Saving Cooperative Energy

D2.2 Thermal

(KPIs)

Prepared by:

ENEA

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About this document

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 695985.

This deliverable corresponds to **D 2.2 Thermal KPIs** of the SCOoPE project. It gathers the Key Performance Indicator on thermal energy consumption in the agro-industries.

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1. Introduction

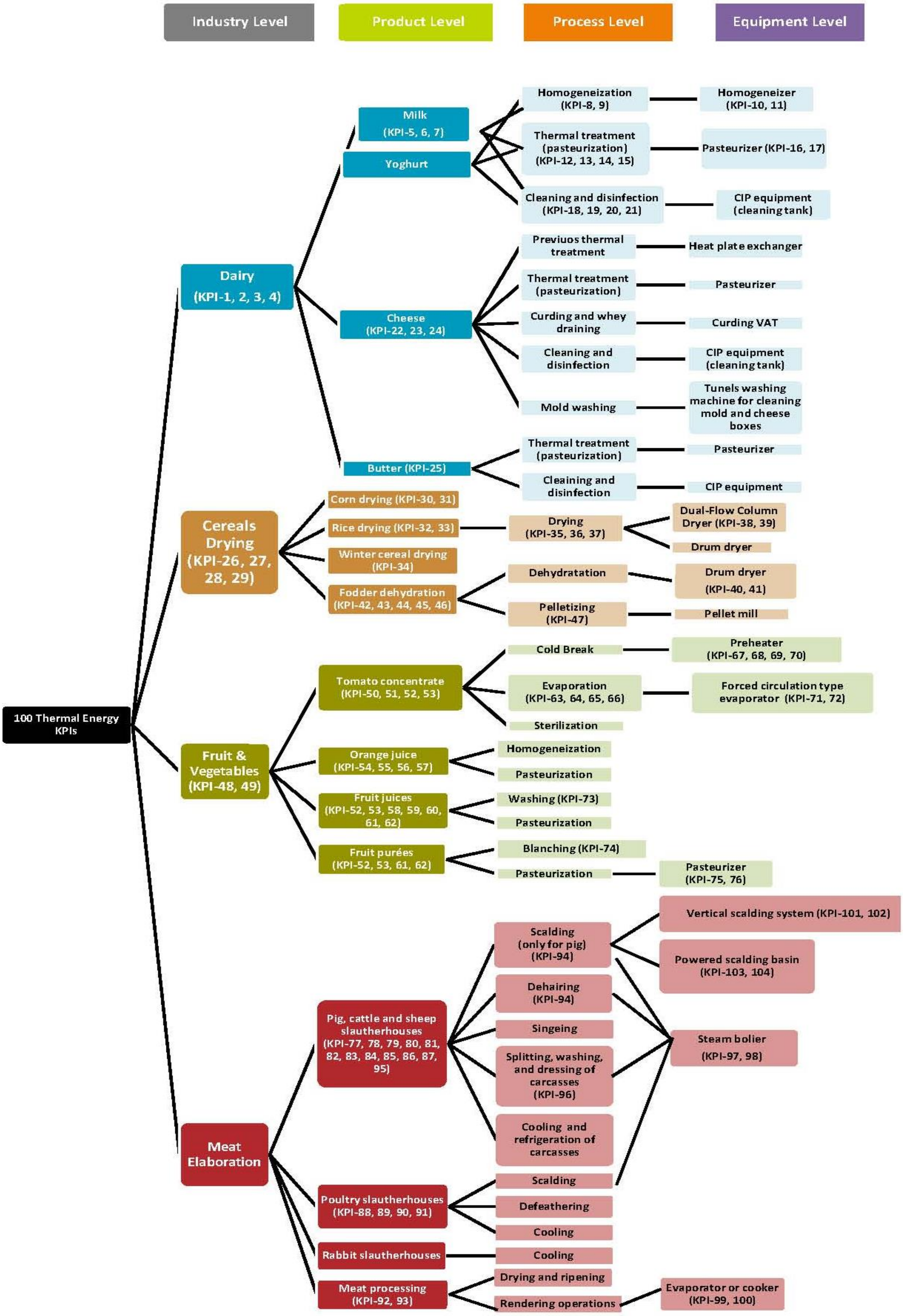

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Figure 1 Scheme of the thermal energy KPIs in the four industrial sectors studied in the SCOoPE project: dairy, meat processing, cereals drying, and fruit and vegetables transformation. Each KPI can be directly visualized on the scheme, according to the four levels, which are – starting from the lower to the upper level – as follows: industry level, product level, process level, and equipment level. In the scheme, only thermal processes of a production line are considered. For each of these KPIs, there is the "average KPI" version and the "best KPI" version.

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2. DAIRY sector

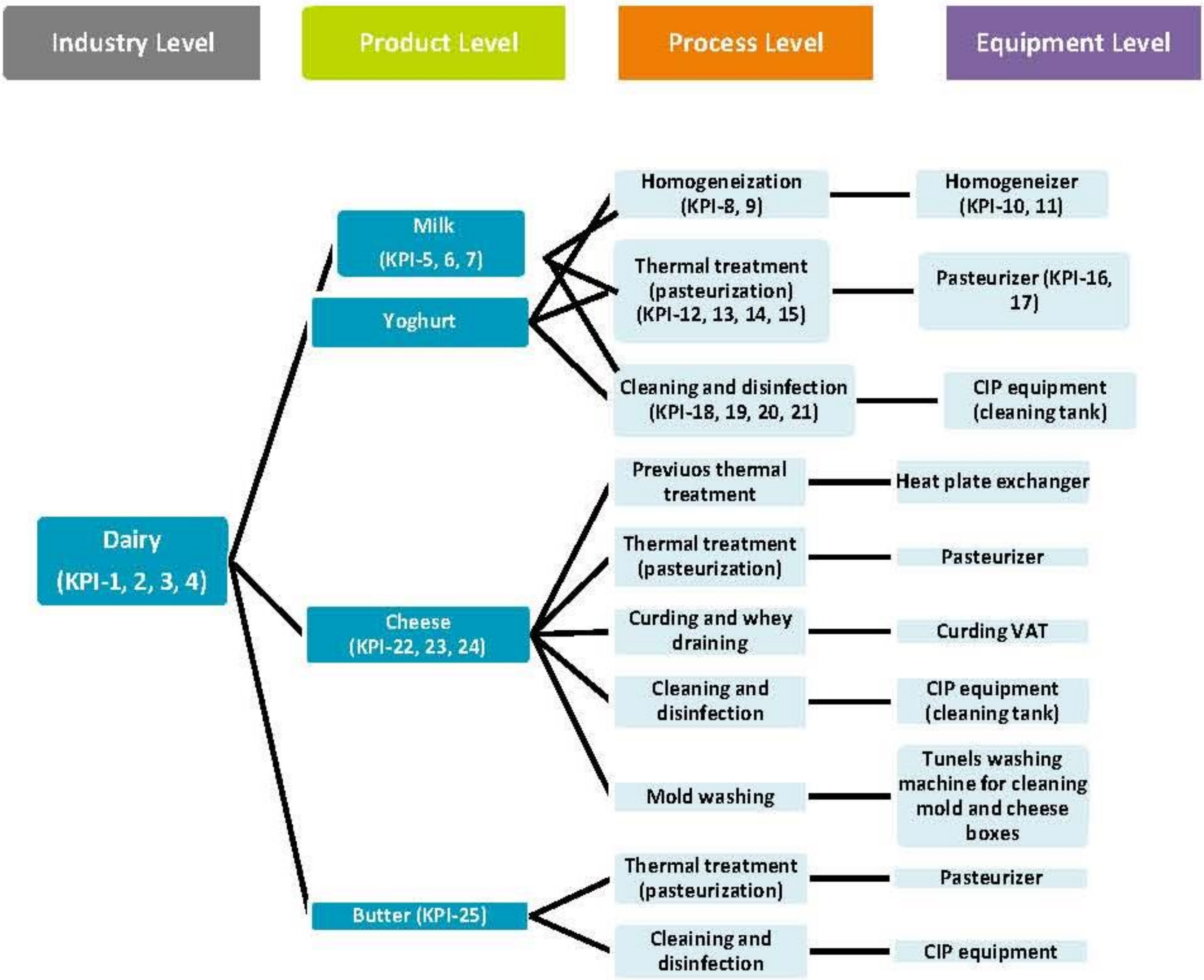

Figure 2 Scheme of the thermal energy KPIs in the dairy sector, according to the four levels, which are – starting from the lower to the upper level – as follows: industry level, product level, process level, and equipment level. In the scheme, only thermal processes of a production line are considered. For most of these KPIs, there is the "average KPI" version and the "best KPI" version.

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2.1. Thermal average KPI-1: Average thermal energy consumption in *kWh/t* for generation of thermal utilities (steam and water) in dairy industries.

INDICATOR	Thermal average KPI-1: Average thermal energy consumption in kWh/t for generation of thermal utilities (steam and water) in dairy industries.			
Sector (NACE code)	10.5	**Subsector**	Dairy	
Level of indicator	Industry level (utilities)			
	Energy in dairy plants directly refers to the utility's generation and consumption such as steam, refrigeration, electricity and water. Steam and water are used as heat exchanger in dairy operations. Water consumption is very high in most of the dairy operations.			
Thermal or electrical process	Thermal processes			
Energy source	Gas			
Description of the indicator	This indicator refers to the average total thermal energy required for generation of utilities (steam and water) used by a dairy processing industry.			
Upper level	---			
Lower level	Product level (white milk, yoghurt, cured cheese, butter)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy per tonne of raw milk entering in the processing line)	**Name**	T aKPI L1 N3
	Average total thermal energy consumption is related to the tonnes of obtained final product.			
Best or average KPI	Average		**KPI Value**	37,27 *kWh/t* 37270 *kWh/kg*
Source	Siemens			

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2.2. Thermal best KPI-2: Best thermal energy consumption in kWh/t for generation of thermal utilities (steam and water) in dairy industries.

INDICATOR	Thermal best KPI-2: Best thermal energy consumption in kWh/t for generation of thermal utilities (steam and water) in dairy industries.			
Sector (NACE code)	10.5	**Subsector**	Dairy	
Level of indicator	Industry level (utilities)			
	Energy in dairy plants directly refers to the utility's generation and consumption such as steam, refrigeration, electricity and water. Steam and water are used as heat transferring medium in dairy operations. Water consumption is very high in most of the dairy operations.			
Thermal or electrical process	Thermal processes			
Energy source	Gas			
Description of the indicator	This indicator refers to the average total thermal energy required for generation of utilities (steam and water) used by a dairy processing industry.			
Upper level	---			
Lower level	Product level (white milk, yoghurt, cured cheese, butter)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy per tonne of raw milk entering in the processing line)	**Name**	T bKPI L1 N3
	Total thermal energy consumption is related to the tonnes of obtained final product.			
Best or average KPI	Best		**KPI Value**	25,93 *kWh/t* 25930 *kWh/kg*
Source	Siemens			

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2.3. Thermal average KPI-3: Average water consumption per raw milk intake (L/L) in dairy industries.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-3: Average water consumption per raw milk intake (L/L) in dairy industries.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td>Subsector</td><td colspan="2">Dairy</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Industry level (water use)</td></tr>
<tr><td colspan="4">Water is used in dairy factories for processing and cleaning, and for the operation of utilities such as cooling and steam production. Water use is related to thermal energy use.
Dairy factories also produce high volumes of moderate high-strength liquid wastes (i.e. with BOD and COD levels). Water and wastewater management can incur costs for dairy processors, and these vary according to the location of the processing plant, the source of water, and the requirements for effluent treatment.
HACCP plans play an important role in ensuring that hygiene standards, which are critical to producing a quality product, are met.
Water consumption is very high in most of the dairy operations.
Many dairy processors track the overall consumption of water by monitoring the ratio of water to raw milk intake.
There are a number of methods that can help to quantify water use and develop a water model, such as to install flow meters in strategic areas to directly measure water use; or to use manufacturers' data to estimate water use form some equipment and compare with actual water use.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Water</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average water consumption in L per volume of processed milk in L.</td></tr>
<tr><td>Upper level</td><td colspan="4">---</td></tr>
<tr><td>Lower level</td><td colspan="4">Product level (white milk, yoghurt, cured cheese, butter)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>L/L
(litres of water used per litres of raw milk intake)</td><td>Name</td><td>T aKPI L1 N3</td></tr>
<tr><td colspan="4">Average total water consumption is directly related to thermal energy consumption in thermal treatments.</td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Average</td><td>KPI Value</td><td>3-10 L/L raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".</td></tr>
</table>

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2.4. Thermal best KPI-4: Best water consumption per raw milk intake (L/L) in dairy industries.

INDICATOR	Thermal best KPI-4: Best water consumption per raw milk intake (L/L) in dairy industries.			
Sector (NACE code)	10.5	**Subsector**	Dairy	
Level of indicator	Industry level (water use)			
	Water is used in dairy factories for processing and cleaning, and for the operation of utilities such as cooling and steam production. Water use is related to thermal energy use. Dairy factories also produce high volumes of moderate high-strength liquid wastes (i.e. with BOD and COD levels). Water and wastewater management can incur costs for dairy processors, and these vary according to the location of the processing plant, the source of water, and the requirements for effluent treatment. HACCP plans play an important role in ensuring that hygiene standards, which are critical to producing a quality product, are met. Water consumption is very high in most of the dairy operations. Many dairy processors track the overall consumption of water by monitoring the ratio of water to raw milk intake. There are a number of methods that can help to quantify water use and develop a water model, such as to install flow meters in strategic areas to directly measure water use; or to use manufacturers' data to estimate water use form some equipment and compare with actual water use.			
Thermal or electrical process	Thermal processes			
Energy source	Water			
Description of the indicator	This indicator refers to the average water consumption in *L* per volume of processed milk in *L*.			
Upper level	---			
Lower level	Product level (white milk, yoghurt, cured cheese, butter)			
Associated variables	**Unit**	*L/L* (litres of water used per litres of raw milk intake)	**Name**	T bKPI L1 N3
	Total water consumption is directly related to thermal energy consumption in thermal treatments.			
Best or average KPI	Best		**KPI Value**	0,07-2,00 *L/L* raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.5. Thermal average KPI-5: Average thermal energy consumption in kWh per L of raw milk transformed into pasteurized milk and/or semi-skimmed milk.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-5: Average thermal energy consumption in kWh per L of raw milk transformed into pasteurized milk and/or semi-skimmed milk.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td>Subsector</td><td colspan="2">Dairy (milk)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (pasteurized milk and semi-skimmed milk)</td></tr>
<tr><td colspan="4">Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. Milk production requires less energy per tonne than cheese production.
White and flavoured milk manufacturing industries producing market milk use thermal energy mainly for homogenization and pasteurization, and also for cleaning and disinfection.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average total thermal energy consumed by a milk processing industry for fluid white milk production.</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (dairy)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (white milk production processing)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/L
(kilowatt hour thermal energy consumed per litre of raw milk intake)</td><td>Name</td><td>T aKPI L2 N3</td></tr>
<tr><td colspan="4">Average total thermal energy consumption is related to the raw milk intake that is the milk entering the processing plant.</td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Average</td><td>KPI Value</td><td>0,195-0,250 kWh/L raw milk intake

195-250 kWh/m^3 raw milk intake

0,7-0,9 GJ/m^3 raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">Elaborated from “Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004”.</td></tr>
</table>

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2.6. Thermal best KPI-6: Best thermal energy consumption in kWh per L of raw milk transformed into pasteurized milk and/or semi-skimmed milk.

INDICATOR	Thermal best KPI-6: Best thermal energy consumption in *kWh* per *L* of raw milk transformed into pasteurized milk and/or semi-skimmed milk.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)	
Level of indicator	Product level (pasteurized milk and semi-skimmed milk)			
	Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. Milk production requires less energy per tonne than cheese production. White and flavoured milk manufacturing industries producing market milk use thermal energy mainly for homogenization and pasteurization, and also for cleaning and disinfection.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a milk processing industry for fluid white milk production.			
Upper level	Industry level (dairy)			
Lower level	Process level (white milk production processing)			
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy consumed per litre of raw milk intake)	**Name**	T bKPI L2 N3
	Total thermal energy consumption is related to the raw milk intake that is the milk entering the processing plant.			
Best or average KPI	Best		**KPI Value**	0,110-0,170 *kWh/L* raw milk intake 110-170 *kWh/m*^{3} raw milk intake 0,4-0,6 *GJ/m*^{3} raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.7. Thermal average KPI-7: Average water consumption per raw milk intake (L/L) for white and flavoured milk production.

INDICATOR	Thermal average KPI-7: Average water consumption per raw milk intake (*L/L*) for white and flavoured milk production.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)	
Level of indicator	Product level (white and flavoured milk, excluding UHT milk)			
	Water is used in milk processing factories for processing and cleaning, and for the operation of utilities such as cooling and steam production. Water use is related to thermal energy use. Milk processing factories also produce high volumes of moderate high-strength liquid wastes (i.e. with BOD and COD levels). Water and wastewater management can incur costs for dairy processors, and these vary according to the location of the processing plant, the source of water, and the requirements for effluent treatment. HACCP plans play an important role in ensuring that hygiene standards, which are critical to producing a quality product, are met. Water consumption is very high in most of the dairy operations. Many milk processors track the overall consumption of water by monitoring the ratio of water to raw milk intake. There are a number of methods that can help to quantify water use and develop a water model, such as to install flow meters in strategic areas to directly measure water use; or to use manufacturers' data to estimate water use form some equipment and compare with actual water use.			
Thermal or electrical process	Thermal processes			
Energy source	Water			
Description of the indicator	This indicator refers to the average water consumption in *L* per volume of processed milk in *L*.			
Upper level	Industry level (dairy)			
Lower level	Process level (thermal treatment including homogenization, pasteurization, and cleaning and disinfection)			
Associated variables	**Unit**	*L/L* (litres of water used per litre of raw milk intake)	**Name**	T aKPI L2 N3
	Average total water consumption is directly related to thermal energy consumption in thermal treatments.			
Best or average KPI	Average		**KPI Value**	1,05-2,21 *L/L* raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.8. Thermal average KPI-8: Average thermal energy consumption in kWh per L of raw milk during homogenization and pasteurization processes for fluid milk and yoghurt production.

INDICATOR	Thermal average KPI-8: Average thermal energy consumption in kWh per L of raw milk during homogenization and pasteurization processes for fluid milk and yoghurt production.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk and yoghurt)	
Level of indicator	Process level (homogenization and pasteurization for fluid milk and yoghurt)			
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the average thermal energy (*kWh*) consumed during the homogenization and pasteurization processes per *L* of transformed raw milk.			
Upper level	Product level (fluid milk and yoghurt)			
Lower level	Equipment level (homogenizer and pasteurizer)			
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy consumed per litre of raw milk intake)	**Name**	T aKPI L3 N3
	This KPI accounts of the overall amount of thermal energy necessary for carrying out the homogenization and pasteurization processes during milk and yoghurt production. Being the major thermal energy consumer processes, an estimation of their energy cost may be directly related to the thermal energy efficiency in the processing plant.			
Best or average KPI	Average		**KPI Value**	0,075-0,250 *kWh/L* raw milk intake 75-250 kWh/m^3 raw milk intake
Source	"Energy Performance Indicator Report: Fluid Milk Plants. Natural Resources Canada 2001".			

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2.9. Thermal best KPI-9: Best thermal energy consumption in kWh per L of raw milk during homogenization and pasteurization processes for fluid milk and yoghurt production.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-9: Best thermal energy consumption in kWh per L of raw milk during homogenization and pasteurization processes for fluid milk and yoghurt production.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td>Subsector</td><td colspan="2">Dairy (milk and yoghurt)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Process level (homogenization and pasteurization for fluid milk and yoghurt)</td></tr>
<tr><td colspan="4">Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one.
White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy (kWh) consumed during the homogenization and pasteurization processes per L of transformed raw milk.</td></tr>
<tr><td>Upper level</td><td colspan="4">Product level (fluid milk and yoghurt)</td></tr>
<tr><td>Lower level</td><td colspan="4">Equipment level (homogenizer and pasteurizer)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/L
(kilowatt hour thermal energy consumed per raw milk intake)</td><td>Name</td><td>T bKPI L3 N3</td></tr>
<tr><td colspan="4">This KPI accounts of the overall amount of thermal energy necessary for carrying out the homogenization and pasteurization processes during milk and yoghurt production. Being the major thermal energy consumer processes, an estimation of their energy cost may be directly related to the thermal energy efficiency in the processing plant.</td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Best</td><td>KPI Value</td><td>0,0526 kWh/L raw milk intake

526 kWh/m^3 raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">“Energy Performance Indicator Report: Fluid Milk Plants. Natural Resources Canada 2001”.</td></tr>
</table>

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2.10. Thermal average KPI-10: Average thermal energy consumption in kWh by the homogenizer per L of raw milk transformed into fluid milk and/or yoghurt.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-10: Average thermal energy consumption in kWh by the homogenizer per L of raw milk transformed into milk and/or yoghurt.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td colspan="2">Subsector</td><td>Dairy (milk and yoghurt)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (homogenizer for white and flavoured milk and yoghurt)</td></tr>
<tr><td colspan="4">Dairy industries require thermal energy for steam and hot water generation, and thermal energy consumption is generally higher than the electrical one.
White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, homogenization process requires 15-20% of the total required energy (electricity plus thermal energy).
Homogenization causes disruption of fat globules into much smaller ones, thus diminishing creaming and the tendency of globules to clump or coalescence. Homogenization of cold milk, in which the fat is essentially solidified, is virtually ineffective, and products of high fat content require a higher homogenization temperature, which lead to a decrease of milk viscosity. Homogenization temperatures normally applied are 55-80 °C, and the pressures are between 10 and 25 MPa (200-250 bar), depending on the product.
A high pressure homogenizer is a pump equipped with one homogenization device or two connected in series, hence the names single-stage and two-stage homogenization.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fuel oil</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy consumed in kWh by the homogenizer per L of raw milk processed.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (homogenization)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/L
(kilowatt hour thermal energy consumed per litre of raw milk intake)</td><td>Name</td><td>T aKPI L4 N3</td></tr>
<tr><td colspan="4">The average KPI value has been estimated considering a standard homogenizer equipment with a maximum capacity of 2000 L/h and an average working capacity of 1000 L/h (that is half of the maximum capacity), and an installed power of 7,08 kW, by using the general equation “energy (kWh) = power (kW) x time (h)”.
Note: The control of homogenizer pressures, in particular pressure drop, will affect the efficiency of the homogenizer and the quality of the product.</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">~0,007 kWh/L raw milk intake
~7 kWh/m^3 raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">Elaborated from “SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.5: Yoghurt and semi-skimmed milk, cured cheese, and butter – November 2016”).</td></tr>
</table>

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2.11. Thermal best KPI-11: Best thermal energy consumption in kWh by the homogenizer per L of raw milk transformed into fluid milk and/or yoghurt.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-11: Best thermal energy consumption in kWh by the homogenizer per L of raw milk transformed into milk and/or yoghurt.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td>Subsector</td><td colspan="2">Dairy (milk and yoghurt)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (homogenizer for white and flavoured milk and yoghurt)</td></tr>
<tr><td colspan="4">Dairy industries require thermal energy for steam and hot water generation, and thermal energy consumption is generally higher than the electrical one.
White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, homogenization process requires 15-20% of the total required energy (electricity plus thermal energy).
Homogenization causes disruption of fat globules into much smaller ones, thus diminishing creaming and the tendency of globules to clump or coalescence. Homogenization of cold milk, in which the fat is essentially solidified, is virtually ineffective, and products of high fat content require a higher homogenization temperature, which lead to a decrease of milk viscosity. Homogenization temperatures normally applied are 55-80 °C, and the pressures are between 10 and 25 MPa (200-250 bar), depending on the product.
A high pressure homogenizer is a pump equipped with one homogenization device or two connected in series, hence the names single-stage and two-stage homogenization.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fuel oil</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the best thermal energy consumed in kWh by the homogenizer per L of raw milk processed.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (homogenization)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/L
(kilowatt hour thermal energy consumed per litre of raw milk intake)</td><td>Name</td><td>T bKPI L4 N3</td></tr>
<tr><td colspan="4">The best KPI value has been estimated considering a standard homogenizer equipment with a maximum capacity of 2000 L/h corresponding to the average working capacity and an installed power of 7,08 kW, by using the general equation “energy (kWh) = power (kW) x time (h)”.
Note: The control of homogenizer pressures, in particular pressure drop, will affect the efficiency of the homogenizer and the quality of the product.</td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Best</td><td>KPI Value</td><td>~0,00354 kWh/L raw milk intake

~3,54 kWh/m^3 raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">Elaborated from “SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.5: Yoghurt and semi-skimmed milk, cured cheese, and butter – November 2016”).</td></tr>
</table>

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2.12. Thermal average KPI-12: Average thermal energy consumption in kWh during pasteurization process per L of raw milk transformed into white and/or flavoured milk and/or yoghurt.

INDICATOR	Thermal average KPI-12: Average thermal energy consumption in kWh during pasteurization process per L of raw milk transformed into white and/or flavoured milk and/or yoghurt.				
Sector (NACE code)	10.5	**Subsector**	Dairy (milk and yoghurt)		
Level of indicator	Process level (pasteurization of white and flavoured milk and yoghurt)				
	Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production. The milk pasteurization is a heat treatment very important in terms of product quality and health safety. In this thermal process, temperatures lower than 100 *°C* affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives, milk is heated at 63 *°C* for 30 seconds. For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 *°C* for 1-2 seconds.				
Thermal or electrical process	Thermal process				
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.				
Description of the indicator	This indicator refers to the average *kWh* thermal energy consumed during the pasteurization process per *L* of milk entering the processing plant.				
Upper level	Product level (milk and yoghurt)				
Lower level	Equipment level (pasteurizer)				
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy consumed per litre of processed raw milk)	**Name**	T aKPI L3 N3	
	Pasteurization process may be improved in order to achieve better energy efficiency and reduce losses. There are several innovative methods, as CHP system, CIP process, solar energy application for heating and cooling, RAS network, etc.				
Best or average KPI	Average	**KPI Value**	0,025-0,030 *kWh/L* raw milk intake 25-30 *kWh/m³* raw milk intake 90-110 *kJ/L* raw milk intake		
Source	Elaborated from “Plan de la asistencia energetic en el sector lácteo quesero. Junta de Castilla León. 2008” and “Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Foof Res*., 34(2) 2015: 98-103”.				

This project, has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 695985

2.13. Thermal best KPI-13: Best thermal energy consumption in kWh during pasteurization process per L of raw milk transformed into white and/or flavoured milk and/or yoghurt.

INDICATOR	Thermal best KPI-13: Best thermal energy consumption in kWh during pasteurization process per L of raw milk transformed into white and/or flavoured milk and/or yoghurt.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk and yoghurt)	
Level of indicator	Process level (pasteurization of white and flavoured milk and yoghurt)			
	Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production. The milk pasteurization is a heat treatment very important in terms of product quality and health safety. In this thermal process, temperatures lower than 100 *°C* affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives, milk is heated at 63 *°C* for 30 seconds. For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 *°C* for 1-2 seconds.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average *kWh* thermal energy consumed during the pasteurization process per *L* of milk entering the processing plant.			
Upper level	Product level (milk and yoghurt)			
Lower level	Equipment level (pasteurizer)			
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy consumed per litre of raw milk intake)	**Name**	T bKPI L3 N3
	Pasteurization process may be improved in order to achieve better energy efficiency and reduce losses. There are several innovative methods, as CHP system, CIP process, solar energy application for heating and cooling, RAS network, etc.			
Best or average KPI	Best	**KPI Value**	<0,022-0,024 *kWh/L* raw milk intake <22-24 *kWh/m*^{3} raw milk intake <80-85 *kJ/L* raw milk intake	
Source	Elaborated from “Plan de la asistencia energetic en el sector lácteo quesero. Junta de Castilla León. 2008” and “Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Foof Res*., 34(2) 2015: 98-103”.			

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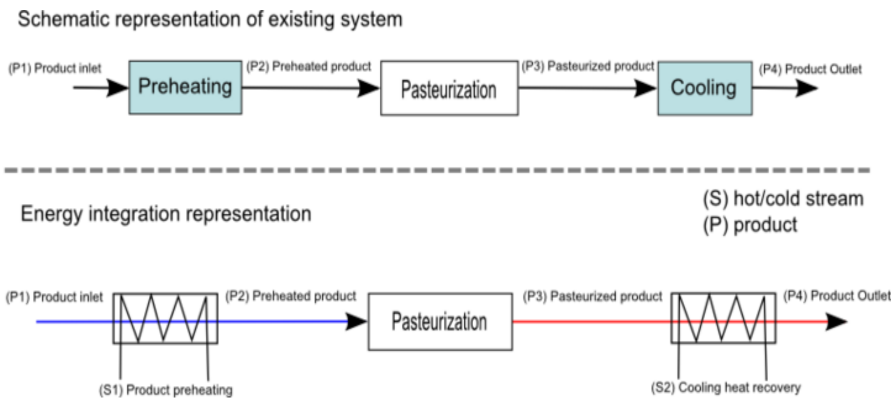
2.14. Thermal average KPI-14: Average amount of steam in kg required for pasteurization of 1 kL of milk.

INDICATOR	Thermal average KPI-14: Average amount of steam in *kg* required for pasteurization of 1 *kL* of milk.		
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)
Level of indicator	Process level (pasteurization of white and flavoured milk)		
	Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production. The milk pasteurization is a heat treatment very important in terms of product quality and health safety. Pasteurization is a thermal process in which temperatures lower than 100 *°C* affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives), milk is heated at 63 *°C* for 30 seconds. For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 *°C* for 1-2 seconds. Several heat exchanger types are available including plate heat exchangers (PHE), straight and corrugated tubular heat exchangers. Pasteurization process may be improved in order to achieve better energy efficiency and reduce losses. There are several innovative methods, as CHP system, CIP process, solar energy application for heating and cooling, RAS network, etc. This KPI, being based on steam measurement, can be applied in systems with direct steam injection. In these systems, the steam has an intimate contact with the product, so heat transfer is maximized. Direct steam injection systems are available in a range of sizes capable of handling product capacities from 240 *L/h* to more than 20000 *L/h*. Steam can also be measured by vortex or differential pressure flow meters.		

<table>
<tr><td colspan="1"></td><td colspan="4">

Technical description of pasteurization:



The product stream is preheated to a preset pasteurization temperature and stays in a standing zone where it is pasteurized. The product is then cooled down (typically by heat recovery) to a target temperature (corresponding to the next operation or to storage conditions).

Preheating (S1): Product preheating from the inlet temperature to the pasteurization temperature.
Cooling (S2): Heat recovery from the pasteurized product from standing zone to the target temperature of the next processing unit or storage tank.

The conversion of "*kg* of steam" to *kW* may be performed through this formula:
kW=[(output-input)*kg/h*]/3600
where "output" is the steam enthalpy at a given pressure and "input" is the enthalpy of feed water. For these calculations, the Steam Table can be used (see for example: http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html

</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy (in the form of steam) from natural gas, biogas, diesel, fuel oil, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average kg of steam required for the pasteurization of 1 kL milk.</td></tr>
<tr><td>Upper level</td><td colspan="4">Product level (milk)</td></tr>
<tr><td>Lower level</td><td colspan="4">Equipment level (pasteurizer)</td></tr>
<tr><td>Associated variables</td><td>Unit</td><td>kg/kL (or kg/1000 L or kg/m^3) (kilograms of steam required per 1 kilolitre (or per 1000 litres or per 1 cubic meter) of processed raw milk)</td><td>Name</td><td>T aKPI L3 N3</td></tr>
</table>

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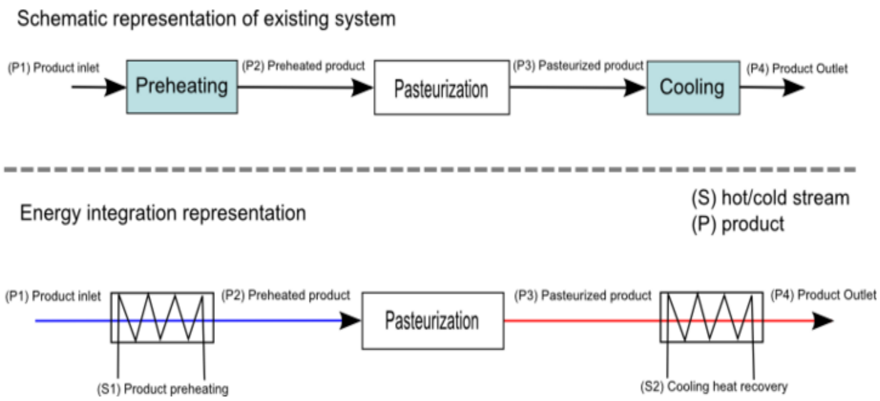
	Steam is, arguably, the most difficult fluid to measure. Notwithstanding, accurate steam measurement helps to identify poor performance of the heat exchanger, predict possible malfunction and optimize energy usage. Steam can be accurately and repeatedly measured by Vortex or Differential Pressure (DP) flow meters. For best performance, use temperature and/or pressure compensated Vortex or DP flow meters. Another possible methods used to measure steam is the enthalpy based method. This method may be used to determine steam consumption in a direct steam injection system. The steam flow rate can be calculated according to the following equation (from Das. Food Processing Operation Analysis, 1st edition. Asian Book Private Limited 2005. Page 149): $W_s = W_p C_p (T_2 - T_1)/(H_s - C_{pc} T_2)$ Where, W_s is the steam flow rate (*kg/h*), W_p is water or product flow rate (*kg/h*), C_p is the specific heat of water or product (*kJ/kg*$^{-°C}$), T_1 is the initial temperature of hot water or product (°*C*), T_2 is final temperature of heated water or product, H_s is enthalpy of steam at an injection pressure (*kJ/kg*), C_{pc} is the specific heat of condensate (*kJ/kg*$^{-°C}$). This method has been often applied in pasteurizers using hot water heating.		
Best or average KPI	Average	**KPI Value**	20-50 *kg/kL* processed milk 20-50 *kg/m*^{3} processed milk
Source	Elaboration from "Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103".		

2.15. Thermal best KPI-15: Best amount of steam in kg required for pasteurization of 1 kL of milk.

INDICATOR	Thermal best KPI-15: Best amount of steam in kg required for pasteurization of 1 kL of milk.		
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)
Level of indicator	Process level (pasteurization of white and flavoured milk)		
	Dairy industries require thermal energy for steam and hot water generation, and, generally, thermal energy consumption is higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production. The milk pasteurization is a heat treatment very important in terms of product quality and health safety. Pasteurization is a thermal process in which temperatures lower than 100 *°C* affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives), milk is heated at 63 *°C* for 30 seconds. For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 *°C* for 1-2 seconds. Several heat exchanger types are available including plate heat exchangers (PHE), straight and corrugated tubular heat exchangers. Pasteurization process may be improved in order to achieve better energy efficiency and reduce losses. There are several innovative methods, as CHP system, CIP process, solar energy application for heating and cooling, RAS network, etc. This KPI, being based on steam measurement, can be applied in systems with direct steam injection. In these systems, the steam has an intimate contact with the product, so heat transfer is maximized. Direct steam injection systems are available in a range of sizes capable of handling product capacities from 240 *L/h* to more than 20000 *L/h*. Steam can also be measured by vortex or differential pressure flow meters.		

<table>
<tr><td></td><td colspan="4">Technical description of pasteurization:


The product stream is preheated to a preset pasteurization temperature and stays in a standing zone where it is pasteurized. The product is then cooled down (typically by heat recovery) to a target temperature (corresponding to the next operation or to storage conditions).

Preheating (S1): Product preheating from the inlet temperature to the pasteurization temperature.
Cooling (S2): Heat recovery from the pasteurized product from standing zone to the target temperature of the next processing unit or storage tank.

The conversion of “kg of steam” to kW may be performed through this formula:
kW=[(output-input) kg/h]/3600
where “output” is the steam enthalpy at a given pressure and “input” is the enthalpy of feed water. For these calculations, the Steam Table can be used (see for example: http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy (in the form of steam) from NG, biogas, diesel, heavy fuel oil, etc..</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average kg of steam required for the pasteurization of 1 kL milk.</td></tr>
<tr><td>Upper level</td><td colspan="4">Product level (milk)</td></tr>
<tr><td>Lower level</td><td colspan="4">Equipment level (pasteurizer)</td></tr>
<tr><td>Associated variables</td><td>Unit</td><td>kg/kL (or kg/1000 L or kg/m^3)
(kilograms of steam required per 1 kilolitre (or per 1000 litres or per 1 cubic meter) of processed raw milk)</td><td>Name</td><td>T bKPI L3 N3</td></tr>
</table>

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	Steam is, arguably, the most difficult fluid to measure. Notwithstanding, accurate steam measurement helps to identify poor performance of the heat exchanger, predict possible malfunction and optimize energy usage. Steam can be accurately and repeatedly measured by Vortex or Differential Pressure (DP) flow meters. For best performance, use temperature and/or pressure compensated Vortex or DP flow meters. Another possible methods used to measure steam is the enthalpy based method. This method may be used to determine steam consumption in a direct steam injection system. The steam flow rate can be calculated according to the following equation (from Das. Food Processing Operation Analysis, 1st edition. Asian Book Private Limited 2005. Page 149): $W_s = W_pC_p(T_2-T_1)/(H_s-C_{pc}T_2)$ Where, W_s is the steam flow rate (*kg/h*), W_p is water or product flow rate (*kg/h*), C_p is the specific heat of water or product (*kJ/kg*$^{-°C}$), T_1 is the initial temperature of hot water or product (°*C*), T_2 is final temperature of heated water or product, H_s is enthalpy of steam at an injection pressure (*kJ/kg*), C_{pc} is the specific heat of condensate (*kJ/kg*$^{-°C}$). This method has been often applied in pasteurizers using hot water heating.		
Best or average KPI	Best	**KPI Value**	<20 *kg/kL* processed milk <20 *kg/m*^{3} processed milk
Source	Elaboration from “Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103”.		

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2.16. Thermal average KPI-16: Average thermal energy consumption in kWh by the pasteurizer per m3 of raw milk transformed into white and/or flavoured milk and/or yoghurt.

INDICATOR	Thermal average KPI-16: Average thermal energy consumption in kWh by the pasteurizer per m3 of raw milk transformed into white and/or flavoured milk and/or yoghurt.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk and yoghurt)	
Level of indicator	Equipment level (pasteurizer for white and flavoured milk and yoghurt)			
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production. The milk pasteurization is a heat treatment very important in terms of product quality and health safety. Pasteurization is a thermal process in which temperatures lower than 100 *°C* affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives), milk is heated at 63 *°C* for 30 seconds. For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 *°C* for 1-2 seconds. Several heat exchanger types are available including plate heat exchangers (PHE), straight and corrugated tubular heat exchangers.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average thermal energy consumed in *kWh* by the pasteurizer for the thermal treatment per *kL* of raw milk processed.			
Upper level	Process level (pasteurization)			
Lower level	---			
Associated variables	**Unit**	*kWh/m*^{3} (kilowatt hour thermal energy consumed per cubic meter of raw milk intake)	**Name**	T aKPI L4 N3
	Thermal energy consumption by the milk pasteurizer is related to 1 kilolitre of processed raw milk. The average KPI value range has been estimated considering a standard pasteurizer equipment with a maximum capacity of 2000 *L/h* and an average working capacity of 1000 *L/h* (that is half of the maximum capacity), and with an installed power of 2,04 *kW*, by using the general equation "energy (*kWh*) = power (*kW*) x time (*h*)".			
Best or average KPI	Average	**KPI Value**	~2 *kWh/m*^{3} raw milk intake ~0,002 *kWh/L* raw milk intake	
Source	From "Deliverable D.3.4 – Extended Value Stream maps of NACE 10.5: Yoghurt and semi-skimmed milk, cured cheese, and butter – November 2016".			

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2.17. Thermal best KPI-17: Best thermal energy consumption in kWh by the pasteurizer per m3 of raw milk transformed into white and/or flavoured milk and/or yoghurt.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-17: Best thermal energy consumption in kWh by the pasteurizer per m3 of raw milk transformed into white and/or flavoured milk and/or yoghurt.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.5</td><td>Subsector</td><td colspan="2">Dairy (milk and yoghurt)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (pasteurizer for white and flavoured milk and yoghurt)</td></tr>
<tr><td colspan="4">Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one.
White and flavoured milk and yoghurt manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, and a lower amount in cleaning and disinfection. In particular, pasteurization process consumes about 25% of the total energy (including both electricity and thermal energy) required for production.
The milk pasteurization is a heat treatment very important in terms of product quality and health safety. Pasteurization is a thermal process in which temperatures lower than 100 °C affect the milk and 90-99% of vegetative forms of microorganisms are eradicated. In the common procedure (batch pasteurization), suitable for small-scale producers and farmers cooperatives), milk is heated at 63 °C for 30 seconds.
For high volume processing, high-temperature short-time (HTST) pasteurization, or flash pasteurization, is the most common method used these days. Then, ultra high temperature (UHT) pasteurization is used by big factories and milk is heated above 135 °C for 1-2 seconds.
Several heat exchanger types are available including plate heat exchangers (PHE), straight and corrugated tubular heat exchangers.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the best thermal energy consumed in kWh by the pasteurizer for the thermal treatment per kL of raw milk processed.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (pasteurization)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/m^3 (kilowatt hour thermal energy consumed per cubic meter of raw milk intake)</td><td>Name</td><td>T bKPI L4 N3</td></tr>
<tr><td colspan="4">Thermal energy consumption by the milk pasteurizer is related to 1 kilolitre of processed raw milk.
The best value of this KPI has been estimated considering a standard pasteurizer equipment working at its maximum capacity of 2000 L/h and with an installed power of 2,04 kW, by using the general equation “energy (kWh) = power (kW) x time (h)”.</td></tr>
<tr><td>Best or average KPI</td><td>Best</td><td>KPI Value</td><td colspan="2">~1 kWh/m^3 raw milk intake
~0,001 kWh/L raw milk intake</td></tr>
<tr><td>Source</td><td colspan="4">From “SCOoPE Deliverable D.3.4 – Extended Value Stream maps of NACE 10.5: Yoghurt and semi-skimmed milk, cured cheese, and butter – November 2016”.</td></tr>
</table>

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2.18. Thermal average KPI-18: Average amount of steam in kg required for milk can container washing per container.

INDICATOR	Thermal average KPI-18: Average amount of steam in kg required for milk can container washing per container.		
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)
Level of indicator	Process level (milk can container cleaning and disinfection in white and flavoured milk production) Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, but also a lower amount in cleaning and disinfection. In particular, cleaning and disinfection processes consume about 10% of the total energy (including both electricity and thermal energy) required for production. All milking equipment, lines, and utensil surfaces that come into contact with milk or dirt must be thoroughly cleaned and sanitized before next milking. Bulk milk tanks also must be cleaned after each milk pickup and sanitized before next milking. The purpose of cleaning is to remove milk soils, organic and mineral solids that form on equipment surfaces after the milk is removed. The purpose of sanitizing is to kill residual microorganisms' present in these surfaces immediately prior to milking. Inadequate or improper cleaning or sanitizing or both allows bacteria to remain on equipment surfaces and to grow and multiply. The development of automatic (CIP) milking and bulk tank systems has been great-time savers for dairy farmers. However, these systems must be properly maintained and regularly checked, at least twice-a-year. A lot of hot water is consumed for cleaning and disinfection. The conversion of "*kg* of steam" to *kW* may be performed through this formula: *kW*=[(output-input)*kg/h*]/3600 where "output" is the steam enthalpy at a given pressure and "input" is the enthalpy of feed water. For these calculations, the Steam Table can be used (see for example: http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).		
Thermal or electrical process	Thermal process		
Energy source	Thermal energy (in the form of steam) from natural gas, biogas, diesel, heavy fuel oil, etc.		
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average *kg* of steam required for cleaning and sanitizing a single container (*can container*).		
Upper level	Product level (fluid milk)		
Lower level	Equipment level (milk can container washer)		

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Associated variables	**Unit**	*kg/container* (kilograms of steam necessary for washing a milk container unit)	**Name**	T aKPI L3 N3
	Heating water for cleaning and sanitizing milking equipment is a twice-daily energy load that is uniform and quite independent of weather and farm events, and might be shifted to alternative energy sources, as for example solar energy. Steam is, arguably, the most difficult fluid to measure. Notwithstanding, accurate steam measurement helps to identify poor performance of the heat exchanger, predict possible malfunction and optimize energy usage. Steam can be accurately and repeatedly measured using Vortex or Differential Pressure (DP) flow meters. For best performance, use temperature and/or pressure compensated Vortex or DP flow meters. Another possible methods used to measure steam is the enthalpy based method. This method may be used to determine steam consumption in a direct steam injection system. The steam flow rate can be calculated according to the following equation (from Das. Food Processing Operation Analysis, 1st edition. Asian Book Private Limited 2005. Page 149): $W_s = W_pC_p(T_2\text{-}T_1)/(H_s\text{-}C_{pc}T_2)$ where, W_s is the steam flow rate (*kg/h*), W_p is water or product flow rate (*kg/h*), C_p is the specific heat of water or product (*kJ/kg*$^{-°C}$), T_1 is the initial temperature of hot water or product (*°C*), T_2 is final temperature of heated water or product, H_s is enthalpy of steam at an injection pressure (*kJ/kg*), C_{pc} is the specific heat of condensate (*kJ/kg*$^{-°C}$).			
Best or average KPI	Average		**KPI Value**	0,2-0,5 *kg* steam/container
Source	Elaboration from "Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103". The value from the original source is specifically related to "can containers" but we could infer that a very similar value may be obtained for other kinds of container, such as 1L glass bottles.			

2.19. Thermal best KPI-19: Best amount of steam in kg required for milk can container washing per container.

INDICATOR	Thermal best KPI-19: Best amount of steam in kg required for milk can container washing per container.		
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)
Level of indicator	Process level (milk can container cleaning and disinfection in white and flavoured milk production)		
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, but also a lower amount in cleaning and disinfection. In particular, cleaning and disinfection processes consume about 10% of the total energy (including both electricity and thermal energy) required for production. All milking equipment, lines, and utensil surfaces that come into contact with milk or dirt must be thoroughly cleaned and sanitized before next milking. Bulk milk tanks also must be cleaned after each milk pickup and sanitized before next milking. The purpose of cleaning is to remove milk soils, organic and mineral solids that form on equipment surfaces after the milk is removed. The purpose of sanitizing is to kill residual microorganisms present in these surfaces immediately prior to milking. Inadequate or improper cleaning or sanitizing or both allows bacteria to remain on equipment surfaces and to grow and multiply. The development of automatic (CIP) milking and bulk tank systems has been great-time savers for dairy farmers. However, these systems must be properly maintained and regularly checked, at least twice-a-year. A lot of hot water is consumed for cleaning and disinfection. The conversion of "*kg* of steam" to *kW* may be performed through this formula: *kW*=[(output-input)*kg/h*]/3600 where "output" is the steam enthalpy at a given pressure and "input" is the enthalpy of feed water. For these calculations, the Steam Table can be used (see for example: http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).		
Thermal or electrical process	Thermal process		
Energy source	Thermal energy (in the form of steam) from natural gas, biogas, diesel, heavy fuel oil, etc.		
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average *kg* of steam required for cleaning and sanitizing a single container (*can container*).		
Upper level	Product level (fluid milk)		
Lower level	Equipment level (milk can container washer)		

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Associated variables	**Unit**	*kg/container* (Kilograms of steam necessary for washing a milk container unit)	**Name**	T bKPI L3 N3
	Heating water for cleaning and sanitizing milking equipment is a twice-daily energy load that is uniform and quite independent of weather and farm events, and might be shifted to alternative energy sources, as for example solar energy. Steam is, arguably, the most difficult fluid to measure. Notwithstanding, accurate steam measurement helps to identify poor performance of the heat exchanger, predict possible malfunction and optimize energy usage. Steam can be accurately and repeatedly measured using Vortex or Differential Pressure (DP) flow meters. For best performance, use temperature and/or pressure compensated Vortex or DP flow meters. Another possible methods used to measure steam is the enthalpy based method. This method may be used to determine steam consumption in a direct steam injection system. The steam flow rate can be calculated according to the following equation (from Das. Food Processing Operation Analysis, 1st edition. Asian Book Private Limited 2005. Page 149): $W_s = W_p C_p (T_2 - T_1)/(H_s - C_{pc} T_2)$ Where, W_s is the steam flow rate (*kg/h*), W_p is water or product flow rate (*kg/h*), C_p is the specific heat of water or product ($kJ/kg^{-°C}$), T_1 is the initial temperature of hot water or product (°*C*), T_2 is final temperature of heated water or product, H_s is enthalpy of steam at an injection pressure (*kJ/kg*), C_{pc} is the specific heat of condensate ($kJ/kg^{-°C}$).			
Best or average KPI	Best	**KPI Value**	<0,2-0,5 *kg* steam/container	
Source	Elaboration from "Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103". The value from the original source is specifically related to "can containers" but we could infer that a very similar value may be obtained for other kinds of container, such as 1L glass bottles.			

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2.20. Thermal average KPI-20: Average thermal energy consumption in kWh in milk can container washing per container.

INDICATOR	Thermal average KPI-20: Average thermal energy consumption in kWh in milk can container washing per container.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)	
Level of indicator	Process level (milk can container cleaning and disinfection in white and flavoured milk production) Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, but also a lower amount in cleaning and disinfection. In particular, cleaning and disinfection processes consume about 10% of the total energy (including both electricity and thermal energy) required for production. All milking equipment, lines, and utensil surfaces that come into contact with milk or dirt must be thoroughly cleaned and sanitized before next milking. Bulk milk tanks also must be cleaned after each milk pickup and sanitized before next milking. The purpose of cleaning is to remove milk soils, organic and mineral solids that form on equipment surfaces after the milk is removed. The purpose of sanitizing is to kill residual microorganisms present on these surfaces immediately prior to milking. Inadequate or improper cleaning or sanitizing or both allows bacteria to remain on equipment surfaces and to grow and multiply. The development of automatic (CIP) milking and bulk tank systems has been great-time savers for dairy farmers. However, these systems must be properly maintained and regularly checked, at least twice-a-year. A lot of hot water is consumed for cleaning and disinfection.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average *kWh* of thermal energy consumed for cleaning and sanitizing a single container (*can container*).			
Upper level	Product level (fluid milk)			
Lower level	Equipment level (milk can container washer)			
Associated variables	**Unit**	*kWh/container* (kilowatt hour thermal energy consumed per washed container)	**Name**	T aKPI L2 N3
	Heating water for cleaning and sanitizing milking equipment is a twice-daily energy load that is uniform and quite independent of weather and farm events, and might be shifted to alternative energy sources, as for example solar energy.			
Best or average KPI	Average		**KPI Value**	0,222-0,305 *kWh/container* 800-1100 *kJ/container*
Source	Elaboration from "Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103". The value from the original source is specifically related to "can containers" but we could infer that a very similar value may be obtained for other kinds of container, such as 1L glass bottles.			

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2.21. Thermal best KPI-21: Best thermal energy consumption in kWh in milk can container washing per container.

INDICATOR	Thermal best KPI-21: Best thermal energy consumption in kWh in milk can container washing per container.			
Sector (NACE code)	10.5	**Subsector**	Dairy (milk)	
Level of indicator	Process level (milk can container cleaning and disinfection in white and flavoured milk production)			
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. White and flavoured milk manufacturing industries use most of thermal energy in the processes of homogenization and pasteurization, but also a lower amount in cleaning and disinfection. In particular, cleaning and disinfection processes consume about 10% of the total energy (including both electricity and thermal energy) required for production. Al milking equipment, lines, and utensil surfaces that come into contact with milk or dirt must be thoroughly cleaned and sanitized before next milking. Bulk milk tanks also must be cleaned after each milk pickup and sanitized before next milking. The purpose of cleaning is to remove milk soils, organic and mineral solids that form on equipment surfaces after the milk is removed. The purpose of sanitizing is to kill residual microorganisms present on these surfaces immediately prior to milking. Inadequate or improper cleaning or sanitizing or both allows bacteria to remain on equipment surfaces and to grow and multiply. The development of automatic (CIP) milking and bulk tank systems has been great-time savers for dairy farmers. However, these systems must be properly maintained and regularly checked, at least twice-a-year. A lot of hot water is consumed for cleaning and disinfection.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average *kJ* of thermal energy consumed for cleaning and sanitizing a single container (*can container*).			
Upper level	Product level (fluid milk)			
Lower level	Equipment level (milk can container washer)			
Associated variables	**Unit**	*kWh/can* (kilowatt hour thermal energy consumed per washed container)	**Name**	T bKPI L2 N3
	Heating water for cleaning and sanitizing milking equipment is a twice-daily energy load that is uniform and quite independent of weather and farm events, and might be shifted to alternative energy sources, as for example solar energy.			
Best or average KPI	Best		**KPI Value**	<0,222 *kWh/container* <800 *kJ/container*
Source	Elaboration from "Prabhakar *et al*. Energy consumption during manufacturing of different dairy products in a commercial dairy plant: a case study. *Asian J. Dairy & Food Res*., 34(2) 2015: 98-103". The value from the original source is specifically related to "can containers" but we could infer that a very similar value may be obtained for other kinds of container, such as 1L glass bottles.			

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2.22. Thermal average KPI-22: Average water consumption per raw milk intake (L/L) for processing of cheese and whey products.

INDICATOR	Thermal average KPI-22: Average water consumption per raw milk intake (L/L) for processing of cheese and whey products.			
Sector (NACE code)	10.5	**Subsector**	Dairy (cheese and whey products)	
Level of indicator	Product level (cheese and whey products)			
	Water is used in cheese and whey product processing factories for processing and cleaning, and for the operation of utilities such as cooling and steam production. Cheese and whey product processing factories also produce high volumes of moderate high-strength liquid wastes (i.e. with BOD and COD levels). Water and wastewater management can incur costs for cheese and whey product processors, and these vary according to the location of the processing plant, the source of water, and the requirements for effluent treatment. HACCP plans play an important role in ensuring that hygiene standards, which are critical for producing a quality product, are met. Water consumption is very high in most of the cheese and whey product processing operations. Many of these processors track the overall consumption of water by monitoring the ratio of water to raw milk intake. There are a number of methods that can help to quantify water use and develop a water model, such as to install flow meters in strategic areas to directly measure water use; or to use manufacturers' data to estimate water use from some equipment and compare with actual water use.			
Thermal or electrical process	Thermal processes			
Energy source	Water			
Description of the indicator	This indicator refers to the average water consumption in *L* per volume of processed milk in *L*.			
Upper level	Industry level (dairy)			
Lower level	Process level (thermal treatment including homogenization, pasteurization, and cleaning and disinfection)			
Associated variables	**Unit**	*L/L* (litres of water used per litre of raw milk entering the plant)	**Name**	T aKPI L2 N3
	Average total water consumption is directly related to thermal energy consumption in thermal treatments.			
Best or average KPI	Average		**KPI Value**	0,64-2,90 *L/L* raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.23. Thermal average KPI-23: Average thermal energy consumption in kWh per m3 of raw milk transformed into cheese/whey products.

INDICATOR	Thermal average KPI-23: Average thermal energy consumption in kWh per m3 of raw milk transformed into cheese/whey products.			
Sector (NACE code)	10.5	**Subsector**	Dairy (cheese and whey products)	
Level of indicator	Product level (cheese and whey products)			
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. Cheese production requires more energy per tonne than milk production, due to the energy required by the whey processing. Cured cheese manufacturing industries use most of thermal energy in the processes of the previous thermal treatment, pasteurization, cleaning and disinfection. Lower amount of thermal energy is also used for curding and whey drying and for mould washing.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a cheese processing industry.			
Upper level	Industry level (dairy)			
Lower level	Process level (cheese and whey product production processes)			
Associated variables	**Unit**	*kWh/m³* (kilowatt hour thermal energy consumed per cubic meter of raw milk intake)	**Name**	T aKPI L2 N3
	Average total thermal energy consumption is related to the raw milk intake that is the milk entering the processing plant.			
Best or average KPI	Average		**KPI Value**	277-555 *kWh/m³* raw milk intake 0,277-0,555 *kWh/L* raw milk intake 1-2 *GJ/m³* raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.24. Thermal best KPI-24: Best thermal energy consumption in kWh per m3 of raw milk transformed into cheese/whey products.

INDICATOR	Thermal best KPI-24: Best thermal energy consumption in kWh per m3 of raw milk transformed into cheese/whey products.			
Sector (NACE code)	10.5	**Subsector**	Dairy (cheese and whey products)	
Level of indicator	Product level (cheese and whey products)			
	Dairy industries require thermal energy for steam and hot water generation, and, thermal energy consumption is generally higher than the electrical one. Cheese production requires more energy per tonne than milk production, due to the energy required by the whey processing. Cured cheese manufacturing industries use most of thermal energy in the processes of the previous thermal treatment, pasteurization, cleaning and disinfection. Lower amount of thermal energy is also used for curding and whey drying and for mould washing.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a cheese processing industry.			
Upper level	Industry level (dairy)			
Lower level	Process level (cheese and whey product production processes)			
Associated variables	**Unit**	*kWh/m³* (kilowatt hour thermal energy consumed per cubic meter of raw milk intake)	**Name**	T bKPI L2 N3
	Best total thermal energy consumption is related to the raw milk intake that is the milk entering the processing plant.			
Best or average KPI	Best		**KPI Value**	83-222 *kWh/m³* raw milk intake 0,083-0,222 *kWh/L* raw milk intake 0,3-0,8 *GJ/m³* raw milk intake
Source	Elaborated from "Eco-efficiency for Dairy Processing Industry – Dairy Australia 2004".			

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2.25. Thermal average KPI-25: Average thermal energy consumption in kWh in direct processes for cheese and butter production per t of product.

INDICATOR	Thermal average KPI-25: Average thermal energy consumption in kWh in direct processes for cheese and for butter production per t of product.			
Sector (NACE code)	10.5	**Subsector**	Dairy (cheese and butter)	
Level of indicator	Product level (cheese and butter)			
	Thermal accounted for in direct processing, in cheese and in butter processing, includes thermal energy required for steam and heating.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal derives mainly from the combustion of natural gas, fuel oil, and coal. Biogas, diesel, LPG and peat combined account for a very small percentage of total fuel use by dairy sector.			
Description of the indicator	This indicator refers to the average thermal energy consumed in direct processes, as steam and heating, in butter and in cheese processing industry.			
Upper level	Industry level (dairy)			
Lower level	Process level (cheese and butter production processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy used per tonne of butter produced)	**Name**	T aKPI L2 N3
	Average thermal energy consumption is related to 1 tonne of final product.			
Best or average KPI	Average		**KPI Value**	<u>In butter:</u> 137 *kWh/t* 0,137 *kWh/kg* <u>In cheese:</u> 475 *kWh/t* 0,475 *kWh/kg*
Source	From "Geraghty. Benchmarking resource efficiency in Irish dairy processing. Enterprise Ireland. Apr. 2011".			

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3. CEREAL DRYING sector

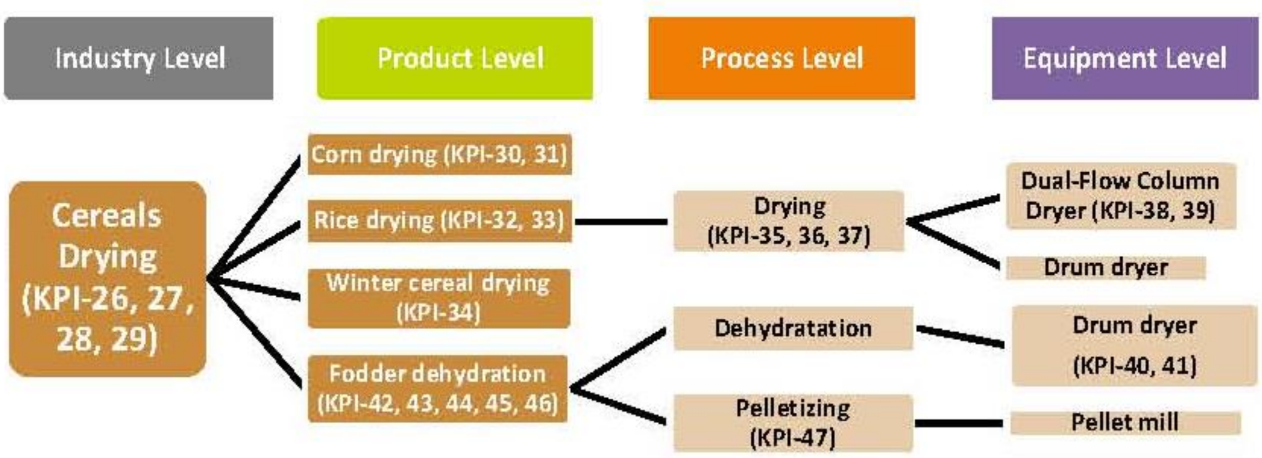

Figure 3. Scheme of the thermal energy KPIs in the cereal drying sector, according to the four levels, which are - starting from the lower level to the upper one – the following: industry level, product level, process level, and equipment level. In the scheme, only thermal processes of a production line are considered. For most of these KPIs, there is the "average KPI" version and the "best KPI" version.

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3.1. Thermal average KPI-26: Thermal energy consumption in kWh by cereal industries divided by the kg of evaporated water.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-26: Thermal energy consumption in kWh by cereal industries divided by the kg of evaporated water.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td colspan="2">Cereal drying (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Industry level (cereal drying)</td></tr>
<tr><td colspan="4">Cereal drying plants’ major energy consumption is due to the specific process of grain drying and the main issue in this process is the energy consumption used for conventional hot air drying process.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Typical energy consumption in existing conventional industrial dryers can range from 3500 to 7000 kJ (with average consumption of 4200 kJ) for 1 kg of evaporated water, depending on the construction of the equipment and dried material. For drying grain samples with higher moisture content, between 20% and 30%, typical energy consumption in conventional industrial dryers ranges from 2500 kJ to 3500 kJ per 1 kg of evaporated water[1].
Furthermore, to assess the energy performance of a drying process, the specific heat consumption, calculated by dividing the energy supplied to the dryer by the mass of water evaporated from the grain, may be used to represent the energy use of a dryer on a per unit mass of water removed basis. The specific heat consumption to dry grains has been reported to range from 2.330 to 2.790 kJ/kg water removed using natural air, 2.790 to 3.490 kJ/kg of water removed when using low Ts, 3.490 to 4.650 kJ/kg water removed for batch-in-bin dryers, and 4.650 to 6.980 kJ/kg of water evaporated when drying at high Ts without recirculation[2].
In this KPI, the average thermal energy consumption is normalized to the amount in kg of evaporated water.</td></tr>
<tr><td>Upper level</td><td colspan="4">---</td></tr>
<tr><td>Lower level</td><td colspan="4">Product level (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/kg (kilowatt hour thermal energy consumed per kilogram of evaporated water)</td><td>Name</td><td>T aKPI L1 N1</td></tr>
<tr><td colspan="4">Energy use for drying cereal grains may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T</td></tr>
</table>

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	increases, energy use decreases), but also on grain quality. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus, it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.		
Best or average KPI	Average	**KPI Value**	0,95-1,95 *kWh/kg* evaporated water 3.500-7.000 *kJ/kg* evaporated water
Source	Elaborated from: [1]"Galić *et al*. An energy efficient corn grains drying process. *Technical Gazette 21,* 6 2014: 1395-1401". [2]"Billiris & Siebenmorgen. Energy use and efficiency of rice-drying systems II. Commercial, cross-flow dryer measurements. *Applied Engineering in Agriculture*, 30(2) 2014: 217-226".		

3.2. Thermal best KPI-27: Thermal energy consumption in kWh by cereal industries divided by the kg of evaporated water.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-27: Thermal energy consumption in kWh by cereal industries divided by the kg of evaporated water.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td colspan="2">Cereal drying (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Industry level (cereal drying)</td></tr>
<tr><td colspan="4">Cereal drying plants’ major energy consumption is due to the specific process of grain drying and the main issue in this process is the energy consumption used for conventional hot air drying process.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Typical energy consumption in existing conventional industrial dryers can range from 3500 kJ to 7000 kJ (with average consumption of 4200 kJ) for 1 kg of evaporated water, depending on the construction of the equipment and dried material. For drying grain samples with higher moisture content, between 20% and 30%, typical energy consumption in conventional industrial dryers ranges from 2500 kJ to 3500 kJ per 1 kg of evaporated water[1].
Furthermore, to assess the energy performance of a drying process, the specific heat consumption, calculated by dividing the energy supplied to the dryer by the mass of water evaporated from the grain, may be used to represent the energy use of a dryer on a per unit mass of water removed basis. The specific heat consumption to dry grains has been reported to range from 2.330 to 2.790 kJ/kg water removed using natural air, 2.790 to 3.490 kJ/kg of water removed when using low Ts, 3.490 to 4.650 kJ/kg water removed for batch-in-bin dryers, and 4.650 to 6.980 kJ/kg of water evaporated when drying at high Ts without recirculation[2].
In KPI-26 the average thermal energy consumption is normalized to the amount in kg of evaporated water.</td></tr>
<tr><td>Upper level</td><td colspan="4">---</td></tr>
<tr><td>Lower level</td><td colspan="4">Product level (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/kg (kilowatt hour thermal energy consumed per kilogram of evaporated water)</td><td>Name</td><td>T bKPI L1 N1</td></tr>
<tr><td colspan="4">Energy use for drying cereal grains may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality.</td></tr>
</table>

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	Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus, it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.		
Best or average KPI	Best	**KPI Value**	~0,555-0,833 *kWh/kg* evaporated water ~2.000-3.000 *kJ/kg* evaporated water
Source	Elaborated from: [1]"Galić *et al*. An energy efficient corn grains drying process. *Technical Gazette 21,* 6 2014: 1395-1401". [2]"Billiris & Siebenmorgen. Energy use and efficiency of rice-drying systems II. Commercial, cross-flow dryer measurements. *Applied Engineering in Agriculture*, 30(2) 2014: 217-226".		

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3.3. Thermal average KPI-28: Thermal energy consumption in kWh by cereal industries divided by the t of cereal crop before drying when moisture content decreases of about 3%.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-28: Thermal energy consumption in kWh by cereal industries divided by the tonnes of cereal crop before drying when moisture content decreases of about 3%.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td colspan="2">Cereal drying (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Industry level (cereal drying)</td></tr>
<tr><td colspan="4">Cereal drying plants' major energy consumption is due to the specific process of grain drying and the main issue in this process is the energy consumption used for conventional hot air drying process.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">The amount of water, or moisture, in a grain kernel is expressed as a percentage value. This indicator to be valid must take into consideration the moisture content (MC) in % of the cereal grain before (MC_i, initial) drying and after (MC_f, final) drying. The $\%MC_f$ of the grain may be selected in the panel control of the dryer equipment. Moisture content depends on relative humidity.
Energy requirements for a commercial, cross-flow dryer with heat recovery have been estimated as 3.520 kJ/kg water removed when drying 21.590 tonnes of corn from an average MC_i of 18% to MC_f 15% using an average ambient T of 6,6 °C. (From "Brinker & Anderley. Energy efficiency data comparison of ten Wisconsin grain dryer installations. ASABE Paper No. 12-1337410. 2012").
Elaborating these data, approximately, it results that:
21.590 tonnes * (1-0,18) = X * (1-0,15)
X = 20.828 tonnes of corn dried to MC_f 15%.
Evaporated water = 21.590-20.828 = 762 tonnes evaporated water.
Total GJ required for evaporating 762 tonnes of water:
762.000 kg * 3.520 kJ/kg = 762.000 * 3.520 * 10^{-6} GJ = 2.682,24 GJ
And GJ required for evaporating 1 tonne of water:
2.682,24 GJ/762 tonnes = 3,52 GJ.</td></tr>
<tr><td>Upper level</td><td colspan="4">---</td></tr>
<tr><td>Lower level</td><td colspan="4">Product level (corn, rice, winter cereals, and fodder)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/t (kilowatt hour thermal energy consumed per tonne of cereal crop before drying)</td><td>Name</td><td>T aKPI L1 N1</td></tr>
<tr><td colspan="4">This indicator applies to drying processes in which a ~3% moisture content change occurs, being the MC in the range of ~11-22%.</td></tr>
</table>

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Best or average KPI	Average	**KPI Value**	The value of this KPI is referred to a process occurring at a temperature around 7-9 °C, and in a process with about a 3% MC decrease. ~972 *kWh/t* of cereal grain before drying ~0,972 *kWh/kg* of cereal grain before drying 3500 *MJ/ t* of cereal grain before drying
Source	Elaborated from "Brinker & Anderley. Energy efficiency data comparison of ten Wisconsin grain dryer installations. *ASABE Paper No*. 12-1337410. 2012".		

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3.4. Thermal best KPI-29: Thermal energy consumption in kWh by cereal industries divided by the t of cereal crop before drying when moisture content decreases of about 3%.

INDICATOR	Thermal bests KPI-29: Thermal energy consumption in kWh by cereal industries divided by the tonnes of cereal crop before drying when moisture content decreases of about 3%.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (corn, rice, winter cereals, and fodder)	
Level of indicator	Industry level (cereal drying)			
	Cereal drying plants' major energy consumption is due to the specific process of grain drying and the main issue in this process is the energy consumption used for conventional hot air drying process.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	The amount of water, or moisture, in a grain kernel is expressed as a percentage value. This indicator to be valid must take into consideration the moisture content (MC) in % of the cereal grain before (MC_i, initial) drying and after (MC_f, final) drying. The %MC_f of the grain may be selected in the panel control of the dryer equipment. Moisture content depends on relative humidity. Energy requirements for a commercial, cross-flow dryer with heat recovery have been estimated as 3.520 *kJ/kg* water removed when drying 21.590 tonnes of corn from an average MC_i of 18% to MC_f 15% using an average ambient T of 6,6 *°C*. (From "Brinker & Anderley. Energy efficiency data comparison of ten Wisconsin grain dryer installations. *ASABE Paper No*. 12-1337410. 2012"). Elaborating these data, approximately, it results that: 21.590 tonnes * (1-0,18) = X * (1-0,15) X = 20.828 tonnes of corn dried to MC_f 15%. Evaporated water = 21.590-20.828 = 762 tonnes evaporated water. Total *GJ* required for evaporating 762 tonnes of water: 762.000 *kg* * 3.520 *kJ/kg* = 762.000 * 3.520 * 10^{-6} *GJ* = 2.682,24 *GJ* And *GJ* required for evaporating 1 tonne of water: 2.682,24 *GJ*/762 tonnes = 3,52 *GJ*.			
Upper level	---			
Lower level	Product level (corn, rice, winter cereals, and fodder)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of cereal crop before drying)	**Name**	T bKPI L1 N1

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	This indicator applies to drying processes in which a ~3% moisture content change occurs, being the MC in the range of ~11-22%.		
Best or average KPI	Best	**KPI Value**	The value of this KPI is referred to a process occurring at a temperature around 7-9 °C, and in a process with about a 3% MC decrease. 550-850 *kWh/t* of cereal grain before drying 0,550-0,850 *kWh/kg* of cereal grain before drying 2000-3000 *MJ/ t* of cereal grain before drying
Source	Elaborated from "Brinker & Anderley. Energy efficiency data comparison of ten Wisconsin grain dryer installations. *ASABE Paper No*. 12-1337410. 2012".		

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3.5. Thermal average KPI-30: Thermal energy consumption in kWh by corn drying plants per kg of evaporated water.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-30: Thermal energy consumption in kWh by corn drying plants per kg of evaporated water.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td colspan="2">Cereal drying (dried corn)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (dried corn)</td></tr>
<tr><td colspan="4">Corn drying is an energy-intensive process and the main issue in contemporary corn drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts.
Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent grain spoilage, which is primarily caused by moulds and insect infestation.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average total thermal energy consumed for corn drying process per kilogram of subtracted water.
It is reported that drying corn requires from 3.250 to 3.750 kJ/kg of water removed at ambient Ts, and from 4.000 to 8.000 kJ/kg of water removed at “high Ts”. (From “Gunasekaran & Thompson. Optimal energy management in grain drying. CRC Critical Reviews in Food Science and Nutrition 25(1): 1-48”).</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (cereal drying)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (corn drying)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/kg (kilowatt hour thermal energy consumed per kilogram of evaporated water)</td><td>Name</td><td>T aKPI L2 N1</td></tr>
<tr><td colspan="4">Both, grain temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 °C. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location.
Energy use for drying corn may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use</td></tr>
</table>

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	decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry corn, so that it is increasingly more difficult to remove water as rice MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.		
Best or average KPI	Average	**KPI Value**	• At ambient temperature: 833 -1111 *kWh/t* evaporated water 0,833 -1,111 *kWh/kg* evaporated water 3.000-4.000 *kJ/kg* evaporated water • At high temperature: 1111-2222 *kWh/t* evaporated water 1,111-2,222 *kWh/kg* evaporated water 4.000-8.000 *kJ/kg* evaporated water
Source	Elaborated from "Gunasekaran & Thompson. Optimal energy management in grain drying. *CRC Critical Reviews in Food Science and Nutrition* 25(1): 1-48".		

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3.6. Thermal best KPI-31: Thermal energy consumption in kWh by corn drying plants per kg of evaporated water.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-31: Thermal energy consumption in kWh by corn drying plants per kg of evaporated water.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td colspan="2">Cereal drying (dried corn)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (dried corn)</td></tr>
<tr><td colspan="4">Corn drying is an energy-intensive process and the main issue in contemporary corn drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts.
Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent grain spoilage, which is primarily caused by moulds and insect infestation.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average total thermal energy consumed for corn drying process per kilogram of subtracted water.
It is reported that drying corn requires from 3.250 to 3.750 kJ/kg of water removed at ambient Ts, and from 4.000 to 8.000 kJ/kg of water removed at “high Ts”. (From “Gunasekaran & Thompson. Optimal energy management in grain drying. CRC Critical Reviews in Food Science and Nutrition 25(1): 1-48”).</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (cereal drying)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (corn drying)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/kg (kilowatt hour thermal energy consumed per kilogram of evaporated water)</td><td>Name</td><td>T bKPI L2 N1</td></tr>
<tr><td colspan="4">Both, grain temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 °C. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location.
Energy use for drying corn may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry corn, so that it is increasingly more difficult to remove water as rice MC decreases. Other factors, such</td></tr>
</table>

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	as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus, it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.		
Best or average KPI	Best	**KPI Value**	• At ambient temperature: ~555 *kWh/t* evaporated water ~0,555 *kWh/kg* evaporated water ~2.000 *kJ/kg* evaporated water • At high temperature: ~833 *kWh/t* evaporated water ~0,833 *kWh/kg* evaporated water ~3.000 *kJ/kg* evaporated water
Source	Elaborated from "Gunasekaran & Thompson. Optimal energy management in grain drying. *CRC Critical Reviews in Food Science and Nutrition* 25(1): 1-48".		

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3.7. Thermal average KPI-32: Thermal energy consumption in kWh by rice drying plants per kg of evaporated water.

INDICATOR	Thermal average KPI-32: Thermal energy consumption in kWh by rice drying plants per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (dried rice)	
Level of indicator	Product level (dried rice)			
	Rice drying is an energy-intensive process and the main issue in contemporary rice drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent grain spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed for rice drying process per kilogram of subtracted water.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (rice drying)			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T aKPI L2 N1
	Grain temperature and moisture content (MC) are critical factors in maintaining quality. Mould and insect activity is greatly reduced below 15 *°C*. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for drying rice may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry rice, so that it is increasingly more difficult to remove water as rice MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Average	**KPI Value**	~1,8-2,8 *kWh/kg* evaporated water ~6500-10000 *kJ/kg* evap. water	
Source	Elaboration from "Billiris & Siebenmorgen. Energy use and efficiency of rice-drying systems II. Commercial, cross-flow dryer measurements. *Applied Engineering in Agriculture*, 30(2) 2014: 217-226".			

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3.8. Thermal best KPI-33: Thermal energy consumption in kWh by rice drying plants per kg of evaporated water.

INDICATOR	Thermal best KPI-33: Thermal energy consumption in kWh by rice drying plants per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (dried rice)	
Level of indicator	Product level (dried rice)			
	Rice drying is an energy-intensive process and the main issue in contemporary rice drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent grain spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed for rice drying process per kilogram of subtracted water.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (rice drying)			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T bKPI L2 N1
	Grain temperature and moisture content (MC) are critical factors in maintaining quality. Mould and insect activity is greatly reduced below 15 *°C*. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for drying rice may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry rice, so that it is increasingly more difficult to remove water as rice MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Best	**KPI Value**	~0,5-1,7 *kWh/kg* evaporated water ~2000-6000 *kJ/kg* evap. water	
Source	Elaboration from “Billiris & Siebenmorgen. Energy use and efficiency of rice-drying systems II. Commercial, cross-flow dryer measurements. *Applied Engineering in Agriculture*, 30(2) 2014: 217-226”.			

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3.9. Thermal average KPI-34: Thermal energy consumption in kWh by winter cereal drying plants per kg of evaporated water.

INDICATOR	Thermal average KPI-34:_Thermal energy consumption in *kWh* by winter cereal drying plants per *kg* of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (winter cereals)	
Level of indicator	Product level (dried winter cereals)			
	Winter cereals' drying is an energy-intensive process and the main issue in contemporary cereal drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent grain spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed for rice drying process per kilogram of subtracted water.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (winter cereals' drying)			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T aKPI L2 N1
	Both, grain temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 *°C*. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for drying rice may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry rice, so that it is increasingly more difficult to remove water as rice MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Average		**KPI Value**	1,222-1,972 *kWh/kg* evaporated water (103-164 *g* of burning oil per *kg* of evaporated water) 1222-1972 *kWh/t* evaporated water 4400-7100 *kJ/kg* evaporated water
Source	From "Jokiniemi, Kautto, et al.. Energy efficiency measurements in grain drying. *Agronomiy Research*, 1:69-75. 2011".			

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3.10. Thermal average KPI-35: Amount of burning oil in g (or kWh thermal energy) used in the cereal grain drying process per kg of evaporated water.

INDICATOR	Thermal average KPI-35: Amount of burning oil in g (or kWh thermal energy) used in the cereal grain drying process per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (corn, rice, winter cereals)	
Level of indicator	Process level (corn, rice, winter cereal drying)			
	The main issue in contemporary cereal grain drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Being drying the major energy consumer process, an estimation of its energy cost may be directly related to the thermal energy efficiency in grain silos. Drying process starts with rapid moisture removal; when the free water on the grain surfaces is removed, water inside the grain must move to the surface and the moisture removal speed decreases.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator gives the amount of the oil fuel used during the drying process divided for the amount of water evaporated (that is the water lost by the grains). Generally, 120 *g* of burning oil is needed per 1 *kg* of evaporated water, corresponding to 5,1 *MJ/kg* water.			
Upper level	Product level (corn, rice, winter cereals)			
Lower level	Equipment level (dual-flow column dryer)			
Associated variables	**Unit**	*g/kg* (or *KWh/kg*) (grams of burning oil (or mega joules of thermal energy) per kilogram of evaporated water	**Name**	T aKPI L2 N1
	Temperature has an effect on water moving speed: high temperatures give higher moving speeds.			
Best or average KPI	Average		**KPI Value**	80-140 *g* burned oil/*kg* of evaporated water 0,972-1,667 *kWh* thermal energy/*kg* evaporated water 3,5-6 *MJ* thermal energy/*kg* evaporated water
Source	http://enpos.weebly.com/			

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3.11. Thermal best KPI-36: Amount of burning oil in g (or kWh thermal energy) used in the cereal grain drying process per kg of evaporated water.

INDICATOR	Thermal best KPI-36: Amount of burning oil in g (or kWh thermal energy) used in the cereal grain drying process per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (corn, rice, winter cereals)	
Level of indicator	Process level (corn, rice, winter cereal drying)			
	The main issue in contemporary cereal grain drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Being drying the major energy consumer process, an estimation of its energy cost may be directly related to the thermal energy efficiency in grain silos. Drying process starts with rapid moisture removal; when the free water on the grain surfaces is removed, water inside the grain must move to the surface and the moisture removal speed decreases.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator gives the amount of the oil fuel used during the drying process divided for the amount of water evaporated (that is the water lost by the grains). Generally, 120 *g* of burning oil is needed per 1 *kg* of evaporated water, corresponding to 5,1 *MJ/kg* water.			
Upper level	Product level (corn, rice, winter cereals)			
Lower level	Equipment level (dual-flow column dryer)			
Associated variables	**Unit**	*g/kg* (or *KWh/kg*) (grams of burning oil (or mega joules of thermal energy) per kilogram of evaporated water	**Name**	T bKPI L2 N1
	Temperature has an effect on water moving speed: high temperatures give higher moving speeds.			
Best or average KPI	Best		**KPI Value**	<70 *g* burned oil/*kg* evaporated water < 0,833 *kWh* thermal energy/*kg* evaporated water < 3 *MJ* thermal energy/*kg* evaporated water
Source	http://enpos.weebly.com/			

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3.12. Thermal average KPI-37: Specific moisture extraction rate (SMER) in kg of evaporated water per kWh in the drying process based on the technology used.

INDICATOR	Thermal average KPI-37: Specific moisture extraction rate (SMER) in kg of evaporated water per kWh in the drying process based on the technology used.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying (corn, rice, winter cereals, fodder)	
Level of indicator	Process level (cereal drying)			
	Being drying the major energy consumer process, an estimation of its energy cost may be directly related to the thermal energy efficiency in grain silos. The mechanism of drying is a complex phenomenon involving combined heat and mass transfer, which in most cases results in products with modified properties. Heat pump dryers (HPD) have a high energy efficiency, with up to 60% reduction in energy costs compared with traditional drying technologies, and their major limitation is the higher initial cost (that is moderate if compared with vacuum drying systems). HPD drying efficiency is 95%, hot air drying efficiency is 35-40%, and vacuum drying is about less than 70%.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the specific moisture extraction rate (SMER) of the drying process. SMER is the performance parameter commonly used for HPD, and it is defined as the ratio of the amount of water evaporated in the dryer to the amount of energy input to the dryer.			
Upper level	Product level (corn, rice, winter cereals, fodder)			
Lower level	Equipment level (mostly HPD, or hot air dryer or vacuum dryer)			
Associated variables	**Unit**	*kg* H_20/*kWh* (kilograms of evaporated water per kilowatt hour)	**Name**	T aKPI L3 N1
	For HPD, the SMER ranges from 1.0 to 4.0 and depends on various factors, such as the ambient conditions, the product moisture content, and its thermo-physical properties, the refrigeration cycle, and the compressor efficiency. The value of SMER decreases with decrease in the drying air temperature, hence it is advisable to use a higher drying temperature provided the product can tolerate it. If a low drying temperature is used then the drying time is longer and the amount of energy consumed for blowing the air becomes significant and should be taken into account.			
Best or average KPI	Average		**KPI Value**	• 0,12-1,28 *kg* H_2O/*kWh* in hot air drying • 0,72-1,2 *kg* H_2O/*kWh* in vacuum drying • 1,0-4,0 *kg* H_2O/*kWh* in heat pump drying
Source	From "Kivevele & Huan. A review on opportunities for development of heat pump drying systems in South Africa. *South Africa Journal of Science*. Vol. 110, N° 5/6, May/June 2014.			

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3.13. Thermal average KPI-38: Thermal energy consumption in kWh by the dual-flow column drier per kg of evaporated water for cereal drying.

INDICATOR	Thermal average KPI-38: Thermal energy consumption in kWh by the dual-flow column dryer per kg of evaporated water for cereal drying.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying	
Level of indicator	Equipment level (dual-flow column dryer)			
	The main issue in contemporary cereal grain drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. The fuel use in grain drying is determined by the amount of water to be removed from the crop. A high-temperature grain drier typically uses 6 *MJ/kg* water removed from the grain when operated at 90 *°C*. When operated at lower temperatures such as 40 *°C* to prevent quality damage, this rises to 10 *MJ/kg* water removed. Thus, for example, to dry grain by 5% from 20% moisture content wet basis (mcwb) requires 62,9 *kg* water per metric ton of 15% mcwb grain to be removed. This needs 10,6 *L/ton* of diesel. A near-ambient temperature grain drier uses mainly fan power to dry grain. The energy required depends on the dryness of the air. In wet regions, supplementary heat would be required for the method to succeed at all. In North of Europe, a typical value is 40 *kWh/t* grain on the same 20-15% basis as above or 2,3 *MJ/kg* water removed. (From "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009"). In grain silos, grain is usually dried by dual-flow column dryers. The central column of a dryer comprises one or more drying stages through which the hot air passes (60 *°C* to 120 *°C* depending on the crop species).			
Thermal or electrical process	Thermal process			
Energy source	The drying air is usually heated by burners fuelled by natural gas or LPG.			
Description of the indicator	This indicator refers to a dual-flow column dryer. The average value of this KPI has been estimated considering a standard column dryer with a maximum capacity of 30 *t/h* and an average working capacity of 15 *t/h* (that is half of the maximum capacity), and with an installed power of 75 *kW* electricity and 10000 *kW* gas, by using the general equation "energy (*kWh*) = power (*kW*) x time (*h*)". This KPI can also be related to the amount of fuel (NG or LPG) used by the burner of the column dryer divided by the amount of evaporated water (in *kg*).			
Upper level	Process level (cereal drying)			
Lower level	---			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per	**Name**	T aKPI L4 N1

		kilogram of evaporated water)		
	Energy use for drying cereals may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry cereals, so that it is increasingly more difficult to remove water as grain MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Average	**KPI Value**		~0,7 *kWh/kg* evaporated water at high temperature ~666,7 *kWh/t* evaporated water at high temperature ~2,5 *MJ/kg* evaporated water at high temperature
Source	Elaborated from "SCOoPE Deliverable D.3.3 – Extended Value Stream Maps of NACE 1.6: arable crops, drying and storage – October 2016" and from "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009".			

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3.14. Thermal best KPI-39: Thermal energy consumption in kWh by the dual-flow column drier per kg of evaporated water for cereal drying.

INDICATOR	Thermal best KPI-39: Thermal energy consumption in kWh by the dual-flow column dryer per kg of evaporated water for cereal drying.			
Sector (NACE code)	1.6	**Subsector**	Cereal drying	
Level of indicator	Equipment level (dual-flow column dryer)			
	The main issue in contemporary cereal grain drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. The fuel use in grain drying is determined by the amount of water to be removed from the crop. A high-temperature grain drier typically uses 6 *MJ/kg* water removed from the grain when operated at 90 *°C*. When operated at lower temperatures such as 40 *°C* to prevent quality damage, this rises to 10 *MJ/kg* water removed. Thus, for example, to dry grain by 5% from 20% moisture content wet basis (mcwb) requires 62,9 *kg* water per metric ton of 15% mcwb grain to be removed. This needs 10,6 *L/ton* of diesel. A near-ambient temperature grain drier uses mainly fan power to dry grain. The energy required depends on the dryness of the air. In wet regions, supplementary heat would be required for the method to succeed at all. In North of Europe, a typical value is 40 *kWh/t* grain on the same 20-15% basis as above or 2,3 *MJ/kg* water removed. (From "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009"). In grain silos, grain is usually dried by dual-flow column dryers. The central column of a dryer comprises one or more drying stages through which the hot air passes (60 *°C* to 120 *°C* depending on the crop species).			
Thermal or electrical process	Thermal process			
Energy source	The drying air is usually heated by burners fuelled by natural gas or LPG.			
Description of the indicator	This indicator refers to a dual-flow column dryer. The best value of this KPI has been estimated considering a standard column dryer working at its maximum capacity of 30 *t/h* and with an installed power of 75 *kW* electricity and 10.000 *kW* gas, by using the general equation "energy (*kWh*) = power (*kW*) x time (*h*)". This KPI can also be related to the amount of fuel (NG or LPG) used by the burner of the column dryer divided by the amount of evaporated water (in *kg*).			
Upper level	Process level (cereal drying)			
Lower level	---			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T bKPI L4 N1

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	Energy use for drying cereals may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on grain quality. Grain moisture content (MC) affects energy requirements to dry cereals, so that it is increasingly more difficult to remove water as grain MC decreases. Other factors, such as the type and variety of grain, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.		
Best or average KPI	Best	**KPI Value**	~0,3 *kWh/kg* evaporated water at high temperature ~333,3 *kWh/t* evaporated water at high temperature ~1,1 *MJ/kg* evaporated water at high temperature
Source	Elaborated from "SCOoPE Deliverable D.3.3 – Extended Value Stream Maps of NACE 1.6: arable crops, drying and storage – October 2016" and from "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009".		

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3.15. Thermal average KPI-40: Thermal energy consumption in kWh by the drum dryer column drier per kg of evaporated water for fodder dehydration.

INDICATOR	Thermal average KPI-40: Thermal energy consumption in *kWh* by the drum dryer per *kg* of evaporated water for fodder dehydration.		
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration
Level of indicator	Equipment level (drum dryer) The main issue in contemporary fodder dehydration process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. The fuel use in fodder dehydration is determined by the amount of water to be removed from the crop. A high-temperature dehydration process typically uses 6 *MJ/kg* water removed from the fodder when operated at 90 *°C*. When operated at lower temperatures such as 40 *°C* to prevent quality damage, this rises to 10 *MJ/kg* water removed. Thus, for example, to dehydrate fodder by 5% from 20% moisture content wet basis (mcwb) requires 62,9 *kg* water per metric ton of 15% mcwb fodder to be removed. This needs 10,6 *L/ton* of diesel. A near-ambient temperature fodder dehydrator uses mainly fan power to dehydrate. The energy required depends on the dryness of the air. In wet regions, supplementary heat would be required for the method to succeed at all. In North of Europe, a typical value is 40 *kWh/t* fodder on the same 20-15% basis as above or 2,3 *MJ/kg* water removed. (From "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009"). In grain silos, grain is usually dried by dual-flow column dryers, but drum dryers operate in a dehydration plant. Drum dryers work similarly to column dryers except that the grain box is horizontal and there is an hot air generator instead of burners. More in details, a drum dryer consists of one or two horizontally mounted hollow cylinder(s) made of high-grade cast iron or stainless steel, a supporting frame, a product feeding system, a scraper, and auxiliaries. The diameter of typical drums ranges from 0,5 to 6 *m* and the length from 1 to 6 *m*. In operation, steam at temperature up to 200 °C heats the inner surface of the drum. The moist material is uniformly applied in a thin layer (0,5-2 *mm*) onto the outer drum surface. Most of the moisture is removed at water boiling temperature. The residence time of the product on the drum ranges from a few seconds to dozens of seconds to reach final moisture contents of often less than 5% (wet basis). The energy consumption in a drum dryer may range between 1,1and 1,6 *kg* of steam per kg of evaporated water, corresponding to energy efficiencies of about 60-90%. Under ideal conditions, the maximum evaporation capacity of a drum dryer can be as high as 80 $kg\ H_2O/h\ m^2$. (From "Tang et al., Drum Drying. Encyclopedia of Agricultural, Food, and Biological Engineering. 2003).		
Thermal or electrical process	Thermal process		

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Energy source	The drying air is usually generated by hot air generators fuelled by natural gas or LPG.			
Description of the indicator	This indicator refers to a drum drier column dryer. The average value of this KPI has been estimated considering a standard drum dryer with a maximum capacity of 20 *t/h* and an average working capacity of 10 *t/h* (that is half of the maximum capacity), and with an installed power of 220 *kW* electricity and 24000 *kW* gas, by using the general equation "energy (*kWh*) = power (*kW*) x time (*h*)". This KPI is related to the amount of fuel (NG or LPG, in tonnes or in kWh) used by the hot air generator of the drum dryer divided by the amount of evaporated water (in *kg*).			
Upper level	Process level (fodder dehydration)			
Lower level	---			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T aKPI L4 N1
	Energy use for fodder dehydration may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drum drying system.			
Best or average KPI	Average	**KPI Value**	~2,4 *kWh/kg* evaporated water at high temperature ~2400 *kWh/t* evaporated water at high temperature ~8,6 *MJ/kg* evaporated water at high temperature	
Source	Elaborated from "SCOoPE Deliverable D.3.3 – Extended Value Stream Maps of NACE 1.6: arable crops, drying and storage – October 2016"; from "Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009"; and from "Tang et al., Drum Drying. Encyclopedia of Agricultural, Food, and Biological Engineering. 2003".			

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3.16. Thermal best KPI-41: Thermal energy consumption in kWh by the drum dryer column drier per kg of evaporated water for fodder dehydration.

<table>
<tr><td>INDICATOR</td><td colspan="3">Thermal best KPI-41: Thermal energy consumption in kWh by the drum dryer per kg of evaporated water for fodder dehydration.</td></tr>
<tr><td>Sector (NACE code)</td><td>1.6</td><td>Subsector</td><td>Fodder dehydration</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="3">Equipment level (drum dryer)</td></tr>
<tr><td colspan="3">The main issue in contemporary cereal grain drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts.
The fuel use in fodder dehydration is determined by the amount of water to be removed from the crop. A high-temperature dehydration process typically uses 6 MJ/kg water removed from the fodder when operated at 90 °C. When operated at lower temperatures such as 40 °C to prevent quality damage, this rises to 10 MJ/kg water removed. Thus, for example, to dehydrate fodder by 5% from 20% moisture content wet basis (mcwb) requires 62,9 kg water per metric ton of 15% mcwb fodder to be removed. This needs 10,6 L/ton of diesel. A near-ambient temperature fodder dehydrator uses mainly fan power to dehydrate. The energy required depends on the dryness of the air. In wet regions, supplementary heat would be required for the method to succeed at all. In North of Europe, a typical value is 40 kWh/t fodder on the same 20-15% basis as above or 2,3 MJ/kg water removed. (From “Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009”).
In grain silos, grain is usually dried by dual-flow column dryers, but drum dryers operate in a dehydration plant. Drum dryers work similarly to column dryers except that the grain box is horizontal and there is an hot air generator instead of burners.
More in details, a drum dryer consists of one or two horizontally mounted hollow cylinder(s) made of high-grade cast iron or stainless steel, a supporting frame, a product feeding system, a scraper, and auxiliaries. The diameter of typical drums ranges from 0,5 to 6 m and the length from 1 to 6 m. In operation, steam at temperature up to 200 °C heats the inner surface of the drum. The moist material is uniformly applied in a thin layer (0,5-2 mm) onto the outer drum surface. Most of the moisture is removed at water boiling temperature. The residence time of the product on the drum ranges from a few seconds to dozens of seconds to reach final moisture contents of often less than 5% (wet basis). The energy consumption in a drum dryer may range between 1,1and 1,6 kg of steam per kg of evaporated water, corresponding to energy efficiencies of about 60-90%. Under ideal conditions, the maximum evaporation capacity of a drum dryer can be as high as 80 kg H_2O/h m^2. (From “Tang et al., Drum Drying. Encyclopedia of Agricultural, Food, and Biological Engineering. 2003).</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="3">Thermal process</td></tr>
</table>

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Energy source	The drying air is usually generated by hot air generators fuelled by natural gas or LPG.
Description of the indicator	This indicator refers to a drum dryer column drier. The best value of this KPI has been estimated considering a standard column dryer working at its maximum capacity of 20 *t/h* and with an installed power of 220 *kW* electricity and 24000 *kW* gas, by using the general equation “energy (*kWh*) = power (*kW*) x time (*h*)”. This KPI can also be related to the amount of fuel (NG or LPG) used by the burner of the column dryer divided by the amount of evaporated water (in *kg*). This KPI is related to the amount of fuel (NG or LPG, in tonnes or in kWh) used by the hot air generator of the drum dryer divided by the amount of evaporated water (in *kg*).
Upper level	Process level (fodder dehydration)
Lower level	---
Associated variables	**Unit**: *kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water) — **Name**: T bKPI L4 N1 Energy use for fodder dehydration may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drum drying system.
Best or average KPI	Best — **KPI Value**: ~1,2 *kWh/kg* evaporated water at high temperature ~1200 *kWh/t* evaporated water at high temperature ~4,3 *MJ/kg* evaporated water at high temperature
Source	Elaborated from “SCOoPE Deliverable D.3.3 – Extended Value Stream Maps of NACE 1.6: arable crops, drying and storage – October 2016”; from “Agricultural mechanization and automation. Volume I – Expenditures and Returns. Edited by McNulthy and Grace 2009”; and from “Tang et al., Drum Drying. Encyclopedia of Agricultural, Food, and Biological Engineering. 2003”.

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3.17. Thermal average KPI-42: Thermal energy consumption in kWh by fodder dehydrating plants per kg of evaporated water.

INDICATOR	Thermal average KPI-42: Thermal energy consumption in kWh by fodder dehydrating plants per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration	
Level of indicator	Product level (dehydrated fodder)			
	Fodder dehydration is an energy-intensive process and the main issue in contemporary fodder drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent fodder spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed for fodder drying process per kilogram of subtracted water.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (fodder dehydration)			
Associated variables	**Unit**	*kWh/kg,* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T aKPI L2 N1
	Both, fodder temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 *°C*. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for dehydrating fodder may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Average		**KPI Value**	0,972-1,389 *kWh/kg* evaporated water 972-1389 *kWh/t* evaporated water 3500-5000 *kJ/kg* evaporated water
Source	Elaboration from "RIELA® GDT 400 Umluft V Continuous Dryer – Maize Drying. DLG Test Report 6167".			

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3.18. Thermal best KPI-43: Thermal energy consumption in kWh by fodder dehydrating plants per kg of evaporated water.

INDICATOR	Thermal best KPI-43: Thermal energy consumption in kWh by fodder dehydrating plants per kg of evaporated water.			
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration	
Level of indicator	Product level (dehydrated fodder)			
	Fodder dehydration is an energy-intensive process and the main issue in contemporary fodder drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent fodder spoilage, which is primarily caused by molds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average total thermal energy consumed for fodder drying process per kilogram of subtracted water.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (fodder dehydration)			
Associated variables	**Unit**	*kWh/kg* (kilowatt hour thermal energy consumed per kilogram of evaporated water)	**Name**	T bKPI L2 N1
	Both, fodder temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 °C. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for dehydrating fodder may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			

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Best or average KPI	Best	**KPI Value**	This value range has been derived from a test performed on fodder maize, in standard conditions for maize drying from 34,5% to 14,5% at 5 °C ambient temperature. 0,833-0,972 *kWh/kg* evaporated water 833-972 *kWh/t* evaporated water 3000-3500 *kJ/kg* evaporated water
Source	Elaboration from "RIELA® GDT 400 Umluft V Continuous Dryer – Maize Drying. DLG Test Report 6167".		

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3.19. Thermal average KPI-44: Thermal energy consumption in kWh by fodder dehydrating plants per t of wet product.

INDICATOR	Thermal average KPI-44: Thermal energy consumption in kWh by fodder dehydrating plants per t of wet product.			
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration	
Level of indicator	Product level (dehydrated fodder) Fodder dehydration is an energy-intensive process and the main issue in contemporary fodder drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent fodder spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average thermal power consumed for fodder drying process per tonne of wet product (before drying), drying from 34,5% to 14.5%.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (fodder dehydration)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of wet product)	**Name**	T aKPI L2 N1
	Both, fodder temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 *°C*. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for dehydrating fodder may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			
Best or average KPI	Average		**KPI Value**	250-400 *kWh/t* wet product
Source	Elaboration from “RIELA® GDT 400 Umluft V Continuous Dryer – Maize Drying. DLG Test Report 6167”.			

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3.20. Thermal best KPI-45: Thermal energy consumption in kWh by fodder dehydrating plants per t of wet product.

INDICATOR	Thermal best KPI-45: Thermal energy consumption in kWh by fodder dehydrating plants per t of wet product.			
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration	
Level of indicator	Product level (dehydrated fodder)			
	Fodder dehydration is an energy-intensive process and the main issue in contemporary fodder drying process is the energy consumption used for conventional hot air drying process. The other issues are dominantly the use of fossil fuels that are environmentally harmful as well as energy loss in hot air conducts. Drying reduces the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. Lowering the moisture content is necessary to prevent fodder spoilage, which is primarily caused by moulds and insect infestation.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This indicator refers to the average thermal power consumed for fodder drying process per tonne of wet product (before drying), drying from 34,5% to 14,5%.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (fodder dehydration)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of wet product)	**Name**	T bKPI L2 N1
	Both, fodder temperature and moisture content (MC) are critical in maintaining quality. Mould and insect activity is greatly reduced below 15 °C. Safe moisture levels for storage depend on grain variety, length of storage, storage structure, and geographical location. Energy use for dehydrating fodder may vary considerably depending on the dryer type and design. Besides the type of dryer, several other factors affect energy use and energy efficiency of the drying process, such as the drying air temperature that has an influence on energy efficiency (as drying air T increases, energy use decreases), but also on fodder quality. Fodder moisture content (MC) affects energy requirements to dehydrate fodder, so that it is increasingly more difficult to remove water as fodder MC decreases. Other factors, such as the type and variety of fodder, the drying air relative humidity, and the airflow rate, affect the drying rate. Thus it is relevant to specify these factors when quantifying the energy use and efficiency of a drying system.			

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Best or average KPI	Best	**KPI Value**	This value range has been derived from a test performed on fodder maize, in standard conditions for maize drying from 34,5% to 14,5% at 5 °C ambient temperature. ~210 *kWh/t* wet product ~0,210 *kWh/kg* wet product ~756 *kJ/kg* wet product
Source	Elaboration from “RIELA® GDT 400 Umluft V Continuous Dryer – Maize Drying. DLG Test Report 6167”.		

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3.21. Thermal average KPI-46: Thermal energy consumption in kWh per t of dehydrated fodder produced.

INDICATOR	Thermal average KPI-46: Thermal energy consumption in kWh per t of dehydrated fodder produced.			
Sector (NACE code)	1.6	**Subsector**	Fodder dehydration	
Level of indicator	Product level (dehydrated fodder)			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels including coal, oil, natural gas and LPG. Only a small number of plants supplement fuel with biogas.			
Description of the indicator	This KPI refers to average thermal energy required for dehydrating 1 tonne of fodder, from a starting about 30% MC to a final 12-14% MC.			
Upper level	Industry level (cereal drying)			
Lower level	Process level (fodder dehydration)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of dehydrated fodder produced)	**Name**	T aKPI L2 N1
Best or average KPI	Average		**KPI Value**	This value range has been derived from fodder dehydrating from ~30 to 12-14% MC. 277,78-555,56 *kWh/t* dehydrated fodder produced 0,278-0,556 *kWh/kg* dehydrated fodder produced 1000-2000 *MJ/t* dehydrated fodder produced
Source	From http://aefa-d.com/consumos-energeticos-evolucion/?lang=en			

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3.22. Thermal average KPI-47: Average total energy consumption (electricity + thermal energy) in kWh per t of feed pellet during pelletizing in feed manufacturing.

INDICATOR	Thermal average KPI-47: Average total energy consumption (electricity + thermal energy) in kWh per t of feed pellet during pelletizing in feed manufacturing.			
Sector (NACE code)	1.6	**Subsector**	Cereals and fodder	
Level of indicator	Process level (grain/fodder pelletizing)			
	Pelletizing process is the most consumable stage of feed manufacturing, consuming on average 80% of total energy per rabbits feed pellets, 83% per poultry feed pellets, and 64% per large animals feed pellets. An efficient pelletizing often requires a steam flow, which is produced by a boiler supplied with fuel.			
Thermal or electrical process	Thermal and electrical process			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc. and electricity.			
Description of the indicator	This indicator accounts of both thermal and electrical energy consumption by the pelletizing process by the pellet mill motor for the manufacturing of different types of animal feed from grains and fodder. The specific energy for pelletizing uses to range from 4 to 40 *kWh/t*.			
Upper level	Product level (grains, fodder)			
Lower level	Equipment level (pellet mill)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour total energy consumed per tonne of feed pellet)	**Name**	T aKPI L3 N1
	An efficient pelletizing often requires a steam flow, which is produced by a boiler supplied with fuel. The use of steam in pelletizing improves pellet durability, in fact added steam provides heat and moisture. Moreover, added steam helps to reduce the energy consumption of the process.			
Best or average KPI	Average		**KPI Value**	• In rabbit feed: ~52,7 *kWh/t* ~0,0527 *kWh/kg* ~190 *kJ/kg* • In poultry feed: ~50 *kWh/t* ~0,05 *kWh/kg* ~180 *kJ/kg* • In large animals feed ~18 *kWh/t* ~0,018 *kWh/kg* ~65 *kJ/kg*
Source	From "Dabbour *et al*. Energy consumption in manufacturing of different types of feed. *2nd International Conference On Biotechnology Applications In Agriculture (ICBAA)* April 2014".			

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4. FRUIT AND VEGETABLES TRANSFORMATION sector

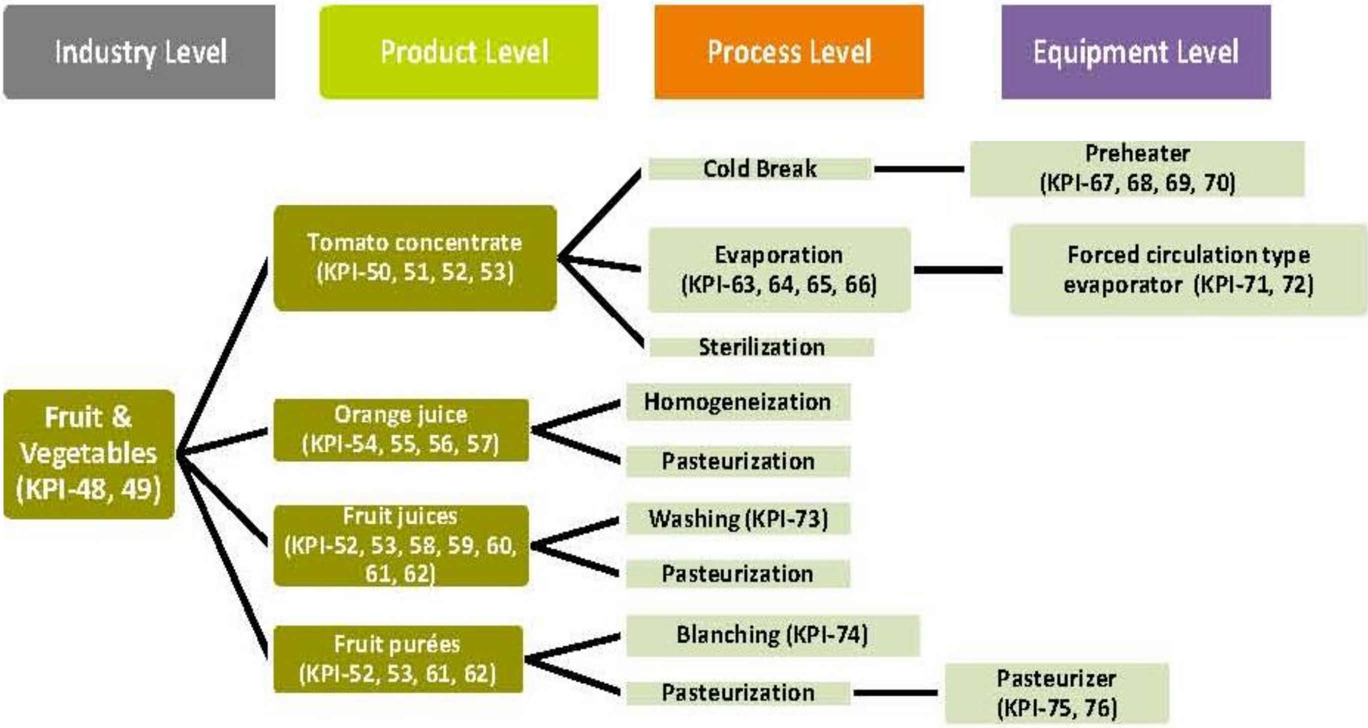

Figure 4. Scheme of the thermal energy KPIs in the fruit and vegetables sector, according to the four levels, which are - starting from the lower level to the upper level – the following: industry level, product level, process level, and equipment level. In the scheme, only thermal processes of a production line are considered. For most of these KPIs, there is the "average KPI" version and the "best KPI" version.

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4.1. Thermal average KPI-48: Average thermal energy consumption in kWh per t of tomato/fruit concentrate, juice, purée product.

INDICATOR	Thermal average KPI-48: Average thermal energy consumption in kWh per t of tomato/fruit concentrate, juice, or purée product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato concentrates, fruit juices and purées)	
Level of indicator	Industrial level (tomato concentrates, fruit juices and purées)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the different thermal processes (evaporation, sterilization, hot and/or cold break) of the tomato concentrates and fruit juices and purées processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard industry of tomato concentrates and fruit juices and purées, and it is related to the amount of processed product (in tonnes).			
Upper level	---			
Lower level	Product level (tomato concentrates, fruit juices and purées)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of final processed product)	**Name**	T aKPI L1 N4
Best or average KPI	Average		**KPI Value**	1888,9-2305,6 *kWh/t* final product 1,89-2,31 *kWh/kg* final product 6,8-8,3 *GJ/t* final product
Source	From “Fruttagel Scpa. Atto amminastrativo. N° Det. Amb. 2016-1507 del 18-05-2016”.			

4.2. Thermal best KPI-49: Best thermal energy consumption in kWh per t of tomato/fruit concentrate, juice, purée product.

INDICATOR	Thermal best KPI-49: Best thermal energy consumption in kWh per t of tomato/fruit concentrate, juice, or purée product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato concentrates, fruit juices and purées)	
Level of indicator	Industrial level (tomato concentrates, fruit juices and purées)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the different thermal processes (evaporation, sterilization, hot and/or cold break) of the tomato concentrates and fruit juices and purées processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard industry of tomato concentrates and fruit juices and purées, and it is related to the amount of processed product (in tonnes).			
Upper level	---			
Lower level	Product level (tomato concentrates, fruit juices and purées)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of final processed product)	**Name**	T bKPI L1 N4
Best or average KPI	Best		**KPI Value**	1250-1944,5 *kWh/t* final product 1,250-1,945 *kWh/kg* final product 4,5-7,0 *GJ/t* final product
Source	From "Fruttagel Scpa. Atto amminastrativo. N° Det. Amb. 2016-1507 del 18-05-2016".			

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4.3. Thermal average KPI-50: Average thermal energy consumption in kWh per t of triple tomato concentrate product.

INDICATOR	Thermal average KPI-50: Average thermal energy consumption in kWh per t of triple tomato concentrate product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (triple tomato concentrate)	
Level of indicator	Product level (triple tomato concentrate)			
	Triple tomato concentrate at 36°-38° Brix is obtained by Cold Break technology. In general, it takes 7 *kg* of fresh tomatoes to make 1 *kg* of triple concentrate. The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the different thermal processes (evaporation, sterilization, hot and/or cold break) of the tomato concentrates processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard industry of tomato concentrates, and it is related to the amount of processed product (in tonnes).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (cold break, evaporation, concentration processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of final processed product)	**Name**	T aKPI L2 N4
Best or average KPI	Average		**KPI Value**	2361-3333 *kWh/t* final product 2,3761-3,333 *kWh/kg* final product 8,5-12 *GJ/t* final product 8500-12000 *kJ/kg* final product
Source	From "ENEA, ENEL, ENI, IASM. Manuale per l'uso razionale dell'energia nel settore delle conserve di pomodoro. December 1985".			

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4.4. Thermal best KPI-51: Best thermal energy consumption in kWh per t of triple tomato concentrate product.

INDICATOR	Thermal best KPI-51: Best thermal energy consumption in kWh per t of triple tomato concentrate product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (triple tomato concentrate)	
Level of indicator	Product level (triple tomato concentrate) Triple tomato concentrate at 36°-38° Brix is obtained by Cold Break technology. In general, it takes 7 *kg* of fresh tomatoes to make 1 *kg* of triple concentrate. The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the different thermal processes (evaporation, sterilization, hot and/or cold break) of the tomato concentrates processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard industry of tomato concentrates, and it is related to the amount of processed product (in tonnes).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (cold break, evaporation, concentration processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per tonne of final processed product)	**Name**	T bKPI L2 N4
Best or average KPI	Best		**KPI Value**	1667-2222 *kWh/t* final product 1,667-2,222 *kWh/kg* final product 6-8 *GJ/t* final product 6000-8000 *kJ/kg* final product
Source	From "ENEA, ENEL, ENI, IASM. Manuale per l'uso razionale dell'energia nel settore delle conserve di pomodoro. December 1985".			

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4.5. Thermal average KPI-52: Average steam mass required in kg for sterilization, pasteurization, and UHT processes, in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of processed final product.

INDICATOR	Thermal average KPI-52: Average steam mass required in kg for sterilization, pasteurization, and UHT processes, in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of processed final product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato juice, purées and paste)	
Level of indicator	Product level (28-30 °Brix tomato juice, purées, and paste)			
	Steam is required in sterilization, pasteurization and UHT processes, determining high energy consumption, particularly in those months/seasons of high tomato production, when machines work at full speed. One of the major advantages of steam is its use as a heat transfer medium since a large amount of heat is released when it condenses into water, with very little steam required carrying large amount of energy. It is also safe, non-toxic and non-flammable, as well as 100% recyclable. As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average *kg* of steam required for the major thermal energy consuming processes per tonne of processed tomato consumed by a standard industry.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (sterilization, pasteurization, and UHT processes)			
Associated variables	**Unit**	*kg/t* (kg of steam per tonne of final processed product)	**Name**	T aKPI L2 N4
	Steam consumption has a direct and significant affect on energy costs.			
Best or average KPI	Average		**KPI Value**	60-80 *kg* steam/*t* final product
Source	From: "European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006".			

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4.6. Thermal best KPI-53: Best steam mass required in kg for sterilization, pasteurization, and UHT processes, in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of processed final product.

INDICATOR	Thermal best KPI-53: Best steam mass required in kg for sterilization, pasteurization, and UHT processes, in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of processed final product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato juice, purées and paste)	
Level of indicator	Product level (28-30 °Brix tomato juice, purées, and paste)			
	Steam is required in sterilization, pasteurization and UHT processes, determining high energy consumption, particularly in those months/seasons of high tomato production, when machines work at full speed. One of the major advantages of steam is its use as a heat transfer medium since a large amount of heat is released when it condenses into water, with very little steam required carrying large amount of energy. It is also safe, non-toxic and non-flammable, as well as 100% recyclable. As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average *kg* of steam required for the major thermal energy consuming processes per tonne of processed tomato consumed by a standard industry.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (sterilization, pasteurization, and UHT processes)			
Associated variables	**Unit**	*kg/t* (kg of steam per tonne of final processed product)	**Name**	T bKPI L2 N4
	Steam consumption has a direct and significant affect on energy costs.			
Best or average KPI	Best		**KPI Value**	60-80 *kg* steam/*t* final product
Source	From: “European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006”.			

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4.7. Thermal average KPI-54: Average thermal energy consumption in kWh per L orange juice product.

INDICATOR	Thermal average KPI-54: Average thermal energy consumption in kWh per L of orange juice product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (orange juice)	
Level of indicator	Product level (orange juice)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the thermal processes (homogenization and pasteurization) of the citrus fruit juices processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed (that is natural gas) by a standard industry of orange juice, and it is related to the amount of processed product (in kilograms or in litres).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (homogenization, pasteurization processes)			
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy per litre of final processed product)	**Name**	T aKPI L2 N4
Best or average KPI	Average		**KPI Value**	0,19 *kWh/L* orange juice product 190 *kWh/m*^{3} orange juice product 0,68 *MJ/L* orange juice product
Source	From "7FP EU Project SENSE. HarmoniSed Environmental Sustainability in the European food and drink chain. Deliverable D2.1: Life cycle assessment of orange juice. 2013".			

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4.8. Thermal best KPI-55: Best thermal energy consumption in kWh per L of orange juice product.

INDICATOR	Thermal best KPI-55: Best thermal energy consumption in kWh per L (or per t) of orange juice product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (orange juice)	
Level of indicator	Product level (orange juice)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the thermal processes (homogenization and pasteurization) of the citrus fruit juices processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed (that is natural gas) by a standard industry of orange juice, and it is related to the amount of processed product (in kilograms or in litres).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (homogenization, pasteurization processes)			
Associated variables	**Unit**	*kWh/L* (kilowatt hour thermal energy per litre of final processed product)	**Name**	T bKPI L2 N4
Best or average KPI	Best		**KPI Value**	~0,139 *kWh/L* orange juice product ~0,139 *kWh/m*^{3} orange juice product ~0,5 *MJ/L* orange juice product
Source	From "7FP EU Project SENSE. HarmoniSed Environmental Sustainability in the European food and drink chain. Deliverable D2.1: Life cycle assessment of orange juice. 2013".			

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4.9. Thermal average KPI-56: Thermal energy consumption in kWh per year in a plant processing on average 100000 t of oranges per year.

INDICATOR	Thermal average KPI-56: Thermal energy consumption in kWh per year in a plant processing on average 100000 t of oranges per year.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (orange juice)	
Level of indicator	Product level (orange juice) In an orange juice processing plant, the thermal processes more energy intensive are homogenization and pasteurization.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed (that is natural gas) in one year by an industry processing on average 100000 *t* oranges per year.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (homogenization, pasteurization processes)			
Associated variables	**Unit**	*kWh/100000 t* (kilowatt hour thermal energy per 100000 tonnes of processed oranges)	**Name**	T aKPI L2 N4
Best or average KPI	Average		**KPI Value**	~222,2 *kWh*/100000 *t* of oranges ~0,00222 *kWh*/*t* of oranges ~800 *MJ*/100000 *t* of oranges
Source	From "7FP EU Project SENSE. HarmoniSed Environmental Sustainability in the European food and drink chain. Deliverable D2.1: Life cycle assessment of orange juice. 2013".			

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4.10. Thermal best KPI-57: Thermal energy consumption in kWh per year in a plant processing on average 100000 t of oranges per year.

INDICATOR	Thermal best KPI-57: Thermal energy consumption in kWh per year in a plant processing on average 100000 t of oranges per year.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (orange juice)	
Level of indicator	Product level (orange juice)			
	In an orange juice processing plant, the thermal processes more energy intensive are homogenization and pasteurization.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed (that is natural gas) in one year by an industry processing on average 100000 *t* oranges per year.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (homogenization, pasteurization processes)			
Associated variables	**Unit**	*kWh/100000 t* (kilowatt hour thermal energy per 100000 tonnes of processed oranges)	**Name**	T bKPI L2 N4
Best or average KPI	Best		**KPI Value**	<166,7 *kWh*/100000 *t* of oranges ~0,006 *kWh*/*t* of oranges <600 *MJ*/100000 *t* of oranges
Source	From "7FP EU Project SENSE. HarmoniSed Environmental Sustainability in the European food and drink chain. Deliverable D2.1: Life cycle assessment of orange juice. 2013".			

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4.11. Thermal average KPI-58: Average thermal energy consumption in kWh per t of fruit juice product.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-58: Average thermal energy consumption in kWh per t of fruit juice product.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (fruit juices)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (fruit juices)</td></tr>
<tr><td colspan="4">The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the thermal processes (as washing and pasteurization) of the fruit juices processing company, and it is supplied by a fuel.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average total thermal energy consumed by a standard fruit juice industry, and it is related to the amount of processed product (in litres).</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (fruit and vegetable transformation)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (washing, pasteurization processes)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/t (kilowatt hour thermal energy per tonne of final processed product)</td><td>Name</td><td>T aKPI L2 N4</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Average</td><td>KPI Value</td><td>~310 kWh/t fruit juice product

~0,310 kWh/kg fruit juice product

1120 MJ/t fruit juice product

1,12 MJ/kg fruit juice product</td></tr>
<tr><td>Source</td><td colspan="4">From “Waheed et al. Energetic analysis of fruit juice processing operations in Nigeria. Energy 33(2008): 35-45”.</td></tr>
</table>

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4.12. Thermal best KPI-59: Best thermal energy consumption in kWh per t of fruit juice product.

INDICATOR	Thermal best KPI-59: Best thermal energy consumption in kWh per t (or per L) of fruit juice product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (fruit juices)	
Level of indicator	Product level (fruit juices)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the thermal processes (as washing and pasteurization) of the fruit juices processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard fruit juice industry, and it is related to the amount of processed product (in litres or in tonnes).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (washing, pasteurization processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy per tonne of final processed product)	**Name**	T bKPI L2 N4
Best or average KPI	Best		**KPI Value**	~140 *kWh/t* fruit juice product ~0,140 *kWh/kg* fruit juice product 500 *MJ/t* fruit juice product 0,5 *MJ/kg* fruit juice product
Source	From "Waheed *et al*. Energetic analysis of fruit juice processing operations in Nigeria. Energy 33(2008): 35-45".			

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4.13. Thermal average KPI-60: Average fuel oil consumption in L per L of fruit juice product.

INDICATOR	Thermal average KPI-60: Average fuel oil consumption in L per L of fruit juice product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (fruit juices)	
Level of indicator	Product level (fruit juices)			
	The value for this indicator can be obtained by assessing fuel consumption for steam production. In general, steam is required in the thermal processes (as washing and pasteurization) of the fruit juices processing company, and it is supplied by a fuel.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by a standard fruit juice industry, and it is related to the amount of processed product (in kilograms or in litres).			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (washing, pasteurization processes)			
Associated variables	**Unit**	*L/L* (litre of fuel oil consumed per litre of fruit juice product)	**Name**	T aKPI L2 N4
	Nguyen Ngoc and Schnitzer (2008) estimated that a mango juice production plant consumes approximately 0,136 *kWh* of electricity, 0,02 *L* of fuel oil, and 20-25 *L* of water for every litre of juice produced, hence generating 10 *L* of wastewater and 350 *g* of solid wastes daily.			
Best or average KPI	Average		**KPI Value**	0,02 *L* of fuel oil/*L* of fruit juice product
Source	From "Nguyen Ngoc & Schnitzer. Waste management towards zero emissions approach in the fruit juice processing industry. In: 1st WSEAS International Conference in Environmental and geological science and engineering. Pages 91-97. 2008".			

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4.14. Thermal average KPI-61: Average thermal energy consumption in kWh/t for steam production due to pasteurization and other thermal processes in fruit juices and purées production.

INDICATOR	Thermal average KPI-61: Average thermal energy consumption in kWh/t for steam production due to pasteurization and other thermal processes in fruit juices and purées production.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (fruit juices and purées)	
Level of indicator	Product level (fruit juices and purées)			
	The major energy consumption in the industries of fruit juices and purées is due to the production of steam for the thermal processes, in particular for the pasteurization. In this specific indicator, thermal energy consumption in toe (tonne of oil equivalent) is calculated per tonne of final product.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the average total thermal energy consumed by fruit juices and purées processing industries for steam production in the pasteurization and the other thermal processes per tonne of product.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (washing, blanching, pasteurization processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumption per tonne of final product)	**Name**	T aKPI L2 N4
Best or average KPI	Average		**KPI Value**	302,38 *kWh/t* final product 0,302 *kWh/kg* final product 0,026 *toe/t* final product
Source	From "Borgarello. Analisi dei consumi energetici nei settori industriali. Ricerca di Sistema Elettrico 2011. Politecnico di Torino".			

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4.15. Thermal best KPI-62: Best thermal energy consumption in kWh/t for steam production due to pasteurization and other thermal processes in fruit juices and purées production.

INDICATOR	Thermal best KPI-62: Best thermal energy consumption in kWh/t for steam production due to pasteurization and other thermal processes in fruit juices and purées production.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (fruit juices and purées)	
Level of indicator	Product level (fruit juices and purées) The major energy consumption in the industries of fruit juices and purées is due to the production of steam for the thermal processes, in particular for the pasteurization. In this specific indicator, thermal energy consumption in toe (tonne of oil equivalent) is calculated per tonne of final product.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	This indicator refers to the average total thermal energy consumed by fruit juices and purées processing industries for steam production in the pasteurization and the other thermal processes per tonne of product.			
Upper level	Industry level (fruit and vegetable transformation)			
Lower level	Process level (washing, blanching, pasteurization processes)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumption per tonne of final product)	**Name**	T bKPI L2 N4
Best or average KPI	Best		**KPI Value**	~35 *kWh/t* final product ~0,035 *kWh/kg* final product 0,003 *toe/t*
Source	From “Borgarello. Analisi dei consumi energetici nei settori industriali. Ricerca di Sistema Elettrico 2011. Politecnico di Torino”.			

4.16. Thermal average KPI-63: Average steam mass required in kg for evaporation process in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of final product.

INDICATOR	Thermal average KPI-63: Average steam mass required in kg for evaporation process in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of final product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato juice, purée and paste)	
Level of indicator	Process level (evaporation of 28-30 °Brix tomato juice, purée, and paste)			
	Evaporation requires a great amount of thermal energy for steam production. This process presents an average water consumption of 100-150 m^3/t. 28-30 °Brix tomato paste, that is "double concentrate" tomato paste, is obtained through the hot-break (HB) process In HB, fresh tomatoes must be heated immediately after chopping to a very high temperature ranging from 85 to 100 °*C*.			
Thermal or electrical process	Thermal process			
Energy source	Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average *kg* of steam required for the evaporation referred to 1 tonne of 28-30 °Brix tomato purée.			
Upper level	Product level (28-30 °Brix tomato juice, purée, and paste)			
Lower level	Equipment level (evaporator)			
Associated variables	**Unit**	*kg/t* (kilogram of steam per tonne of 28-30 °Brix tomato purée)	**Name**	T aKPI L3 N4
	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) **q** = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (*http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*).			
Best or average KPI	Average		**KPI Value**	1500-1800 *kg* steam/*t* of 28-30 °Brix tomato purée
Source	From: "European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006". *http://www.engineeringtoolbox.com/steam-heating-process-d_437.html* *http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*			

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4.17. Thermal best KPI-64: Best steam mass required in kg for evaporation process in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of final product.

INDICATOR	Thermal best KPI-64: Best steam mass required in kg for evaporation process in the manufacturing of 28-30 °Brix tomato juice, purée, and paste, divided by the t of final product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato juice, purée and paste)	
Level of indicator	Process level (evaporation of 28-30 °Brix tomato juice, purée, and paste)			
	Evaporation requires a great amount of thermal energy for steam production. This process presents an average water consumption of 100-150 *m^3/t*. 28-30 °Brix tomato paste, that is "double concentrate" tomato paste, is obtained through the hot-break (HB) process In HB, fresh tomatoes must be heated immediately after chopping to a very high temperature ranging from 85 to 100 *°C*.			
Thermal or electrical process	Thermal process			
Energy source	Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average *kg* of steam required for the evaporation referred to 1 tonne of 28-30 °Brix tomato purée.			
Upper level	Product level (28-30 °Brix tomato juice, purée, and paste)			
Lower level	Equipment level (evaporator)			
Associated variables	**Unit**	*kg/t* (kilogram of steam per tonne of 28-30 °Brix tomato purée)	**Name**	T bKPI L3 N4
	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) **q** = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (*http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*).			
Best or average KPI	Best		**KPI Value**	<1500 *kg* steam/*t* of 28-30 °Brix tomato purée
Source	From: "European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006". *http://www.engineeringtoolbox.com/steam-heating-process-d_437.html* *http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*			

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4.18. Thermal average KPI-65: Average steam mass required in kg for evaporation process in the manufacturing of 36-40 °Brix tomato juice, purée, and paste, divided by the t of final product.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-65: Average steam mass required in kg for evaporation process in the manufacturing of 36-40 °Brix tomato juice, purée, and paste, divided by the t of final product.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (tomato juice, purée and paste)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Process level (evaporation of 36-40 °Brix tomato juice, purée, and paste)</td></tr>
<tr><td colspan="4">Evaporation requires a great amount of thermal energy for steam production. This process presents an average water consumption of 100-150 m³/t.
As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.
“Triple concentrate” tomato paste contains more than 36% solid material (36-40 °Brix) and it is obtained by cold-break (CB) technology, where chopped tomatoes are heated at a lower temperature ranging from 65 to 75 °C. This temperature does not cause the complete inactivation of pectolytic enzymes, but guarantees an optimal performance in the following juice extraction and refining phases.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Steam consumption has a direct and significant affect on energy costs.
This indicator refers to the average kg of steam required for the evaporation referred to 1 tonne of 36-40 °Brix tomato purée (triple tomato concentrate).</td></tr>
<tr><td>Upper level</td><td colspan="4">Product level (36-40 °Brix tomato juice, purée, and paste)</td></tr>
<tr><td>Lower level</td><td colspan="4">Equipment level (evaporator)</td></tr>
<tr><td>Associated variables</td><td>Unit</td><td>kg/t
(kilogram of steam per tonne of 36-40 °Brix tomato purée)</td><td>Name</td><td>T aKPI L3 N4</td></tr>
</table>

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	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) **q** = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (*http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*).		
Best or average KPI	Average	**KPI Value**	1950-2340 *kg* steam/*t* of 36-40 °Brix tomato purée
Source	From: "European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006". *http://www.engineeringtoolbox.com/steam-heating-process-d_437.html* *http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*		

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4.19. Thermal best KPI-66: Best steam mass required in kg for evaporation process in the manufacturing of 36-40 °Brix tomato juice, purée, and paste, divided by the t of final product.

INDICATOR	Thermal best KPI-66: Best steam mass required in kg for evaporation process in the manufacturing of 36-40 °Brix tomato juice, purée, and paste, divided by the t of final product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato juice, purée and paste)	
Level of indicator	Process level (evaporation of 36-40 °Brix tomato juice, purée, and paste)			
	Evaporation requires a great amount of thermal energy for steam production. This process presents an average water consumption of 100-150 m^3/t. As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure. "Triple concentrate" tomato paste contains more than 36% solid material (36-40 °Brix) and it is obtained by cold-break (CB) technology, where chopped tomatoes are heated at a lower temperature ranging from 65 to 75 *°C*. This temperature does not cause the complete inactivation of pectolytic enzymes, but guarantees an optimal performance in the following juice extraction and refining phases.			
Thermal or electrical process	Thermal process			
Energy source	Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.			
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average *kg* of steam required for the evaporation referred to 1 tonne of 36-40 °Brix tomato purée (triple tomato concentrate).			
Upper level	Product level (36-40 °Brix tomato juice, purée, and paste)			
Lower level	Equipment level (evaporator)			
Associated variables	**Unit**	*kg/t* (kilogram of steam per tonne of 36-40 °Brix tomato purée)	**Name**	T bKPI L3 N4

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	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) **q** = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (*http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*).		
Best or average KPI	Best	**KPI Value**	<1950 *kg* steam/*t* of 36-40 °Brix tomato purée
Source	From: "European Commission. Integrated Pollution Prevent and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. 2006". *http://www.engineeringtoolbox.com/steam-heating-process-d_437.html* *http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*		

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4.20. Thermal average KPI-67: Average steam mass required in kg used by the preheater in hot-break per t of "double concentrate" tomato paste produced (28-30 °Brix).

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-67: Average steam mass required in kg used by the preheater in hot-break per t of "double concentrate" tomato paste produced (28-30 °Brix).</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (tomato paste)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (preheater in hot-break)</td></tr>
<tr><td colspan="4">This indicator refers to the thermal energy consumed by the preheater in the hot-break (HB) process for the production of 28-30 °Brix tomato paste that is "double concentrate" tomato paste. In HB, fresh tomatoes are heated immediately after chopping to a high temperature ranging from 85 to 100 °C. As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, natural gas, biomass, waste, etc..</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average amount in kg of steam consumed by the preheater in the HB process per tonne of double concentrate tomato paste produced.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (HB)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kg/t (kilograms of consumed steam per tonne of double concentrate tomato paste produced (28-30 °Brix))</td><td>Name</td><td>T aKPI L4 N4</td></tr>
<tr><td colspan="4">Calculating the amount of steam knowing the heat transfer rate:
$\mathbf{m_s = q/h_e}$
where $\mathbf{m_s}$ = mass of steam (kg/s)
$\mathbf{q}$ = calculated heat transfer (kW)
$\mathbf{h_e}$ = evaporation energy of steam (kJ/kg).
The evaporation energy at different steam pressures can be found in the Steam Tables (http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">~140 kg of steam/t of double concentrate tomato paste produced (28-30 °Brix)</td></tr>
<tr><td>Source</td><td colspan="4">Elaboration of data from the website http://tomato-machinery.com/
http://www.engineeringtoolbox.com/steam-heating-process-d_437.html
http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html</td></tr>
</table>

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4.21. Thermal best KPI-68: Best steam mass required in kg used by the preheater in hot-break per t of "double concentrate" tomato paste produced (28-30 °Brix).

INDICATOR	Thermal best KPI-68: Best steam mass required in kg used by the preheater in hot-break per t of "double concentrate" tomato paste produced (28-30 °Brix).			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato paste)	
Level of indicator	Equipment level (preheater in hot-break)			
	This indicator refers to the thermal energy consumed by the preheater in the hot-break (HB) process for the production of 28-30 °Brix tomato paste that is "double concentrate" tomato paste. In HB, fresh tomatoes are heated immediately after chopping to a high temperature ranging from 85 to 100 *°C*. As an energy medium, the measurement of steam is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from fossil fuels, natural gas, biomass, waste, etc..			
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average amount in *kg* of steam consumed by the preheater in the HB process per tonne of double concentrate tomato paste produced.			
Upper level	Process level (HB)			
Lower level	---			
Associated variables	**Unit**	*kg/t* (kilograms of consumed steam per tonne of double concentrate tomato paste produced (28-30 °Brix))	**Name**	T bKPI L4 N4
	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) **q** = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (*http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html*).			
Best or average KPI	Best	**KPI Value**	<140 *kg* of steam/*t* of double concentrate tomato paste produced (28-30 °Brix)	
Source	Elaboration of data from the website http://tomato-machinery.com/ http://www.engineeringtoolbox.com/steam-heating-process-d_437.html http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html			

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4.22. Thermal average KPI-69: Average steam mass required in kg utilized by the preheater in cold-break per t of "triple concentrate" tomato paste produced (36-40 °Brix).

INDICATOR	Thermal average KPI-69: Average steam mass required in *kg* utilized by the preheater in cold-break per *t* of "triple concentrate" tomato paste produced (36-40 °Brix).			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato paste)	
Level of indicator	Equipment level (preheater in cold-break)			
	This indicator refers to the thermal energy consumed by the preheater in the cold-break (CB) process for the production of 36-40 °Brix tomato paste (i.e. containing more than 36% solid material), that is "triple concentrate" tomato paste. In CB technology, chopped tomatoes are heated at a temperature lower than in the hot-break (HB), ranging from 65 to 75 *°C*. This temperature does not cause the complete inactivation of pectolytic enzymes, but guarantees an optimal performance in the following juice extraction and refining phases. Here, steam is the thermal energy medium, and its measurement is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from fossil fuels, natural gas, biomass, waste, etc..			
Description of the indicator	Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average kg of steam consumed by the preheater in the CB process per tonne of triple concentrate tomato paste produced.			
Upper level	Process level (CB)			
Lower level	---			
Associated variables	**Unit**	*kg/t* (kilograms of consumed steam per tonne of triple concentrate tomato paste produced (36-40 °Brix))	**Name**	T aKPI L4 N4
	Calculating the amount of steam knowing the heat transfer rate: $\mathbf{m_s = q/h_e}$ where $\mathbf{m_s}$ = mass of steam (*kg/s*) $\mathbf{q}$ = calculated heat transfer (*kW*) $\mathbf{h_e}$ = evaporation energy of steam (*kJ/kg*). The evaporation energy at different steam pressures can be found in the Steam Tables (http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).			
Best or average KPI	Average	**KPI Value**	~180 *kg* of steam/*t* of double concentrate tomato paste produced (36-40 °Brix)	
Source	Elaboration of data from the website http://tomato-machinery.com/ http://www.engineeringtoolbox.com/steam-heating-process-d_437.html http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html			

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4.23. Thermal best KPI-70: Best steam mass required in kg utilized by the preheater in cold-break per t of “triple concentrate” tomato paste produced (36-40 °Brix).

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-70: Best steam mass required in kg utilized by the preheater in cold-break per t of “triple concentrate” tomato paste produced (36-40 °Brix).</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (tomato paste)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (preheater in cold-break)</td></tr>
<tr><td colspan="4">This indicator refers to the thermal energy consumed by the preheater in the cold-break (CB) process for the production of 36-40 °Brix tomato paste (i.e. containing more than 36% solid material), that is “triple concentrate” tomato paste. In CB technology, chopped tomatoes are heated at a temperature lower than in the hot-break (HB), ranging from 65 to 75 °C. This temperature does not cause the complete inactivation of pectolytic enzymes, but guarantees an optimal performance in the following juice extraction and refining phases.
Here, steam is the thermal energy medium, and its measurement is in fact the measurement of the flow of energy. However, steam is difficult to measure accurately as it is sensitive to changes in temperature and pressure, which change its composition, creating different types of steam. There are three categories of steam: wet, saturated and superheated, and also according to that there are a number of important design and installation considerations when selecting the most appropriate steam flow meter, including accuracy, repeatability, and turndown ratio, multivariable versus discreet components, as well as installation and maintenance costs. By using the latest technology it is possible to measure steam mass and steam energy, as well as temperature and pressure.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, natural gas, biomass, waste, etc..</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">Steam consumption has a direct and significant affect on energy costs. This indicator refers to the average kg of steam consumed by the preheater in the CB process per tonne of triple concentrate tomato paste produced.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (CB)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kg/t
(kilograms of consumed steam per tonne of triple concentrate tomato paste produced (36-40 °Brix))</td><td>Name</td><td>T bKPI L4 N4</td></tr>
<tr><td colspan="4">Calculating the amount of steam knowing the heat transfer rate:
$\mathbf{m_s = q/h_e}$
where $\mathbf{m_s}$ = mass of steam (kg/s)
$\mathbf{q}$ = calculated heat transfer (kW)
$\mathbf{h_e}$ = evaporation energy of steam (kJ/kg).
The evaporation energy at different steam pressures can be found in the Steam Tables (http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).</td></tr>
<tr><td>Best or average KPI</td><td>Best</td><td>KPI Value</td><td colspan="2"><140 kg of steam/t of double concentrate tomato paste produced (36-40 °Brix)</td></tr>
<tr><td>Source</td><td colspan="4">Elaboration of data from the website http://tomato-machinery.com/
http://www.engineeringtoolbox.com/steam-heating-process-d_437.html
http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html</td></tr>
</table>

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4.24. Thermal average KPI-71: Average thermal energy consumption in kWh by the evaporator per t of fresh processed tomatoes, in the 28-30 °Brix tomato paste processing line.

INDICATOR	Thermal average KPI-71: Average thermal energy consumption in kWh by the evaporator per t of fresh processed tomatoes, in the 28-30 °Brix tomato paste processing line.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato paste)	
Level of indicator	Equipment level (evaporator)			
	Evaporation is the most energy intensive step of the whole tomato processing line. Evaporation, or concentration by boiling, is the partial removal of water from liquid foods by boiling off water vapor. It increases the solids content of a food and hence preserves it by a reduction in water activity. Evaporation is used to pre-concentrate foods (tomato and fruit juices) prior to drying, freezing or sterilization and hence to reduce their weight and volume. The entire concentration process takes place under vacuum condition at low temperatures. The evaporative capacity of tomato juice concentrators is influenced by the juice viscosity: at high Brix % corresponds more output. In a forced circulation (FC) type evaporator, the solution to be evaporated circulated by circulation pump through the heat exchangers tubes with high velocity from bottom to the top. In an evaporation/concentration plant, the major operating cost is for the production of the steam which is obtained in a boiler. The multiple-effect evaporator design allows energy savings thus reducing operating costs. Evaporation is more energy expensive than other concentration methods, but it allows to achieve a higher degree of concentration.			
Thermal or electrical process	Thermal process			
Energy source	Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the average *kWh* of thermal energy consumed by the evaporator per *t* of processed fresh tomatoes.			
Upper level	Process level (evaporation)			
Lower level	---			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy per tonne of fresh processed tomato (for 28-30 °Brix tomato paste))	**Name**	T aKPI L4 N4
	The specific value of this KPI refers to 28-30 °C tomato paste as end product.			
Best or average KPI	Average	**KPI Value**	70-110 *kWh/t* processed fresh tomatoes 0,07-0,11 *kWh/kg* processed fresh tomatoes 250-400 *MJ/t* processed fresh tomatoes	
Source	From "Karakaya & Özilgen. Energy utilization and carbon dioxide emission in fresh, paste, whole-peeled, diced, and juiced tomato production processes. *Energy* 36(2011): 5101-5110".			

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Saving Cooperative Energy

4.25. Thermal best KPI-72: Best thermal energy consumption in kWh by the evaporator per t of fresh processed tomatoes, in the 28-30 °Brix tomato paste processing line.

INDICATOR	Thermal best KPI-72: Best thermal energy consumption in kWh by the evaporator per t of fresh processed tomatoes, in the 28-30 °Brix tomato paste processing line.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (tomato paste)	
Level of indicator	Equipment level (evaporator)			
	Evaporation is the most energy intensive step of the whole tomato processing line. Evaporation, or concentration by boiling, is the partial removal of water from liquid foods by boiling off water vapor. It increases the solids content of a food and hence preserves it by a reduction in water activity. Evaporation is used to pre-concentrate foods (tomato and fruit juices) prior to drying, freezing or sterilization and hence to reduce their weight and volume. The entire concentration process takes place under vacuum condition at low temperatures. The evaporative capacity of tomato juice concentrators is influenced by the juice viscosity: at high Brix % corresponds more output. In a forced circulation (FC) type evaporator, the solution to be evaporated circulated by circulation pump through the heat exchangers tubes with high velocity from bottom to the top. In an evaporation/concentration plant, the major operating cost is for the production of the steam which is obtained in a boiler. The multiple-effect evaporator design allows energy savings thus reducing operating costs. Evaporation is more energy expensive than other concentration methods, but it allows to achieve a higher degree of concentration.			
Thermal or electrical process	Thermal process			
Energy source	Steam consumed by the evaporator, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the average *kWh* of thermal energy consumed by the evaporator per *t* of processed fresh tomatoes.			
Upper level	Process level (evaporation)			
Lower level	---			
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy per tonne of fresh processed tomato (for 28-30 °Brix tomato paste))	**Name**	T bKPI L4 N4
	The specific value of this KPI refers to 28-30 °C tomato paste as end product.			
Best or average KPI	Best	**KPI Value**	55-80 *kWh/t* of processed fresh tomatoes 0,055-0,08 *kWh/kg* processed fresh tomatoes 200-300 *MJ/t* of processed fresh tomatoes	
Source	From “Karakaya & Özilgen. Energy utilization and carbon dioxide emission in fresh, paste, whole-peeled, diced, and juiced tomato production processes. *Energy* 36(2011): 5101-5110”.			

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4.26. Thermal average KPI-73: Average thermal energy consumption in kWh for hot water in washing, including fruit washing and can washing, per t of fruit juice product.

INDICATOR	Thermal average KPI-73: Average thermal energy consumption in kWh for hot water in washing, including fruit washing and can washing, per t of fruit juice product.			
Sector (NACE code)	10.3	**Subsector**	Fruit and vegetable transformation (fruit juice)	
Level of indicator	Process level (fruit washing and can washing in fruit juice production)			
	Washing of fruits is done in specially designed washing machines. The water in the washer must be changes continuously, fresh water coming in while dirty water is carried away by the overflow. To minimize microflora, washing is best done by adding to the water some germicidal and detergent preparation. Washing is often done using hot water, and generally involve the use of high pressure water sprays, soaking, agitated tanks, and flumes to remove fruit surface contaminants. Washing in hot water is a highly energy intensive process, thus water efficiency and heat recovery are likely to be key energy saving strategies in fruit juice canning.			
Thermal or electrical process	Thermal processes			
Energy source	Steam consumed by the boiler to produce hot water, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc..			
Description of the indicator	This indicator refers to the water used for washing both the fruit and the container, and is related to the average thermal energy consumed in *kWh* to produce hot water for washing per *kg* of fruit juice produced.			
Upper level	Product level (fruit juices)			
Lower level	Equipment level (fruit washer and can washer)			
Associated variables	**Unit**	*kWh/t* (kilowatt hour of thermal energy required per tonne of fruit juice product)	**Name**	T aKPI L3 N4
Best or average KPI	Average	**KPI Value**	In total ~278 *kWh/t* of fruit juice (~140 *kWh/t* for fruit washing and ~140 *kWh/t* for can washing) In total ~0,278 *kWh/kg* of fruit juice (~0,14 *kWh/kg* for fruit washing and ~0,14 *kWh/kg* for can washing) In total ~1000 *kJ/kg* of fruit juice (~500 *kJ/kg* for fruit washing and ~500 *kJ/kg* for can washing)	
Source	From "Masanet *et al*.. Energy efficiency improvement and cost saving opportunities for the fruit and vegetable processing industry. An ENERGY STAR Guide for Energy and Plant Manager. March 2008".			

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4.27. Thermal average KPI-74: Average effluent discharged in kL due to blanching process per t of product.

INDICATOR	Thermal average KPI-74: Average effluent discharged in *kL* due to blanching process per *t* of product.
Sector (NACE code)	10.3 — **Subsector**: Fruit and vegetable transformation (fruit purée)
Level of indicator	Process level (blanching for fruit purée, etc.) For many fruit and vegetables as well as seafood that are frozen, canned, or dehydrated, blanching inactivate enzymes and reduces microbial loads to improve food safety and increase shelf life. Blanching equipment: A) In immersion and deluge water blanching equipment, product is exposed directly to food-grade water that typically ranges in temperature from70 to 100 °*C*. B) With steam blanching, product is exposed directly to food-grade steam that is typically 100 °*C*. Most water blanchers and steam blanchers require steam that is produced by a boiler. With water blanching, the steam heats the water and the product; with steam blanching, the steam is applied directly to the product. Compared to the most modern water blanchers, steam blanchers use approximately half the steam. Compared to older water blanchers, steam blanchers can often reduce steam use by as much as 80%. Thus, steam blanching strongly reduces volumes of wastewater to be discharged. Steam blanching is the preferred technology from a wastewater perspective, allowing cost savings associated with procuring water, treating wastewater, operating the boiler, etc.
Thermal or electrical process	Thermal process
Energy source	Steam consumed by the boiler, which in turn requires thermal energy from natural gas, biogas, diesel, heavy fuel oil, etc.
Description of the indicator	This indicator refers to the average wastewater in *kL* produced by the blanching equipment for the processing of 1 tonne of fruit. The value of this indicator will strongly depend on the equipment installed and for this reason three different average values will be considered, one value per specific type of blanching equipment.
Upper level	Product level (fruit purée)
Lower level	Equipment level (blancher)
Associated variables	**Unit**: *kL/t* (kilolitres of wastewater per tonne of fruit) — **Name**: T aKPI L3 N4 Because the boiler is one of the most expensive pieces of equipment to operate in a food processing plant, given the high coast of energy, steam consumption has a direct and significant affect on energy cost. Like energy costs, water use and wastewater effluent are directly correlated to the volume of steam used. Steam blanchers require half the steam of water blanchers, therefore, half the volume of water is needed for the operation and half the volume of wastewater is discharged.
Best or average KPI	Best — **KPI Value**: • 1 kL wastewater to be discharged per tonne of product in <u>draper blanching</u> • 0,5 kL wastewater to be discharged per tonne of product in <u>hot water blanching</u> • 0,2 kL wastewater to be discharged per tonne of product in <u>steam blanching</u>
Source	Elaborated from "Key Technology. Steam blanching Vs. water blanching: cost, efficiency, and product quality. White paper.

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4.28. Thermal average KPI-75: Average steam mass in kg utilized by the pasteurizer in fruit purées production, divided by the t of the final product.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-75: Average steam mass in kg utilized by the pasteurizer in fruit purées production, divided by the t of the final product.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (fruit purée)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (pasteurizer in fruit purées)</td></tr>
<tr><td colspan="4">For fruit purées, as well as for fruit juices, pasteurization is a mild thermal process. Liquids are heated to a temperature below 100 °C for a sufficient amount of time to destroy pathogenic microorganisms (pasteurization usually occurs through a rapid heating at 92 °C in tubular or plate heat exchangers for 30 seconds).
Energy and water consumption in pasteurization are quite relevant.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average kg of steam consumed by the pasteurizer during fruit purées production.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (pasteurization)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kg/t
(kilograms of consumed steam per tonne of final product)</td><td>Name</td><td>T aKPI L4 N4</td></tr>
<tr><td colspan="4">Calculating the amount of steam knowing the heat transfer rate:
$\mathbf{m_s = q/h_e}$
where $\mathbf{m_s}$ = mass of steam (kg/s)
$\mathbf{q}$ = calculated heat transfer (kW)
$\mathbf{h_e}$ = evaporation energy of steam (kJ/kg).
The evaporation energy at different steam pressures can be found int the Steam Tables (http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">~150 kg of steam/t of fruit purées</td></tr>
<tr><td>Source</td><td colspan="4">Elaboration of data from the website http://tomato-machinery.com/
http://www.engineeringtoolbox.com/steam-heating-process-d_437.html
http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html</td></tr>
</table>

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4.29. Thermal best KPI-76: Best steam mass in kg utilized by the pasteurizer in fruit purées production, divided by the t of the final product.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal best KPI-76: Best steam mass in kg utilized by the pasteurizer in fruit purées production, divided by the t of the final product.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.3</td><td>Subsector</td><td colspan="2">Fruit and vegetable transformation (fruit purée)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (pasteurizer in fruit purées)</td></tr>
<tr><td colspan="4">For fruit purées, as well as for fruit juices, pasteurization is a mild thermal process. Liquids are heated to a temperature below 100 °C for a sufficient amount of time to destroy pathogenic microorganisms (pasteurization usually occurs through a rapid heating at 92 °C in tubular or plate heat exchangers for 30 seconds).
Energy and water consumption in pasteurization are quite relevant.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average kg of steam consumed by the pasteurizer during fruit purées production.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (pasteurization)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kg/t
(kilograms of consumed steam per tonne of final product)</td><td>Name</td><td>T bKPI L4 N4</td></tr>
<tr><td colspan="4">Calculating the amount of steam knowing the heat transfer rate:
$\mathbf{m_s = q/h_e}$
where $\mathbf{m_s}$ = mass of steam (kg/s)
q = calculated heat transfer (kW)
$\mathbf{h_e}$ = evaporation energy of steam (kJ/kg).
The evaporation energy at different steam pressures can be found int the Steam Tables (http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html).</td></tr>
<tr><td>Best or average KPI</td><td>Best</td><td>KPI Value</td><td colspan="2">~100 kg of steam/t of fruit purées</td></tr>
<tr><td>Source</td><td colspan="4">Elaboration of data from the website http://tomato-machinery.com/
http://www.engineeringtoolbox.com/steam-heating-process-d_437.html
http://www.engineeringtoolbox.com/saturated-steam-properties-d_101.html</td></tr>
</table>

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5. MEAT PROCESSING sector

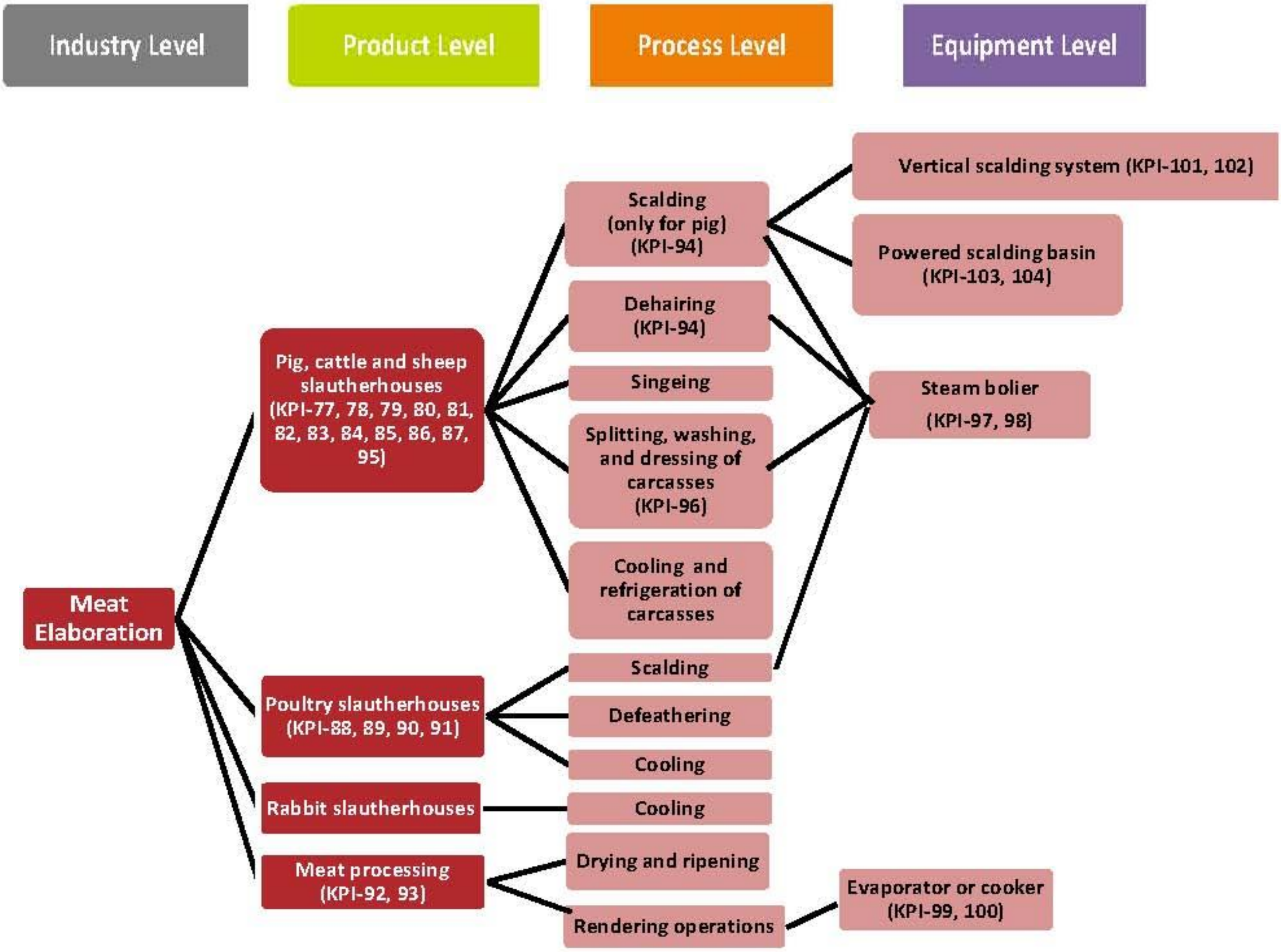

Figure 5. Scheme of the thermal energy KPIs in the meat processing sector, according to the four levels, which are - starting from the lower level to the upper level – the following: industry level, product level, process level, and equipment level. In the scheme, only thermal processes of a production line are considered. For many of these KPIs, there is the "average KPI" version and the "best KPI" version.

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5.1. Thermal average KPI-77: Average thermal energy consumption in kWh per t of meat in pig slaughterhouse.

INDICATOR	Thermal average KPI-77: Average thermal energy consumption in *kWh* per *t* of meat in pig slaughterhouse.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig)	
Level of indicator	Product level (pig slaughterhouse) Overall energy consumption will depend on the types of activities occurring at an abattoir. For example rendering, if it occurs on site, will add substantially to overall energy consumption. Pig scalding is an energy-consuming process specific to pig abattoirs. Approximately 80–85% of an abattoir's total energy need is for thermal energy, in the form of steam or hot water, produced from the combustion of fuels in on-site boilers.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, natural gas, etc.			
Description of the indicator	This indicator is referred to the thermal energy consumption of a specific plant per unit of physical output (i.e. per pig meat).			
Upper level	Industry level (meat elaboration)			
Lower level	Process level (scalding, dehairing, singeing, cooling, and in general all major thermal processes in pig slaughterhouse)			
Associated variables	**Unit**	*kWh/Mg* (kilowatt hour thermal energy consumed per tonne of pig meat)	**Name**	T aKPI N2 L2
Best or average KPI	Average	**KPI Value**	37,0-52,0 *kWh/t* of pig meat 0,037-0,052 *kWh/kg* of pig meat	
Source	From "Wojdalski J, Dróżdż B, Lipiński P (2010) Energy consumption efficiency in a small meat processing plant. Współczesne zagadnienia rozwoju sektora energetycznego i rolniczego. SGGW, 110-121 (in Polish: Efektywność zużycia energii w małym zakładzie przetwórstwa mięsnego)".			

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5.2. Thermal average KPI-78: Total average energy consumption (electricity + thermal energy) in kWh per head of pig slaughtered in pig meat processing.

INDICATOR	Thermal average KPI-78: Total average energy consumption (electricity + thermal energy) in *kWh* per head of pig slaughtered in pig meat processing.
Sector (NACE code)	10.1 — **Subsector**: Meat elaboration (pig)
Level of indicator	Product level (pig slaughterhouse) In pig slaughterhouse, moderate levels of both electrical and thermal (boiler fuel) energy are consumed in a wide range of processes and applications. Electrical energy is used in cooling, lighting, process equipment (saws, hoists, conveyors and packing machines), refrigeration, and wastewater treatment. Refrigeration, which includes chilled stores, air-conditioned areas, freezers and cold-stores, is consistently the most energy-intensive application in any pig processing plant. By comparison, thermal energy is primarily used to heat water for a wide array of cleaning & disinfection applications, in singeing to flame treat the carcass and in meat processing. This indicator refers to the average TOTAL energy consumed per pig.
Thermal or electrical process	Thermal and electrical processes
Energy source	Thermal energy from fossil fuels, natural gas, etc. for thermal processes and electricity for electrical processes.
Description of the indicator	Average total energy consumption, including both thermal energy and electricity, in kWh, per pig slaughtered. The value of this indicator (total energy consumption) is an average among different Northern European countries, that showed the following values: • 20-28 *kWh*/pig in Ireland • 36,6 *kWh*/pig in Sweden • 52 *kWh*/pig in Norway • 64 *kWh*/pig in Finland • 22-26 *kWh*/pig in Denmark.
Upper level	Industry level (meat elaboration)
Lower level	Process level (including all processes in pig slaughterhouse)
Associated variables	**Unit**: *kWh*/pig (kilowatt hour total energy per pig) — **Name**: T aKPI L2 N2
Best or average KPI	Average — **KPI Value**: 20<40>65 *kWh*/pig
Source	From: “Enterprise Ireland. Sustainable practices in Irish pig processing. June 2010”.

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5.3. Thermal best KPI-79: Total best energy consumption (electricity + thermal energy) in kWh per head of pig slaughtered in pig meat processing.

INDICATOR	Thermal best KPI-79: Total average energy consumption (electricity + thermal energy) in kWh per head of pig slaughtered in pig meat processing.		
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig)
Level of indicator	Product level (pig slaughterhouse)		
	In pig slaughterhouse, moderate levels of both electrical and thermal (boiler fuel) energy are consumed in a wide range of processes and applications. Electrical energy is used in cooling, lighting, process equipment (saws, hoists, conveyors and packing machines), refrigeration and wastewater treatment. Refrigeration, which includes chilled stores, air-conditioned areas, freezers and cold-stores, is consistently the most energy-intensive application in any pig processing plant. By comparison, thermal energy is primarily used to heat water for a wide array of cleaning & disinfection applications, in singeing to flame treat the carcass and in meat processing. This indicator refers to the average TOTAL energy consumed per pig.		
Thermal or electrical process	Thermal and electrical processes		
Energy source	Thermal energy from fossil fuels, natural gas, etc. for thermal processes and electricity for electrical processes.		
Description of the indicator	Average total energy consumption, including both thermal energy and electricity, in kWh, per pig slaughtered. A selection of benchmark for energy consumption has been established in a number of countries, as Denmark and Canada. For example, in Denmark, that may be considered as a model country, KPI values for total energy consumption according to the technology utilised resulted: • 125 kWh/pig with a traditional technology • 50 kWh/pig with an average technology • 30 kWh/pig with a best available technology.		
Upper level	Industry level (meat elaboration)		
Lower level	Process level (including all processes in pig slaughterhouse)		
Associated variables	**Unit**	*kWh*/pig (kilowatt hour total energy per pig)	**Name** T bKPI L2 N2
Best or average KPI	Best	**KPI Value**	30 *kWh*/pig slaughtered
Source	From: "Enterprise Ireland. Sustainable practices in Irish pig processing. June 2010".		

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5.4. Thermal average KPI-80: Total average water consumption in L per head of pig slaughtered in pig meat processing.

INDICATOR	Thermal average KPI-80: Total average water consumption in *L* per head of pig slaughtered in pig meat processing.		
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig)
Level of indicator	Product level (pig slaughterhouse) In pig slaughterhouse, hygiene standards necessitate the use of large quantities of fresh water. Water is used for numerous purposes including: • Livestock receipt and holding (8%); • Slaughter (32%); • Washing of casings & offal (24%); • Scalding (3%) • Hair removal (8%) • Cleaning of knives & equipment, floors, work-surfaces, etc. (25%). This is an indirect indicator, since it refers to the total amount of water consumed. But in some of the upper listed processes, water need to be hot, and generating hot water requires thermal energy. Thus, a measure of the water consumption is an indirect measure of the thermal energy required (as well as an indirect measure of the total energy required).		
Thermal or electrical process	Thermal processes requiring hot water		
Energy source	Thermal energy from fossil fuels, natural gas, etc.		
Description of the indicator	These indicators refer to the average total water consumption, in litres, per pig slaughtered. A selection of benchmark for water consumption has been established in a number of countries, as Denmark and Canada. For example, in Denmark, that may be considered as a model country, KPI values according to the technology utilised resulted: • 1400 *L*/pig with a traditional technology • 700 *L*/pig with an average technology • 300 *L*/pig with a best available technology.		
Upper level	Industry level (meat elaboration)		
Lower level	Process level (including all processes in pig slaughterhouse)		
Associated variables	**Unit**: *L*/pig (litres of water per pig)	**Name**	T aKPI L2 N2
Best or average KPI	Average	**KPI Value**	600-900 *L* water consumed/pig slaughtered
Source	From: "Enterprise Ireland. Sustainable practices in Irish pig processing. June 2010".		

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5.5. Thermal best KPI-81: Total best water consumption in L per head of pig slaughtered in pig meat processing.

INDICATOR	Thermal best KPI-81: Total average water consumption in L per head of pig slaughtered in pig meat processing.				
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig)		
Level of indicator	Product level (pig slaughterhouse)				
	In pig slaughterhouse, hygiene standards necessitate the use of large quantities of fresh water. Water is used for numerous purposes including: • Livestock receipt and holding (8%); • Slaughter (32%); • Washing of casings & offal (24%); • Scalding (3%) • Hair removal (8%) • Cleaning of knives & equipment, floors, work-surfaces, etc. (25%). This is an indirect indicator, since it refers to the total amount of water consumed. But in some of the upper listed processes, water need to be hot, and generating hot water requires thermal energy. Thus, a measure of the water consumption is an indirect measure of the thermal energy required (as well as an indirect measure of the total energy required).				
Thermal or electrical process	Thermal processes requiring hot water				
Energy source	Thermal energy from fossil fuels, natural gas, etc.				
Description of the indicator	These indicators refer to the average total water consumption, in litres, per pig slaughtered. A selection of benchmark for water consumption has been established in a number of countries, as Denmark and Canada. For example, in Denmark, that may be considered as a model country, KPI values according to the technology utilised resulted: • 1400 *L*/pig with a traditional technology • 700 *L*/pig with an average technology • 300 *L*/pig with a best available technology.				
Upper level	Industry level (meat elaboration)				
Lower level	Process level (including all processes in pig slaughterhouse)				
Associated variables	**Unit**	*L*/pig (litres of water per pig)	**Name**	T bKPI L2 N2	
Best or average KPI	Best	**KPI Value**	300 *L* water consumed/pig slaughtered		
Source	From: "Enterprise Ireland. Sustainable practices in Irish pig processing. June 2010".				

5.6. Thermal average KPI-82: Average thermal energy consumption in kWh per t of meat batter in meat processing plants.

INDICATOR	Thermal average KPI-82: Average thermal energy consumption in kWh per t of meat batter in meat processing plants.				
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (meat batter)		
Level of indicator	Product level (meat batter)				
Thermal or electrical process	Thermal processes				
Energy source	Thermal energy from fossil fuels, natural gas, etc.				
Description of the indicator	This indicator is referred to the thermal energy consumption of a specific plant per unit of physical output (i.e. per *kg* of meat batter).				
Upper level	Industry level (meat elaboration)				
Lower level	Process level (scalding, dehairing, defeathering, singeing, cooling, drying, ripening, and in general all major thermal processes in meat elaboration)				
Associated variables	**Unit**	GJ/Mg of meat batter Gigajoules thermal energy consumed per mega gram of meat batter	**Name**	T aKPI L2 N2	
Best or average KPI	Average	**KPI Value**	1636-16139 *kWh/t* of meat batter 1,636-1,6139 *kWh/kg* of meat batter 5,89-58,1 *GJ/Mg* of meat batter		
Source	From: "WS Atkins Int. (1998). Environmental protection in the agro-food industry. Environmental Standards (in Polish: Ochrona środowiskaw przemyśle rolno spożywczym. Standardy środowiskowe)(31st ed.). Warszawa: FAPA. 78, 87, 106-107".				

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5.7. Thermal average KPI-83: Average total energy consumption (electricity + thermal energy) in kWh per t of hot standard carcass weight in meat abattoirs.

INDICATOR	Thermal average KPI-83: Average total energy consumption (electricity + thermal energy) in *kWh* per *t* of hot standard carcass weight in meat abattoirs.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration	
Level of indicator	Product level (meat slaughtering) Approximately 80–85% of total energy consumed by abattoirs is provided by thermal energy from the combustion of fuels in on-site boilers. Thermal energy is used to heat water for cleaning, pig scalding, rendering, blood coagulation and blood drying. The remaining 15–20% of energy is provided by electricity, which is used for operating equipment in the slaughter and boning areas, for by-product processing, and for refrigeration and compressed air.			
Thermal or electrical process	Electrical and thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes; electricity for electrical processes.			
Description of the indicator	This indicator refers to the average total energy, including both electricity and thermal energy, consumed by a slaughter abattoir per tonne of hot standard carcass weight (HSCW).			
Upper level	Industry level (meat elaboration)			
Lower level	Process level			
Associated variables	**Unit**	kWh/t HSCW (kilowatt hour total energy per tonne of hot standard carcass weight)	**Name**	T aKPI L2 N2
Best or average KPI	Average	**KPI Value**	333,33-1333,33 *kWh/t* of hot standard carcass weight 0,333-1,333 *kWh/kg* of hot standard carcass weight 1200-4800 *MJ/t* of hot standard carcass weight	
Source	From "Cleaner production assessment in meat processing. Prepared by COW Consulting Engineers and Planners AS, Denmark".			

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5.8. Thermal average KPI-84: Average thermal energy consumption in kWh per t of pig dry weight in pig meat abattoirs.

INDICATOR	Thermal average KPI-84: Average thermal energy consumption in *kWh* per *t* of pig dry weight in pig meat abattoirs.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig)	
Level of indicator	Product level (pig slaughtering)			
	Approximately 80–85% of total energy consumed by abattoirs is provided by thermal energy from the combustion of fuels in on-site boilers. Thermal energy is used to heat water for cleaning, pig scalding, rendering, blood coagulation and blood drying. The remaining 15–20% of energy is provided by electricity, which is used for operating equipment in the slaughter and boning areas, for by-product processing, and for refrigeration and compressed air.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes.			
Description of the indicator	This indicator refers to the average thermal energy consumed by a pig slaughter abattoir per tonne of pig dry weight (DW).			
Upper level	Industry level (meat elaboration)			
Lower level	Process level (cleaning, pig scalding, rendering, blood coagulation, blood drying, etc.)			
Associated variables	**Unit**	*kWh/t* DW (kilowatt hour thermal energy per tonne of pig dry weight)	**Name**	T aKPI L2 N2
Best or average KPI	Average	**KPI Value**	140-250 *kWh/t* of pig dry weight 0,140-0,250 *kWh/kg* of pig dry weight 500-900 *MJ/t* of pig dry weight	
Source	From "Cleaner production assessment in meat processing. Prepared by COW Consulting Engineers and Planners AS, Denmark".			

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5.9. Thermal average KPI-85: Average thermal energy consumption in kWh per t of cattle dry weight in cattle meat abattoirs.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-85: Average thermal energy consumption in kWh per t of cattle dry weight in cattle meat abattoirs.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td>Subsector</td><td colspan="2">Meat elaboration (cattle slaughterhouses))</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (cattle slaughtering)</td></tr>
<tr><td colspan="4">Approximately 80–85% of total energy consumed by abattoirs is provided by thermal energy from the combustion of fuels in on-site boilers. Thermal energy is used to heat water for cleaning, pig scalding, rendering, blood coagulation and blood drying. The remaining 15–20% of energy is provided by electricity, which is used for operating equipment in the slaughter and boning areas, for by-product processing, and for refrigeration and compressed air.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy consumed by a cattle slaughter abattoir per tonne of cattle dry weight (DW).</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (meat elaboration)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (cleaning, rendering, blood coagulation, blood drying, etc.)</td></tr>
<tr><td>Associated variables</td><td>Unit</td><td>kWh/t DW (kilowatt hour thermal energy per tonne of cattle dry weight)</td><td>Name</td><td>T aKPI L2 N3</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">55-140 kWh/t of cattle dry weight

0,055-0,140 kWh/kg of cattle dry weight

200-500 MJ/t of cattle dry weight</td></tr>
<tr><td>Source</td><td colspan="4">From “Cleaner production assessment in meat processing. Prepared by COW Consulting Engineers and Planners AS, Denmark”.</td></tr>
</table>

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5.10. Thermal average KPI-86: Total energy (electricity + thermal energy) in kWh required to produce a t of beef.

<table>
<tr><td>INDICATOR</td><td colspan="5">Thermal average KPI-86: Total energy (electricity + thermal energy) in kWh required to produce a t of beef.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td colspan="2">Subsector</td><td colspan="2">Meat elaboration (cattle slaughterhouses)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="5">Product level (beef)</td></tr>
<tr><td colspan="5">Recent survey works have shown that typically 50-80% of energy used in an abattoir/cutting plant is provided by electricity, with the other 20-50% coming from thermal energy.
Electricity is usually used for refrigeration and compressed air, as well as for ventilation, lighting, powering the operating equipment in the slaughter, boning and by-product processing areas, e.g. saws, hoists, conveyors, packing machines, and electrical stimulation. Electricity is also used by abattoirs for on-site rendering plants. Gas and oil are primarily used to provide heat and hot water for the factories (e.g. for scalding, knife sterilization, cleaning process areas and machinery, by product processing and heating).
Cattle and sheep abattoirs tend to need significantly less hot water than pig plants. A pig abattoir could have 80% of its energy in the form of thermal energy (e.g. heating scalding tanks, raising steam, singeing), whereas in comparison cattle and lamb abattoirs tend to require about 30-50% thermal energy.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="5">Thermal and electrical processes</td></tr>
<tr><td>Energy source</td><td colspan="5">Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes; electricity for electrical processes.</td></tr>
<tr><td>Description of the indicator</td><td colspan="5">This indicator refers to the average TOTAL energy consumed by a beef processing industry per tonne of beef.</td></tr>
<tr><td>Upper level</td><td colspan="5">Industry level (meat elaboration)</td></tr>
<tr><td>Lower level</td><td colspan="5">Process level (slaughtering, cutting and retail packing)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td colspan="2">kWh/t
(kilowatt hour total energy consumed per tonne of processed beef)</td><td>Name</td><td>T aKPI L2 N2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="3">775 kWh/t of processed beef

0,775 kWh/kg of processed beef</td></tr>
<tr><td>Source</td><td colspan="5">From “Resource use in the British beef and lamb processing sector. Factsheet 4. January 2011”.</td></tr>
</table>

This project. has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 695985

5.11. Thermal average KPI-87: Total energy (electricity + thermal energy) in kWh required to produce a t of sheep meat.

<table>
<tr><td>INDICATOR</td><td colspan="5">Thermal average KPI-87: Total energy (electricity + thermal energy) in kWh required to produce a t of sheep meat.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td colspan="2">Subsector</td><td colspan="2">Meat elaboration (sheep slaughterhouses)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="5">Product level (sheep meat)</td></tr>
<tr><td colspan="5">Recent survey works have shown that typically 50-80% of energy used in an abattoir/cutting plant is provided by electricity, with the other 20-50 coming from thermal energy.
Electricity is usually used for refrigeration and compressed air, as well as for ventilation, lighting, powering the operating equipment in the slaughter, boning and by-product processing areas, e.g. saws, hoists, conveyors, packing machines, and electrical stimulation. Electricity is also used by abattoirs for on-site rendering plants. Gas and oil are primarily used to provide heat and hot water for the factories (e.g. for scalding, knife sterilization, cleaning process areas and machinery, by product processing and heating).
Cattle and sheep abattoirs tend to need significantly less hot water than pig plants. A pig abattoir could have 80% of its energy in the form of thermal energy (e.g. heating scalding tanks, raising steam, singeing), whereas in comparison cattle and lamb abattoirs tend to require about 30-50% thermal energy.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="5">Thermal and electrical processes</td></tr>
<tr><td>Energy source</td><td colspan="5">Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes; electricity for electrical processes.</td></tr>
<tr><td>Description of the indicator</td><td colspan="5">This indicator refers to the average TOTAL energy consumed by a sheep meat processing industry per tonne of sheep meat.</td></tr>
<tr><td>Upper level</td><td colspan="5">Industry level (meat elaboration)</td></tr>
<tr><td>Lower level</td><td colspan="5">Process level (slaughtering, cutting and retail packing)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td colspan="2">kWh/t (kilowatt hour total energy consumed per tonne of processed sheep meat)</td><td>Name</td><td>T aKPI L2 N2</td></tr>
<tr><td colspan="5">In general, sheep processing uses less than pigs or cattle principally because:
• less bulky animal therefore less energy is required for chilling;
• sheep meat is not normally aged for too long;
• The stomachs are not normally processed so less hot water is used;
• Many sheep companies ship a lot of their product out as whole carcasses rather than deboning and vacuum packing.</td></tr>
<tr><td>Best or average KPI</td><td colspan="2">Average</td><td>KPI Value</td><td colspan="2">685 kWh/t of processed sheep meat

0,685 kWh/kg of processed sheep meat</td></tr>
<tr><td>Source</td><td colspan="5">From “Resource use in the British beef and lamb processing sector. Factsheet 4. January 2011”.</td></tr>
</table>

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5.12. Thermal average KPI-88: Average thermal energy consumption in kWh per chicken head in poultry processing industries.

INDICATOR	Thermal average KPI-88: Average thermal energy consumption in *kWh* per chicken head in poultry processing industries.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (poultry slaughterhouses)	
Level of indicator	Product level (chicken)			
	Poultry processing facilities use energy to heat water and produce steam for process applications, cleaning purposes, and for the operation of mechanical and electrical equipment, refrigeration and air compressors. During the chicken treatment, in average plants, water consumption has been evaluated in 15-20 *L* per chicken head.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.			
Description of the indicator	This indicator refers to the average thermal energy consumed by a chicken processing industry per chicken head.			
Upper level	Industry level (meat elaboration)			
Lower level	Process level (thermal processes as scalding, defeathering, and cooling in poultry slaughterhouses)			
Associated variables	**Unit**	*kWh*/chicken head (kilowatt hour thermal energy consumed per chicken head)	**Name**	T aKPI L2 N2
Best or average KPI	Average	**KPI Value**	0,22 *kWh*/chicken head	
Source	Elaborated from "Environmental, Health, and Safety Guidelines for Poultry Processing. IFC - International Finance Corporation. April 2007".			

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5.13. Thermal best KPI-89: Best thermal energy consumption in kWh per t of slaughtered chicken in poultry processing industries.

INDICATOR	Thermal best KPI-89: Best thermal energy consumption in *kWh* per *t* of slaughtered chicken in poultry processing industries.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (poultry slaughterhouses)	
Level of indicator	Product level (chicken)			
	Poultry processing facilities use energy to heat water and produce steam for process applications, cleaning purposes, and for the operation of mechanical and electrical equipment, refrigeration and air compressors. During the chicken treatment, in best performing plants, water consumption has been evaluated in about 10 *L* per *kg* of slaughtered chicken.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.			
Description of the indicator	This indicator refers to the average thermal energy consumed by a chicken processing industry per *t* of processed animal.			
Upper level	Industry level (meat elaboration)			
Lower level	Process level (thermal processes as scalding, defeathering, and cooling in poultry slaughterhouses)			
Associated variables	**Unit**	kWh/t (kilowatt hour thermal energy consumed per tonne of slaughtered chicken)	**Name**	T bKPI L2 N2
Best or average KPI	Best	**KPI Value**	~120 *kWh/t* of slaughtered chicken ~0,12 *kWh/kg* of slaughtered chicken	
Source	Elaborated from "Environmental, Health, and Safety Guidelines for Poultry Processing. IFC - International Finance Corporation. April 2007".			

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5.14. Thermal average KPI-90: Average thermal energy consumption in kWh per duck head in poultry processing industries.

INDICATOR	Thermal average KPI-90: Average thermal energy consumption in *kWh* per duck head in poultry processing industries.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (poultry slaughterhouses)	
Level of indicator	Product level (duck)			
	Poultry processing facilities use energy to heat water and produce steam for process applications, cleaning purposes, and for the operation of mechanical and electrical equipment, refrigeration and air compressors. During the duck treatment, in average plants, water consumption has been evaluated in 43 *L* per duck head.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.			
Description of the indicator	This indicator refers to the average thermal energy consumed by a duck processing industry per head of animal.			
Upper level	Industry level (meat elaboration)			
Lower level	Process level (thermal processes as scalding, defeathering, and cooling in poultry slaughterhouses)			
Associated variables	**Unit**	*kWh*/duck head (kilowatt hour thermal energy consumed per duck head)	**Name**	T aKPI L2 N2
Best or average KPI	Average	**KPI Value**	0,97 *kWh*/duck head	
Source	Elaborated from “Environmental, Health, and Safety Guidelines for Poultry Processing. IFC - International Finance Corporation. April 2007”.			

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5.15. Thermal average KPI-91: Average thermal energy consumption in kWh per kg of slaughtered duck in poultry processing industries.

INDICATOR	Thermal average KPI-91: Average thermal energy consumption in *kWh* per duck *t* of slaughtered duck in poultry processing industries.
Sector (NACE code)	10.1 | **Subsector** | Meat elaboration (poultry slaughterhouses)
Level of indicator	Product level (duck) Poultry processing facilities use energy to heat water and produce steam for process applications, cleaning purposes, and for the operation of mechanical and electrical equipment, refrigeration and air compressors. During the duck treatment, in best performing plants, water consumption has been evaluated in 5-10 *L* per *kg* of slaughtered duck.
Thermal or electrical process	Thermal processes
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.
Description of the indicator	This indicator refers to the average thermal energy consumed by a duck processing industry per *t* of slaughtered animal.
Upper level	Industry level (meat elaboration)
Lower level	Process level (thermal processes as scalding, defeathering, and cooling in poultry slaughterhouses)
Associated variables	**Unit** | *kWh*/t (kilowatt hour thermal energy consumed per tonne of slaughtered duck) | **Name** | T aKPI L2 N2
Best or average KPI	Average | **KPI Value** | ~250 *kWh/t* of slaughtered duck ~0,25 *kWh/kg* of slaughtered duck
Source	Elaborated from “Environmental, Health, and Safety Guidelines for Poultry Processing. IFC - International Finance Corporation. April 2007”.

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5.16. Thermal average KPI-92: Average thermal energy consumption in kWh per t of treated meat in the production of cured sausages.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-92: Average thermal energy consumption in kWh per t of treated meat in the production of cured sausages.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td colspan="2">Subsector</td><td>Meat elaboration (sausages)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (meat processing: cured sausages)</td></tr>
<tr><td colspan="4">The most important process from the energy consumption point of view is the drying (curing) process. Once sausages are prepared, they are introduced and kept for a certain time in specific drying chambers, under specific temperature, relative humidity, and ventilation conditions.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, including coal, oil, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy in kWh required per tonne of processed cured sausages.</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (meat processing)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (drying, curing)</td></tr>
<tr><td>Associated variables</td><td>Unit</td><td>kWh/t
(kilowatt hour thermal energy consumed per tonne of treated meat)</td><td>Name</td><td>T aKPI L2 N2</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">693 kWh/t of treated meat

0,693 kWh/kg of treated meat</td></tr>
<tr><td>Source</td><td colspan="4">From “Eficiencia energetica en empresas del sector agroalimentario 2. Agencia extremeña de la energía. 2014”.</td></tr>
</table>

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5.17. Thermal average KPI-93: Average thermal energy consumption in kWh per t of treated meat in the production of dry-cured ham.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-93: Average thermal energy consumption in kWh per t of treated meat in the production of dry-cured ham.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td>Subsector</td><td colspan="2">Meat elaboration (cured ham)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Product level (meat processing: dry-cured ham)</td></tr>
<tr><td colspan="4">Curing refers to adding a curing agent, generally a salt, to develop certain flavours and desired color. This process is very energy intensive. Time is one of the main factors contributing to the high energy demand, since long process times are needed for several chemical processes taking place within the ham, which are necessary to achieve desired quality. A small reduction in processing time means a huge reduction in energy use due to the high energy need.
Drying consists of water removal from the product by evaporation which is driven by a concentration gradient between the drying air and the being dried product.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal processes</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, including coal, oil, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy in kWh required per tonne of processed dry-cured ham.</td></tr>
<tr><td>Upper level</td><td colspan="4">Industry level (meat processing)</td></tr>
<tr><td>Lower level</td><td colspan="4">Process level (drying, curing)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/t (kilowatt hour thermal energy consumed per tonne of treated meat)</td><td>Name</td><td>T aKPI L2 N2</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">500 kWh/t of treated meat

0,500 kWh/kg of treated meat</td></tr>
<tr><td>Source</td><td colspan="4">From “Eficiencia energetic en empresas del sector agroalimentario 2. Agencia extremeña de la energía. 2014”.</td></tr>
</table>

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5.18. Thermal average KPI-94: Average thermal energy consumption in kWh per t of treated meat by the processes of scalding and dehairing.

INDICATOR	Thermal average KPI-94: Average thermal energy consumption in *kWh* per *t* of treated meat by the processes of scalding and dehairing.				
Sector (NACE code)	10.1	**Subsector**	Meat elaboration		
Level of indicator	Process level (scalding and dehairing) Scalding and dehairing are the major thermal energy consuming processes in meat slaughterhouse.				
Thermal or electrical process	Thermal processes				
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.				
Description of the indicator	This indicator refers to the average thermal energy consumed in *kWh* during the processes of scalding and dehairing per *t* of processed meat.				
Upper level	Product level (processed meat)				
Lower level	Equipment level (scalding and dehairing machines)				
Associated variables	**Unit**	*kWh/t* (kilowatt hour thermal energy consumed per t of treated meat)	**Name**	T aKPI L3 N2	
Best or average KPI	Average	**KPI Value**	29 *kWh/t* of treated meat 29000 *kWh/kg* of treated meat 104 *kJ/kg* of treated meat		
Source	From "Eficiencia energetic en empresas del sector agroalimentario 2. Agencia extremeña de la energía. 2014".				

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5.19. Thermal average KPI-95: Average thermal energy consumption in kWh per t of processed meat in cattle and sheep slaughtering.

INDICATOR	Thermal average KPI-95: Average thermal energy consumption in *kWh* per *t* of processed meat in cattle and sheep slaughtering.				
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (cattle and sheep slaughterhouses)		
Level of indicator	Product level (cattle and sheep slaughtering)				
	Cattle and sheep abattoirs tend to need significantly less hot water than pig plants. A pig abattoir could have 80% of its energy in the form of thermal energy (e.g. heating scalding tanks, raising steam, singeing), whereas in comparison cattle and lamb abattoirs tend to require about 30-50% thermal energy.				
Thermal or electrical process	Thermal processes				
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc, for thermal processes				
Description of the indicator	This indicator refers to the average thermal energy consumed by a slaughter abattoir per tonne of cattle or sheep meat.				
Upper level	Product level (cattle, sheep slaughterhouses)				
Lower level	Equipment level (slaughtering machineries)				
Associated variables	**Unit**	kWh/t (kilowatt hour thermal energy consumed per tonne of processed cattle or sheep meat	**Name**	T aKPI L2 N2	
Best or average KPI	Average	**KPI Value**	46 *kWh/t* of processed cattle or sheep meat 46000 *kWh/kg* of processed cattle or sheep meat		
Source	From "Resource use in the British beef and lamb processing sector. Factsheet 4. January 2011".				

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5.20. Thermal average KPI-96: Average natural gas consumption in kWh per 1000 lb.BW of beef in beef packing processing plants due to carcass wash.

<table>
<tr><td>INDICATOR</td><td colspan="5">Thermal average KPI-96: Average natural gas consumption in kWh per 1000 lb.BW of beef in beef packing processing plants due to carcass wash.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td>Subsector</td><td colspan="3">Meat elaboration</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="5">Process level (carcass wash in cattle processing)</td></tr>
<tr><td colspan="5">Antimicrobial interventions are automated or manual processes that aim at reducing microbial contamination on the beef carcass using water, steam, and organic chemicals. Cattle processing requires several antimicrobial interventions, such as pre-evisceration wash, organic acid spraying, carcass wash and thermal pasteurization. For those antimicrobial interventions, in a representative plant*, water use corresponds to 16%, energy use corresponds to 12%, and wastewater production is a small portion of the overall use and production.
Carcass washing, among the antimicrobial interventions, uses to be the highest natural gas consumer.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="5">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="5">In general natural gas</td></tr>
<tr><td>Description of the indicator</td><td colspan="5">Natural gas is used by boilers for water heating</td></tr>
<tr><td>Upper level</td><td colspan="5">Product level (packed beef meet)</td></tr>
<tr><td>Lower level</td><td colspan="5">Equipment level (carcass washer)</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td colspan="2">kWh/1000 lb.BW (kilowatt hour natural gas consumed per 1000 pounds of live body weight)</td><td>Name</td><td>T aKPI L3 N2</td></tr>
<tr><td colspan="5">1000 lb = 453,6 kg = 0,454 t</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="3">4 kWh natural gas/1000 lb.BW

8,82 kWh natural gas/t.BW

0,009 kWh natural gas/kg.BW

14,43 MJ natural gas /1000 lb.BW (equivalent to 18,2 cubic foot per head).</td></tr>
<tr><td>Source</td><td colspan="5">From: “Ziara (2015). Water and energy use and wastewater production in a beef packing plant. Civil Engineering Theses, Dissertations, and Student Research. Paper 81).</td></tr>
</table>

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5.21. Thermal average KPI-97: Combustion efficiency of steam boilers.

INDICATOR	Thermal average KPI-97: Combustion efficiency of steam boilers.
Sector (NACE code)	10.1 | **Subsector** | Meat elaboration
Level of indicator	Equipment level (boiler) Thermal energy in the form of steam and hot water accounts for a significant portion (40 to 80%) of energy consumption at small to medium meat processing facilities. The boiler efficiency is a measure of the heat input into the boiler and how much heat is converted into useable steam. Boiler efficiency is typically best at 85% with most ranging from 75 to 85%.
Thermal or electrical process	Thermal processes
Energy source	Thermal energy in the form of steam or hot water from fossil fuels, natural gas, etc.
Description of the indicator	Example calculation for estimating boiler combustion efficiency. Before beginning to improve the efficiency of a boiler, it is important to establish its current level of combustion efficiency. It may be done by performing the following steps: Step 1. Use an oxygen analyser (portable or permanent analyser) to measure the oxygen (by volume) in the flue gas. Step 2. Measure the flue gas exit temperature using existing monitoring or a portable thermocouple. Step 3. Estimate the combustion efficiency using a boiler combustion efficiency curve.
Upper level	Process level (thermal processes in meat elaboration)
Lower level	---
Associated variables	**Unit** | % (percentage) | **Name** | T aKPI L4 N2 Energy saving actions include: • Review of the boiler efficiency • Reduction of the stack losses. On well-designed natural gas-fired systems, an excess air level of 10% is attainable. An often stated rule of thumb is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40 *°F* (4,4 *°C*) reduction in stack gas temperature.
Best or average KPI	Average | **KPI Value** | 75-85%
Source	From: "Australian Meat Industry Council. Meat technology update. Prepared by Energetics Pty Ltd. April 2013".

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5.22. Thermal best KPI-98: Combustion efficiency of steam boilers.

INDICATOR	Thermal best KPI-98: Combustion efficiency of steam boilers.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration	
Level of indicator	Equipment level (boiler)			
	Thermal energy in the form of steam and hot water accounts for a significant portion (40 to 80%) of energy consumption at small to medium meat processing facilities. The boiler efficiency is a measure of the heat input into the boiler and how much heat is converted into useable steam. Boiler efficiency is typically best at 85% with most ranging from 75 to 85%.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy in the form of steam or hot water from fossil fuels, natural gas, etc.			
Description of the indicator	Example calculation for estimating boiler combustion efficiency. Before beginning to improve the efficiency of a boiler, it is important to establish its current level of combustion efficiency. It may be done by performing the following steps: Step 1. Use an oxygen analyser (portable or permanent analyser) to measure the oxygen (by volume) in the flue gas. Step 2. Measure the flue gas exit temperature using existing monitoring or a portable thermocouple. Step 3. Estimate the combustion efficiency using a boiler combustion efficiency curve.			
Upper level	Process level (thermal processes in meat elaboration)			
Lower level	---			
Associated variables	**Unit**	% (percentage)	**Name**	T bKPI L4 N2
	Energy saving actions include: • Review of the boiler efficiency • Reduction of the stack losses. On well-designed natural gas-fired systems, an excess air level of 10% is attainable. An often stated rule of thumb is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40 °F (4,4 °C) reduction in stack gas temperature.			
Best or average KPI	Best	**KPI Value**	85%	
Source	From: “Australian Meat Industry Council. Meat technology update. Prepared by Energetics Pty Ltd. April 2013”.			

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5.23. Thermal average KPI-99: Thermal operating cost in kWh thermal energy required for 1 kg of water evaporation.

INDICATOR	Thermal average KPI-99: Thermal operating cost in *kWh* thermal energy required for 1 *kg* of water evaporation.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration	
Level of indicator	Equipment level (evaporator or cooker in rendering operations)			
	Whether rendered products are used in feed for ruminants, poultry, swine, pets, or for industrial uses of fatty acids, rendering operations and how they are performed will influence production costs. As the main driving force in the evaporation of water from the raw material, steam is the single most costly part of the energy balance. Steam usage for the evaporation is a main consideration in the selection of a rendering system. Theoretically, the best achievable is 0,76 *kg* of steam to evaporate 1 *kg* of water, and anything over 1,50 *kg* of steam may indicate poor efficiency.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, natural gas, etc.			
Description of the indicator	This indicator describes the efficiency of an evaporator or a cooker that may be used in a meat processing plant with on-site rendering facilities.			
Upper level	Process level (thermal rendering processes in meat elaboration)			
Lower level	---			
Associated variables	**Unit**	kWh/kg (kilowatt hour thermal energy per kilogram of evaporated water)	**Name**	T aKPI L4 N2
	As energy costs appear to be on the rise for the future, it is essential that steam usage be evaluated, controlled, and conserved. Any leak must be addressed immediately.			
Best or average KPI	Average	**KPI Value**	0,556-0,972 *kWh/kg* of evaporated water 2000-3500 *kJ/kg* of evaporated water	
Source	From: "Anderson. Rendering Operations. In Essential Rendering: all about the animal by-products industry. 2006".			

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5.24. Thermal best KPI-100: Thermal operating cost in kWh thermal energy required for 1 kg of water evaporation.

INDICATOR	Thermal best KPI-100: Thermal operating cost in *kWh* thermal energy required for 1 *kg* of water evaporation.				
Sector (NACE code)	10.1	**Subsector**	Meat elaboration		
Level of indicator	Equipment level (evaporator or cooker in rendering operations)				
	Whether rendered products are used in feed for ruminants, poultry, swine, pets, or for industrial uses of fatty acids, rendering operations and how they are performed will influence production costs. As the main driving force in the evaporation of water from the raw material, steam is the single most costly part of the energy balance. Steam usage for the evaporation is a main consideration in the selection of a rendering system. Theoretically, the best achievable is 0,76 *kg* of steam to evaporate 1 *kg* of water, and anything over 1,50 *kg* of steam may indicate poor efficiency.				
Thermal or electrical process	Thermal processes				
Energy source	Thermal energy from fossil fuels, natural gas, etc.				
Description of the indicator	This indicator describes the efficiency of an evaporator or a cooker that may be used in a meat processing plant with on-site rendering facilities.				
Upper level	Process level (thermal rendering processes in meat elaboration)				
Lower level	---				
Associated variables	**Unit**	kWh/kg (kilowatt hour thermal energy per kilogram of evaporated water)	**Name**	T bKPI L4 N2	
	As energy costs appear to be on the rise for the future, it is essential that steam usage be evaluated, controlled, and conserved. Any leak must be addressed immediately.				
Best or average KPI	Best	**KPI Value**	~0,515 *kWh/kg* of evaporated water ~1860,8 *kJ/kg* of evaporated water		
Source	From: "Anderson. Rendering Operations. In Essential Rendering: all about the animal by-products industry. 2006".				

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5.25. Thermal average KPI-101: Average thermal energy consumption in kWh per pig by the vertical scalding system in pig processing industries.

<table>
<tr><td>INDICATOR</td><td colspan="4">Thermal average KPI-101: Average thermal energy consumption in kWh per pig by the vertical scalding system in pig processing industries.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td>Subsector</td><td colspan="2">Meat elaboration (pig slaughterhouse)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="4">Equipment level (vertical scalding system)</td></tr>
<tr><td colspan="4">After stunning and bleeding, the next process in pig, cattle, sheep, and poultry slaughterhouses is scalding, whose objective is to soften the epidermis for make easier the later hair extraction. By raising the temperature at level of the pig hair-root, the connective tissue is dissolved and the hairs are then loosened.
Vertical condensation scalding process, in which pigs are hanging vertically, involves the use of a double walled tunnel in which steam – generated from a water bath at its bottom, is blown over the carcass and through a ventilator located over the condenser. The temperature in the tunnel is controlled by a thermostat at 61 to 64 °C. Lung contamination is reduced as pigs are never immersed in water.
This indicator has been developed by considering a vertical scalding system with an average capacity of about 270 pigs/h and an installed power of about 22,5 kW.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="4">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="4">Thermal energy from fossil fuels, including coal, oil, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="4">This indicator refers to the average thermal energy consumed by a vertical scalding machine per pig.</td></tr>
<tr><td>Upper level</td><td colspan="4">Process level (scalding)</td></tr>
<tr><td>Lower level</td><td colspan="4">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td>kWh/pig (kilojoules thermal energy consumed per pig)</td><td>Name</td><td>T aKPI L4 N2</td></tr>
<tr><td colspan="4">Scalding is performed by treating carcasses with hot water or steam. The time and the temperature of the heat treatment are primarily determined by the need for efficient removal of the bristles or feathers by the dehairer/defeatherer.</td></tr>
<tr><td>Best or average KPI</td><td>Average</td><td>KPI Value</td><td colspan="2">0,083 kWh/pig

300 kJ/pig</td></tr>
<tr><td>Source</td><td colspan="4">Elaborated from “SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.1: Slaughterhouse and quartering – October 2016”.</td></tr>
</table>

This project. has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement n° 695985

5.26. Thermal best KPI-102: Best thermal energy consumption in kWh per pig by the vertical scalding system in pig processing industries.

<table>
<tr><td>INDICATOR</td><td colspan="5">Thermal best KPI-102: Average thermal energy consumption in kWh per pig by the vertical scalding system in pig processing industries.</td></tr>
<tr><td>Sector (NACE code)</td><td>10.1</td><td colspan="2">Subsector</td><td colspan="2">Meat elaboration (pig slaughterhouse)</td></tr>
<tr><td rowspan="2">Level of indicator</td><td colspan="5">Equipment level (vertical scalding system)</td></tr>
<tr><td colspan="5">After stunning and bleeding, the next process in pig, cattle, sheep, and poultry slaughterhouses is scalding, whose objective is to soften the epidermis for make easier the later hair extraction. By raising the temperature at level of the pig hair-root, the connective tissue is dissolved and the hairs are then loosened.
Vertical condensation scalding process, in which pigs are hanging vertically, involves the use of a double walled tunnel in which steam – generated from a water bath at its bottom, is blown over the carcass and through a ventilator located over the condenser. The temperature in the tunnel is controlled by a thermostat at 61 to 64 °C. Lung contamination is reduced as pigs are never immersed in water.
This indicator has been developed by considering a vertical scalding system with an average capacity of about 420 pigs/h (as the maximum capacity) and an installed power of about 15 kW.</td></tr>
<tr><td>Thermal or electrical process</td><td colspan="5">Thermal process</td></tr>
<tr><td>Energy source</td><td colspan="5">Thermal energy from fossil fuels, including coal, oil, natural gas, etc.</td></tr>
<tr><td>Description of the indicator</td><td colspan="5">This indicator refers to the lower value of thermal energy consumed by a vertical scalding machine per pig.</td></tr>
<tr><td>Upper level</td><td colspan="5">Process level (scalding)</td></tr>
<tr><td>Lower level</td><td colspan="5">---</td></tr>
<tr><td rowspan="2">Associated variables</td><td>Unit</td><td colspan="2">kWh/pig (kilojoules thermal energy consumed per pig)</td><td>Name</td><td>T bKPI L4 N2</td></tr>
<tr><td colspan="5">Scalding is performed by treating carcasses with hot water or steam. The time and the temperature of the heat treatment are primarily determined by the need for efficient removal of the bristles or feathers by the dehairer/defeatherer.</td></tr>
<tr><td>Best or average KPI</td><td>Best</td><td>KPI Value</td><td colspan="3">~0,035 kWh/pig
~128,6 kJ/pig</td></tr>
<tr><td>Source</td><td colspan="5">Elaborated from “SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.1: Slaughterhouse and quartering – October 2016”.</td></tr>
</table>

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5.27. Thermal average KPI-103: Average thermal energy consumption in kWh per pig by a powered scalding basin in pig processing industries.

INDICATOR	Thermal average KPI-103: Average thermal energy consumption in *kWh* per pig by the vertical scalding system in pig processing industries.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig slaughterhouse)	
Level of indicator	Equipment level (powered scalding basin)			
	After stunning and bleeding, the next process in pig, cattle, sheep, and poultry slaughterhouses is scalding, whose objective is to soften the epidermis for make easier the later hair extraction. By raising the temperature at level of the pig hair-root, the connective tissue is dissolved and the hairs are then loosened. With a powered scalding basin, the scalding is performed by immersing the pigs into the scalding water. The basin is fitted with water and steam inlets.			
Thermal or electrical process	Thermal process			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.			
Description of the indicator	This indicator refers to the average thermal energy consumed by a powered scalding basin machine per pig.			
Upper level	Process level (scalding)			
Lower level	---			
Associated variables	**Unit**	*kWh*/pig (kilowatt hour thermal energy consumed per pig)	**Name**	T aKPI L4 N2
	Scalding is performed by treating carcasses with hot water or steam. The time and the temperature of the heat treatment are primarily determined by the need for efficient removal of the bristles or feathers by the dehairer.			
Best or average KPI	Average	**KPI Value**	0,008 *kWh*/pig 30 *kJ*/pig	
Source	Elaborated from “SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.1: Slaughterhouse and quartering – October 2016”.			

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5.28. Thermal best KPI-104: Best thermal energy consumption in kWh per pig by a powered scalding basin in pig processing industries.

INDICATOR	Thermal best KPI-104: Best thermal energy consumption in *kWh* per pig by the vertical scalding system in pig processing industries.			
Sector (NACE code)	10.1	**Subsector**	Meat elaboration (pig slaughterhouse)	
Level of indicator	Equipment level (powered scalding basin) After stunning and bleeding, the next process in pig, cattle, sheep, and poultry slaughterhouses is scalding, whose objective is to soften the epidermis for make easier the later hair extraction. By raising the temperature at level of the pig hair-root, the connective tissue is dissolved and the hairs are then loosened. With a powered scalding basin, the scalding is performed by immersing the pigs into the scalding water. The basin is fitted with water and steam inlets.			
Thermal or electrical process	Thermal processes			
Energy source	Thermal energy from fossil fuels, including coal, oil, natural gas, etc.			
Description of the indicator	This indicator refers to the lower value of thermal energy consumed by a powered scalding basin machine per pig.			
Upper level	Process level (scalding)			
Lower level	---			
Associated variables	**Unit**	*kWh*/pig (kilowatt hour thermal energy consumed per pig)	**Name**	T bKPI L4 N2
	Scalding is performed by treating carcasses with hot water or steam. The time and the temperature of the heat treatment are primarily determined by the need for efficient removal of the bristles or feathers by the dehairer.			
Best or average KPI	Best	**KPI Value**	~0,006 *kWh*/pig ~22,5 *kJ*/pig	
Source	Elaborated from "SCOoPE Deliverable D.3.4 – Extended Value Stream Maps of NACE 10.1: Slaughterhouse and quartering – October 2016".			

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