic bolt stunner

| RECOMMENDATIONS | ENVIRONMENTAL BENEFITS |
| --- | --- |
| **Maintain the lowest possible air generation pressure.** Check the minimum operating pressure of the connected equipment and any pressure loss in the network, as energy consumption increases with higher compressed air pressure. | Increased energy efficiency. |
| **Draw the intake air from outside.** Whenever possible, position outside air intakes facing north, as drawing in cooler air reduces operating costs (by approximately 3%). | Increased energy efficiency. |
| **Detect air leaks in the compressed air network and create a leak control and maintenance plan.** | Increased energy efficiency. |
| **Ensure all pneumatic tools operate at the minimum pressure required for high productivity,** as higher pressure increases energy costs. | Increased energy efficiency. |
| **Analyze the possibility of zoning the compressed air system by demand schedules, different pressure levels, or for large, specific demands.** Using staggered pressure levels reduces energy consumption, air usage, and leaks. | Increased energy efficiency. |
| **Recover the heat generated by compressor cooling.** Analyze different options for recovering heat from compressors, as the energy involved in compressor cooling is significant. | Increased energy efficiency. |

## Monitoring for Energy Consumption Control

Monitoring and remote control systems provide information on the energy parameters of an industrial facility, optimizing energy consumption management. Systems with remote control capabilities enable remote actions on the monitored installation.

These systems are essential tools for energy management, enabling efficiency studies and reports, and informing decision-making to optimize energy consumption. Appendix VII presents various energy consumption indicators that can be used to achieve significant energy savings.

The Association of Energy Efficiency Companies (A3E) published a guide, “Monitoring and Control Systems as a Tool for Improving Energy Efficiency,” which describes the components and benefits of implementing such systems.

Key benefits include:

- **Real-time monitoring:** These systems provide real-time visualization of energy consumption, variables, and indicators for the facilities being monitored, allowing for verification of the impact of energy-saving measures.
- **Detection of inefficiencies:** Identification of issues such as incorrect sizing of contracted power, unwanted latent consumption, and consumption outside of scheduled hours.
- **Reduced management time:** These systems enable remote actions and automated data processing, reducing the time needed for information analysis.

**Correct decision-making and reduced management time resulting from the implementation of a monitoring and remote control system often lead to cost savings of 5% to 20% on energy bills.**

The scope of the monitoring and remote control system depends on several factors, including the system's level of control (monitoring, management, or automation) and the level of measurement detail (at the supply level, by subsystems, or at each relevant energy consumption point).

The basic components of an energy consumption monitoring system are:

- **Meters and sensors:** These provide information on energy consumption and other relevant variables, and can be modular or wireless.
- **Concentrators:** Data loggers or data concentrators are field devices that collect data and transmit it to SCADA, BMS, EMS, etc. They typically run on Linux.

- **Communications:** Communication systems connect and transmit information between all the devices in the monitoring and remote control system. These can be local (radio modems) or global (routers and GPRS/3G modems).
- **Software/energy management platform:** Analysis tool.

The software or energy management platform processes and analyzes the raw measurement data to facilitate data interpretation and decision-making for the energy manager.

Data analysis can be automated, performed by the platform itself, or manual, performed by the energy manager.

**Main Characteristics of EMS and SCADA Monitoring Systems**

An energy monitoring and analysis system is known as an EMS (Energy Management System). In both industrial and building settings, they are used to analyze and monitor energy consumption, influencing variables (such as temperature) and KPIs. These platforms aggregate all monitored information, which is essential for detecting unusual consumption, proposing energy efficiency measures and verifying the resulting savings.

SCADA, which stands for Supervisory Control and Data Acquisition, is a system designed primarily for operating industrial processes such as power generation, production processes, water treatment, and chemical production and processing. Its main characteristic is that it works in real time. These systems are complementary and may share some functionalities.

# Implementing an Energy Efficiency Plan and Energy Audits

An energy efficiency plan involves defining and calculating the specific energy consumption of the activity (or activities), establishing annual key performance indicators (KPIs) (e.g., for specific energy consumption), and planning periodic improvement objectives and related actions. The plan is adapted to the specific characteristics of the facility.

Technical Description

An energy efficiency plan and energy audits are part of the environmental management system (EMS), and include the following:

- Energy flow diagrams;
- Establishing energy efficiency targets;
- Implementing actions to achieve these targets.

Energy audits are conducted at least annually to ensure that the objectives of the energy efficiency plan are met.

Achieving energy efficiency requires structured attention to energy use to continuously reduce consumption, improve production efficiency, and sustain improvements at the company level. This provides a structure and foundation for determining energy efficiency, identifying improvement opportunities, and ensuring continuous improvement. All effective energy and environmental efficiency management standards, programs, and guides incorporate the concept of continuous improvement, meaning that energy management is an ongoing process, not a project with a defined end.

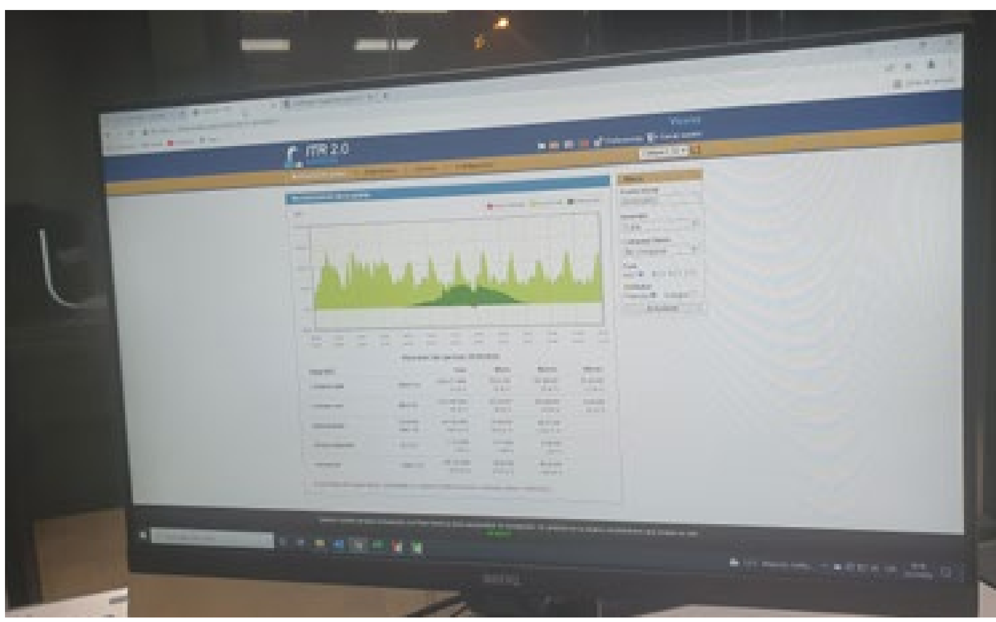
**Several process designs exist, but most management systems are based on the Plan-Do-Check-Act (PDCA) approach, which is widely used in other business management contexts. ISO 50001 is one of the most widely used standards worldwide for energy efficiency management systems.**

Solar panels installed on slaughterhouse and cutting plant roofs

## Renewable Energies

With rising energy prices in recent years and decreasing costs of solar panels, photovoltaic self-consumption has become a compelling option for economic savings and environmental sustainability in the meat industry, which typically has large roof areas suitable for solar panel installation.

A hybrid solar panel can generate both electricity and hot water simultaneously, offering multiple applications. This allows for greater utilization of solar irradiation and increased energy production per unit area.



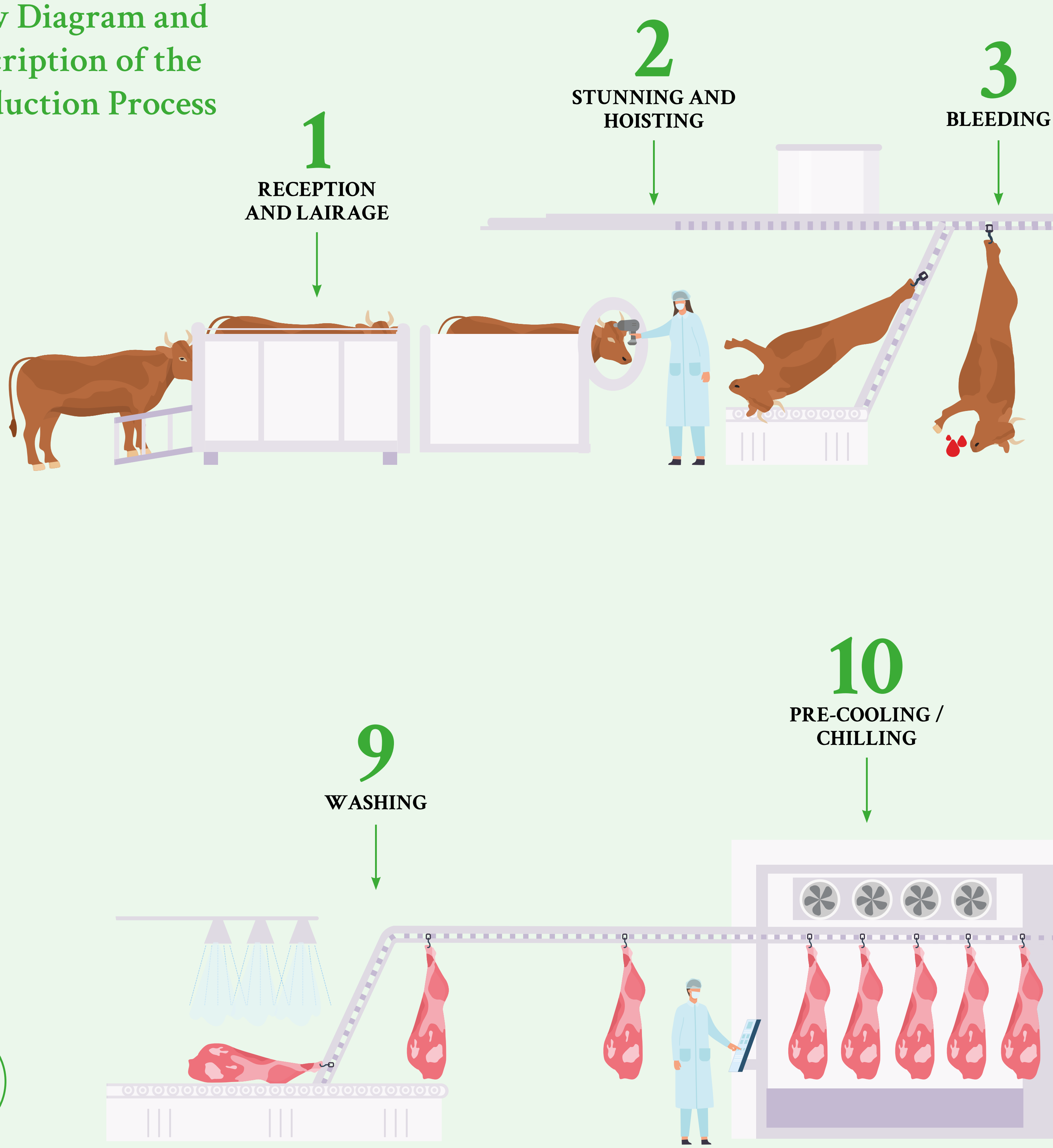

Solar energy monitoring and management software

# 8

# Appendixes

# Appendix I

## Flow Diagram and Description of the Production Process




5
SKINNING
7
EVISCERATION
8
CARCASS SPLITTING
4
LEG-HORN REMOVAL
6
HEAD REMOVAL
12
CHILLING / FREEZING
11
CUTTING

Unloading cattle

## Reception and Lairage

Ensuring adequate on-farm nutrition and good animal health is crucial for obtaining high-quality carcasses and respecting animal welfare during transport to the slaughterhouse.

Animals should be transported humanely and loaded onto trucks equipped with platforms that are preferably level with the truck bed. These platforms should have a non-slip surface and be long enough to allow for proper unloading, preventing injuries and subsequent waste, which also provides environmental benefits.

Lairage

Trucks are cleaned and disinfected after unloading. Most slaughterhouses have a designated area for these operations. Straw bedding and manure from the truck are collected as solid waste, and the wash water is collected as wastewater.

Ideally, animals should arrive at the slaughterhouse clean, as washing them at the facility can cause problems during slaughter if they are not dry enough. Wet hides can deteriorate, and there is a risk of *E. coli* O157 contamination of the carcass.

Animals are held in lairage pens for a few hours before slaughter. This allows the animals to recover from transport stress and for their adrenaline and glycogen levels to return to normal, which improves meat quality. Animals must have access to water at all times while in the lairage pens. The sanitary conditions and feeding regime of the animals upon arrival at the slaughterhouse can impact certain environmental aspects, such as the amount of manure excreted, gastric content per animal, and methane produced and released into the atmosphere. Lairage pens are cleaned after each use. Straw and manure from delivery vehicles and lairage pens can be used as fertilizer, subject to public health regulations.


Stunning


Hoisting

## Stunning and Hoisting

Animals are moved from the lairage pens to the slaughter area individually or in small groups, where they are stunned and slaughtered. Animals are stunned to render them insensible until death occurs from blood loss.

Restraint facilities should be designed, constructed, and maintained to ensure optimal application of the stunning method and prevent injuries or bruising to the animals. Slaughterhouse operators must ensure that animals are not placed in restraint equipment until the stunner operator is ready to stun the animal as quickly as possible, preventing unnecessary bruising and struggling.

Various stunning methods are used, including mechanical, electrical, and gas stunning. Mechanical methods are typically used for cattle and sheep, electrical methods for pigs and sheep, and gas stunning for pigs.

Captive bolt guns are generally used for mechanical stunning. They are activated by expanding gas from an air compressor or a blank ammunition cartridge.

The interval between stunning and bleeding (stun-to-stick interval) should be as short as possible to ensure that the stunned animal does not regain consciousness before death. Rapid bleeding prevents the animal from regaining consciousness. Ideally, bleeding should begin within 15 seconds of stunning.

After stunning, the animals are hung by one or both hind legs on an overhead rail that conveys the carcasses through the different processing stages to the chiller. Animals can also be transported on a conveyor belt.

## Bleeding

Animals must be bled by making an incision in at least one of the carotid arteries or the vessels from which they originate. This process helps preserve the meat by removing a growth medium for microorganisms.

Carcasses are bled into a tank to collect the blood. In some slaughterhouses, the blood tanks are only large enough to hold the blood from a few animals. This ensures that if the blood from one animal is contaminated or a carcass is rejected during veterinary inspection, only a small amount of blood needs to be discarded.

The blood container typically has two drains: one for pumping blood into a tanker truck for disposal, and the other for cleaning water. Some slaughterhouses have installed additional blood drains in other areas of the process, such as on the leg platform where the hind legs are skinned.

In cattle and pig slaughterhouses, some of the blood can be hygienically collected for human consumption, such as for making blood sausage, or for pharmaceutical use.

Bleeding can also be done using a hollow tubular knife with a suction system attached. In this process, some of the blood can be collected for sale as a by-product. The hygienic quality of the collected blood significantly affects its value and potential uses.

Vertical bleeding using a trocar is the traditional method, allowing blood collection while the animal moves through the bleeding area. This method carries a significant risk of blood contamination from feces, urine, dirt, or gastric contents regurgitated during the final moments of dying. In horizontal bleeding, the animal is positioned horizontally and perpendicular to the transport line, separating the bleeding point from the rest of the animal. This allows for more hygienic blood collection.

The suction knife is, in principle, the ideal method for hygienic blood collection, as the blood is pumped directly from the animal to a tank without intermediate contamination. With this technique, the collected blood has added value due to its hygienic quality, and can be used for human consumption, such as for extracting plasma proteins or hemoglobin.

However, this system is not widely used due to its low blood extraction efficiency (it leaves residues that fall into other areas of the slaughterhouse and end up in wastewater), and its incompatibility with high slaughter speeds. **Blood has a high organic pollutant load, making proper collection, storage, and management critical from an environmental perspective.**

Some slaughterhouses have traditionally allowed all or a significant portion of the collected blood to be sent to their wastewater treatment plant (WWTP). This has always been considered poor practice due to the high chemical oxygen demand (COD) and biological oxygen demand (BOD) of blood, and because it eliminates the possibility of using the blood for other purposes.

Bleeding process

Shank and horn removal

## Shank and Horn Removal

After the animals have been stunned and bled, and before skinning, the feet and horns are removed. Feet can be removed using a knife or shears, while horns are typically removed with shears.

The tail and udder/testicles are also removed manually with a knife. In some slaughterhouses, the operator makes a small cut in the neck to allow more blood to drain before removing the head.

Heads are handled in a separate room. The tongue and cheeks can also be removed for human consumption, in accordance with legal regulations. Subsequently, cattle heads are washed, inspected and dyed as specified risk material (SRM) for disposal. SRM includes the skull, brain, and eyes, but excludes the jaw.

Hooves are traditionally used in glue manufacturing, but they can also be crushed for use in pet food or to produce fertilizers.

Skinning

## Skinning

Before skinning, the rectum of the carcass is usually tied off, even before the feet and horns are removed. Later, when the head is removed from the carcass, the esophagus is tied off, preventing contamination of the carcass by the contents of the digestive tract.

Skinning begins at the rear of the animal, where the skinning of the legs was completed. A mechanical hide puller folds the hide downward while the animal is suspended, preventing the hide from coming into contact with the meat and thus minimizing the risk of microbial contamination.

Hide pullers consist of two chains that hook onto the hide and wind around a drum, pulling the hide off. The hides are then supplied to tanneries for the production of leather goods.

## Evisceration

Evisceration involves the manual removal of the respiratory and digestive organs. This includes removing the bladder and uterus (if present), the intestines and mesentery, the rumen and other stomach compartments, and the liver. After the diaphragm is cut, the pluck – consisting of the heart, lungs, and trachea– is also removed. The offal is then placed on trays for inspection, and taken to the offal processing area. The intestines (from the duodenum to the rectum), along with the mesentery, are classified as specified risk material (SRM).

Other offal, such as the lungs and trachea from all animals and the rumen from cattle, can be used in pet food production. To process the rumen, it is first opened on a table, and its contents are removed. This can be done using a wet or dry process. In the wet process, the rumen is opened under running water, creating a slurry that is screened and then pumped to a holding area. The dry process involves opening the rumen without water and manually removing the contents, which are then transported to a collection point via a pneumatic system or screw conveyor. Rumen contents are typically disposed of by spreading them on agricultural land, pending veterinary approval. Some companies use a piston compactor to reduce the volume of the rumen contents, making them easier to handle.

Once the rumen is emptied, it is washed with running or recirculated water.

Most slaughterhouses utilize a central compressed air system to power their equipment. This compressed air is often used to pneumatically convey the rumen contents to the collection point.

Some slaughterhouses employ specialized equipment to chop, wash, and centrifuge the remaining offal before it is sent to a processing company. This process can reduce the volume of offal by more than half.

**Carcass washing in the evisceration area is generally unnecessary unless contamination from damaged viscera occurs.**

## Carcass Splitting

Following evisceration, in accordance with Regulation 999/2001, which outlines measures to prevent, control and eradicate specific transmissible spongiform encephalopathies, the spinal cord is removed from cattle older than 12 months, and the vertebral column is extracted from cattle over two years of age. This material, designated as SRM, is dyed blue and handled as Category 1 material.

Carcass splitting

Certain slaughterhouses employ a vacuum system to suction spinal cord material directly into the SRM waste container. In other facilities, the spinal cord is extracted manually, and the cavity is sanitized with a device combining suction and steam spray.

Carcasses are split longitudinally and presented for veterinary post-mortem inspection. The veterinary inspection determines whether the carcass is suitable for human consumption and, accordingly, whether it will be processed for consumption or sent to animal by-product treatment facilities.

If the animal is classified as unfit (Category 1 material), it is stored in holding coolers before being transferred to a Category 1 by-product processing plant.

Carcasses or wholesale cuts presented for sale that include the vertebral column, in cases where removal is required, will be clearly identified with a red band on the label.

## Washing

Once carcasses have been split, they are rinsed with water to remove any remaining blood and fat, and reduce the level of surface microorganisms. Cold potable water is typically used, though the exact volume and duration of the washing process are not specified. It is recommended to use small volumes of water under pressure, although it is uncertain whether this process effectively reduces the surface level of microorganisms. Alternative methods, such as disinfectants, hot water, or steam could be promising options for the future. The carcasses are allowed to drain for a short period (10-15 minutes) before being weighed, classified, and sent to the refrigeration area. At each production stage, the meat is visually inspected to maintain quality standards.

Carcass washing

Pre-cooling / chilling

## Pre-Cooling / Chilling

Carcasses are chilled to reduce microbial growth, a process which typically occurs in two phases. In the first phase, carcasses are placed in a cold room at a temperature of -3 to 0°C for two hours to quickly lower their internal temperature, which is around 40°C. They are then moved to rooms set between 0° and 4°C until they are transferred to the cutting room.

The carcasses may then be stored in a refrigerated warehouse to further condition the meat before it is dispatched to cutting plants or wholesalers for further processing. The storage time varies depending on the degree of maturation required by the customer.

## Cutting

In the cutting rooms, the half carcasses from the slaughterhouse are deboned and split into smaller cuts, with the degree of division varying by facility. This is generally done in rooms adjacent to the slaughterhouse.

Cutting can be performed "hot" or "cold," depending on whether the carcass has been chilled, and whether technical and sanitary requirements are met. Hot cutting allows for rapid chilling of the cuts, although the temperature conditions can promote rapid microbial growth. The cutting process is carried out in a refrigerated room that is maintained at a temperature of 12°C.

**A significant technological advancement has been the use of mechanical arms for quartering beef, which greatly facilitates deboning.**

The resulting cuts can be packaged using two main methods, depending on the size of the cuts. Large cuts are generally vacuum-packed, while small cuts are typically packaged in air, or in a controlled or modified atmosphere.

Carcasses and offal must undergo chilling treatments, following a cooling curve that ensures a steady temperature decrease to at least 7°C for carcasses and 3°C for offal. This process is performed in cooling or freezing chambers or tunnels. In the chilling chambers, carcasses are kept at a temperature near 4°C, with relative humidity ranging between 80-90%. Unlike chilling, which allows for storage from a few days to a few weeks, freezing involves reducing the temperature well below 0°C, generally -18°C for meat, enabling storage for several months. Freezing is done in blast tunnels or freezing chambers with intense air circulation. The air temperature must be between -30 and -35°C, sometimes reaching -40°C. The relative humidity must be very high, at least 95%.

Slaughter line prior to slaughter

## Slaughterhouse Cleaning

Many slaughterhouse operators wash processing areas with hot water during production breaks to maintain hygiene. All processing equipment and containers must be cleaned and disinfected several times a day, and again at the end of the day to prepare for the next shift.

The cleaning process involves removing meat, fat, and other residues which are collected throughout the shift, and storing them for proper disposal or use in accordance with regulations.

Certain areas are lightly hosed down at regular intervals throughout the shift, but hose cleaning contaminates the water with solid materials. During production breaks, some drain collection containers are emptied into waste bins. Each drain point typically has a grate covering and a collection container equipped with a 4 mm mesh.

At the end of shifts, processing areas are typically dry-cleaned to eliminate any residual meat, then hosed down with low-pressure hot water to remove any remaining debris. Drain collection containers are emptied into waste bins. A diluted food-grade foam detergent is then applied to all surfaces. After approximately 20 minutes, the surfaces are rinsed with high-pressure hot water. Some slaughterhouses use disinfectants that require rinsing, while others spray a highly diluted disinfectant over the surfaces and let it air-dry.

Hooks, shackles, and similar equipment are often cleaned on-site using a similar method. Numerous cleaning products are authorized for use in the food industry, some with traditional chemical formulations, and others that are biotechnology-based. Some are tailored for specific or difficult cleaning tasks, while others serve general purposes.

Hygiene requirements prohibit the use of high-pressure, low-volume (HPLV) sprayers in meat areas during processing, as the atomized water can cause airborne contamination. However, they can be used for cleaning at the end of production. Good hygiene is crucial for food safety, and is subject to strict EU and Member State regulations.

Overusing water, however, can adversely affect hygiene. For example, excessive humidity, combined with the constant movement of machinery and the close proximity of carcasses on the slaughter line, can result in contamination from splashes and aerosols.

Reviews of cleaning agent use in slaughterhouses often show that selecting more appropriate products can decrease chemical usage, and in some cases, improve hygiene standards. It is not uncommon to find that excessive doses of cleaning agents are being used, particularly with manual dosing. Properly configured automated dosing systems eliminate the risk of overdosing. Automated dosing also enhances health and safety by minimizing exposure to harmful substances and reducing manual handling. Adequate training and operator oversight are critical in all cases. **Opportunities frequently exist to minimize the environmental impact of cleaning agents by selecting/replacing and using them appropriately.**

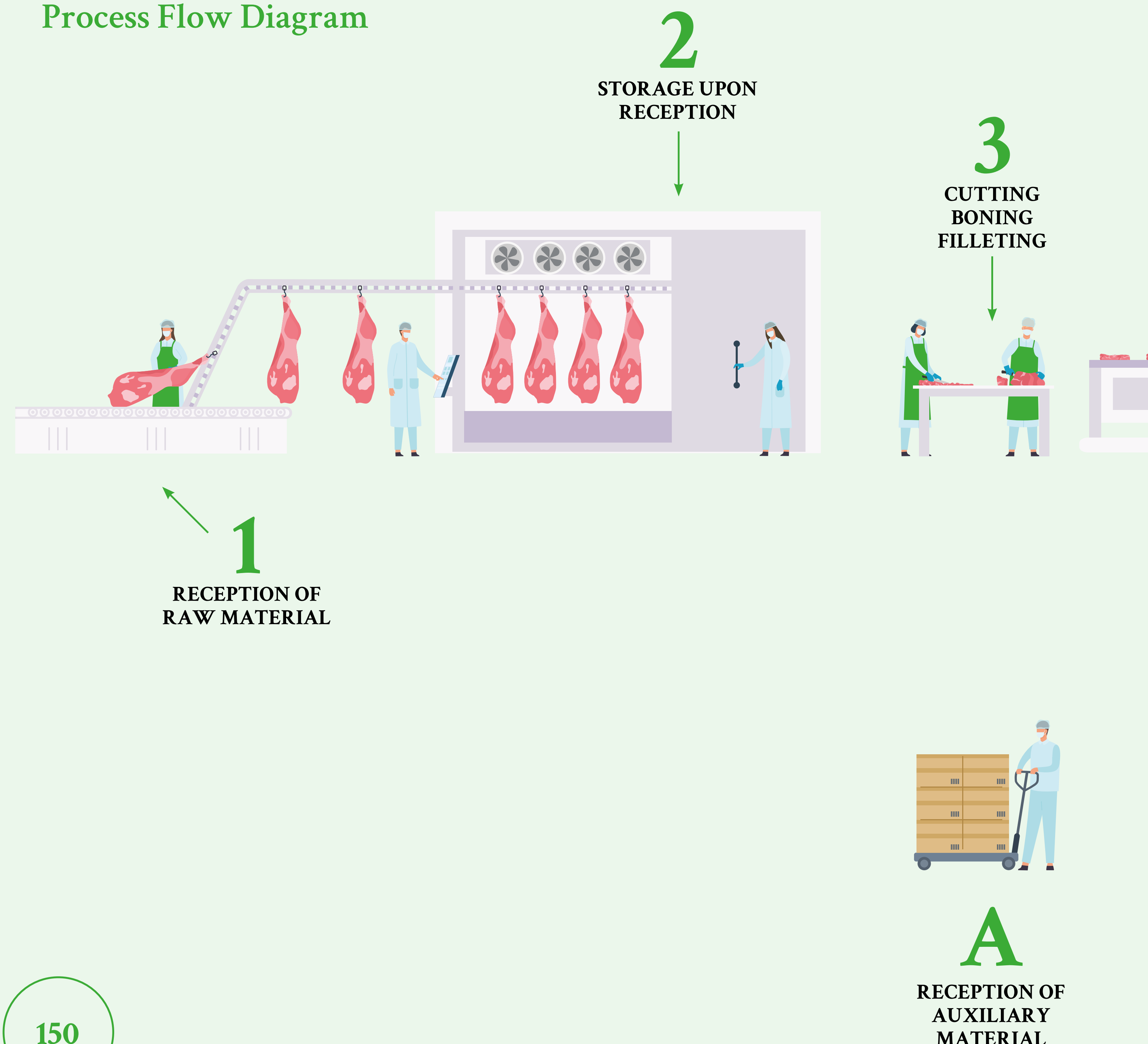
In many slaughterhouses, cleaning personnel often remove floor grates and dispose of meat residues directly into the drainage system. Once meat scraps and residues enter the wastewater stream, they are exposed to turbulence, pumping, and mechanical screening. This process breaks down the meat, releasing high-COD substances, fats, and suspended or colloidal solids into the water.

Treating wastewater, either on-site or at municipal treatment plants, can be costly. The breakdown of fats and suspended solids accelerates in hot water. **Reviewing cleaning practices can also reveal excessive energy consumption for water heating and potentially excessive water use.**

Slaughter line prior to slaughter

# Appendix II

## Cutting / Filleting Process Flow Diagram

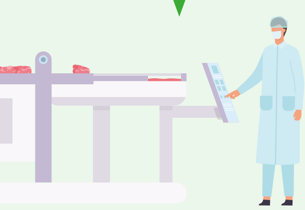


**5**

**COLD AND FROZEN STORAGE**

**4**

**PACKAGING AND LABELING**



**6**

**DISPATCH AND TRANSPORT**

**B**

**ROOM TEMPERATURE STORAGE**

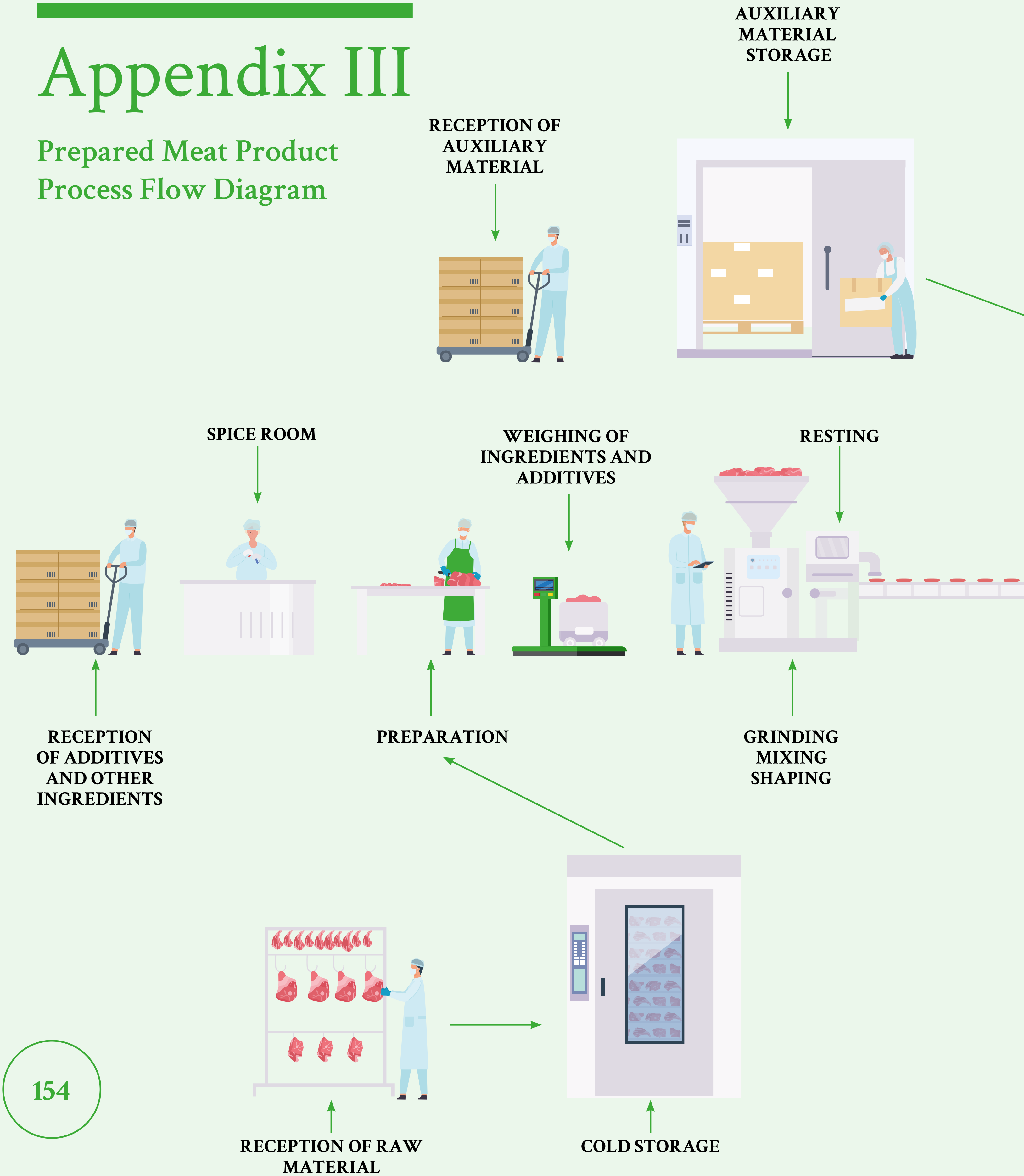
## Cutting and Slicing Plant

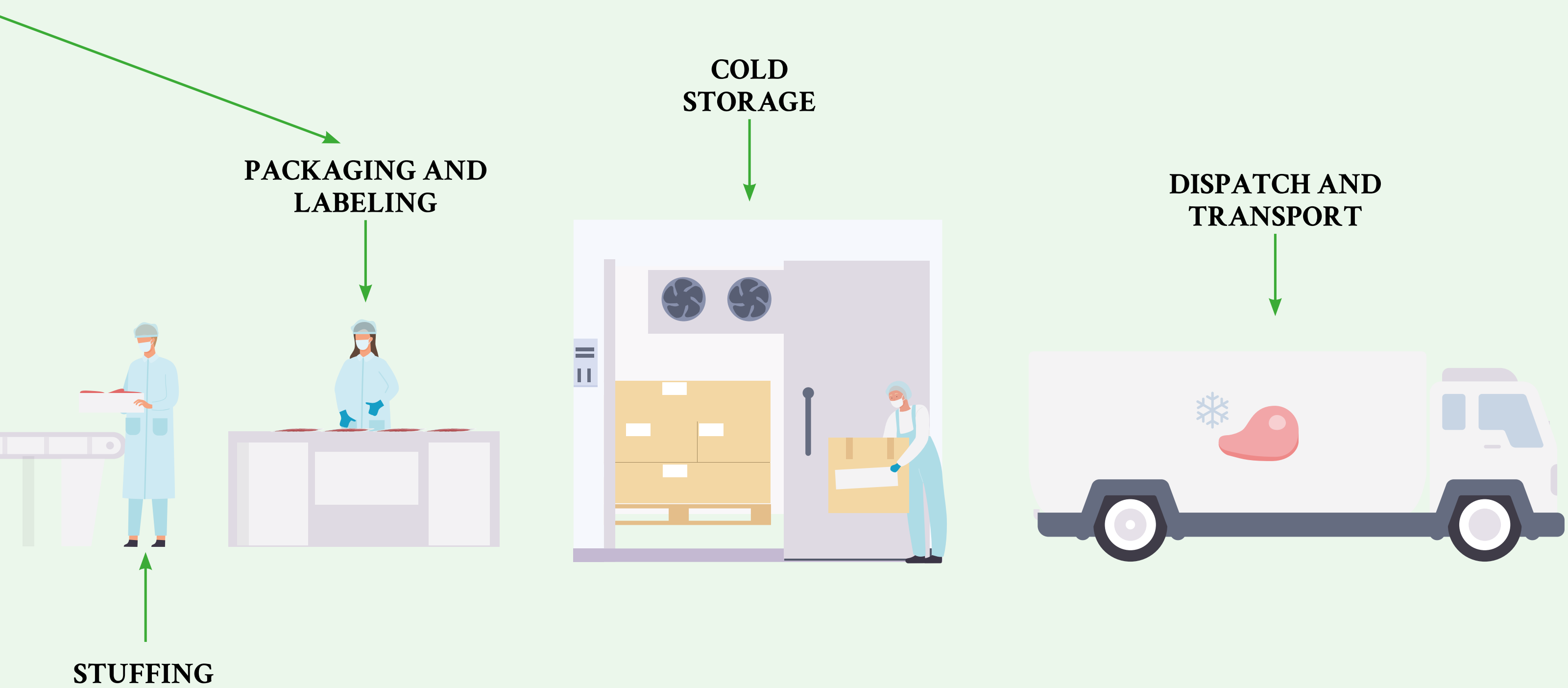
Meat cuts are chilled until processing begins. Cutting and slicing of fresh meat typically occurs in a dedicated white room, where raw materials are transformed into commercial cuts or materials for further processing. Prepared cuts can be vacuum-packed, packaged in modified atmosphere packaging (MAP), etc., and then labeled. After packaging, the meat is cold-stored until it is shipped. **Packaging temperature** is one of the most crucial factors. All rooms **must have thermographs**, and must never operate at temperatures above **12ºC** during any phase of the process. Ideally, maintain an average temperature at or below **7ºC**.

The primary benefit of white rooms for the meat sector is **air purity**, and white rooms in the meat industry must **always be fitted with high-efficiency HEPA filters**.

# Appendix III

## Prepared Meat Product Process Flow Diagram






This stage involves preparing raw materials and specific ingredients prior to processing. The minced meat is blended with ingredients and additives. Beef is used to prepare products such as ground meat and hamburgers.

The product is then packaged, labeled, and stored in a refrigerated chamber.

# Appendix IV Environmental Aspects of Slaughterhouse Activity

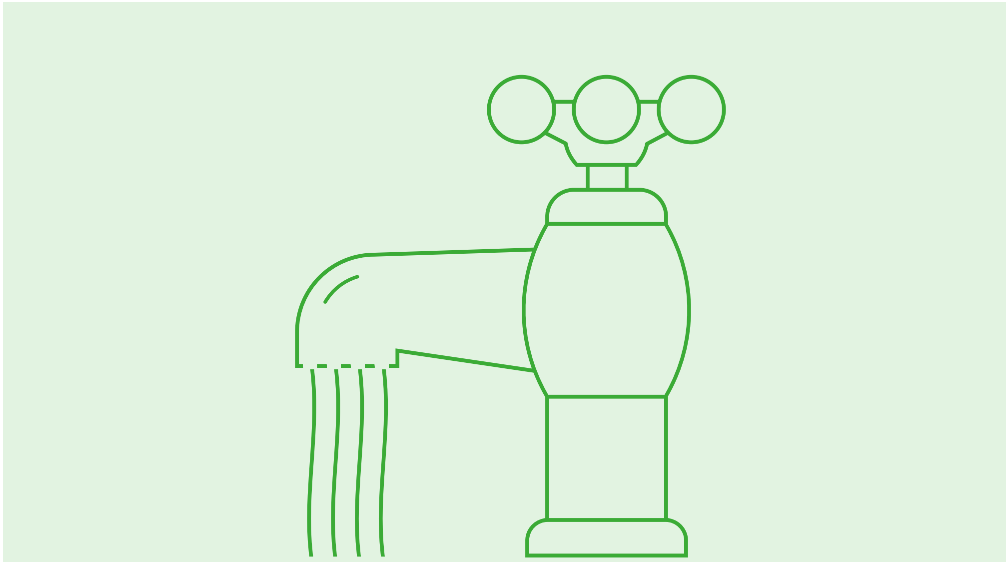
## Water Consumption

Per BREF guidelines for the meat sector, water usage in Spanish slaughterhouses falls between 1 and 6.4 $m^3$ per ton of carcass, with an average of 3.4 $m^3$ per ton. This figure accounts for the total water volume from all sources, used both in slaughterhouse operations and auxiliary processes. Water use increases significantly when the facility also processes by-products like tripe.

**Cleaning water and boiler circuits often require treatment to reduce hardness and conductivity, including decalcification, deionization, or activated carbon filtration. These treatment processes can generate wastewater with high conductivity or extreme pH levels.**

Maintaining proper hygiene requires frequent cleaning and disinfection of facilities, and the floor area is a crucial factor, regardless of the number of cattle slaughtered. This means that water needed for end-of-day cleaning and disinfection in slaughter and processing areas depends more on the size of the facility than on the number of animals slaughtered. Conversely, other high-water activities like vehicle cleaning, carcass washing, and intermediate cleaning during processing depend more on the daily number of animals.

The primary water demand comes from cleaning and disinfecting equipment, facilities, and vehicles. Water is also essential throughout the production process, used for washing animals in lairage, cleaning carcasses and offal, and rinsing at various stages of slaughter and dressing.



**The volume of water used depends on several factors, including the size and age of the plant, the level of automation, and the specific cleaning and disinfection techniques employed.**

Water usage is governed by EU and national meat regulations, requiring potable water for most washing and rinsing, which restricts reuse within slaughterhouses. **Excessive water use is an environmental and economic concern, and places an additional burden on the Wastewater Treatment Plant (WWTP).**

Efforts to cut water usage, through savings or internal wastewater reuse, are constrained by limited data on partial consumption and regulations mandating potable water. Water reuse is allowed for auxiliary processes like fire systems, but potable water mandates restrict broader reuse possibilities.

## Energy Consumption

The greatest energy demand in a cattle slaughterhouse and cutting plant is electricity for refrigeration. Most slaughterhouses have backup generators to guarantee continuing operations during power outages.

Typically, each refrigerated room has a self-contained direct expansion unit, including a compressor, evaporator, and condenser. Larger plants sometimes have a centralized room for compressors and condensers.

Carcasses must be cooled to 7°C before leaving the slaughterhouse, and offal must not exceed 3°C. Cooling smaller cuts requires less energy than cooling whole or half carcasses. Slaughterhouses and cutting plants typically rely on electricity for 50-80% of their energy needs, with the remaining 20-50% coming from thermal sources.

Electricity powers various aspects of the slaughterhouse, including refrigeration, compressed air, ventilation, lighting, and operational equipment in the slaughter, deboning, and by-product processing areas, including saws, forklifts, conveyors, packers, and electrical stimulation devices. Electricity also supports on-site rendering plants and wastewater treatment.

**Refrigeration systems represent a significant portion of energy use in slaughterhouses, accounting for 45-90% of electricity consumption during operation, and nearly 100% during non-production periods. These systems cool work areas, cold stores, and freezers.**

Thermal energy is primarily used for cleaning and disinfecting equipment, work surfaces, and utensils, as well as for washing carcasses and offal, and processing by-products.

Hot water is the primary thermal energy carrier in slaughterhouses, with steam used less frequently, both supplied from the boiler room to various facility areas. Gas and oil serve mainly to produce heat and hot water for operations.

**Cattle and sheep slaughterhouses generally require less hot water than pig slaughterhouses. While pig slaughterhouses may use up to 80% thermal energy for processes like heating scald tanks, raising steam, and singeing, cattle and lamb facilities typically require only 30-50%.**

The SCOoPE project reports **specific electrical consumption per ton of beef at 36-150 kWh/t of carcass, including all electricity used in production and auxiliary processes**. These figures align with the "BREF on BATs in the Slaughterhouses and Animal By-products Industries" report for UK beef and pork slaughterhouses, which reports a range of 36-154 kWh per ton of carcass.

**Thermal energy, based on SCOoPE project data, averages between 55-140 kWh per ton of carcass.**

Energy usage figures differ depending on the referenced sources. The following data, gathered from different references, provides an overview of energy consumption:

Energy consumption data from UNEP (United Nations Environment Programme) and the Danish EPA is outlined in the table below.

## Table 7: Energy Consumption at Slaughterhouses

### Source: "Cleaner Production Assessment in Meat Processing". UNEP & Danish EPA (2000).

| | | ELECTRICITY | THERMAL ENERGY |
|---|---|---|---|
| **Canada** | Pork | 70-300 kWh/t carcass | 138-250kWh/t carcass |
| | Beef | 70-250 kWh/t carcass | 55.5-138 kWh/t carcass |

- The "BREF on BATs in the Slaughterhouses and Animal By-products Industries" report includes an example of energy use in a Danish beef slaughterhouse.

## Table 8: Breakdown of Electricity Consumption in a Danish Slaughterhouse

### Source: "BREF on BATs in the Slaughterhouses and Animal By-products Industries".

| ENERGY SOURCE | % |
|---|---|
| **Electrical** | 40 |
| **Thermal** | 50 |
| **Recovered Energy** | 10 |

In this example, electrical and thermal energy consumption are comparable, although variations exist based on the reference sources.

**The refrigeration system accounts for the bulk of electrical energy consumption.**

In a Danish beef slaughterhouse, electricity consumption is distributed as follows:

## Table 9: Breakdown of Electrical Energy Consumption in a Danish Beef Slaughterhouse

Source: "BREF on BATs in the Slaughterhouses and Animal By-products Industries".

| BREAKDOWN OF CONSUMPTION | % |
|---|---|
| **Cold generation plant** | **45** |
| **Compressed air generation** | 10 |
| **Lighting** | 10 |
| **Equipment** | 10 |
| **Ventilation** | 5 |
| **Miscellaneous** | 25 |

The breakdown of thermal energy consumption in the same Danish beef slaughterhouse is as follows:

## Table 10: Breakdown of Thermal Energy Consumption in a Danish Beef Slaughterhouse

Source: "BREF on BATs in the Slaughterhouses and Animal By-products Industries".

| BREAKDOWN OF CONSUMPTION | % |
|---|---|
| **Space heating** | 13 |
| **Total water heating** | 80 |
| **Up to 40ºC** | 5 |
| **UP TO 60ºC** | **54** |
| **Up to 82ºC** | 21 |
| **Heat loss** | 7 |

**Heating water to 60°C for cleaning facilities and equipment accounts for the largest share of thermal energy use.**

# Atmospheric Emissions

The primary source of air emissions in a slaughterhouse are the combustion gases produced by the boiler room. These gases include carbon dioxide ($CO_2$), nitrogen oxides (NOx), sulfur oxides (SOx), and carbon monoxide (CO). $CO_2$ emissions are directly related to the amount of thermal energy used.

Consequently, the amount of $CO_2$ emitted depends on fuel consumption specifics and, more precisely, on the relationship between the fuel's carbon content and its calorific value. $SO_2$ emissions largely depend on the fuel type and composition. Facilities using only natural gas produce insignificant sulfur emissions, or none at all. Facilities using fuel oil emit sulfur, although they now typically use low-sulfur fuel oil (LSFO) with a sulfur content below 1%. NOx emissions depend on the fuel composition and combustion conditions, including combustion temperature, excess air, flame shape, combustion chamber geometry, and burner design. CO emissions are generally insignificant in the meat sector, and typically result from boiler malfunction or incomplete combustion.

Other less significant air emissions, typically diffuse in nature, include: refrigerant gases from cooling systems, and methane, ammonia and particles from manure and slurry.

Directly measuring these emissions is challenging due to their diffuse nature, requiring mass balance calculations or emission factors, which may not always reflect local conditions.

**Refrigeration systems, commonly using ammonia ($NH_3$) or hydrofluorocarbons (HFCs) as refrigerants or heat transfer fluids, can experience leaks or failures in lines or during recharging.**

Regulation (EC) No. 2037/2000, on substances that deplete the ozone layer, progressively limited the use of pure HCFCs, prohibiting "new" HCFCs on January 1, 2010, and extending the ban to all HCFCs on January 1, 2015.

HFCs represent a newer generation of refrigerants, which, lacking chlorine, are far less damaging to the ozone layer. **However, they still contribute to global warming, with known effects on rising global temperatures.**

The most widely used refrigerants in industrial refrigeration today include ammonia, R134A and R404A (HFCs).

From January 1, 2020, the European F-Gas Regulation banned HFC refrigerants with a Global Warming Potential (GWP) over 2500 in new installations. And as of 2022, those with a GWP over 150 are also banned, significantly transforming the industrial refrigeration industry and requiring the use of alternative refrigerants.

**Ammonia offers several advantages as a refrigerant: it is eco-friendly, does not contribute to global warming, and has suitable thermodynamic properties, resulting in efficient systems. Its distinct odor makes it easy to detect leaks.**

**Carbon dioxide ($CO_2$ R-744) is another alternative to HFCs. It does not damage the ozone layer, has a low global warming potential, and is a natural refrigerant. It is an odorless, colorless fluid that is denser than air.**

During anaerobic fermentation of manure and slurry, gases such as methane ($CH_4$) and ammonia ($NH_3$) are released into the atmosphere. Methane is a greenhouse gas, while ammonia poses occupational health risks and has environmental implications.

**Due to the short stabling period in slaughterhouses, these gas emissions are generally minimal. Proper collection and storage of livestock manure is essential to prevent these gas emissions.**

## Wastewater

**The most critical environmental impact associated with slaughterhouses stems from water emissions, which are intrinsically tied to the industry's high water consumption—a pressing environmental challenge.** Carcass slaughtering and processing involve significant water consumption, and generate elevated concentrations of BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), and TSS (Total Suspended Solids). The decomposition of solids releases fats and suspended colloidal particles, exacerbating BOD and COD levels.

**Equipment and facility cleaning ranks as one of the largest sources of wastewater, both in volume and organic load.** Commonly used detergents are alkaline foam formulations, which enhance efficacy in removing the fat and protein residues inherent to the meat processing industry. Disinfectants commonly employed in the meat industry include quaternary ammonium salts and hypochlorite compounds, known for their active chlorine release. **Product selection should balance operational effectiveness with environmental considerations, such as toxicity, ecotoxicity, biodegradability, COD, and the presence of phosphorus, nitrogen, or free chlorine.**

**Blood has the highest COD concentration of all liquid slaughterhouse waste. Its pollution potential and the large quantities handled make it a key environmental concern requiring evaluation and control.**

Water-based freezing and refrigeration systems generate high volumes of wastewater, reaching up to 25% of total consumption. While these systems produce water at elevated temperatures, the degree of contamination is typically minimal.

The table on the following page summarizes the primary production stages responsible for generating wastewater, along with their associated contaminants.

## Table 11: Wastewater-Generating Stages and Associated Pollutants

### Source: Manual de buenas prácticas y sostenibilidad ambiental en el sector agroalimentario: Instalaciones para el sacrificio de animales.

| STAGE | MAJORITY COMPONENT | MAIN COMPONENT |
|---|---|---|
| **Lairage** | Manure and slurry carried in cleaning operations | H-$NH_3$ |
| **Bleeding** | Blood | COD, C/N ratio |
| **Evisceration** | Pieces of viscera, fat and blood | TSS, OM, $PO_4$3-, salts and fats |
| **Carcass washing** | | Flow |
| **Cleaning of equipment and facilities** | Detergents and organic matter | Flow and BOD5 |
| **Refrigeration** | | Temp. and flow |

## Wastewater Composition

Slaughterhouse wastewater primarily consists of organic matter and suspended solids. It may also contain remnants of raw materials like bones, skin fragments, and intestinal contents. The specific composition and concentration depend on several factors, including:

- Suspended solids;
- High organic load from blood, fat, manure, etc.;
- High fat levels;
- Contaminants: Critical indicators such as BOD, COD, TSS, conductivity, and pH can fluctuate based on cleaning procedures and the use of caustic and acidic agents;
- High levels of nitrogen, phosphorus, and salt;
- The raw material and its final presentation;
- Industry type (multi-product or not), production system, production level.

**The table below details the characteristics of untreated slaughterhouse wastewater (raw sewage).**

## Table 12: Characteristics of Untreated Slaughterhouse Wastewater

Source: Guía práctica para la depuración de aguas residuales en la industria alimentaria.

| PARAMETERS | MAX | MIN | AVERAGE |
|---|---|---|---|
| **COD (mg/l)** | 35,000 | 774 | 10,259 |
| **BOD5 (mg/l)** | 5,350 | 500 | 2,500 |
| **SS (mg/l)** | 5,000 | 220 | 2,102 |
| **Oils and fats (mg/l)** | 1,200 | 23 | 474 |
| **TN (mg/l)** | 750 | 48 | 252 |
| **TP (mg/l)** | 90 | 10 | 40 |
| **Cl (mg/l)** | 1,000 | 649 | 825 |
| **pH** | 8 | 6 | 7 |

**Typically, 80-95% of the water consumed becomes wastewater. This wastewater is characterized by high concentrations of organic matter, suspended solids, oils, and fats, as well as a high degree of biodegradability.**

## Waste Generation

In addition to animal by-products, waste is also generated from sewage treatment, packaging, refrigeration system maintenance, cleaning, administrative tasks, etc.

## Animal By-Products

**Animal By-Products (ABP) not intended for human consumption are the most significant waste generated in slaughterhouses, both in quantity and diversity. Legislation establishes their categorization and the conditions for their management and treatment.**

The main by-products generated in the slaughterhouse are manure, slurry, blood (which can be considered a by-product depending on the hygienic conditions during collection, transport and storage, and the available external management options), and SRM.


### Specified Risk Material (SRM)

This material is managed in accordance with specific health legislation, which outlines regulatory procedures for collection, storage, handling, and disposal by slaughterhouses. Specified Risk Material (SRM) refers to the tissues and organs defined in Commission Regulation (EU) 2015/728, which amends the definition found in Annex V of Regulation (EC) No 999/2001 of the European Parliament and of the Council laying down rules for the prevention, control, and eradication of certain transmissible spongiform encephalopathies.

### Blood

Blood has a high organic load, and collecting it separately from wastewater significantly reduces the pollution load of the latter. This also reduces contamination by nitrogen and other pollutants. **Consequently, any technique eliminating blood discharge in favor of recovery constitutes a significant environmental improvement, and the more hygienic the blood collection, the greater its potential for recovery.**

### Manure and Slurry

Manure and slurry are livestock excreta generated primarily during reception and lairage. Excreta is also present in the stomachs and intestines of animals at the time of slaughter.

**Segregated collection of manure facilitates its use as fertilizer. However, manure is often washed into the drainage system during cleaning, significantly increasing the pollutant load of the wastewater.**

## Sewage Sludge

Sewage sludge is a type of mud generated during the different stages of wastewater treatment. **Its characteristics include high humidity and significant capacity for biological degradation, requiring prompt intervention to prevent foul odor issues. These two characteristics make it difficult and expensive to manage.**

## Hazardous Waste

Hazardous waste is generated during the maintenance of equipment and facilities (used oils, fluorescent tubes, solvents, hazardous packaging waste, etc.), cleaning, and laboratory work. It is typically separated and stored in containers suitable for its characteristics, representing small quantities that are delivered to authorized waste management facilities in accordance with waste regulations.

## Other Waste

Non-hazardous waste, such as plastic, cardboard, metal, wood, trash, and packaging waste, is generated during on-site packaging processes. This waste has minimal impact due to its limited generation.


## Odors

Odors generated by the storage and handling of blood, slurry, occupied lairage, and inedible offal storage are the most problematic. Other potential sources of odor include patio areas, unwashed by-product containers, and wastewater treatment plants (including the initial solids separation stage).

## Noise

The primary sources of noise and vibration pollution are animals during unloading and sorting, vehicle movements, compressors, air conditioners, and fans.

## Summary of Environmental Impacts and Risks

The following table summarizes the most significant environmental impacts of cattle slaughterhouse activities.

## Table 13: Environmental Risks in a Slaughterhouse

### Source: Manual de buenas prácticas y sostenibilidad ambiental en el sector agroalimentario: Instalaciones para el sacrificio de animales.

| PROCESSES | ENVIRONMENTAL ASPECTS | ENVIRONMENTAL RISKS |
|---|---|---|
| **Lairage** | Generation of slurry and manure | Inadequate management of waste, straw bedding, and manure |
| | Generation of foul odors | |
| **Bleeding** | Blood spills | Inadequate wastewater management<br><br>Legal non-compliances |
| **Skinning** | Discharge of wastewater with a low organic load | Inadequate wastewater management<br><br>Legal non-compliances |
| | Water consumption | |
| | Energy consumption | |
| **Evisceration** | Production of solid waste from evisceration | Inadequate management of solid waste composed of pieces of viscera, fats, blood, and digestive contents<br><br>Inadequate wastewater management<br><br>Legal non-compliances |
| | Production of low flows of water with traces of blood, fat, and digestive contents | |
| | Water consumption | |
| | Energy consumption | |

| PROCESSES | ENVIRONMENTAL ASPECTS | ENVIRONMENTAL RISKS |
|---|---|---|
| **Carcass washing** | Discharge of wastewater with a high organic load<br>Water consumption | Inadequate wastewater management<br>Legal non-compliances |
| **Refrigeration** | Noise generation<br>Risks of refrigerant gas leaks<br>Energy consumption | Risks of high levels of environmental intrusion<br>Legal non-compliances<br>Inadequate management of refrigerant gases<br>Risk of bacterial contamination of cooling towers |
| **Freezing** | Noise generation<br>Energy consumption | Risks of high levels of environmental intrusion<br>Legal non-compliances |
| **Cleaning of equipment and facilities** | Generation of wastewater with a high organic load and presence of detergents and disinfectants<br>Water consumption | Inadequate wastewater management<br>Legal non-compliances |
| **Waste collection and storage** | Generation of foul odors | Inadequate waste management and treatment |

# Appendix V Specific Wastewater Treatments

## Pretreatment Screening, Grit Removal, and Degreasing

The first stage of wastewater treatment aims to eliminate easily separable pollutants through physical processes, preventing problems in subsequent treatment stages.

Maintenance costs depend on whether cleaning is manual or automatic. Generated waste is disposed of as municipal waste. If the waste allows, sand and fats are managed by an authorized entity.

Screening processes utilize grates, screens, or most commonly, rotary screens, along with degreasing to eliminate fats and other floating matter that is lighter than water.

Rotary screens consist of a cylindrical filter with a slowly rotating horizontal axis. Water falls from above into the screen, while dirt remains on the exterior and is evacuated to a temporary container by a fixed scraper. The mesh size is 0.2 to 2.0 mm. Head losses are high, around 2 m, often requiring additional pumping. Rotary screens are often susceptible to clogging from coagulated fats, requiring thorough maintenance.

## Shredding

The objective is to shred solid matter present in the water. This operation does not improve raw water quality, as the solids are not removed, and are returned to the water for further treatment. Recommended only if screening is not implemented.

## Grit Removal

Higher-density matter (e.g., sand) with diameters greater than 0.2 mm is removed. The two most common types are aerated (helical flow) and static horizontal flow, where water flows horizontally.

## Degreasing

Fats and other floating matter lighter than water are removed. The two most common types are aerated (air is injected into the tank bottom) and static (water exits below a partitioned tank).

Grit removal and degreasing are typically performed in the same stage or with the same equipment. The flow rate and industrial waste input will influence the design of equipment for waste removal or fat separation. Weather influences hydraulics if the facility lacks a separate drainage network (sand entrainment).

This equipment has visual and noise impacts. To minimize odor impact, periodic removal of extracted waste is necessary, and/or the grit removal tank should be closed, and generated gases extracted. Head loss is influenced by the equipment selected.

Aerobic homogenization tanks at a biological wastewater treatment plant using a membrane ultrafiltration system

## Equalization / Neutralization / Homogenization

There are differences between various flow regulation treatments, neutralization processes, and homogenization tanks for contaminated flows.

These systems improve process performance by maintaining more homogeneous flow and loads. They reduce effluent concentration fluctuations and stabilize pH.

Constant feeding can be maintained, even during industrial production stoppages, ensuring stability. Effluent quality and secondary sedimentation tank performance are improved by operating with constant solid loads.

This improves facility control and facilitates operation and maintenance scheduling by working under constant conditions. It also optimizes facility size and reduces treatment plant oversizing, minimizing the size and costs of downstream treatment units.

Regulating water flow to the treatment plant involves smoothing out flow peaks and valleys. If suspended solids are present, agitation is necessary in the regulation ponds or tanks to prevent settling.

## Primary (Physicochemical) Treatment

This treatment reduces suspended solids in wastewater by a certain percentage. The main physical-chemical processes in primary treatment are sedimentation, flotation, coagulation-flocculation, and filtration. Costs vary based on the technology used. Generated waste is disposed of as primary sludge, or mixed with secondary sludge (both are dewatered). Equipment maintenance addresses corrosion effects on metal components, and impacts on concrete.

### Coagulation-Flocculation Treatment

In many cases, some suspended matter consists of very small particles forming stable colloids due to inter-particle interactions. Consequently, they have extremely slow sedimentation rates, making traditional mechanical treatment impractical.

To remove suspended matter, chemical reagents are added to first destabilize the colloidal suspension (coagulation), and then promote particle flocculation for sedimentation. Coagulants are typically chemicals that, in solution, provide a charge opposite to that of the colloid. Salts with high charge/mass ratio cations ($Fe^{3+}$, $Al^{3+}$) are commonly used with organic polyelectrolytes to promote flocculation. Polyelectrolyte dosage is much lower than for salts, resulting in higher efficacy and cost-effectiveness.

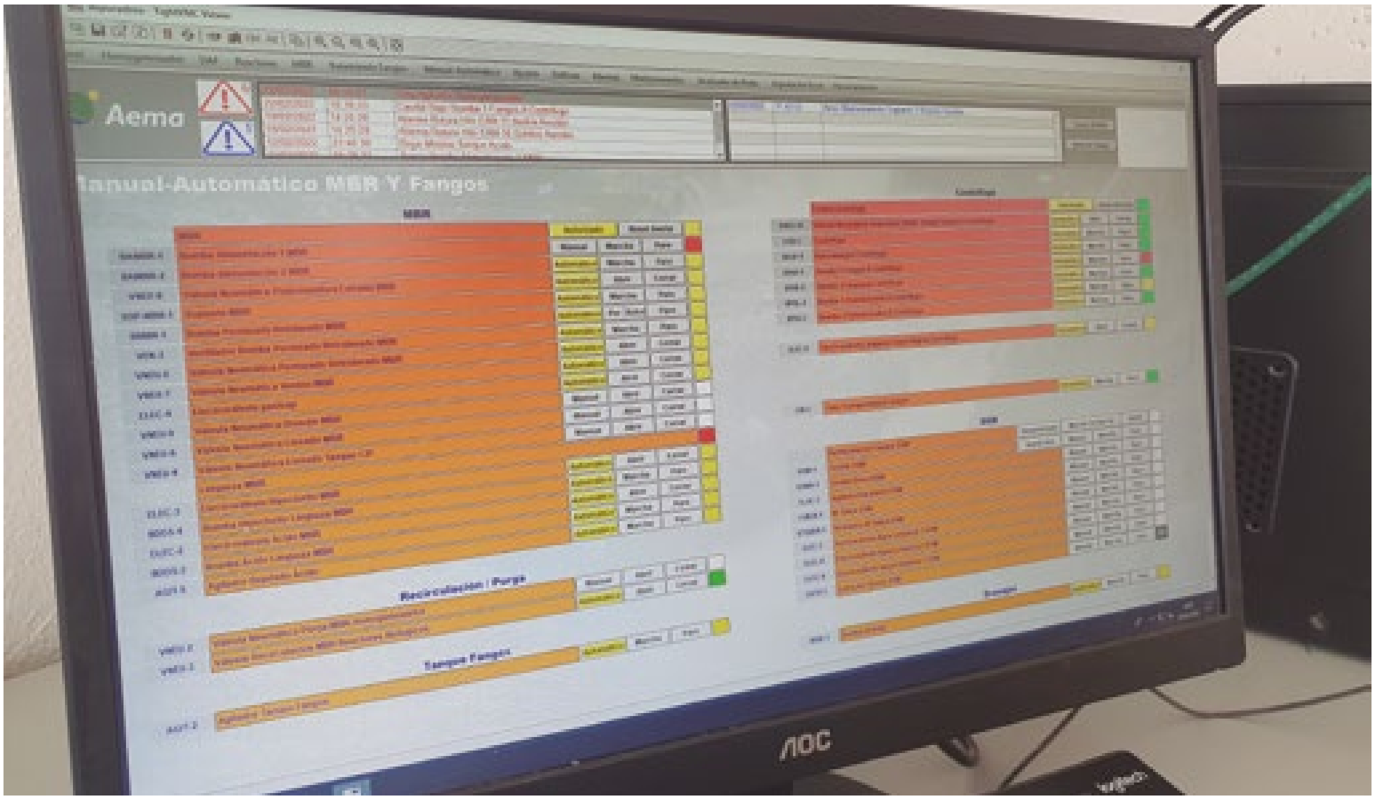
## Secondary Treatment (Biological Treatment)

This treatment involves a series of important biological processes for wastewater treatment, all utilizing microorganisms (primarily bacteria) to eliminate biodegradable organic matter (both colloidal and dissolved) and compounds containing nutrient elements (nitrogen and phosphorus).

Aerobic treatment is based on the principle of converting organic matter into carbon dioxide and sludge (biomass). This conversion occurs by supplying oxygen to the reactor, either mechanically through agitation or by diffusion.

Reliable removal of chemical oxygen demand (COD) and nutrient load is essential. This requires efficient plant operation, enabling periods of oxygen inflow and non-aeration periods to finalize nitrogen removal via denitrification.

**Monitoring energy consumption during aeration is critical for managing overall energy costs effectively. Compliance with limits and reliable energy efficiency are crucial for wastewater treatment plant operation.**




Monitoring software for wastewater treatment plant operation

There are two types of monitoring system:

- Time-based, oxygen ($O_2$), or oxidation-reduction potential controls (ORP, also known as redox). Due to their low cost, nitrification-denitrification processes with biological phosphate removal, controlled by redox potential (enhanced by incorporating an oxygen loop in the control loop), have been a widespread technical-economic solution.
- $NH^{4+}$ and/or nitrate control. Nitrogen removal processes are commonly controlled by continuously analyzing nitrate or ammonium concentrations in aeration tanks. This technology has high installation and maintenance costs, including high maintenance labor costs due to equipment complexity.

Biological treatments can be aerobic or anaerobic. In the meat industry, particularly in slaughterhouses, installing **aerobic systems or a combination of aerobic and anaerobic systems is more common.**

Microorganisms can be classified by their growth mediums as follows:

### Aerobic Treatment

Biological systems featuring suspended biomass, where microorganisms form flocs, include the following:

- Extended aeration: conventional activated sludge.
- Membrane Bioreactor (MBR):

  MBRs can operate with higher solid concentrations (up to 15,000 mg/l), resulting in longer sludge ages and a smaller installation footprint, and eliminating the need for a separate decanter.

  This system improves the removal of organic matter, ammonia, and nitrogen and achieves very low effluent phosphorus concentrations, while also addressing salts present in the water.

  This system has several advantages. It meets the strictest quality limits (COD, SS, N, P, conductivity, etc.), thus eliminating or reducing the need for disinfection. The effluent is high-quality and suitable for reuse.

  Maintenance and operation are easy, membrane lifespan can exceed 10 years, and sludge production is reduced, eliminating problems inherent to sludge settling.

- Sequential Batch Reactors (SBR).

Fixed-biomass biological systems where microorganisms attach to a support medium, forming a biofilm. These systems include:

- Rotating biological contactors (biodiscs).
- Biological filters.

### Anaerobic Treatment

**UASB Treatment:** This treatment is newer than the aerobic biological process. In this process, the organic matter of wastewater is transformed into biogas using UASB (Upflow Anaerobic Sludge Blanket) technology. Also known as UASB reactors, these are a type of tubular bioreactor that operates continuously. In this upflow system, the influent enters through the bottom of the reactor, crosses the entire longitudinal profile, and exits through the top. These anaerobic reactors contain microorganisms that group together, forming biogranules.

Anaerobic biological processes are more efficient and economical, with influent containing high concentrations of biodegradable organic compounds.

**Compared to aerobic processes, anaerobic processes consume less energy and produce biogas, which can be used for electricity generation via cogeneration. Anaerobic systems also produce significantly less sludge.**

Weather, particularly low temperatures, impacts anaerobic processes by slowing metabolic reaction rates.

Operation and maintenance are complex and costly.

## Tertiary Treatment

Tertiary treatment aims to remove any remaining organic load and pollutants not addressed by secondary treatment, including nutrients (phosphorus and nitrogen), and pathogens. These processes are biological or physicochemical, with physicochemical treatment being the most common.

Tertiary treatment is recommended when the facility discharges into a public waterway or when water reuse is intended.

# Appendix VI
# Refrigerant Gases

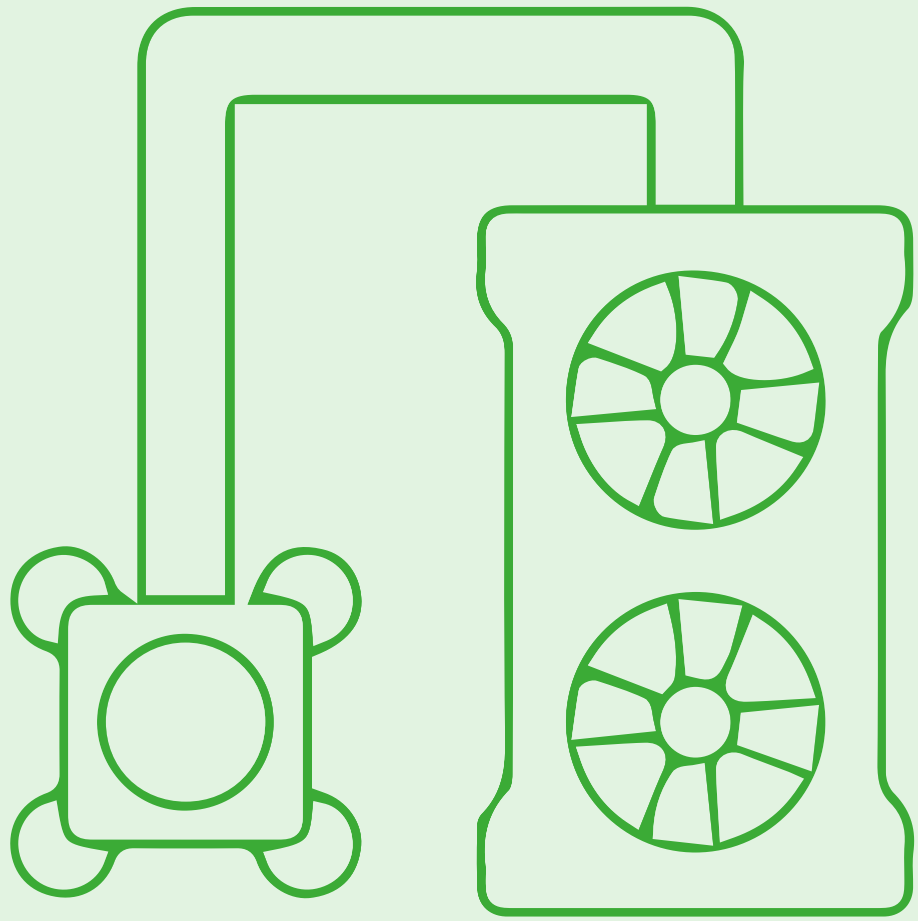
## Table 14: Refrigerant Gases Currently in Use

Source: Itarcon. https://www.intarcon.com/refrigerantes-mas-utilizados/

| REFRIGERANT | COMMERCIAL REFRIGERATION | INDUSTRIAL REFRIGERATION | EQUIPMENT TYPE |
|---|---|---|---|
| **R-404A** | ✔ | | COMPACT<br>SEMI-COMPACT |
| **R-454A** | ✔ | | |
| **R-448A** | ✔ | | |
| **R-449A** | ✔ | | |
| **R-134A** | ✔ | | |
| **R-513A** | ✔ | | |
| **R-450A** | ✔ | | |
| **R-290 (Propane)** | ✔ | ✔ | COMPACT CHILLERS |
| **R-152A** | | ✔ | CHILLERS |
| **R-744 A ($CO_2$)** | ✔ | ✔ | DIRECT EXPANSION UNITS |
| **R-717 (Ammonia)** | | ✔ | INDIRECT UNITS |

| GROUP | SAFETY CLASS | ODP (1) | GWP 100 (2) | PER (3) |
|---|---|---|---|---|
| L1 | A1 | 0 | 3,922 | 2 |
| L1 | A1 | 0 | 2,140 | 2 |
| L1 | A1 | 0 | 1,387 | 2 |
| L1 | A1 | 0 | 1,396 | 2 |
| L1 | A1 | 0 | 1,430 | 2 |
| L1 | A1 | 0 | 631.4 | 2 |
| L1 | A1 | 0 | 604.7 | 2 |
| L3 | A3 | 0 | 3 | 1 |
| L2 | A2 | 0 | 124 | 1 |
| L1 | A1 | 0 | 1 | 2 |
| L2 | A2 | 0 | 0 | 1 |

(1) ODP: Ozone Depletion Potential
(2) GWP 100: Global Warming Potential (100-year)
(3) Refrigerant classification according to PER: Pressure Equipment Regulations



**As of 2020, regulations prohibit the installation of new systems using refrigerants with a Global Warming Potential (GWP) exceeding 2500. And, since 2022, refrigerants used in centralized direct expansion systems over 40kW must have a GWP below 150.**

R404A is therefore prohibited in new EU equipment, and for recharging existing systems containing more than 10 kg of R-404A. Various manufacturers and distributors have released direct replacement refrigerants for R-404A.

Current alternatives under consideration include natural refrigerants such as R-717 (Ammonia), R-600A (Isobutane), and R-290 (Propane). While these have very low GWPs, some are highly flammable, toxic, or corrosive, requiring significant safety precautions.

- **R-717 (Ammonia)**

  Ammonia has been used since the 19th century and remains widely used in commercial refrigeration. Many professionals now consider it the refrigerant of the future due to its suitable thermodynamic properties, leading to efficient systems. Its distinct odor makes it easy to detect leaks.

# Alternatives to R-134A and R-404A

## (Replacement Refrigerants for Commercial and Industrial Refrigeration)

- **$CO_2$**

Carbon dioxide (R-744), with its various technological applications, is considered a long-term solution, as it is a natural refrigerant with minimal GWP. Advantages of this system include:

- $CO_2$ is a natural, clean, and environmentally friendly refrigerant.

- Its low production cost makes it a safe and economical refrigeration option.

- $CO_2$ is non-corrosive, non-flammable, and non-toxic.

- It offers high efficiency due to high heat transfer coefficients and thermal conductivity.

- Its high volumetric refrigeration capacity (six times greater than R-404A) allows for smaller compressors, components, and piping. Its constant evaporation temperature allows for smaller temperature differentials in evaporators and heat exchangers, resulting in significantly lower energy consumption.

- Its low viscosity in liquid and gas lines allows for smaller piping, minimizing system cost.

- High cascade efficiency: it performs well in cascade systems, achieving excellent efficiency and performance at low temperatures.

- **R-454C and R-454A**

The hydrofluoroolefin (HFO)-based R-454C is a mildly flammable refrigerant with a **GWP below 150**, suitable for **replacing R-404A and R-22.** Its similar performance simplifies and reduces the cost of implementation in new equipment without major modifications.

The slightly flammable azeotropic mixture R-454A is designed as an alternative for low-, medium-, and high-temperature applications in new systems. It has a GWP of 145. It offers similar capacity to R-404A, a wider operating range than propane or air conditioning refrigerants, and high energy efficiency.

**R-152A**

R-152A (difluoroethane) is an eco-friendly, medium-temperature refrigerant and an R-134A replacement. It is ozone-friendly and has a GWP of 124.

Despite its slight flammability (class A2), R-152A is gaining attention due to F-gas Regulation limitations to address global warming, the search for low-GWP refrigerants, and the Spanish tax on gases with GWPs over 150. R-152A has been commonly used as an aerosol propellant, foaming agent, and a component of refrigerant mixtures, but its use has been limited to automotive and commercial refrigeration.

R-152A also offers superior thermodynamic characteristics compared to R-134A and HFOs. R-152A's superior physical properties lead to a roughly 20% increase in the heat transfer coefficient in evaporators compared to R-134A. Lower gas viscosity results in a 30% reduction in suction line pressure drop. R-152A's lower molecular weight results in high latent heat of vaporization, higher compressor volumetric efficiency, and improved COP in the refrigeration cycle, with a discharge temperature approximately 10K higher than R-134A.

R-152A has a slightly lower operating pressure (-10%) than R-134A at the same evaporation temperature. Despite this, **its refrigerating capacity is nearly identical (-1% compared to R-134A), making R-152A a suitable replacement in the same refrigeration system.**

# Appendix VII Main Energy Consumption Indicators

## Electrical Energy

### Product KPIs

This section presents the key performance indicators (KPIs) for the beef sector identified by the SCOoPE project.

**Specific Electricity Consumption (SEC) per Ton of Beef Carcass**

This indicator represents the total electricity required to produce one ton of beef carcass, including auxiliary processes. This value is determined by the equation SEC = E/BC (kWh/t), where E is the annual electricity consumption and BC is the annual tonnage of produced beef carcasses (t). The processing plant's electricity bill provides the annual consumption data. If the facility includes processes beyond beef carcass production, consumption must be disaggregated by sector. The methodology is based on audits referenced in Nunes et al. (2016).

This indicator is influenced by industry size, and is generally higher for smaller facilities.

**Average Specific Electricity Consumption (SEC): 150 kWh/t of carcass**

**Optimal Specific Electricity Consumption (SEC): 36 kWh/t of carcass**

## Industry KPIs

These indicators reflect the overall electrical performance of the facility. This includes the consumption of the entire facility, including auxiliary and horizontal activities.

### Average Cost of Electricity

This indicator includes all electrical energy consumption, including auxiliary processes. The cost includes all aspects and related taxes. This indicator can be calculated by compiling a full year of electricity bills. Data on electricity costs are available from Eurostat (2016).

**Average Electricity Cost: €0.12/kWh**

**Optimal Electricity Cost: €0.05/kWh**

### Load Factor

This term, used by utility companies, expresses the amount of electricity used during a period compared to the amount that could have been used at peak demand. This KPI, expressed as a percentage, is calculated as average demand (kWh) divided by peak demand (kWh). Load factor is typically calculated monthly. The load factor formula uses data from the electricity bill. First, obtain the monthly energy consumption (kWh) for the desired month. Next, obtain the peak demand (kWh) from the electricity bill. The maximum possible energy consumption (kWh/month) at peak demand can be calculated by multiplying the peak demand (kWh) by the number of hours in the month. Finally, divide the actual electricity consumption (kWh/month) by the maximum possible consumption at peak demand (kWh) to obtain the load factor for that month. The annual load factor can be calculated by averaging the monthly values.

This indicator quantifies changes in electricity usage behavior at a location. This indicator can help determine the optimal contracted power.

**Average Load Factor: 50%**

**Optimal Load Factor: 80%**

### Average Minimum Overall Demand

This indicator includes all electrical energy consumption, including the facility's auxiliary processes.

This indicator aims to identify the minimum power required by a facility at its lowest utilization point. This minimum use point might be 2 a.m. for some facilities, and 11 p.m. for others. It is calculated as a percentage, with minimum demand (kWh) divided by average demand (kWh). Regardless of the time of day, this serves as a key indicator of opportunities to better control the facility's load profile and reduce electricity consumption over time. This indicator typically requires specific measurements of electricity demand at 2 a.m. or 11 p.m., unless such data is already available. Digital electrical energy analyzers or similar tools can be used for these measurements. Measurement periods should accurately reflect typical operational parameters. This indicator depends on the facility's operating systems outside of production periods.

**Average Minimum Demand: 30%**

**Optimal Minimum Demand: 0%**

### Average Power Factor

This indicator is the ratio of real power flowing to the industry to apparent power in the industry. The annual average can usually be calculated from a full year of electricity bills. First, use the bills to calculate the total annual electrical consumption (EC, in kWh) and the total annual reactive energy consumption (REC, in kVArh – kilovolt ampere reactive hour). The REC/EC ratio is a trigonometric function of the electrical system. As REC/EC is the tangent of the system's angle, the angle itself can be calculated. The cosine of this angle is the annual average power system value. Installing capacitor banks is economically viable if it offsets the increased electricity bill from reactive power. Reactive power must be measured and shown on the electricity bill.

This indicator depends mainly on the installation of capacitor banks. Technically, it depends on the ratio of industry power (kWh) to installed capacitor power (kVAr).

**Average power factor: 0.95**

**Optimal power factor: 1**

### Fixed Electricity Charges

Percentage of fixed costs to total electricity costs (excluding taxes), calculated as: (pending charges + energy costs + taxes) as a percentage.

This indicator can be easily calculated by compiling a full year of electricity bills. All necessary information (pending charges, energy costs, and taxes) is included in the bill. This indicator depends greatly on the power contracted with the electricity company. A common problem that increases this KPI is excessive contracted power (percentage of fixed costs to total electricity costs).

**Average Fixed Electricity Charges: 15%**

**Optimal Fixed Electricity Charges: 8%**

### Use of Electricity Source

This indicator shows the percentage of on-site electricity relative to the total electricity used. This KPI generally requires specific measurements of electricity supply from different sources, unless such data is already available. Electrical power analyzers or similar tools can be used to take these measurements. Measurement periods should accurately reflect typical operational parameters. Once the electricity supply distribution from different sources is determined, the percentage of on-site electricity relative to the electricity source can be calculated, taking into account the effectiveness of this concept for the different sources. Data on the percentage of on-site electricity for different sources can be found in Eurostat, 2016. This KPI depends on the facility's electricity sources. These sources need to be identified and quantified as a percentage, typically on an annual basis.

**Average Use of Electricity Source: 30%**

**Optimal Use of Electricity Source: 100%**

### Sustainability Index

Percentage of on-site electrical energy from sustainable sources relative to the total electrical energy of the site.

This KPI generally requires specific measurements of electricity supply from different sources, unless such data is already available. Electrical power analyzers or similar tools can be used to take these measurements. Measurement periods should accurately reflect typical operational parameters.

The importance of renewable energy sources relative to the EU-28 grid grew from 13.5% to 24.5% between 2004 and 2014. Data on the relative importance of renewable energy sources relative to net electricity generation in the EU-28 can be found in Eurostat 2016.

This KPI depends on the facility's electricity sources. These sources need to be identified and quantified as a percentage, typically on an annual basis.

**Average Sustainability Index: 24.9%**

**Optimal Sustainability Index: 100%**

## Process KPIs

These indicators show the electricity consumption of three typical, facility-wide processes: lighting, compressed air, and HVAC in rooms and other spaces.

### Energy Performance Indicator: Lighting (LEC)

This performance indicator assesses the energy efficiency of lighting, per square meter of lit space, per year. It does not include energy use from other auxiliary processes at the facility.

It is calculated as LEC=E/LS (kWh/$m^2$), where E is the annual electricity consumption from lighting (in kWh), and LS is the surface area of the lit spaces (in $m^2$).

Calculating this KPI generally requires specific measurements of electricity consumption from lighting, unless such data is already available. Electrical power analyzers or similar tools can be used to take these measurements, and measurement periods should accurately reflect typical operational parameters. The annual consumption should be calculated or estimated from the collected data. The area of the lit spaces must also be determined to calculate the indicator per unit area. This indicator depends on the lighting requirements of the spaces.

**Average Lighting Electricity Consumption (LEC): 40 kWh/$m^2$**

**Optimal Lighting Electricity Consumption (LEC): 10 kWh/$m^2$**

### Energy Performance Indicator: Compressed Air (CAC)

This performance indicator assesses the energy efficiency of compressed air production per ton of product. It does not include energy use from other auxiliary processes at the facility.

It is calculated as CAC = E/CA (kWh/$m^2$), where E is the annual electricity consumption from compressed air (in kWh), and CA is the total conditioned area (in $m^2$).

Calculating this KPI generally requires specific measurements of electricity consumption from compressed air, unless such data is already available. Electrical power analyzers or similar tools can be used to take these measurements, and measurement periods should accurately reflect typical operational parameters. The calculated or estimated monthly or annual consumption should be analyzed using the collected data. The total tons of product processed during this period must also be determined.

**Average Compressed Air Electricity Consumption (CAC): 5 kWh/t**

**Optimal Compressed Air Electricity Consumption (CAC): 2 kWh/t**

### Energy Performance Indicator: Air Conditioning (ACC)

This performance indicator assesses the energy efficiency of air conditioning systems by measuring annual electricity consumption per square meter of conditioned floor area. It does not include energy use from other auxiliary processes at the facility.

It is calculated as ACC = E/CA ($kWh/m^2$), where E is the annual electricity consumption for air conditioning (in kWh), and CA is the total conditioned area (in $m^2$).

Calculating this KPI generally requires specific measurements of AC electricity consumption, unless such data is already available. Electrical power analyzers or similar tools can be used to take these measurements, and measurement periods should accurately reflect typical operational parameters. The calculated or estimated monthly or annual consumption should be analyzed using the collected data. The total area of cooled spaces is also required to determine the indicator per unit area.

This indicator is influenced by external factors such as outdoor temperature and climate conditions, as well as internal factors such as the set-point temperature of the air-conditioned spaces.

**Average Air Conditioning Electricity Consumption (ACC): 30 $kWh/m^2$**

**Optimal Air Conditioning Electricity Consumption (ACC): 10 $kWh/m^2$**

The following performance indicators track energy use for product cooling, refrigeration, and freezing operations.

### Use of Cold Room Volume (UCR)

This performance indicator shows the annual production (refrigerated in cold rooms) per unit volume of cold room space.

It is calculated as UCR = RM/total V ($t/m^3$), where RM is the annual amount of refrigerated meat (in tons) and total V is the total cold room volume (in $m^3$).

Annual production (in tons) can be obtained from the facility's production logs. It must be verified that all the production was refrigerated in the cold rooms under consideration. The internal dimensions (in $m^3$) of the cold rooms can be measured with infrared rangefinders, as described in Nunes et al. (2016). Partially loaded cold rooms reduce the indicator value, and using them wastes energy.

**Average Use of Cold Room Volume (UCR): 0.7 $t/m^3$**

**Optimal Use of Cold Room Volume (UCR): 2.5 $t/m^3$**

### Cold Room Cooling Capacity (CRCC)

This performance indicator shows the average power of all refrigeration compressors (total P) per unit volume of cold room space (total V).

It is calculated as CRCC = total P/total V(kWh/$m^3$), where total P is the average measured power of all refrigeration compressors (in kWh) and total V is the total volume of the cold rooms (in $m^3$).

The total power of all refrigeration compressors (total P) can be measured in an audit using digital network analyzers. The average value obtained over the measurement period should provide a close estimate of the annual average. Measurement periods should accurately reflect typical operational parameters. This electrical power (total P) can also be determined using a digital multimeter and a clamp meter to measure voltage (V), current (A), and power factor (PF) for three-phase electrical supply systems. This indicator can be calculated using the following equation: total P = 1.732 * V * A * PF. The internal dimensions of the cold rooms can be measured with an infrared rangefinder. This indicator depends on the cold room temperature and other technical factors, including the local climate and the maintenance of the cold room.

**Average Installed Cold Room Cooling Capacity (CRCC): 0.1 kW/$m^3$**

**Optimal Installed Cold Room Cooling Capacity (CRCC): 0.032 kW/$m^3$**

### Specific Electricity Consumption: Cold Rooms (SEC)

This performance indicator shows the annual electrical energy consumed in cooling cold room space (per unit volume).

It is calculated as SEC = E/total V (kWh/$m^3$), where E is the annual electrical energy consumption of the cold room (in kWh) and total V is the total cold room volume (in $m^3$).

The facility's total electrical energy consumption can be obtained from the electricity bill. To determine the annual consumption of cold rooms, measurements must be obtained using digital analyzers or network analyzers. This data can then be used to extrapolate total cold room consumption. The internal dimensions of the cold rooms can be measured with infrared rangefinders. This indicator depends on the cold room temperature and other technical factors, including the local climate and the maintenance of the cold room.

**Average Specific Electricity Consumption (SEC) per Cold Room: 350 kWh/$m^3$**

**Optimal Specific Electricity Consumption (SEC) per Cold Room: 120 kWh/$m^3$**

## Equipment KPIs

These performance indicators gauge the efficiency of a range of equipment: air conditioning units, chillers, heat pumps, compressors, and electric motors.

### Air Conditioning Energy Efficiency Ratio (ACEER)

This performance indicator quantifies the Energy Efficiency Ratio (EER) for an air conditioning unit.

It is calculated as ACEER = Thermal Energy Output (kWh) / Electrical Energy Input (kWh).

Air conditioning unit EER can be determined via audit using digital network analyzers, measuring electrical energy input, and calculating thermal energy output based on process temperatures. Measurement periods should accurately reflect typical operational parameters. Equipment age can, in some cases, provide a basis for EER estimation. The methodology is grounded in experimental work documented by Carlsson-Kamyama and Faist (2000).

Several factors influence this ratio, notably the temperature of the incoming and outgoing fluid, as well as the age of the air conditioning unit.

**Average Air Conditioning Energy Efficiency Ratio (ACEER): 4**

**Optimal Air Conditioning Energy Efficiency Ratio (ACEER): 6**

### Chiller Efficiency (CEER)

This performance indicator quantifies the Energy Efficiency Ratio (EER) of a chiller.

It is calculated as CEER = Thermal Energy Output (kWh) / Electrical Energy Input (kWh). Chiller EER can be determined through an audit using digital power analyzers to measure electrical energy consumption. Process temperatures can be used to calculate thermal energy output. Measurement periods should accurately reflect typical operational parameters. Equipment age can, in some cases, provide a basis for EER estimation. The methodology is grounded in experimental work documented by Carlsson-Kamyama and Faist (2000). Several factors influence this indicator, notably the temperature of the incoming and outgoing fluid, as well as the age of the chiller.

**Average Chiller Energy Efficiency Ratio (CEER): 4**

**Optimal Chiller Energy Efficiency Ratio (CEER): 6**

### Heat Pump Efficiency (HPEER)

This performance indicator quantifies the Energy Efficiency Ratio (EER) of a heat pump.

It is calculated as HPEER = Thermal Energy Output (kWh) / Electrical Energy Input (kWh).

Heat pump EER can be determined through an audit using digital power analyzers to measure electrical energy consumption. Process temperatures can be used to calculate thermal energy output. Measurement periods should accurately reflect typical operational parameters. Equipment age can, in some cases, provide a basis for EER estimation. The methodology is grounded in experimental work documented by Carlsson-Kamyama and Faist (2000).

Several factors influence this ratio, notably the temperature of the incoming and outgoing fluid, as well as the age of the heat pump.

**Average Heat Pump Energy Efficiency Ratio (HPEER): 4**

**Optimal Heat Pump Energy Efficiency Ratio (HPEER): 6**

### Compressor Energy Efficiency (CEE)

This performance indicator quantifies the efficiency of an electric compressor.

Isentropic efficiency, in the context of compressors and pumps, is defined as the ratio of work input for an isentropic process compared to the actual process, given the same incoming and outgoing pressures. Electric compressor efficiency can be determined through specific measurements. Measurement periods should accurately reflect typical operational parameters. Equipment age can, in some cases, provide a basis for efficiency estimation. The methodology is grounded in experimental work documented by Carlsson-Kamyama and Faist (2000).

Several factors influence this indicator, notably the temperature of the incoming and outgoing fluid, as well as the age of the electric compressor.

**Average Compressor Energy Efficiency (CEE): 0.8**

**Optimal Compressor Energy Efficiency (CEE): 0.9**

### Electric Motor Efficiency (EME)

This performance indicator quantifies the efficiency of an electric motor.

It is calculated as EME = Mechanical Energy Output (kWh) / Electrical Energy Input (kWh).

Electric motor efficiency can be determined through an audit using digital power analyzers to measure electrical energy consumption and mechanical energy output. Measurement periods should accurately reflect typical operational parameters. Equipment age can, in some cases, provide a basis for efficiency estimation. The methodology is grounded in experimental work documented by Carlsson-Kamyama and Faist (2000).

Several factors influence this metric, particularly the age of the electric motor.

**Average Electric Motor Efficiency (EME): 0.85**

**Optimal Electric Motor Efficiency (EME): 0.99**

# Thermal Energy + Electrical Energy

## Product KPIs

**Average total energy consumption
(electricity + thermal energy) in beef slaughterhouses, measured in kWh per metric ton of hot standard carcass weight, typically falls between 333.33 and 1333.33.**

### Total Energy (Thermal Energy + Electrical Energy) for Processed Beef

Slaughterhouses and cutting plants typically rely on electricity for 50-80% of their energy needs, with the remaining 20-50% coming from thermal sources. Slaughterhouses rely heavily on electricity to power a range of critical functions, from refrigeration, compressed air, ventilation, and lighting, to the equipment used in slaughtering, deboning, and by-product processing. Examples of electricity-powered equipment include saws, forklifts, conveyors, packaging machines, and electrical stimulation systems. Electricity also powers on-site rendering plants at slaughterhouses. Heat and hot water generation in slaughterhouses rely primarily on gas and oil, supporting processes such as scalding, knife sterilization, cleaning, and product processing and heating. Cattle and sheep slaughterhouses generally require less hot water than pig slaughterhouses. While pig slaughterhouses may use up to 80% thermal energy for processes like heating scald tanks, raising steam, and singeing, cattle and lamb facilities typically require only 30-50%.

Average TOTAL energy use by a beef processing industry per ton of processed beef. This metric encompasses the entire beef processing chain, from slaughter and cutting to retail packaging.

**The industry benchmark for total energy consumption is 755 kWh per metric ton of processed beef.**

# Thermal Energy

**Thermal energy consumption in beef slaughterhouses is typically measured in kWh per metric ton of dry cattle weight.**

**Average thermal energy consumption ranges from 55 to 140 kWh/t of dry cattle weight.**

# Appendix VIII European and State Environmental Legislation Applicable to the Sector

## Atmospheric Pollution

- **Law 34/2007**, of 15 November, on air quality and atmospheric protection.
- **Royal Decree 100/2011,** of 28 January, updating the list of potentially polluting activities of the atmosphere and establishing the basic provisions for its application.
- **Decree 833/1975,** which develops Law 38/1972 on the protection of the atmospheric environment (repealed except for Annex IV for Group C installations).
- **Royal Decree 1042/2017,** of 22 December, on the limitation of atmospheric emissions of certain pollutants from medium combustion plants, and updating Annex IV of Law 34/2007, of 15 November, on air quality and protection of the atmosphere. Correction of errors.
- **Royal Decree 795/2010,** of 16 June, regulating the marketing and handling of fluorinated gases and equipment based thereon, as well as the certification of professionals who use them.
- **Regulation (EC) No 1005/2009** of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer.

## Refrigerant Gases

- **Royal Decree 138/2011,** of 4 February, approving the safety regulation for refrigeration installations and their supplementary technical instructions.
- **Royal Decree 1042/2013,** of 27 December, approving the Regulation of the tax on fluorinated greenhouse gases.
- **Law 6/2018,** of 3 July, on the general state budget for the year 2018. Article 85 (modification of the previous regulation).
- **Regulation (EU) No 517/2014** of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases. “F-Gas Regulation”.
- **Royal Decree 115/2017,** of 17 February, regulating the marketing and handling of fluorinated gases and equipment based thereon, as well as the certification of professionals who use them, and establishing the technical requirements for installations carrying out activities that emit fluorinated gases.

## Noise Control

- **Law 37/2003,** of 17 November, on noise.
- **Royal Decree 1513/2005,** of 16 December, which develops Law 37/2003, of 17 November, on noise, as regards the assessment and management of environmental noise.
- **Royal Decree 524/2006,** of 28 April, amending Royal Decree 212/2002, of 22 February, regulating noise emissions in the environment due to certain machines for outdoor use.
- **Royal Decree 1367/2007,** of 19 October, which develops Law 37/2003, of 17 November, on noise, as regards noise zoning, quality objectives and noise emissions.

## Water Pollution

- **Royal Decree 9/2008,** of 11 January, amending the Regulation of the public water domain, approved by Royal Decree 849/1986, of 11 April.
- **Royal Decree-Law 4/2007,** of 13 April, amending the revised text of the water law, approved by Royal Legislative Decree 1/2001, of 20 July.
- **Royal Decree 606/2003,** of 23 May, amending Royal Decree 849/1986, of 11 April, approving the Regulation of the public water domain, which develops the preliminary Titles I, IV, V, VI, and VII of Law 29/1985, of 3 August, on waters.
- **Legislative Royal Decree 1/2001,** of 20 July, approving the revised text of the water law.
- **Order AAA/2056/2014,** of 27 October, approving official authorization request and declaration of discharge forms.
- **Royal Decree 849/1986,** of 11 April, approving the Regulation of the public water domain, which develops the preliminary titles, I, IV, V, VI, and VII of Law 29/1985, of 3 August, on waters.
- **Regulation (EU) 2020/741** of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. This Regulation shall apply from 26 June 2023.

## Waste

- **Law 7/2022,** of 8 April, on waste and contaminated soils for a circular economy.
- **Law 5/2013,** of 11 June, amending Law 16/2002, of 1 July, on integrated pollution prevention and control, and Law 22/2011, of 28 July, on waste and contaminated soils.
- **Royal Decree 833/1988,** of 20 July, approving the Regulation for the implementation of Law 20/1986, Basic Law on toxic and hazardous waste.

- **Royal Decree 952/1997,** of 20 June, amending the Regulation for the implementation of Law 20/1986, of 14 May, Basic Law on toxic and hazardous waste, approved by Royal Decree 833/1988, of 20 July.

- **Order MAM/304/2002,** of 8 February, publishing the waste recovery and disposal operations and the European waste list.

- **Law 11/1997,** of 24 April, on packaging and packaging waste.

- **Royal Decree 782/1998,** of 30 April, approving the regulation for the development and implementation of Law 11/1997, of 24 April,1 on packaging and packaging waste.

- **Order AAA/1783/2013,** of 1 October, amending Annex I of the Regulation for the development and implementation of Law 11/1997, of 24 April, on packaging and packaging waste, approved by Royal Decree 782/1998, of 30 April.

- **Royal Decree 1481/2001,** of 27 December, regulating the disposal of waste by deposit in landfills.

- **Order AAA/661/2013,** of 18 April, amending Annexes I, II, and III of Royal Decree 1481/2001, of 27 December, regulating the disposal of waste by deposit in landfills.

## Soil Contamination

- **Royal Decree 9/2005,** of 14 January, establishing the list of potentially soil-polluting activities and the criteria and standards for the declaration of contaminated soil.

## Environmental Impact

- **Law 21/2013,** of 9 December, on environmental assessment.

- **Legislative Royal Decree 1/2016,** of 16 December, approving the revised text of the Law on integrated pollution prevention and control.

## ABP Regulations

- **Regulation (EC) No 1069/2009** of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption, and repealing Regulation (EC) No 1774/2002.

- **Commission Regulation (EU) No 142/2011** of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption, and

Council Directive 97/78/EC as regards certain samples and units exempt from veterinary checks at the border under that Directive.

- **Regulation (EC) No 999/2001** of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies.

- **Commission Regulation (EU) 2015/728** of 6 May 2015 amending the definition of specified risk material laid down in Annex V to Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies.

- **Commission Regulation (EU) 2021/1372** of 17 August 2021 amending Annex IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council as regards the prohibition of feeding non-ruminant farmed animals, other than fur animals, with animal-derived proteins.

- **Royal Decree 476/2014,** of 13 June, regulating the national register of movements of animal by-products and derived products not intended for human consumption.

- **Royal Decree 894/2013, of** 15 November, amending Royal Decree 1528/2012, of 8 November, establishing the rules applicable to animal by-products and derived products not intended for human consumption.

- **Royal Decree 1528/2012,** of 8 November, establishing the rules applicable to animal by-products and derived products not intended for human consumption.

- **Order APA 1556/2002** of 21 June repealing Order APA/67/2002, of 18 January, and establishing a new control system for the destination of by-products generated in the meat food chain.

- **Royal Decree 1632/2011,** of 14 November, regulating the feeding of certain species of wild fauna with animal by-products not intended for human consumption.

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