

# **INTECUS GmbH**

Waste Management and Environment-Integrating Management



## **Cleaner Production in Food Industry – Material and energy flows in food industry**

Durango, March 09th, 2011

## **Agenda**

### 1. Material flows

1.1 General

1.2 Water

1.3 Air emissions

1.4 Loss of materials

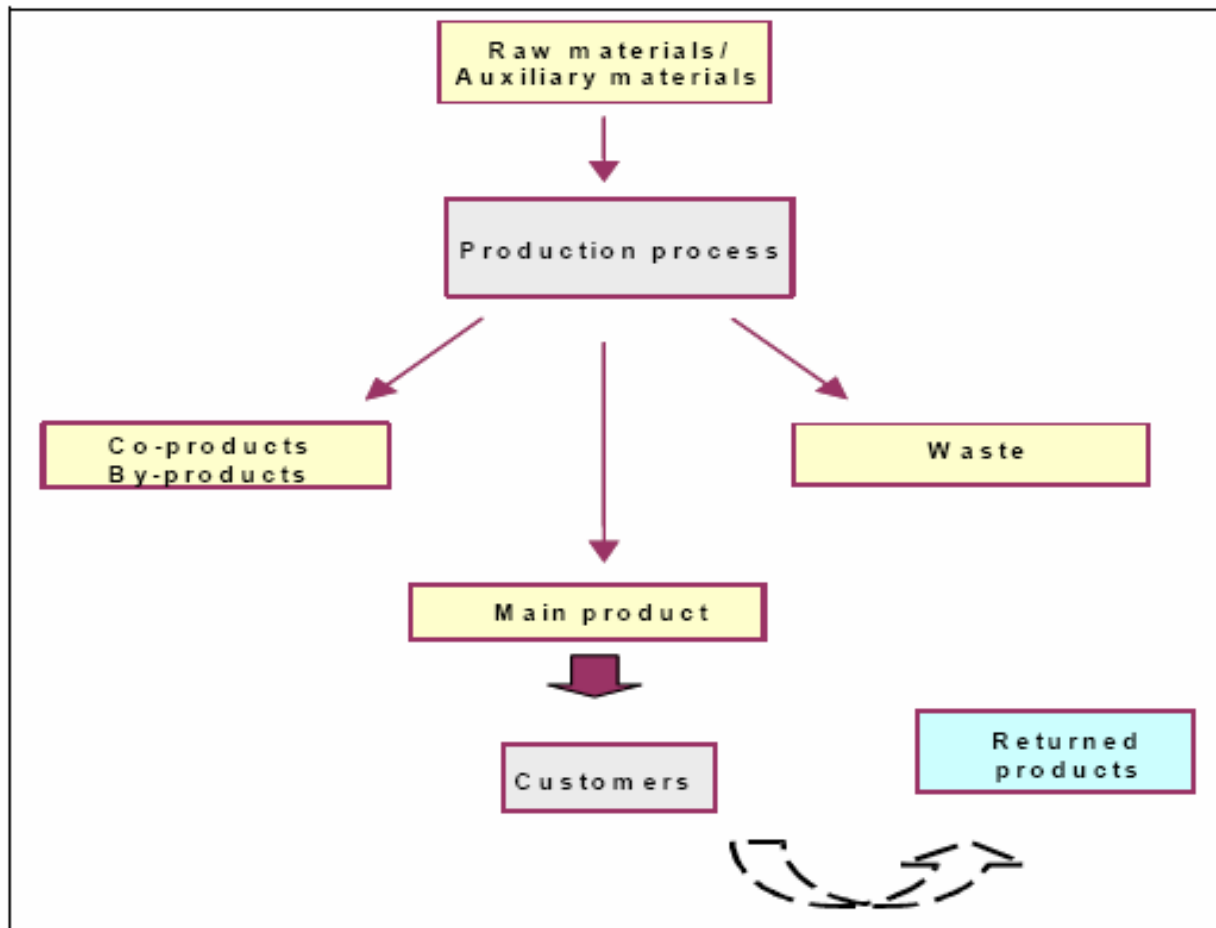
### 2. Energy flows

2.1 Energy in food sector

2.2 Energy efficient design

# 1. Material flows

## 1.1 General



- co-product: material, intentionally and unavoidably, created in the same process and at the same time as the main product
- by-product: residual material which arises during the manufacture of a product
- returned products: returned from retailers and wholesalers because they do not meet the required specification or because their shelf-life has expired

# 1. Material flows

## 1.1 General - Comparison by benchmarking

- benchmarking is a technique used to assess performance against either internal or industry standards
- typically, benchmarks are expressed as ratios, but can be expressed as percentages, e.g. of efficiency
- data on waste minimization, water and energy consumption, odor, noise and emissions to air and waste water, are generally relevant

Performance monitor	Measurement
Air emissions	Mass of emission per unit of production or per unit of raw material
Waste water	Volume of water, mass of contaminants or BOD/COD per unit of production or per unit of raw material
Solid waste	Mass of waste per unit of production or per unit of raw material
Energy resources	Energy use per unit of production or per unit of raw material
Utilities and services	Use of water, compressed air or steam per unit of production or per unit of raw material
Other	Consumption of specific materials, e.g. packaging, per unit of production

**Quantitative benchmarking parameters applicable in the food sector**

## 1. Material flows

### 1.1 General - Comparison by benchmarking

- mostly utilities' consumption are compared against production = quantitative benchmarking
- good indication of the efficiency and also of wastage occurring within the process
- percentage of raw materials going to the final main products is variable and waste minimization is generally considered as a cost effective goal for all manufacturers but benchmarks are not readily available

# 1. Material flows

## 1.1 General - Comparison by benchmarking

Production process	% of raw material in the main final product
Fish canning	35 – 70
Fish filleting, curing, salting and smoking	25 – 50
Crustacean processing	40 – 50
Mollusc processing	50 – 80
Milk, butter and cream production	~99
Yoghurt production	94 – 98
Fresh, soft and cooked cheese production	10 – 15
White wine production	70 – 80
Red wine production	70 – 80
Fruit and vegetable juice production	50 – 70
Fruit and vegetable processing and preservation	70 – 95
Vegetable oils and fats production, i.e. crude vegetable oil, protein rich meal, lecithin and fatty acids from oilseeds	30 – 60
Maize starch production	62.5
Maize starch production (including animal feed)	99
Potato starch production	20
Potato starch production (including animal feed)	30 – 35
Wheat starch production	50
Wheat starch production (including animal feed)	99
Food and animal feed production from sugar beet	25 – 50

**Percentage of raw materials which end up in the final product in some processes**

## 1. Material flows

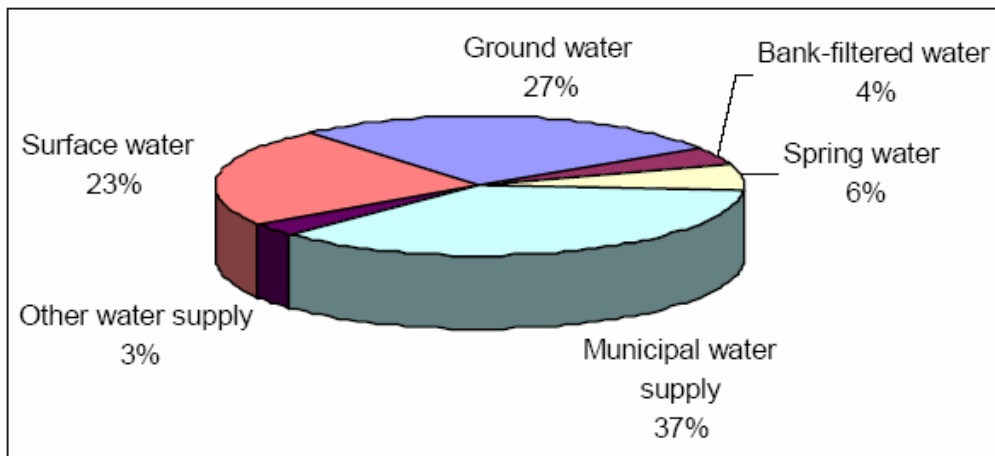
### 1.2 Water –Water consumption

- one of the most important environmental issues in the food sector
- used for
  - for cooling and cleaning
  - as a raw material, especially for the drinks industry
  - as process water, e.g. for washing raw materials, intermediates and products
  - for cooking, dissolving and for transportation
  - as auxiliary water, e.g. for the production of vapor and vacuum
  - as sanitary water
- data on waste minimization, water and energy consumption, odor, noise and emissions to air and waste water, are generally relevant

# 1. Material flows

## 1.2 Water –Water consumption – Figures from Germany

- total industrial water consumption: 8,500 million m<sup>3</sup>
- water consumption in the food sector: 304 million m<sup>3</sup>
- actual water consumption in the food sector: 1,730 million m<sup>3</sup>
- ⇒ water is reused up to five times
- water is used as
  - cooling water (834 million m<sup>3</sup>)
  - process water (438 million m<sup>3</sup>)
- 66 % of the total fresh water used in the German food sector is of drinking water quality (up to 98 % in dairies and beverage industry)



**Water consumption by the German food industries**

## 1. Material flows

### 1.2 Water – Waste water

- waste water sources:

- washing of the raw material
- steeping of raw material
- water used for transporting or fluming raw material or waste
- cleaning of installations, process lines, equipment and process areas
- cleaning of product containers
- blow-down from steam boilers
- once-through cooling water or bleed from closed-circuit cooling water systems
- backwash from regeneration of the WWTP
- freezer defrost water
- storm-water run-off

## 1. Material flows

### 1.2 Water – Waste water - Quantity

- water not used as an ingredient or getting lost by evaporation, ultimately appears in the waste water stream
- substantial reductions in the volume of waste water generated in this sector can be achieved through waste minimization techniques
- no simple relationship between the amount of water used in cleaning and hygiene standards
  - ⇒ food safety legislation requirements prevent water use minimization from causing unsatisfactory levels of cleanliness, hygiene or product quality
- waste water flow-rates vary on a daily, weekly or seasonal basis depending on production and cleaning patterns

# 1. Material flows

## 1.2 Water – Waste water - Composition

- food waste water is extremely variable in composition, but typically high in both, COD and BOD<sub>5</sub> (levels can be 10 to 100 times higher than those of domestic waste water)

BOD <sub>5</sub> content
0.65 kg/kg carbohydrate
0.89 kg/kg fat
1.03 kg/kg protein
0.07 – 0.10 kg/l milk
0.18 – 0.37 kg/kg meat
0.06 – 0.09 kg/kg fruit or vegetables

*BOD5 equivalent of general food sector constituents and some products*

- concentration of soluble solids varies from negligible to as high as 120,000 mg/l
- waste water from meat and dairy facilities contain high concentrations of edible fats and oils

# 1. Material flows

## 1.2 Water – Waste water - Composition

- food waste water vary from very acidic to very alkaline, affecting factors can be:
  - the natural pH of the raw material
  - pH adjustment of fluming water to prevent raw material deterioration
  - use of caustic or acid solutions in processing operations
  - use of caustic or acid solutions in cleaning operations
  - acidic waste streams, e.g. acid whey
  - acid-forming reactions in the waste water, e.g. high yeast content waste water, lactic and formic acids from degrading milk content
  - nature of raw water source, either hard or soft
  
- normally waste water from food production contains few compounds having an adverse effect on WWTPs or receiving waters, exceptions are:
  - salt where large amounts are used, e.g. pickling and cheese-making
  - pesticide residues not readily degraded during treatment
  - residues and by-products from the use of chemical disinfection techniques
  - some cleaning products

## 1. Material flows

### 1.2 Water – Waste water - Composition

- pathogenic organisms are an issue only in meat or fish processing facilities
- plant nutrients may be an issue for biological WWTP, because of a lack on nitrogen and phosphorus (ideal BOD:N:P-ratio is 100:5:1), in some special cases also an excess of these elements (use of large quantities of phosphoric acid or nitric acid) can cause to a release of N or P to the final discharge water under anaerobic conditions
- sources of fugitive and unscheduled emissions, i.e. accidental releases, are:
  - contaminated storm-waters
  - storage tank leaks
  - pipework leaks
  - spillages
  - bund drains
  - leakages from flanges, pumps, seals and valve glands

## 1. Material flows

### 1.2 Water - Main water consuming processes - Meat and poultry manufacturing

- production of waste water is the main environmental impact
- overall water consumption is up to 20 m<sup>3</sup>/t
- significant quantities of water (3–5 m<sup>3</sup>/t) are used for washing and thawing meat
- water used for thawing can be re-circulated in a closed-circuit and used again
- other major water consuming steps are, e.g. pasteurizing, sterilizing, cooling, cleaning and disinfection
- stringent hygiene measures are applied to the cutting and chilling of carcasses which lead to relatively large quantities of waste water arising from equipment and installation cleaning

# 1. Material flows

## 1.2 Water - Main water consuming processes - Fish and shellfish

- to meet quality and hygiene standards, the fish sector uses high quantities of water
- water is used for transporting fish and viscera, for cleaning the installation and the equipment, for washing raw materials and products, and for thawing
- Typical figures for fresh water consumption are for thawing, about 1 m<sup>3</sup>/t fish; for filleting 5 to 11 m<sup>3</sup>/t fish, and for canning, 15 m<sup>3</sup>/t fish.

Production	Water consumption (m <sup>3</sup> /t raw fish)	COD (kg/t raw fish)
Herring filleting	3.3 – 10	Up to 95
Mackerel		
Cleaning and head cut	20	270
Thawing included	26 – 32	
White fish processing		
Fresh fish	4.8	5 – 36
Thawing included	9.8	
Shrimp processing	23 – 32	100 – 130

**Specific water consumption and organic load in Nordic countries**

# 1. Material flows

## 1.2 Water - Main water consuming processes - Fruit and vegetables

- water is used mainly during washing, also during peeling and blanching

Product category	Water consumption (m <sup>3</sup> /t product)
Canned fruit	2.5 – 4.0
Canned vegetables	3.5 – 6.0
Frozen vegetables	5.0 – 8.5
Fruit juices	6.5
Jams	6.0
Baby food	6.0 – 9.0

*Water consumption levels achieved in fruit and vegetable installations [WorldBank, 1998]*

## 1. Material flows

### 1.2 Water - Main water consuming processes - Vegetable oils and fats

- processes with the most significant water consumption are crude oil production; chemical neutralization and subsequent oil washing and deodorization
- water consumption depends on the type of process, e.g. water consumption for pressing-only is minimal, on the type of cooling and vacuum installation, and on the type and age of oilseeds, e.g. soft seeds like rapeseed require different amounts of water than soybeans
- during crude oil production
  - 0.2 – 14 m<sup>3</sup> water/t oilseed are consumed for cooling purposes
  - chemical neutralization of crude oil consumes water at a rate of 1–1.5 m<sup>3</sup>/t of product
  - deodorization of neutralized and bleached oil and bleached edible fat consumes 10 – 30 m<sup>3</sup>/t product
  - water consumed during the hardening of vegetable oil is mainly used for cooling and vacuum purposes and ranges from 2.2–7 m<sup>3</sup>/t oil

# 1. Material flows

## 1.2 Water - Main water consuming processes - Dairy products

- water consumption is mainly associated with cleaning operations
- in average water consumption is between 1-5 l/kg milk

Product	Water consumption* (l/kg processed milk)	
	Min	Max
Market milk and yoghurt	0.8	25
Cheese and whey	1.0	60
Milk powder, cheese and/or liquid products	1.2	60
*Cooling water is included		

*Water consumption in European dairies  
[European Dairy Association, 2002]*

- ice-cream installations have a water consumption in the range 3.6–10.3 l/kg of produced ice-cream [Nordic Council of Ministers, et al., 2001]
- ice-cream installations without water recycling in the cooling system, the water consumption can increase to of 10–325 l/kg of product

# 1. Material flows

## 1.2 Water - Main water consuming processes - Starch

- water consumption depends on the starch and starch derived products produced
- water consumption also differs according to the raw material used
- due to the higher water content of potatoes, the potato starch process requires less water than the cereal starch process

Raw material	Water consumption (m <sup>3</sup> /t raw material used)	
	Min	Max
Maize	1.7	3
Wheat	1.7	2.5
Potato	0.7	1.5

**Water consumption in the starch industry**  
*[CIAA-AAC-UFE, 2002]*

# 1. Material flows

## 1.2 Water - Main water consuming processes - Drinks

- water consumption is in the range of 6–14 m<sup>3</sup>/m<sup>3</sup> product
- in breweries, water is mainly used for mashing, heat transfer and cleaning operations, water consumption for modern breweries generally ranges from 0.4–1 m<sup>3</sup>/hl

Department	Specific water consumption (m <sup>3</sup> /hl beer produced)			
	Measured**		Literature	
	from	to	from	to
Brewhouse	0.130	0.236	0.174	0.26
Cold storage			0.11	0.24
Fermentation cellar	0.032	0.053	0.04	0.08
Storage cellar	0.024	0.067	0.01	0.06
Filtering cellar	0.031	0.109	0.01	0.076
Bottling cellar	0.059	0.163	0.09	0.098
Cask cellar	0.013	0.061	0.01	0.12
Miscellaneous*	0.20	0.204	0.026	0.397
<b>TOTAL PROCESS</b>	<b>0.489</b>	<b>0.893</b>	<b>0.470</b>	<b>1.331</b>
*Estimates				
**Measurements by Heidemann, Rosenwinkel and Seyfried (1990 to 1992) or brewery figures				

**Water consumption for different brewery processes in Germany**

## 1. Material flows

### 1.3 Air emissions

- can be divided into ducted, diffuse, and fugitive emissions
- only ducted emissions can be treated
- diffuse and fugitive emissions can only be prevented or minimized
- main air pollutants from food production are:
  - dust
  - VOCs and odor (some caused by VOCs)
  - refrigerants containing ammonia and halogen
  - products of combustion, such as CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub>

## 1. Material flows

### 1.3 Air emissions

- sources of ducted emissions are:
  - process emissions, released through a vent pipe by the process equipment and inherent to the running of the installation, e.g. in frying, boiling, cooking operations
  - waste gases from purge vents or preheating equipment, which are used only on start-up or shut-down operations
  - emissions from vents from storage and handling operations, e.g. transfers, the loading and unloading of products, raw materials and intermediates
  - flue-gases from units providing energy, such as process furnaces, steam boilers, combined heat and power units, gas turbines, gas engines
  - waste gases from emission control equipment, such as filters, thermal oxidizers or adsorbers
  - waste gases from solvent regeneration, e.g. in vegetable oil extraction
  - discharges of safety relief devices, e.g. safety vents and safety valves
  - exhaust of general ventilation systems
  - exhaust of vents from captured diffuse and/or fugitive sources, e.g. diffuse sources installed within an enclosure or building

## 1. Material flows

### 1.3 Air emissions

- sources of diffuse emissions are:
  - process emissions by the process equipment and inherent to the running of the installation, released from a large surface or through openings
  - working losses and breathing losses from storage equipment and during handling operations, e.g. filling of drums, trucks or containers
  - emissions from flares
  - secondary emissions, resulting from the handling or disposal of waste, e.g. volatile material from sewers, waste water handling facilities or cooling water

## 1. Material flows

### 1.3 Air emissions

- sources of fugitive emissions are:
  - odor losses during storage, filling and emptying of bulk tanks and silos
  - stripping of malodorous compounds from a WWTP resulting in releases to air and/or odor problems
  - storage tank vents
  - pipe-work leaks
  - fumigation
  - vapor losses during storage, filling and emptying of bulk solvent tanks and drums, including hose decoupling
  - burst discs and relief valve discharges
  - leakages from flanges, pumps, seals and valve glands
  - building losses from windows, doors, etc.
  - settling ponds
  - cooling towers and cooling ponds

## 1. Material flows

### 1.4 Loss of materials

- Exceed weight/volume specification
  - loss of products by overfilling, because all filling equipments operate with average filling weights and underweight products must be avoided
  - overfilling is of high economic significance, but normally of no environmental significance
  - regular check-weighing to avoid economic losses and to ensure a reliable mass balance of the process
  
- Spillage
  - spillage of products results in products being unfit for human consumption
  - it increases the amounts of losses and waste
  - routinely occurring spillage indicates poor equipment design, poor maintenance or poor operation, which often causes a considerable loss of product and packaging material
  - spillage during manual handling, the working procedures may be at fault

## 1. Material flows

### 1.4 Loss of materials

- Leakage/Overflow
  - leakage of liquid product from pipe joints and overflow from tanks may be an important source of loss of material and waste
  - can be caused, e.g. by obsolete gaskets or faulty high level alarm switches
  
- Product defects/Returned product
  - products not meeting the required specification, including over-produced fresh products
  - can be a major source of loss of materials and waste
  
- Inherent loss
  - loss of materials and waste which is unavoidable by design of equipment
  - products purged through the equipment with water at the end of production or at product change-over

## 1. Material flows

### 1.4 Loss of materials

- Retained material
  - occurs when liquid products or ingredients cannot freely drain to the next stage in the process (e.g. losses in traps or dips in pipelines)
  - adhesion of very viscous products to the pipeline and tank walls
  
- Heat deposited waste
  - deposition of the product onto the heat-exchange surface by heating of products
  - containing and recycling or recovering back into the process is possible in some cases

## 2. Energy flows

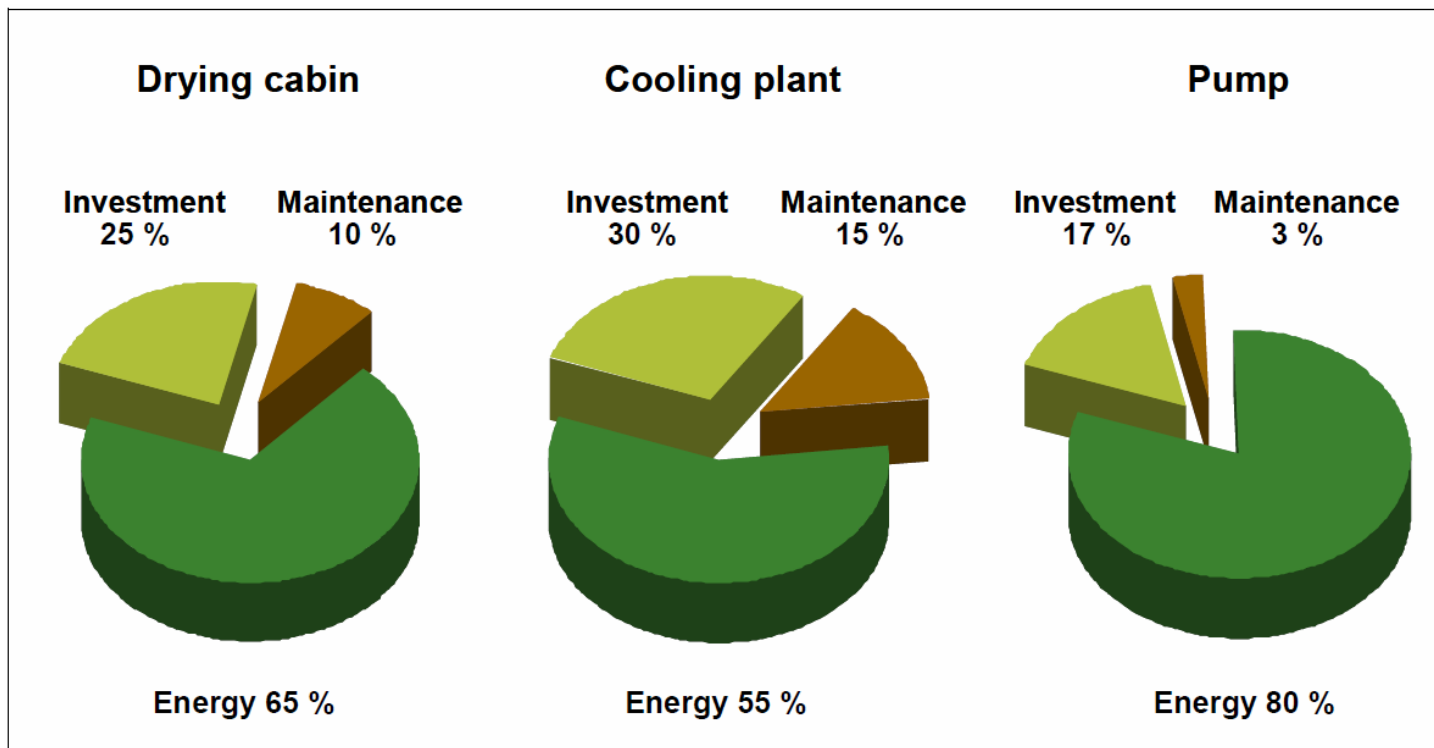
### 2.1 Energy in food sector

- energy is needed in food sector for processing, storage, to maintain freshness and to ensure food safety
- under European conditions 29 % of energy consumption in the food sector is used for process heating, 16 % for cooling and refrigeration
- nevertheless, heating and cooling are regional factors of energy consumption according to climate conditions
- climate conditions influences also the energy efficiency, e.g. efficiency of wet cooling systems is affected by ambient temperature and dew point

## 2. Energy flows

### 2.2 Energy efficient design

- energy is an important cost driving factor
- 20-30 % of energy consumption can be saved by energy efficient design

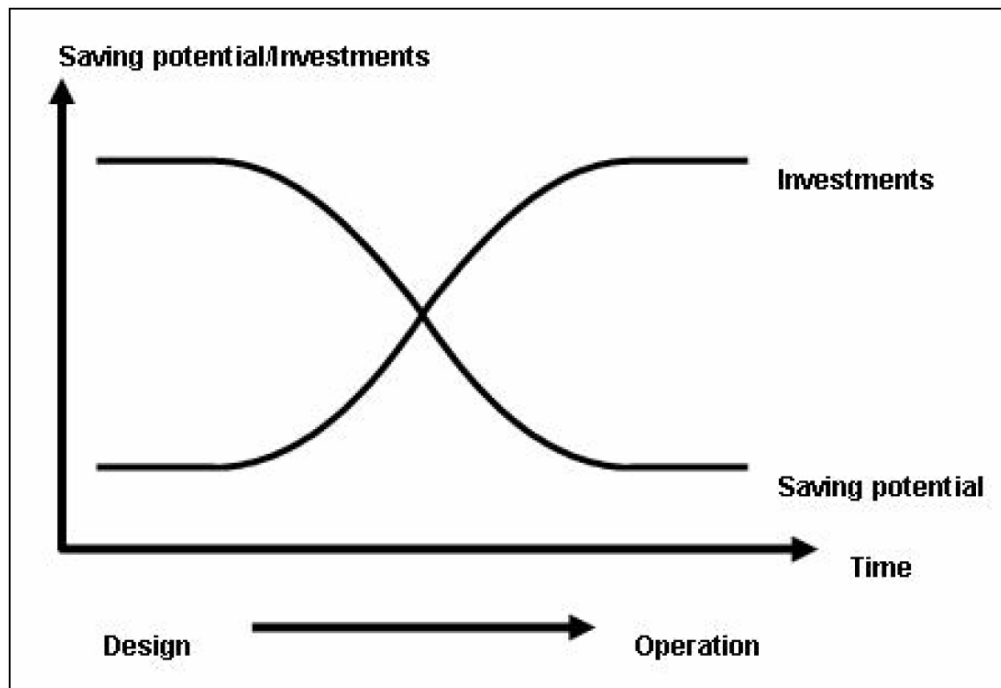


**Examples of total costs of ownership of typical industrial equipment in food industries (over 10 year time)**

## 2. Energy flows

### 2.2 Energy efficient design

- in planning phase of a new plant or installation lifetime energy costs of processes, equipment and utility systems should be assessed
- the energy saving potential is much higher in the planning phase connected with lower needs on investment costs



**Examples of total costs of ownership of typical industrial equipment in food industries (over 10 year time)**

## 2. Energy flows

### 2.2 Energy efficient design

- typical questions of energy efficiency design:
  - airflow requirement in planned installations: What can be done to reduce the airflow of the heating, ventilation and air conditioning system?
  - low temperature requirement of brine in a cooling system: Which processes should be changed or optimized to reduce the cooling load and to raise the brine temperature?
  - heat load in a drying process: Which process parameters and plant principles can be changed in order to minimize the heat load?
  - need for steam in a process: Could hot water be used so waste heat can be utilized for heating purposes?
  - pressure needed for compressed air: Can the pressure be reduced, or the system split into high and medium pressure systems?

## 2. Energy flows

### 2.2 Energy efficient design

Construction phase	EED activity
Basic design/ conceptual design	<ul style="list-style-type: none"> <li>enforced data collection regarding energy usage for new facilities</li> <li>assessment of the real energy needs</li> <li>assessment of lifetime energy costs</li> <li>review of basic design parameters influencing energy consumption</li> <li>identification of key persons and parties influencing energy efficiency for new facilities</li> <li>minimisation of energy services</li> <li>introduction of best available technology</li> </ul>
Detailed design	<ul style="list-style-type: none"> <li>design of optimal process plants and utility systems</li> <li>assessment of needs for control and instrumentation</li> <li>process integration/heat recovery systems (pinch methodology)</li> <li>minimisation of pressure losses, temperature losses, etc.</li> <li>selection of efficient motors, drives, pumps, etc.</li> <li>supplementary specifications to tendering material regarding energy efficiency</li> </ul>
Tendering process	<ul style="list-style-type: none"> <li>ask tenders and manufacturers for more energy efficient solutions</li> <li>quality control of plant designs and specifications in tenders</li> </ul>
Construction and erection	<ul style="list-style-type: none"> <li>quality control of specifications for installed equipment as compared to equipment specified in tenders</li> </ul>
Commissioning	<ul style="list-style-type: none"> <li>optimisation of processes and utilities according to specifications</li> </ul>
Operational phase	<ul style="list-style-type: none"> <li>energy audits</li> <li>energy management</li> </ul>

**Examples of activities during the energy efficient design of a new industrial site**

## 2. Energy flows

### 2.2 Energy efficient design

Company	Savings (EUR/year)	Saving (%)	Investments (EUR)	Payback (years)
<u>Food ingredients:</u> <ul style="list-style-type: none"> <li>• new cooling concepts</li> <li>• change of fermentation process</li> <li>• reduced HVAC in packaging areas</li> <li>• heat recovery from fermentors</li> <li>• new lighting principles</li> </ul>	130000	30	115000	0.8
<u>Sweets:</u> <ul style="list-style-type: none"> <li>• improved control of drying process</li> <li>• optimise cooling circuit</li> <li>• reduced infrared drying of products</li> <li>• reduced compressed air pressure</li> <li>• cheaper heat source (district heating)</li> </ul>	65000	20	50000	0.7
<u>Ready meals:</u> <ul style="list-style-type: none"> <li>• change of heat source for ovens</li> <li>• new freezing technology</li> <li>• new heat recovery concept</li> <li>• optimised NH<sub>3</sub> cooling plant</li> <li>• optimised heat exchangers</li> </ul>	740000	30	1500000	2.1

**Achieved savings and investments in three pilot projects of energy efficient design**

## 2. Energy flows

### 2.2 Energy efficient design

- technical solutions applicable in the food sector:
  - process control systems to ensure a good energy management
  - steam systems: minimizing energy consumption in process by calculating thermodynamically feasible energy targets and achieving them by optimizing heat recovery systems, energy supply methods and process operating conditions
  - direct heat recovery by the use of heat exchangers
  - use of energy efficient electric motors adapted to the needs of the process
  - use of energy efficient compressed air systems, e.g. variable speed drives in case of fluctuate process requirements
  - suitable pumping systems and pipeline works

## 2. Energy flows

### 2.2 Energy efficient design

- technical solutions applicable in the food sector:
  - well planned heating, ventilation and air conditioning systems, particularly regarding
    - power of the chilling/heat pump
    - minimized heating or cooling space
    - optimized ventilation needs
    - use of free cooling (e.g. use of cool air at night)
    - indirect/direct heating systems
    - use of overheated steam

### 3. Conclusions

- water plays an important role in mass flows of the food sector
- air emissions of the food sector can have an significant influence on the environment
- losses of raw materials can be economically relevant
- energy is an important cost factor
- energy efficient design of installations can save costs

**Muchas gracias por su atención!**

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