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Report prepared by: Sidenor - R&D Department /
Email: **inigo.unamuno@sidenor.com**

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1. Executive summary

The present work analyses the processes and subprocesses of each sector involved in Tasio project (steel, cement, glass and petrochemical) from an energetic point of view to determine which processes have the highest energetic consumption and define the system limits in order to perform the material and energy balance. In this way, this information will be very useful to define what industrial processes have a higher potential of heat recovery.

In each selected industry, the waste heat stream is investigated in terms of its waste heat quantity (the approximate energy contained in the waste heat stream), and quality (typical exhaust temperatures). For the steel industry, selected processes are: Electric Arc Furnaces (EAF) and rolling mills; in cement industry, clinker production is considered; in glass industry, float glass production. These energy intensive industries were chosen due to their large heat recovery potential.

2. Energy Intensive Industries description

3.1 Cement Industry

Cement is the world's most widely used construction material. Cement is the binding material that is mixed with an aggregate such as sand or gravel and water to form concrete. Over three tons of concrete are produced each year per person for the entire global population, making it the most widely used manufactured product in the world.

Clinker is an intermediate product in the cement manufacturing process, which is produced by burning finely ground raw materials (mainly limestone and clay or shale). These materials are fused into new mineralogical phases when heated to around 1450° C (flame temperature around 2500°C) in a rotary kiln (see figure 1). This burned product is called clinker. Clinker is ground into a fine powder with small quantities of gypsum and other components to become cement. Ordinary Portland Cement (OPC) generally contains at least 90 percent clinker.

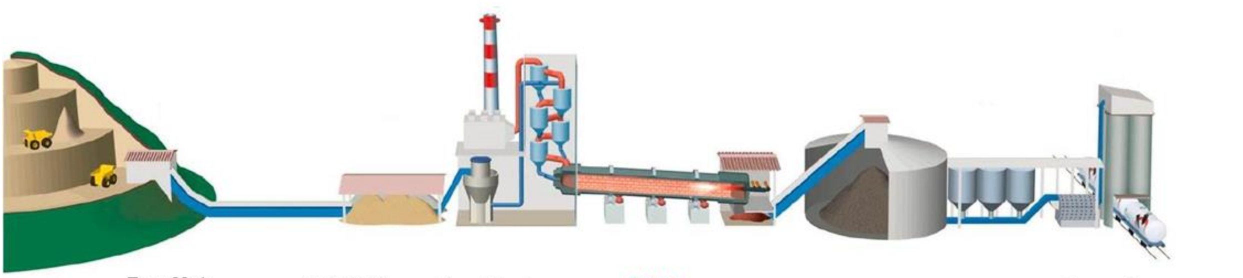

Figure 1: Typical scheme of dry process cement production. The clinker burning kiln system represents the thermal part of cement manufacturing process

The cement industry has a significant environmental footprint due to the extensive amounts of energy and raw materials used in the process. Cement manufacturing is energy intensive—the WBCSD Cement Sustainability Initiative (CSI) indicates that in 2011 the average thermal energy and electricity consumed to produce one ton of clinker among its reporting companies was 3610 MJ and 106 kWh respectively, although these values can vary greatly depending on the age and configuration of clinker kilns (GNRDatabase 2013, CSI). The thermal energy for the kiln process is provided mainly by fossil fuel (mainly hard coal, lignite, to a lesser extend oil and gas). Around 10% of thermal fuel is nowadays provided by combustible waste material (mainly in mature countries) and biomass derived fuels from wood processing and agricultural activities (e.g. crop residues).

Consequently, cement manufacture releases a great deal of carbon dioxide (CO_2). In fact, cement production is responsible for about five percent of total global CO_2 emissions (IEA 2009). The CO_2 emissions result from fuel consumption in the kiln and the de-carbonation of limestone to produce CaO ($CaCO_3$ + Heat => CaO + CO_2). Typically, 40 percent of direct CO_2 emissions for OPC come from combusting fuel required to drive the reactions necessary to make clinker; 60 percent comes from the de-carbonation reaction itself. Cement plants can be flexible in the fuel used, however today in most countries the primary fuel in use is coal because it is relatively low cost and the coal ash can add necessary minerals to the cement product. Indirect emissions from electric power consumption and internal transport contribute another 10 percent to overall CO_2 emissions (WBCSD/IEA 2009).

Clinker burning kiln system

The raw material (lime and clay) is burned to clinker using a fossil fuel fired rotating kilns. The raw material is preheated using a suspension pre-heater. The hot clinker leaving the kiln is cooled down from 1450°C to ~100°C by a grate type air cooler. Half of the cooling air is used as pre-heated combustion air for the kiln burner – the other half of the cooling air is vented.

Due to the fact that the energy cost contribution represents the biggest part of the cost of cement manufacturing, the cement industry permanently strive for technologies and initiatives to reduce energy input by improving energy efficiency of the burning process. According WBCSD (CIS 2011) the average thermal energy consumption of the global cement industry has been decreased by 16% in the last 20 years (1990: 4260 – 2011: 3560 MJ/t $_{clinker}$).

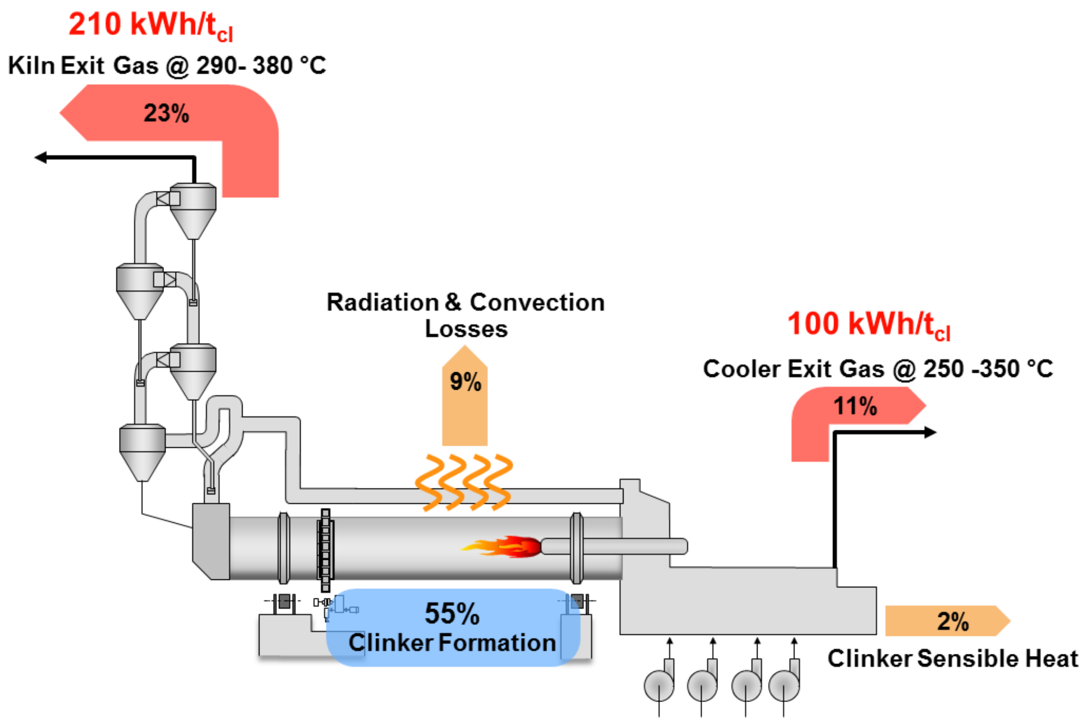

Figure 2: Energy output flows of a modern dry type clinker kiln.

A typical (European) dry type clinker kiln requires approximately 3300 MJ/t$_{clinker}$ thermal input. 55% percent of this energy is used for clinker formation (de-carbonization limestone and fusing of the clinker mineral). In the specific case of Cementi Rossi, the distribution of the input and output energy onto various components can be best represented by the Sankey diagram as shown in Figures 3. It is clear from these figures that 50% of the energy is a useful energy to the system. The other main thermal flows are the two gas streams from the kiln and the cooler. The two streams are merged in a mixing chamber, called “node”. The heat in the node is partly used to dry raw materials. The residual heat can be recovered by heat exchanger and either used for district heating or low temperature power generation.

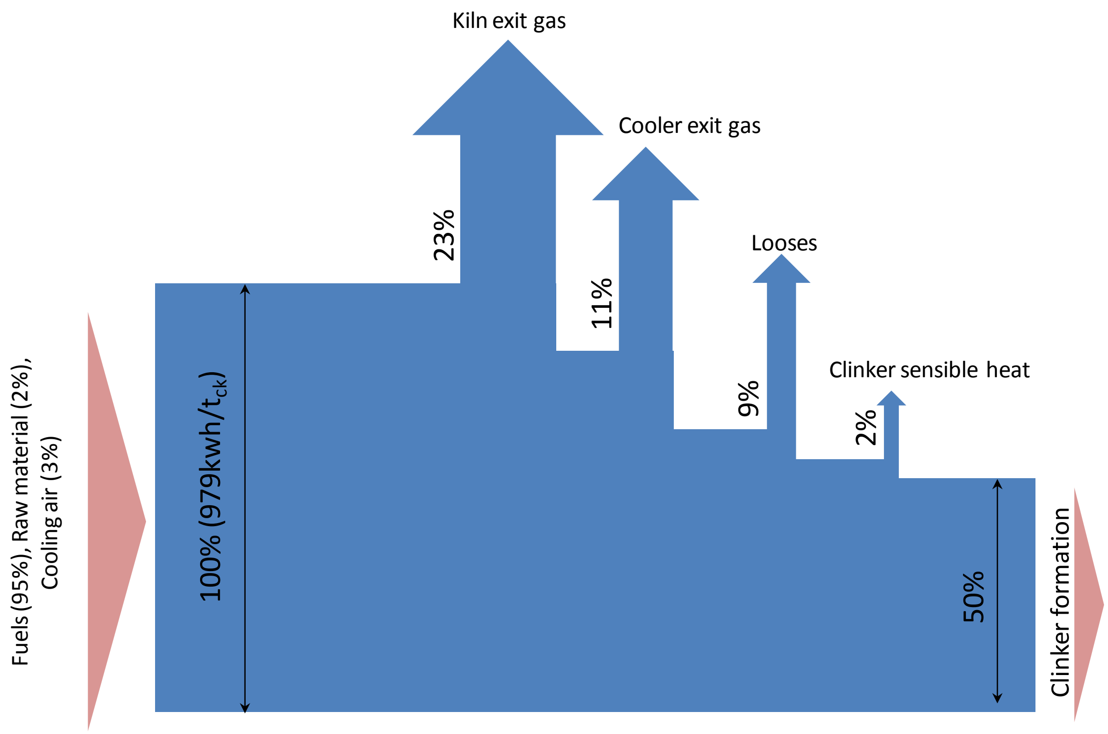

Figure 3. Sankey diagram of energy balance for Cementi Rossi plant.

<u>Other Heat Sources in a Cement Manufacturing Process</u>

The clinker kiln is the main thermal process in cement manufacturing, and its exit gas can be recovered and used for power generation. In the cement grinding and additives drying processes exhaust gas and heated materials of significant quantity exit the systems. The energy content of those streams is in the range of 1-5 MW_{therma} – but the temperatures levels are only around 90 – 120°C. Studies and pilot projects done proved the technical feasibilities of the valorization of those heat sources (EU FP7 - project "LOVE" 2010-2014). Economic feasibility of such power generation systems is not reached at current equipment cost and electricity prices.

3.2 Glass

Glass sector has not changed greatly in the last 30 years. In the hollow glass manufacturing, the melting furnace is the main energy consumer. Energy efficiency has increased slightly through the use of finite element simulations to optimize furnace design and a slow improvement on refractory materials.

Furnace design concepts have not changed. Regenerative furnaces have been used since the oil crisis of the 70s. The energy efficiency of the previous furnaces (much cheaper to build) was around 10% in the best cases, where today, efficiencies are about 40%.

The hollow glass manufacturing process is straightforward. Raw materials are mixed, heated and cooled after glass is formed as container. There is after a reheat to anneal the glass and after the bottles and jars are inspected.

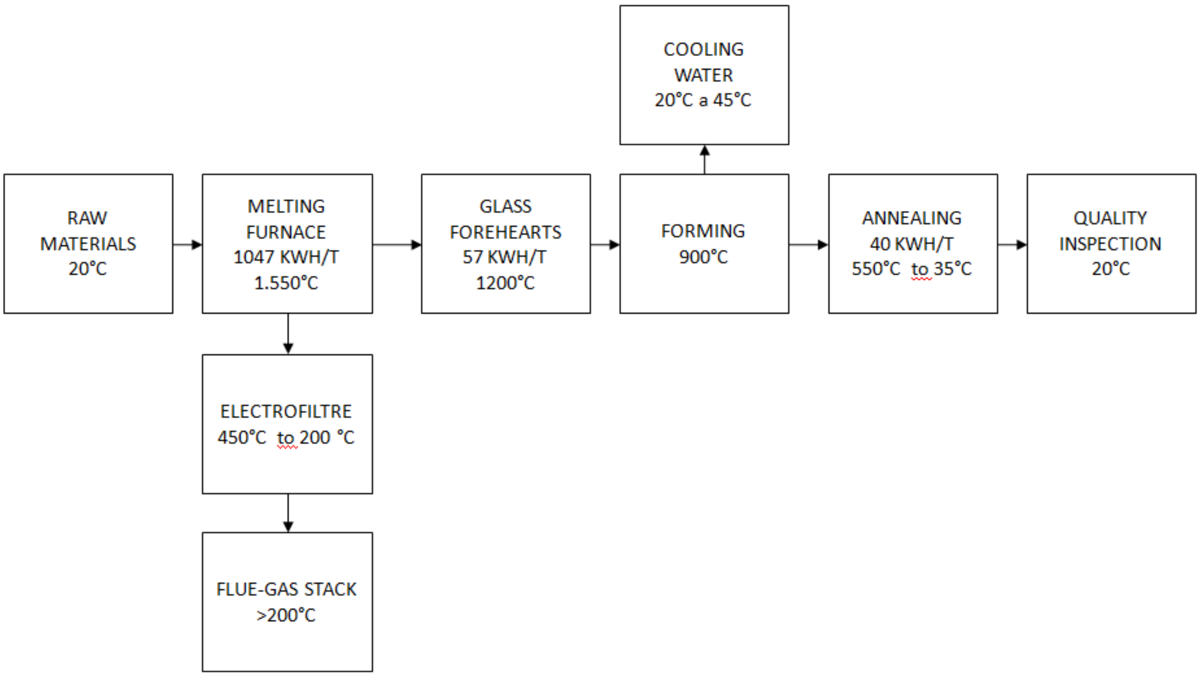

Figure 4: Layout of the hollow glass production process showing the main steps

In general as it can be seen in Table 1, the Furnace is by far the main gas consumer in a glass factory. It can be said that normally the projects to reduce the consumption there will be the most interesting.

	FURNACE	FOREHEARTH	FORMING	ANNEALING	COLD END	OTHERS	TOTAL ENERGY
GAS	87%	5%	0%	5%	1%	2%	85%
POWER	30%	1%	45%	1%	10%	13%	15%

Table 1 Distribution of energy consumption in a glass factory

On the other hand the electricity use is more evenly divided, between the furnace and the forming process. In the forming process, the compressed air accounts for the biggest percentage of electricity consumption.

In a glass factory, several different furnaces are usually installed. The average in Europe is 2 furnaces per factory with an annual production of around 200.000 tons of glass.

Fflue gases can be mixed to reduce the capital costs of a waste heat recovery system. This waste heat, is usually between 200 and 450ºC depending on whether there is an electrofilter installed. Flue gases are diluted with ambient air if an electrofilter is installed to protect it.

Glass melting furnace description

Hollow glass melting furnaces can be end fired or cross fired, depending on the tonnage of the furnace, with the end fired being the most usual ones.

In the figure 5 the regenerative chambers can be seen in the left part in vertical, where the flue gases go through before exiting to preheat the combustion air.

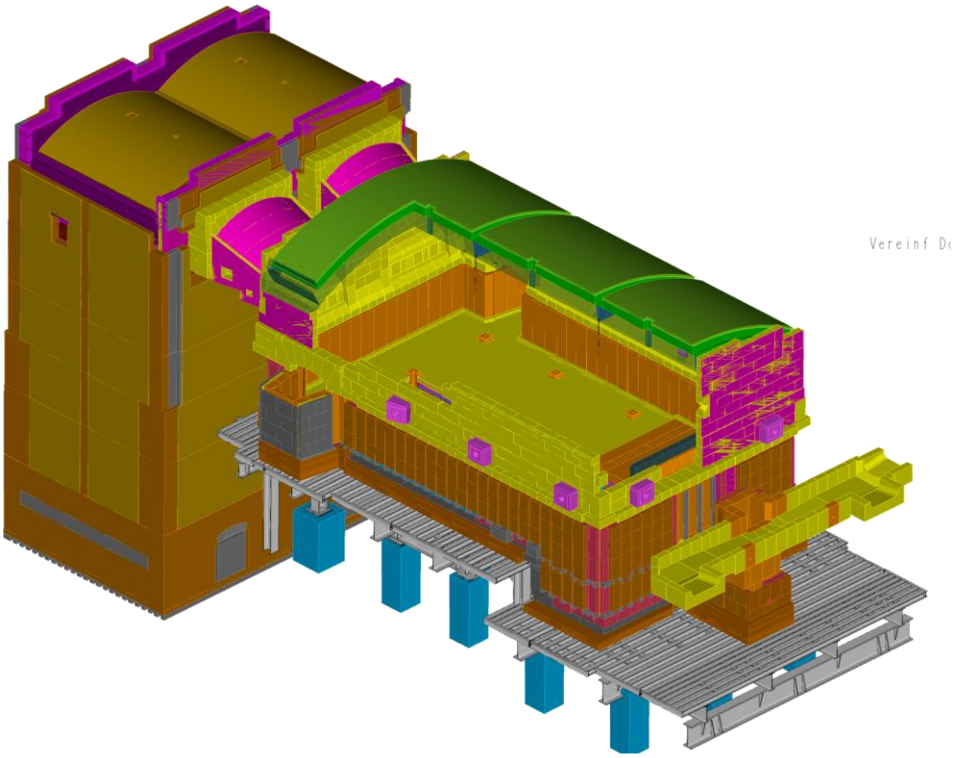

Figure 5: Drawing of a conventional melting furnace used by the glass furnace

Analysing in detail the behaviour of this furnace, and according to Figure 6, half of the total gas energy is recovered in the form of preheated air. Some of the alternatives to reduce the total consumption of the glass furnaces have been trying to preheat also the raw materials. This kind of installation is only suitable for furnaces using very high recycled glass percentages and even in those cases suffer from serious clogging problems.

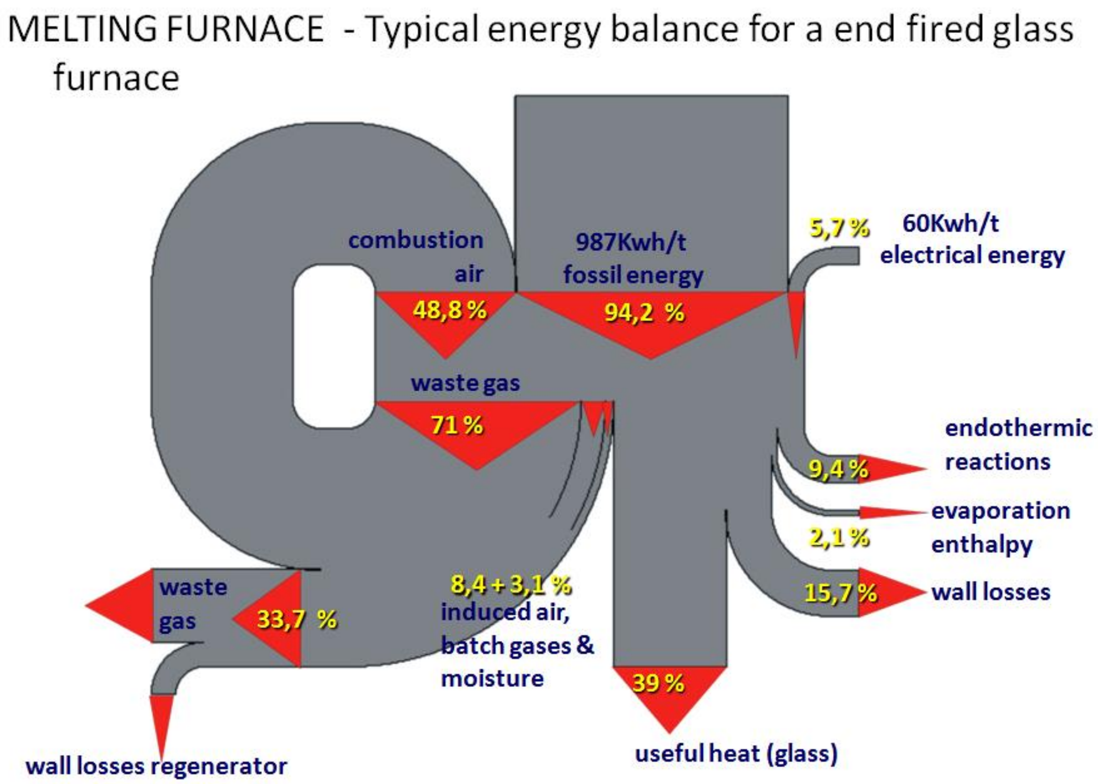

Figure 6: Energy balance of an end fired glass furnace

The analysis of the energy loss leads to the conclusion that , only the waste gas looks promising in terms of total quantity, and quality of energy. Wall losses, for example, another important cause for losses, suffer from one important problem.

Corrosion of the glass walls for example is directly influenced by wall temperature. Trying to reduce energy losses through the wall would increase the internal temperature and that would increase exponentially the wall corrosion, affecting the furnace life.

3.3 Steel industry

During the last decades, the steel industry has experienced significant advances in the development of new techniques for the energy efficiency. There are numerous opportunities along the steelmaking process for implementing energy efficiency technologies. In Figure 7 some typical examples are highlighted. The largest waste heat potential within steelmaking plants, electric arc furnace (EAF) and reheating furnace (RHF), are related to the main processes and will be analysed following. Apart from the main aggregates, in a steel plant there are several other waste heat sources, as the slag pit, CCM roller table / cooling bed or cooling lines in the rolling mill although they provide only heat radiation which could be used in a heat exchanger for small recovery solutions like e.g. warm water solutions. Energy recovery from steel mill slags is not presently performed because of the difficulty of the industrial implementation.

Smaller improvements can be easily implemented without big actions. Such measures can be a modified plant operation, simple plant upgrades, or smaller automation packages. The identification of improvements requires a survey of the existing installations, and a subsequent study of the individual improvements in terms of feasibility, reliability, as well as cost-benefit considerations. For a more decisive impact on the energy balance of a steel plant, bigger actions are required.

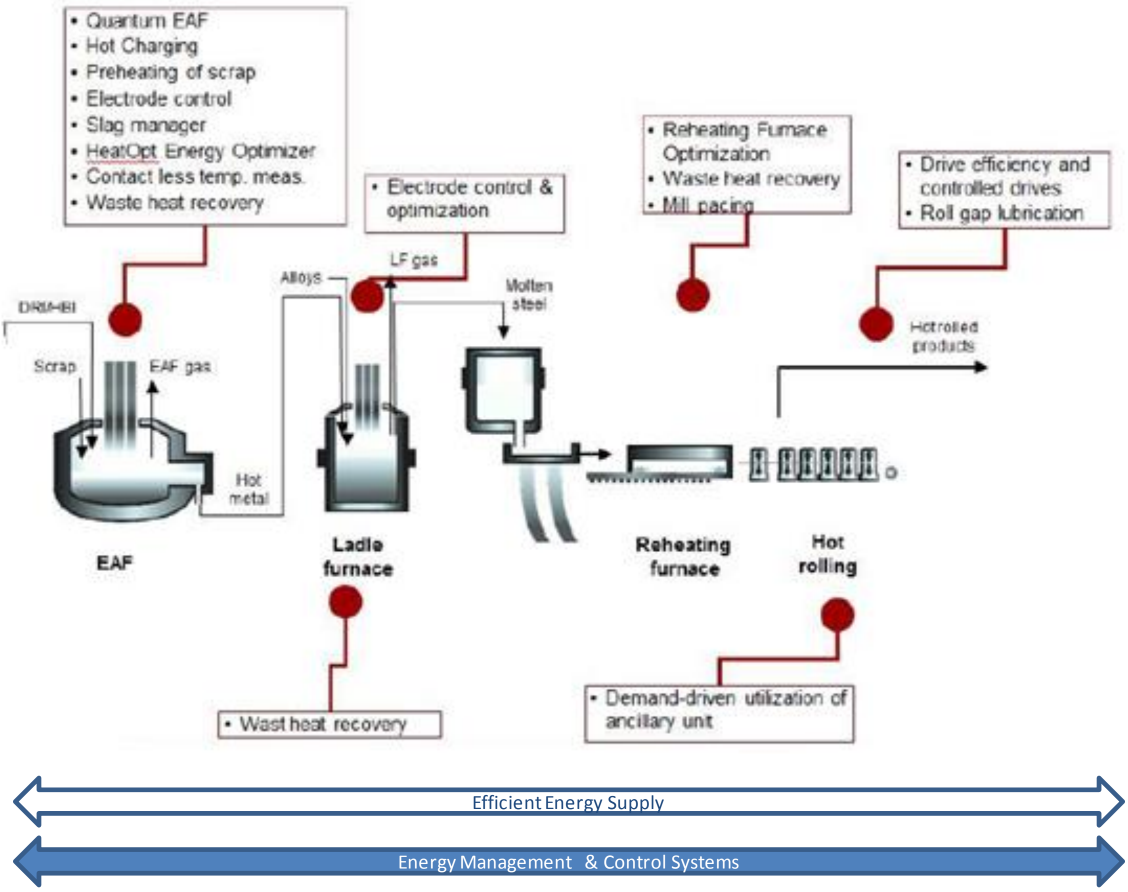

Figure 7: Typical energy saving potentials of electric steelmaking plants.

An analysis of the involved electric steelmaking plant in TASIO project has been carried out with a particular focus on process routes and energy consumptions.

Sidenor Basauri Works is a steelmaking company which produces special steel long products, devoted to a high extent for automotive applications. Production facilities at Sidenor Basauri plant include a 140 t electric arc furnace (AC), secondary metallurgy station (two ladle furnaces sharing a vacuum tank degasser and VOD) and continuous casting (bloom of 300x400 mm sq and billets of 185 and 155 mm sq section) process followed by direct rolling.

Figure 8 depicts the production flow of Sidenor Basauri Works.

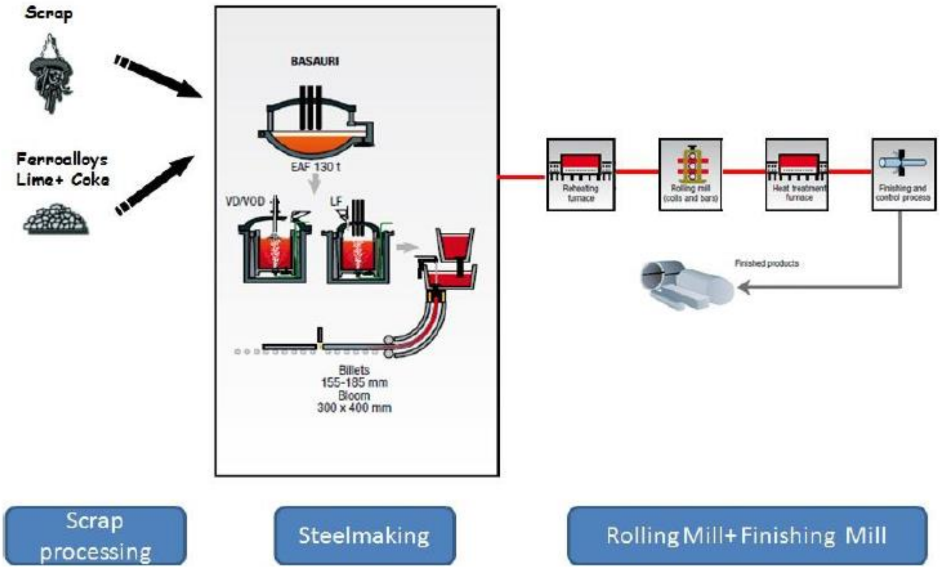

Figure 8: Flow diagram of the production of Sidenor Basauri Works

The process starts with the materials reception and storage. The scrap is classified by quality groups, based on density and trace elements criteria. Depending on the grade of steel to be manufactured, specified by customers, the scrap is loaded into baskets that are transported to the EAF. For a furnace of 140 tonnes existing in Basauri usually 2 baskets are needed to complete the load. Charging scrap from the basket to the EAF is done through 2 cranes.

The scrap melting process is carried out in a DEMAG AC EAF, with 6.3 m diameter and with a capacity of 130 tLS. The annual production capacity is approximately. 750,000 tons. The scrap is melted by the energy released created between the electrodes by passing electric current through them and chemical energy. Oxygen is injected to speed the melting and oxidation processes, achieving a reduction in processing times and energy consumption. The oxidation processes generate undesirable elements in the steel and become part of the slag to be subsequently removed. In the last stage of the melting process, slag foaming process is performed under conditions that allow the improvement of both metallic yield and energy performance, and control active oxygen steel bath. To achieve this foamy slag controlled injection of O2 and C in the final stage is required.

Once the melting process is finished and conditions, temperature and oxygen activity, are achieved, the liquid steel is tapped into the ladle, through a hole in the bottom of the furnace (EBT). During the secondary metallurgy, process basically involves adjusting the composition of the steel by the addition of ferroalloys (refining process) and removal of hydrogen and nitrogen, achieve good deoxidation and cleanness of steel. To homogenize the temperature of the steel and the composition, the steel is stirred by injecting argon through a porous plug located at the bottom of the ladle. Systems ferroalloy addition may be performed by conveyor through a hole in the furnace roof, or by addition of these elements by wire.

The secondary metallurgy is divided into two stations, one heating with two positions (LF1 and LF2) and a vacuum degasser (VLD). Once temperature conditions and composition in the liquid steel are reached, the ladle is raised in a turret for casting liquid steel into a tundish which six strands in the case of billet casting or four strands for bloom casting. The casting speed varies depending on the section to be cast, the steel composition and the temperature. After solidifying the bar, it is then cut to lengths provided (oxyfuel area) remaining in any of the three previous cooling beds transfer to the rolling mill.

The semifinished product thus obtained is called billet and in the case of Sidenor Basauri has a square cross section of 185 mm and 155 mm. GSE Basauri has also the possibility to cast bloom of 300 x400 mm sq.

Concerning rolling mill, Sidenor´s medium size bar mill at Basauri Plant produces straight round bar from 25 to 100 mm and includes a walking hearth furnace that reheats the steel billets up to rolling temperature of approximately 1,200°C with radiant roof, a three high roughing mill, a continuous mill composed by 8 conventional stands in H-V (horizontal-vertical) arrangement and a finishing block with 3 rigid stands.

The historical yearly energy flows have been analysed for the total site including all production shops (steel mill and rolling mill) and auxiliary process units as well. Table 2 gives an overview about the use of energy in different production shops of the plant based on data of the year 2014.

Table 2: Use of Electricity and Natural Gas at Sidenor Basauri plant in 2014

	Electricity (%)	Natural Gas (%)
Steelmaking	85,22	34,94
Rolling Mill	2,37	41,91
Heat Treatment	3,44	22,55
Black Finishing	0,71	
Bright Finishing	0,58	
Oxygen Plant	4,29	
Compressed Air	1,73	
Industrial Water	1,08	
Logistics	0,05	
Quality Control	0,15	
Structure	0,04	
Others	0,34	0,60
Total Works	100,00	100,00

The electrical energy is mainly used in the steel shop for melting. The reheating furnace of the rolling mill is the main consumer of natural gas. The rest of consumptions are aggregated under Auxiliaries in the complete balance. The optimization for industrial furnaces in the steel plants, namely EAFs in the melt shop, or reheating furnaces in the rolling mill, is a wide discussion, but there are only a few basic targets: Product quality, maximized output, maintenance cost, operation cost, where operation cost of course means energy consumption in the first place. Given the fact that scrap prices are not directly in the hands of the steel plant, energy costs remain the biggest cost driver that can be controlled by the plant. Sidenor plant in Basauri needs around 524 GWh of electricity and the equivalent of 302 GWh from natural gas per year.

In the steel sector there are different industrial processes that present a relevant amount of waste heat, exploitable through a heat recovery unit: the scraps melting process through electric arc furnaces or the heat recovery from a re-heating furnace, employed in the rolling mill process. A short analysis of the energy balance in each case in Sidenor Basauri plant is done hereafter.

Electric Arc Furnace (EAF) description

According to the Table 2, the most important energy sources in the EAF process are electricity and natural gas. During the melting process the following types of energy concur:

- thermal energy from the electrical arc;
- thermal energy from the combustion of natural gas or other gaseous or liquid fuels;
- chemical energy from the exothermic reactions occurring in the furnace by metal oxidation.

The energy consumption of the EAF is the balance of the three aforementioned inputs. In the example of Figure 9 an overall balance of a Sidenor Basauri EAF is shown regarding energy input (electric, fossil, additional) and output (via off gas, energy content of steel and various heat losses) with a comparably input of 360 kWh/t electrical energy, 220 kWh/t through fuel combustion and 144 kWh/t through metal oxidation which corresponds to a total of 726 kWh/t. From this input, 455 kWh/t are needed to melt and superheat the scrap to tap temperature and to liquefy and superheat the slag, around 100 kWh/t are furnace losses and 197 kWh/t are as sensible heat in the off-gas. Typically ~30% of the brought in primary energy input is lost in the off gas. In addition, the energy losses linked to the off-gas are not easy to handle, because of the EAF batch process, which doesn't provide continuous volume flow rates or offgas temperatures.

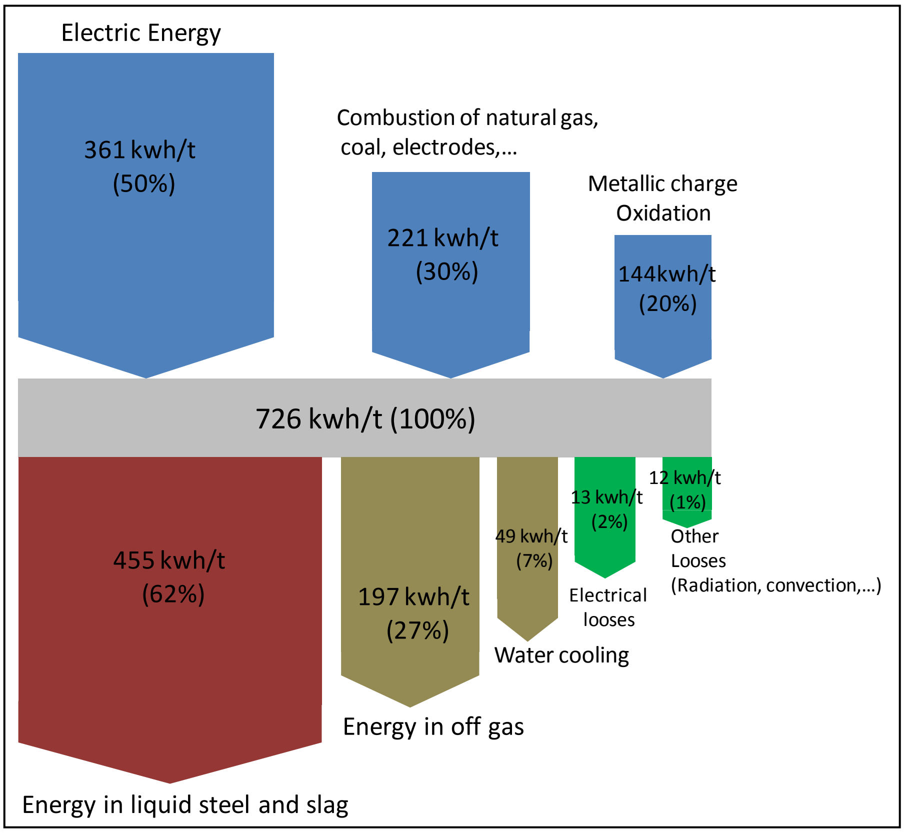

Figure 9: Energy balance for Sidenor EAF Basauri plant

The 'Energy input' comprises on the one hand the electrical energy input, and on the other hand the chemical energy input. The latter one consists of the energy input by burner gas, by oxygen input through lance wall injectors and by the heat liberated by the exothermic reactions.

The 'Energy output' consists of consumed energy to melt the steel and slag and energy losses by off-gas and water cooling, and overall radiation losses. The thermal losses are calculated by the water-cooled panels and the roof are calculated from the cooling water flow rates and the difference between inlet and outlet temperatures.

It is clear that the heat recovery from EAF certainly presents a great potential due to the high temperatures (1.000 to 1.400 °C) and flow rates (of 400.000 Nm3/h up to more than 600.000 Nm3/h) of the exhaust gases at the output. In contrast, according to the experience, this type of heat recovery presents some technical problems related to:

- Content of dust
- Significant variations in temperature and fumes flow inside of production cycles;
- Environmental constraints on emissions

Reheating Furnace (RHF) description

In the case of reheating furnaces, the diagram of the reheating furnace (RHF) system is shown as Figure 10. It consists of 3 zones: preheating zone, heating zone and soaking zone. In the case of Sidenor RHF, the heat from the exhaust gases is captured downstream of the combustion of air preheater before the stack at rather low temperatures.

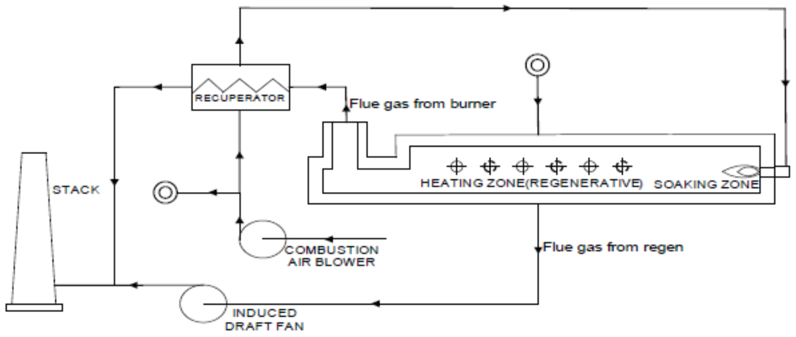

Figure 10: Diagram of the reheating furnace

The Sankey Diagram of energy balance for a typical reheating furnace in case study is presented in Figure 11.

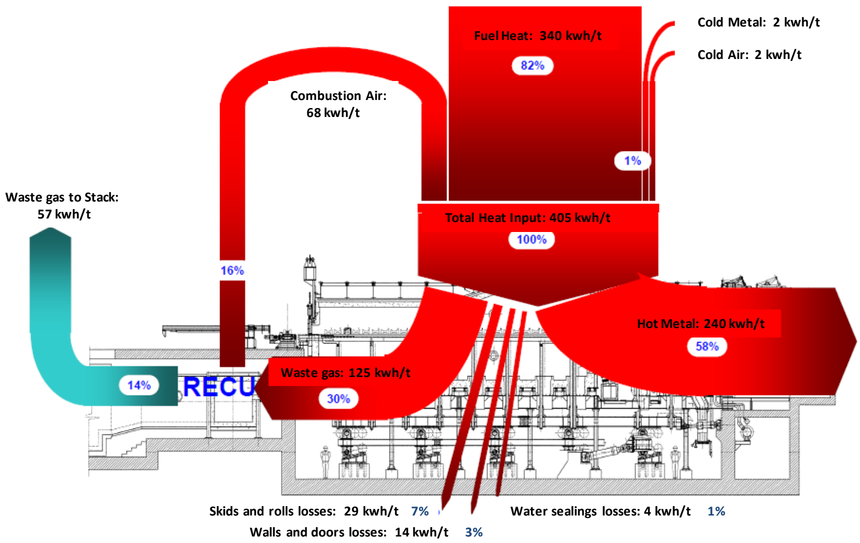

Figure 11: Sankey Diagram of the reheating furnace

From Sankey diagram in Figure 11, the total heat input into the case study consists of sensible heat from combustion of burners by 340 kWh/t (82%) and sensible heat from preheated air at recuperator by 68 kWh/t (16%). Moreover, the total heat output are composed of sensible heat into billet, sensible heat of flue gas from the reheating furnace to recuperator, and heat loss in wall and doors, heat loss from opening, and other losses by 240 kWh/t (58%), 125 kWh/t (30%), 47 kWh/t (12%), respectively.

In the case of Sidenor plant, the reheating furnace is equipped with an efficient heat recovery system. This is fully necessary for the energy efficiency of the furnace, preheating the combustion air from the outgoing exhaust gas. Monitoring systems and preventive maintenance is used in order to check on a regular basis the exchangers' efficiency. As can be seen in figure 11, for the RHF, the flow of energy corresponding to the exhaust gas is slightly less than 30 % of the heat from the combustion of natural gas, which can be estimated, on average, to be about 405 kWh/t. It is clear that an additional system recovery for pre-heat combustion air, mentioned above, is at least advisable.

3.4 Petrochemical industry

The petroleum treatment world (about 4.400 Million of t/y of petroleum processed), alias refineries, are multifaceted industrial enterprises that internally present a very complex and integrated process units. Refineries are classified according to the number of processes available for transforming crude into petroleum products. From the number of working steps, in which the oil is subjected to reach the formulation and distribution of products, results that, in a refinery, one of the main cost items (about 50% of total costs) is represented by the energy consumption, divided into fuels (Fuel gas and fuel oil), steam and electric energy.

Refinery processes

Crude oil and natural gas are mixtures of many different hydrocarbons and small amount of impurities. Refineries are complex plants where the combination and sequence of processes are usually very specific to the characteristics of the raw materials (crude oil and natural gas) and the products to be produced. In a refinery, portions of the outputs from some processes are fed back into the same process, fed to new processes, fed back to a previous process or blended with other outputs to form finished products.

A medium size refinery treats in the range of 100-200 k barrels per day bpd (4 Mt-8 Mt/year).The production of a large number of fuels is by far the most important function of refineries and will generally determine the overall configuration and operation. Nevertheless, some refineries also produce valuable non-fuel products, such as feed stocks for the chemical and petrochemical industries.

The refining of crude oil into usable petroleum products can be separated into two phases and a number of supporting operations.

The first phase is the desalting of crude oil and the subsequent distillation into its various components or 'fractions'. A further distillation of the lighter components and naphtha is carried out to recover methane and ethane for use as refinery fuel, LPG (propane and butane), gasoline-blending components and petrochemical feedstocks. This light product separation is done in every refinery.

The second phase is made up of three different types of 'downstream' process to change the molecular structure of hydrocarbon molecules either by breaking them into smaller molecules, joining them to form larger molecules, or reshaping them into higher quality molecules. The goal of these processes is to convert some of the distillation fractions into marketable petroleum products through a combination of downstream processes. The amounts of the various products obtained are determined almost entirely by the crude composition

The main six basic refining processes are as follows:

- Separation: This is achieved by raising temperature of the input crude supply in pipes that pass through a furnace heated to circa 360°C. This vaporizes individual fractions of the crude feed which then condense and separate out on trays within the column according to the varying boiling points and densities petroleum products. This process is known as simple distillation (topping and hydroskimming). In addition the application of a vacuum enables the products to vaporize at lower temperatures, which is known as vacuum distillation.

- Reforming: This process changes the configuration of individual molecules as in catalytic reforming and isomerisation. This process is commonly used in the final stages of gasoline production.

- Treating: This process uses catalysts, electrolysis and hydrogen to chemically remove contamination such as salts, nickel, vanadium, sulphur and nitrogen oxides. Examples of treatment processes include: hydrogenating, hydrofining, hydrodesulphurisation.

- Cracking: This process breaks down large hydrocarbon molecules into smaller ones in the presence of a catalyst. A catalyst is used to speed up the rate of reaction. The catalysts (example: alumina) can be recycled numerous times. Chemical reactions utilizing catalysts can be used in the presence of hydrogen or steam (examples: catalytic cracking, hydrocracking). Alternatively with the application of very high temperatures heat alone breaks down large hydrocarbon molecules. This process is known as thermal cracking. A common process used in European refineries is known as visbreaking.

- Coking: Residues, the carbon-rich heavy ends of the refinery process are 'cooked' at high temperatures (600°C) to produce lighter products such as gasoil and naphtha.

- Deep Conversion: Combines carbon extraction with the addition of hydrogen. This process is designed to convert the heaviest fractions (refinery residue or bottoms) into lighter and marketable products. Process includes coking, residue catalytic cracking and de-asphalting.

The refinery configuration can range from single topping for crude distillation to high conversion refinery and it depends on the various factors such as: crude oil characteristics, market requirements etc. Figure 12 shows a scheme of an Italian refinery

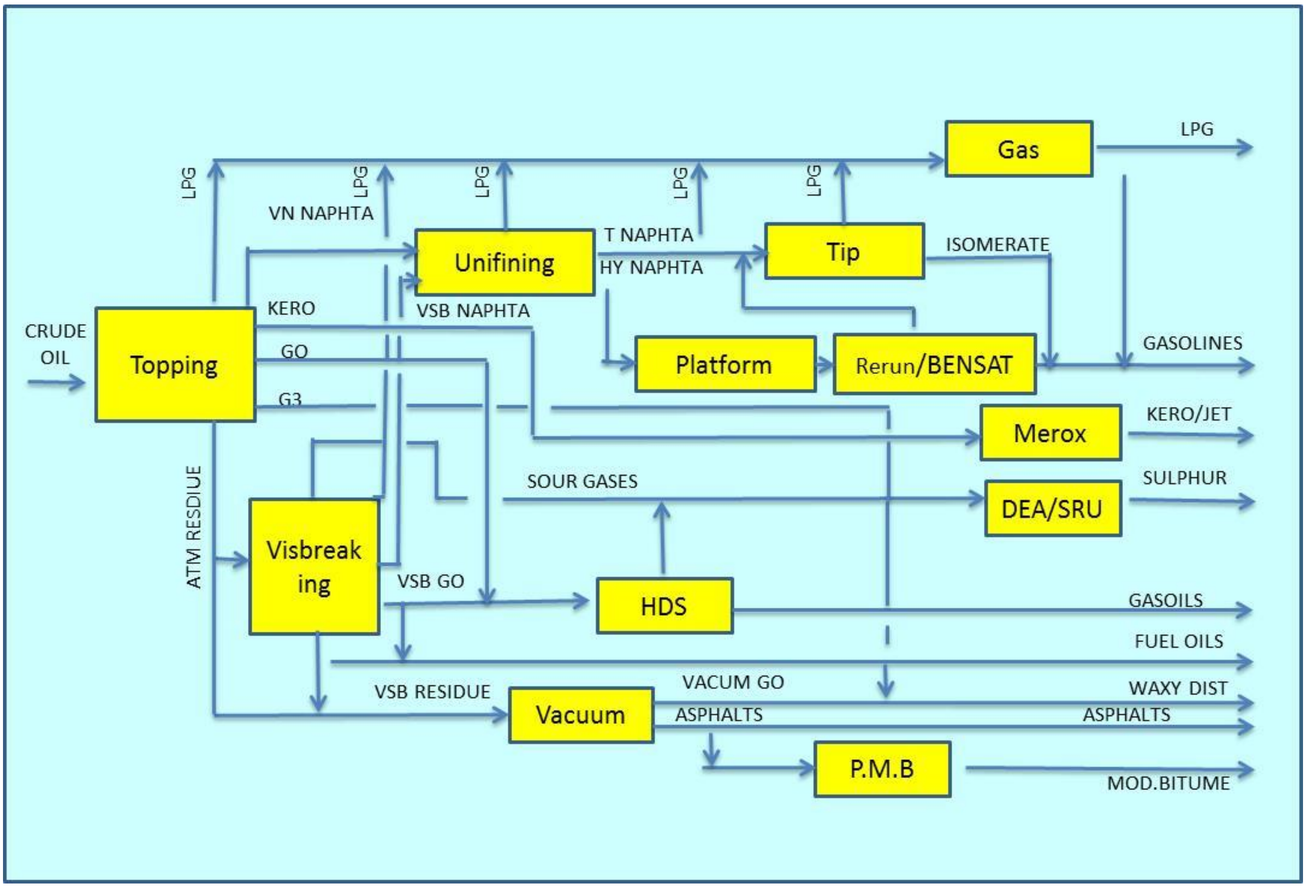

Figure 12: Refinery process scheme

The description of the units shown in Figure 12 is as follows:

- Topping also known as crude distillation unit (CDU) or atmospheric distillation units receives crude oil pumped form the storage tanks where it is fed from sediments and free water by gravity. It goes through a series of heat exchangers where it is heated with hot products coming out from the distillation column and by the exchange with heat form pumped liquid streams.This distillation process removes undesirable components like sulphur, nitrogen, and metal compounds and limiting the aromatic components:

  Typical products form this unit are:

  1) Liquefied petroleum gas (LPG)
  2) Light naphtha
  3) Kerosene
  4) Gas oil (GO)
  5) Heavy gas oil (G3)
  6) Atmospheric residue

  The capacity of this unit is about 92.400 bpd.

- Visbreaker: The visbreaking is a mild thermal cracking of topping residue to produce light products and cracked material of lower viscosity that can be used as oil fuel. The main reaction in visbreaking is thermal cracking of heavy hydrocarbons. Reaction temperatures range from 450°C to 480°C, and operating pressures vary from 3-10 bar. The “vis-broken products” are immediately quenched to stop the cracking reaction. The capacity of this unit is about 30.000 bpd.

- Vacuum The topping and the visbreaking residues are sent directly to the vacuum unit. The feed enters vacuum tower at the lower part of the column where the distillation occurs at very low pressure. The vacuum distillation column is equipped with packing for fractionation and heat exchange zones. This allows the reduction of the pressure drop in the column which is necessary for creating a low vacuum in the lower section of the column. This unit produces bitumen and asphalts the capacity is about 12.000 bpd.

- Total Isomerization process (TIP). The is the process in which light straight chain paraffin coming from the unifiner unit are transformed with proper catalyst into branched chains with the same carbon number and high octane numbers. The plant capacity is 9.000 bpd.

- Platformer. This process produces fuel with high octane numbers and hydrogen using heavy nafta. In this unit the feed is treated by passing with hydrogen over a catalyst to convert the sulphur and nitrogen compounds to hydrogen sulphide and ammonia in order to prevent poisoning of the expensive platformer catalysts. The capacity of this unit is about 15.000 bpd.

- Merox unit (mercaptan oxidation). The Merox process is based on the ability of an organometallic catalyst to accelerate the oxidation of mercaptans to disulfides at near ambient temperatures and pressures. This consists of a reactor, which contains a bed of specially selected activated charcoal impregnated with Merox reagent and wetted with caustic solution. Air is injected into the feed hydrocarbon stream ahead of the reactor and in passing through the catalyst-impregnated bed, the mercaptans in the feed are oxidized to disulfides. The capacity of this unit is about 12.000 bpd

- Bensant unit. This process consists in aromatics saturation catalysts to reduce the benzene contained in the distillate, in order to avoid product contamination and catalyst poisoning. It is realized to complete the C5-C6 isomerization, to remove the natural benzene concentrated by aggressive reformer feed pre-fractionation, and also to remove the benzene that has been produced in the reformer. This unit permits to produce fuel with low benzene concentration.

- Hydrodesulphurization (HDS) is a catalytic chemical process widely used to remove sulfur (S) by means of hydrogen addition from refined petroleum products such as gasoline or petrol, jet fuel, kerosene, diesel fuel, and fuel oils. The purpose of removing the sulfur is to reduce the sulfur dioxide emissions that result from using those fuels in automotive vehicles, aircraft, railroad locomotives, ships, gas or oil burning power plants, residential and industrial furnaces, and other forms of fuel combustion. Another important reason for removing sulfur from the naphtha streams within a petroleum refinery is that sulfur, even in extremely low concentrations, poisons the noble metal catalysts (platinum and rhenium) in the catalytic reforming units that are subsequently used to upgrade the octane rating of the naphtha streams.

- DEA/SRU (Sulfur plant) This process permits to remove the H_2S into the off-gas coming from the Hydrodesulphurization unit and visbreaking trough an amine solution absorber. The resultant rich amine is then routed into the regenerator to produce regenerated or "lean" amine that is recycled for reuse in the absorber. The stripped overhead gas from the regenerator is concentrated H_2S and CO_2. Gases with an H_2S content of over 25% are suitable for the recovery of sulfur in straight-through Claus plants.

- Unifiner: The light naphtha coming from the topping unit is fed to a unifining process unit where it is catalytically desulphusized. The process that utilizes catalyst and a hydrogen-rich gas stream to remove sulphur, oxygen and nitrogen contaminants from the light naphtha. The process also removes organometallic compounds, and saturates olefinic compounds. The main function of the process is to lower the sulphur and nitrogen levels in the light naphtha which is required for two reasons. First sulphur and nitrogen compounds are poisons for the downstream units and second the lower sulphur product is required in order to be a viable blending component for finished gasoline.

Refinery energetic flowchart

Petroleum refining is one of the most energy-intensive industries. The actual specific consumptions of a sample of European refineries ranging from 1.0 ÷ 4.0 GJ/t of crude (0,024÷0,1 ton of oil equivalent/t of crude depending on the size of the plant). In other words: around 2,4 ÷10% of the crude feedstock received is used in the refinery.

Currently, in many refineries, periodic efforts have been made to improve the steam balance and eliminate obviously wasteful plumes of exhaust steam. A rule of thumb used by some refiners is that it takes 1 barrel of oil-equivalent energy to process 10 barrels of crude oil.

In typical refining processes, feed streams are normally heated, either to effect a physical separation (crude unit fractionation) or to provide energy for a heat-absorbing reaction (e. g., catalytic reforming).

Specifically, petroleum refining processes use energy in the form of fuel, steam, or electrical energy for the following functions:

1) To heat crude units and other process feed streams.

2) To make steam for mechanical-driven turbines to power major compressors and some large pumps; for process heating, steam-stripping, and steam-jet vacuum ejectors.

3) To heat reboilers (steam-fired or fuel-fired) .

4) To power most pumps and the fans in air coolers (usually with electric motors.)

Figure 13 shows the flow of energy into the typical refinery, as well as the form and amount of energy losses from the system.

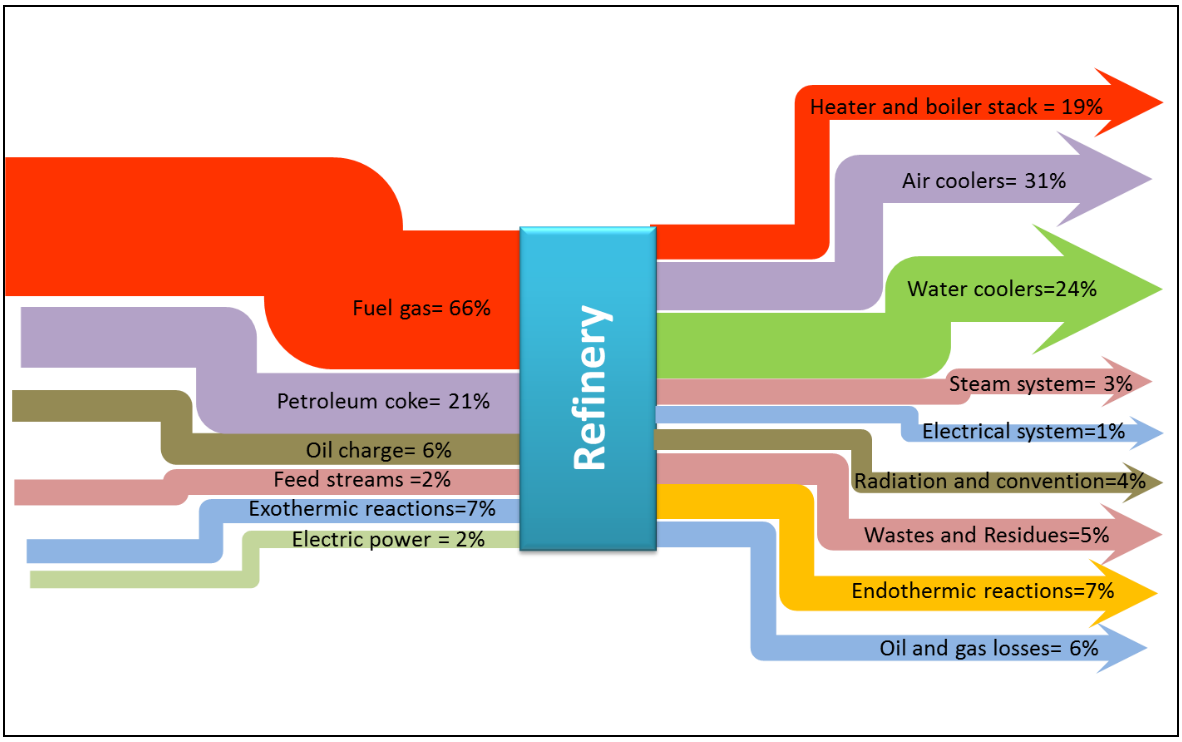

Figure 13: Refinery energetic flowchart

On the basis of the data reported in figure 13 the following considerations can be done:

1) Fuel gas provide about the 66% of the total inlet energy.

2) Heat rejected by air and water cooled heat exchangers used to cool recycle and product streams is about 50% of the global energy losses.

3) Unrecovered heat in flue gases from heater and boiler stack is about 20% of the global heat losses.

4) Organic landfilled wastes and residues is about 5% of the global heat losses.

5) Convection and radiation losses from hot equipment, transitional tanks and piping is about 4% of the global heat losses

6. Conclusions

This deliverable presents the results of research performed to investigate the different processes and subprocesses in the cement, glass, steel industries and petrochemical sectors involved in the Tasio project from an energetic point of view. It has shown that the potential of the plants for energy savings is enormous and applying today´s concepts, it is estimated that somewhere between 20 to 50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products.

To stay competive, it is crucial for the sectors involved in Tasio project to operate the different described plants at a high degree of energy effciency. As the industrial sector continues making efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emission-free and less-costly energy resource.

The evaluation of the overall results shows an interesting potential of heat recovery, for example, for electricity generation. There are already working examples of plants around the world in many of the most interesting sectors considered.