2012-2015 Triennium Work Reports

WOC 5.1 – Committee Report

INDUSTRIAL GAS UTILIZATION

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2012-2015 Triennium Work Report
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Industrial gas utilization

Report of WOC 5, SG 5.1

Executive Summary

The aim of SG 5.1 Industry is to analyse and investigate the efficient use of gas in industrial sector, giving suggestions and recommendations to gas industry in order to enhance opportunities for the development of the role of gas in this sector. During the triennium 2012-2015, WOC Study Group 5.1 produced a report on the industrial use of gas. The report aims at summarizing the work done in the triennium, focusing on methods and proposals to enhance the role of gas in the energy mix on final uses. In order to develop the role of gas as leading fuel for the growth of industry, main streams were focused to become either guiding items for gas utilization and best practices by means of case studies. Each stream looked at technologies using gas in the industrial sector, focusing on methodological approach, economical and regulatory analysis.

Energy efficiency at final use side is nowadays considered the "most available and cheapest form of energy", so relevant methods and technology applications are represented, driven by gas. Flexibility and cleanness of the use of natural gas are exploited by analysing technologies permitting fuel switching from other primary fuels, or electricity, to gas. To go in deep into gas utilization, also Gas-To-Power solutions have been investigated, both for power generation only and for combined heat and power (chp) in industry. Examples of combination of gas and renewables and small applications of LNG plants for industry are analysed.

Keeping in mind the above mentioned analysis and the outlooks on the gas utilization in the fuel mix, recommendations for gas industry are summarized.

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Introduction

This document aims at investigating the present and potential future role of natural gas in the energy final uses in the industrial sector, giving some suggestions for the development of gas industry based on the efficient use of gas in the energy mix.
The importance of natural gas in the world economy has increased in the last decades, due to its ecological compatibility with respect to oil and coal and to the efficiency that it permits in final uses.
In a context of reduction of availability of fossil energies, increase of volatility of the energy prices, reduction of carbon emission and economic crisis, the most important challenge for this century for industrial market will be to reduce drastically their energy consumption in order to increase the profitability of their industrial processes. In all the international studies made to define the energy directives or the energy strategies of the countries, the first stage of this commitment type is the implementation of an energy efficiency approach and energy audit.
In this frame of global reduction of fossil energy consumption, opportunities to promote natural gas appliances and new business opportunities could be available for Gas Companies to answer to this renewed mix of industrial demand. A first goal of the report will be to do a kind of technology guide on "How to promote, in the frame of energy efficiency approach, the development of natural gas appliances through the implementation".
In order to establish low-carbon society, it is necessary to introduce more natural gas in the power generation sector as well as industrial sector. To this extent, fuel switching to natural gas from other fossil fuel is important, however, it is not so simple. It is of course required that natural gas price should maintain reasonable price competitiveness and furthermore, the introduction of state-of-the-art technology and the most efficient technology which can achieve significant energy savings are indispensable. The aim of this part of report is to give information and technical and economic analysis of gas driven technologies for fuel switching. But since "electricity is set to remain the fastest-growing final form of energy worldwide" (WEO – IEA 2014), also the point of conversion between gas and electricity has to be investigated.
To have a comprehensive representation of driver in gas use role in industry, combination of gas with renewables and gas to power generation by gas have been explored and update with respect to previous triennium report, by means of case studies.
Moreover, due to the evolution of technologies, LNG plants are now available to feed natural gas directly to industry. The possibility to use LNG in industry by means of Small Scale LNG plants has been represented.

According to World Energy Outlook 2014 by IEA, global gas use will continue to grow in all scenarios there analysed, if compared with today's levels: various scenarios have been supposed, depending on the way that government policies evolve. For example, in the New Policies Scenario, gas demand is expected to be 5.4 tcm in 2040; this means that gas will draw level with coal as the second-largest fuel in the global energy mix, after oil.

In this report a data collection, analysis and compilations of information on natural gas consumption have been performed.

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Authors would like to acknowledge the other committees of WOC 5, which contributed to the discussion and made it possible synergies on cross items relating to energy efficiency and fuel switch.

Authors would like to acknowledge Chairman, Vice-Chairman and Secretary of WOC5 and the other committees of WOC 5, that contributed to the discussion and made it possible synergies on cross items relating to energy efficiency and fuel switch.

Special acknowledgement to all the French Team managing the current Triennium and to the Coordination Committee Chairman and Secretary for taking part to crucial meetings and supporting discussions on scope and method of work.

Acknowledgements to all Countries which organized WOC 5 meetings, arranging technical visits and plenary sessions showing programs in each country on energy. Special thanks to African members of IGU who organized a work session during the meeting in Algiers, putting on this work their knowledge and programs for development of gas industry.

Moreover, methods and information from gas industry were of outmost importance to describe the path for gas industry development.

Sources of information, graphs, labelling are pointed out on the specific chapters and pages.

Aims

The aim of this work of SG 5.1 Industry is to analyse and investigate the efficient use of gas in industrial sector, giving suggestions and recommendations to gas industry in order to enhance opportunities for development of the role of gas in this sector.

Methods

To achieve this objective, during the triennium 2012-2015, WOC 5.1 produced a report on the industrial use of gas, focusing on selected technological items.

After a recognition of the natural gas market which contains the analysis of the different use of gas in industrial sectors for main countries, the report analyses specific items which were selected by the team following main drivers suggested by organization. Each item was organized and studied in deep by item-leaders who lead sub-teams composed by the various participants of WOC 5.1. Each item leader organized the work and presented it during the meetings and group sessions. In successive meetings the report was discussed by all participants.

WOC 5 sessions were completed by technical visit organized by hosting countries, so the team had the opportunity to do surveys on the industrial use of gas directly on utilization plants.

The main items that have been investigated in the report are:

- Fuel switch
- Energy Efficiency
- Gas to power
- Combination of natural gas and renewables
- Small scale LNG use for industry

Owing to the variety and complexity of the items on industrial gas utilization, selection of the main drivers to be used to represent the study was discussed and shared by the members of the group.
The method followed for the analysis and representation of each item was discussed by the team, putting on a specific order the drivers to be used. As a result, Technologies (equipment, techniques), Economics (finance, investment) and Mechamism (politics, strategies) were the drivers chosen.

FinalIy, main trends in industrial use of gas as well as recommendations to the Gas Industry are also presented.

Results

In the following pages, results of analysis, discussions, country reports and case studies are showed. As above mentioned, this section of the report is structured in the following chapters:

1. MARKET SITUATION AND TRENDS ON INDUSTRIAL USES OF NATURAL GAS, pag. 6 and Appendix 1

2. FUEL SWITCH, pag. 12

3. ENERGY EFFICIENCY, pag. 47

4. GAS TO POWER, pag. 103

5. COMBINATION OF GAS WITH RENEWABLES, pag. 118

6. SMALL SCALE LNG FOR INDUSTRY, pag. 134

1. MARKET SITUATION AND TRENDS ON INDUSTRIAL USES OF NATURAL GAS

Authors: Irina Kirshina, Vladislav Karasevic, Alexey Zorya

Introduction

Within recent decades, the role and importance of natural gas in the energy balance of the world economy has been constantly increasing not only due to its high efficiency as an energy resource and raw for industry, but also due to its higher ecological compatibility as compared to oil and coal. This trend will also continue in the future, and perhaps it will be even intensified through cheaper technologies of natural gas liquefaction and construction of new gas pipelines.

Is this study, a data collection, analysis and compilation of information on natural gas consumption within industrial sector in countries of the world have been performed. Besides, it provides information on the total natural gas consumption by regions of the world, and analyzes the structure of natural gas consumption by branches and sectors, as well as dynamics of its consumption for the last 5 years (2009-2013).
Furthermore, a comparison of the structure and dynamics of natural gas consumption of various countries has been done, including the influence of economical, technological and other factors on them.
The structure of natural gas consumption has been analyzed by the following regions of the world: Europe, CIS, America, Asia, Pacific, Africa, Middle-East

The study enables to represent in a generalized view the basic results on the structure and dynamics of natural gas consumption within industrial sector by countries of the world for 2009 - 2013 period.

The statistics show that natural gas is rapidly strengthening its position in all markets, and that is not surprisingly, since this is the most ecologically clean type of fuel.

The study objectives were:

- to compile and analyze information on natural gas consumption within industrial sector in countries of the world;
- to present information on the total natural gas consumption by regions of the world;
- to analyze the structure and dynamics of natural gas consumption within industrial sector over the last 5 years.
- to make a comparison of the structure and dynamics of natural gas consumption in various countries, considering the economic, technological and other factors influence on them;
- to evaluate the perspectives of industrial sector natural gas uses in countries of the world;
- to outline main arrangements aimed at efficiency improvement of industrial uses of natural gas.

Methods are:

- processing of statistical information of the Enerdata-base and periodicals;
- application of the system analysis method;

- methods of clustering, comparison, computational and analytical, as well as science-based generalization techniques;
- comparative analysis.

The report comprises 66 text pages, including 51 illustrations and 20 database tables.

Natural gas consumption in the world

The structure of natural gas consumption was analyzed by the regions of the world (Fig. 1)

Fig. 1. Regions of the world

In course of time the scope and structure of energy resources consumption in the world economics have been undergoing significant changes under the influence of demand and supply. The general structure of consumption is shown in Figure 2.

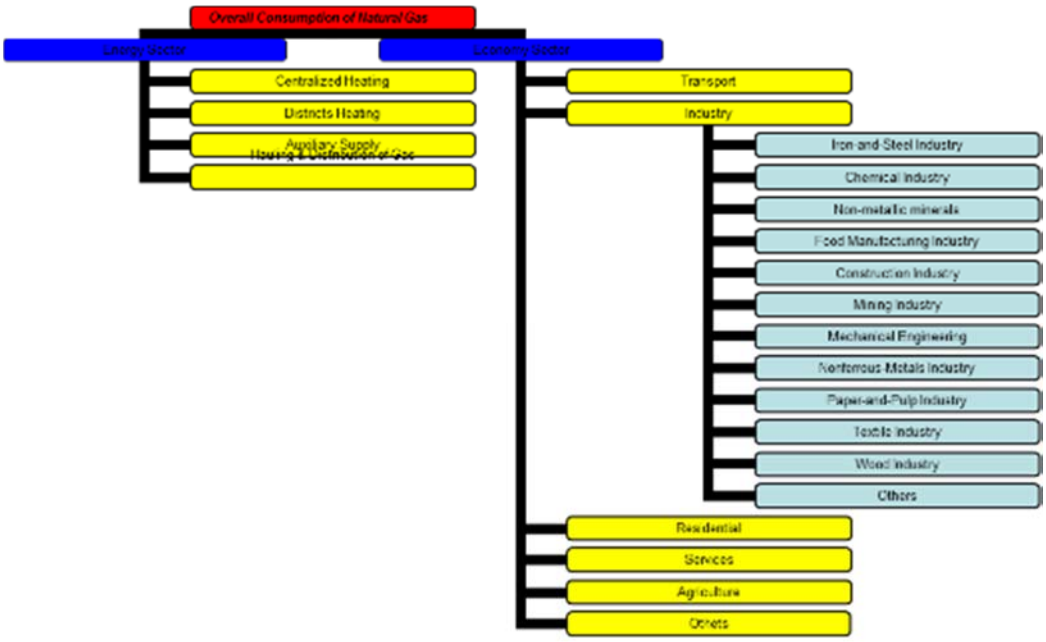


Fig. 2. General consumption of natural gas

For the period of 2009–2013, the world consumption of natural gas increased by 15,6% (Table 1). The major factor of growth in natural gas consumption is the world economy development, in consequence of which there is an increase in global industrial production on one side, and a growth of consumer preferences and purchasing power of population on the other side. Ecological compatibility, efficiency and processability of this energy resource and raw set conditions for high growth rates of demand for it in the future too. The maximum growth of the natural gas consumption for the last 5 years was in the period from 2009 to 2010 (increased by 8,8 %).

Table 1. Dynamics of natural gas consumption in the world for 2009-2013.

Natural gas consumption	**Unit**	**Year**				
		2009	2010	2011	2012	2013
World	bcm	3 052,5	3 322,94	3 381,47	3 487,77	3 528,86

According to various estimates the rate of growth of its consumption totally in the world onward will be 2–3%/year.

Figure 3 represents the consumption of the natural gas during the period from 2009 to 2013 by regions of the world.

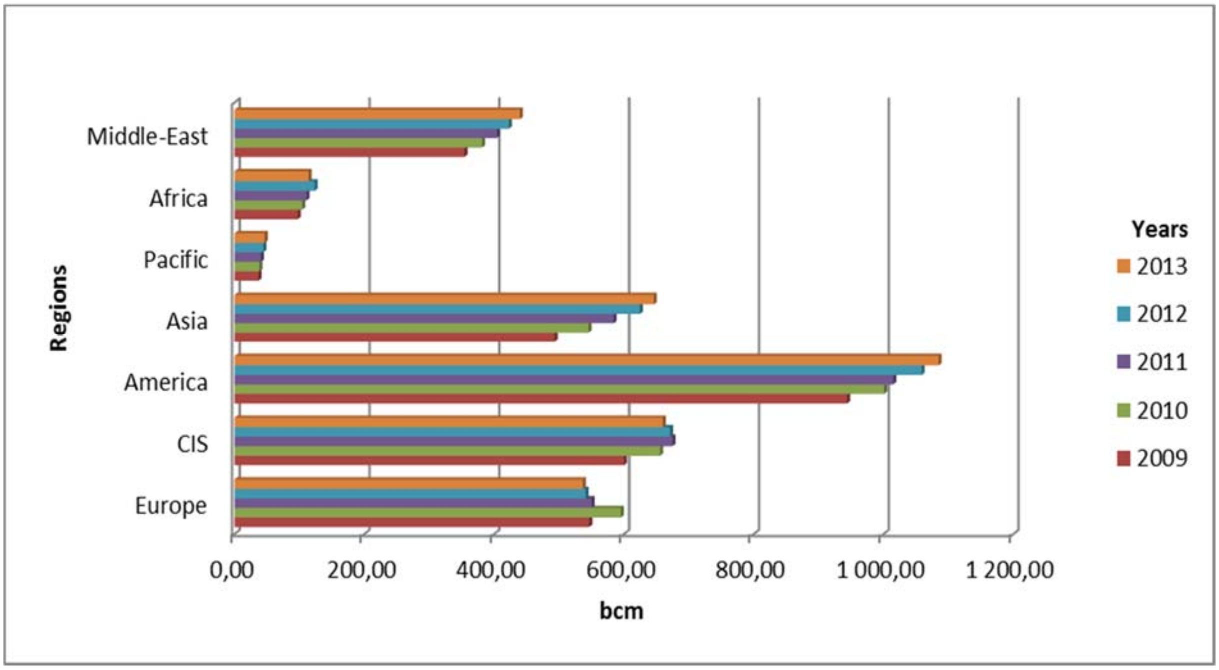


Fig. 3. Natural gas consumption by regions of the world

Among a number of demand drivers for natural gas, the determinating ones are the paces of development of the world economy and its power-consuming branches of industry, such as electrical energy industry, chemical industry, metal manufacture and some others. Also, the demand is influenced by consumption of service industries, public sector and households. In these economy segments there are multidirectional effects of lots of factors. On the one hand, new energy-saving technologies and products that appear on the market decrease the demand for natural gas, but on the other hand, an increase in power consumption-to-personnel ratio of service industries, public sector and households leads to its growth.

Studying the regional structure of gas consumption, it can be noted that America is the major gas consuming region. During the period from 2009 to 2013 the consumption of natural gas in

America has increased by 15% (from 944,02 to 1 084,78 bcm) (Table 2). Then, the CIS countries should be mentioned. It should be noted that consumption of natural gas in this region from 2009 to 2013 has increased by 10% (from 600,29 bcm to 660,11 bcm). Another situation can be observed on the European continent too. Its share in the world natural gas consumption during 2009 - 2013 tended to decrease from 546,89 bcm to 536,89 bcm. The significant growth (31%) of natural gas consumption can be observed in Asia. The consumption of natural gas has also significantly increased in Middle-East region (24%). Africa shows the growth of 17% during the period from 2009 to 2013. Pacific's share in the world natural gas consumption is the lowest one (around 46,75 bcm in 2013).

Table 2. Natural gas consumption by regions of the world in 2009 – 2013.

Regions of the world	**Unit**	**Year**				
		2009	2010	2011	2012	2013
Europe	bcm	546,89	595,65	550,37	541,13	536,89
CIS	bcm	600,29	655,75	674,97	671,40	660,11
America	bcm	944,02	1 001,05	1 015,13	1 059,05	1 084,78
Asia	bcm	493,43	545,52	584,49	624,93	646,27
Pacific	bcm	37,23	38,77	40,83	44,48	46,75
Africa	bcm	97,74	104,57	111,30	123,80	114,44
Middle-East	bcm	354,46	381,63	404,39	422,98	439,62

Below, the structure of natural gas consumption within industrial sector in countries of the world is reviewed in more detail.

Industrial natural gas consumption by regions of the world

The industrial sector uses more delivered energy than any other end-use sector, consuming about one-half of the world's total delivered energy. The industrial sector comprises a diverse set of industries, including manufacturing (food, paper, chemicals, refining, iron and steel, nonferrous metals, nonmetallic minerals, and others) and nonmanufacturing (agriculture, mining, and construction). The mix and intensity of fuels consumed in the industrial sector vary across regions and countries, depending on the level and mix of economic activity and technological development, among other factors. Energy is consumed in the industrial sector for a wide range of purposes, such as processing, assembly, producing steam, cogeneration, heating, air conditioning, and lighting in buildings. Industrial sector energy consumption also includes natural gas and petroleum products (naphtha and natural gas liquids) used as feedstocks to produce non-energy products, such as fertilizers for agriculture and petrochemicals for the manufacture of plastics.[1]
Natural gas consumption within industrial sector is about 23% of the world natural gas consumption.

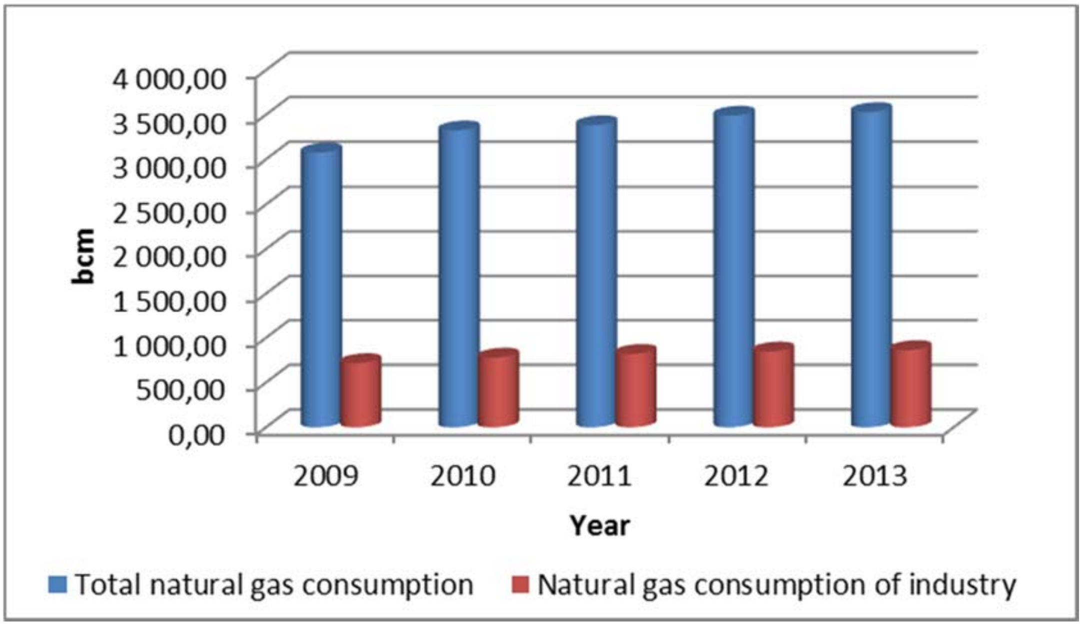


Fig. 4. Dynamics of natural gas consumption within industrial sector and totally in the world

Similarly to the situation with the world natural gas consumption from 2009 to 2013, natural gas consumption within industrial sector increased from 716,24 bcm to 862,59 bcm, (Table 3 and Figure 4). In total, from 2009 to 2013 industrial natural gas consumption increased by 20%, that accounts for 146,35 bcm.

[1] U.S. Energy Information Administration

Table 3. Natural gas consumption within industrial sector in the world

Natural gas consumption	**Unit**	**Year**				
		2009	2010	2011	2012	2013
Total natural gas consumption	bcm	3 052,5	3 322,94	3 381,47	3 487,77	3 528,86
Natural gas consumption of industry	bcm	716,24	777,79	819,39	846,16	862,59

Table 4. Natural gas consumption within industrial sector by the regions of the world

Regions of the world	**Unit**	**Year**				
		2009	2010	2011	2012	2013
Europe	bcm	117,71	130,33	131,62	131,47	132,47
CIS	bcm	94,10	109,62	110,21	108,69	105,05
America	bcm	236,68	262,88	263,54	272,48	278,20
Asia	bcm	121,34	119,58	138,17	147,20	156,89
Pacific	bcm	10,59	11,13	11,20	12,83	13,58
Africa	bcm	23,64	26,60	26,73	29,86	28,52
Middle-East	bcm	112,19	117,65	137,91	143,62	147,87

The analysis of the presented information makes it possible to note that the natural gas consumption during the period from 2009 to 2013 had a trend of increasing.

America has been the world leader in natural gas consumption within industrial sector (around 33% of the world's natural gas consumption within industrial sector). In this region the natural gas consumption within industrial sector increased from 236,68 to 278,20 bcm.

Natural gas consumption within industrial sector in the Asian countries is also increasing at a quick rate. From 2009 to 2013 natural gas consumption in this region increased approximately by 30% (from 121,34 bcm to 156,89 bcm). The third place for the natural gas consumption within industrial sector takes Middle-East region, during the period from 2009 to 2013 the consumption increased by 32% (from 112,19 bcm to 147,87 bcm).

Also natural gas consumption within industrial sector in European countries increased by 12,5 %.

Shares of African and Pacific countries in the world's industrial sector consumption of natural gas is relatively small, but also tends to growth.

Natural gas consumption in CIS countries during the period from 2009 to 2013 increased by 11,6%. A little drop (3,3%) in natural gas consumption in CIS countries took place during the period from 2012 to 2013.

In the APPENDIX 1 each region of the world is reviewed in more detail.

2. FUEL SWITCHING

Authors: Katz SATO, Toshikuni OHASHI, Yuuki SHIBATA

Introduction

In the World Energy Outlook2013, IEA mentioned that major changes have begun to occur in the energy sector, using the phrase "Many of the long-held tenets of the energy sector are being rewritten."

Next points are considered as the major trigger of the changes.

- The importance of CO2 reduction to prevent global warming
- The Reduction of the dependence or the abolition of nuclear power plants, after the disaster of Fukushima nuclear power plants
- The shale gas revolution in the USA

Global warming problem has prompted a shift in the use of natural gas with low CO2 emissions and in the use renewable energy in the countries such as EU nations and Japan.

However, countries such as China, India which have not imposed strong obligations to reduce CO2, resulted to heavily depend on coal fired power plant.

Also in the USA, Germany, South Korea, coal-fired power accounts for maximum share in power sector.

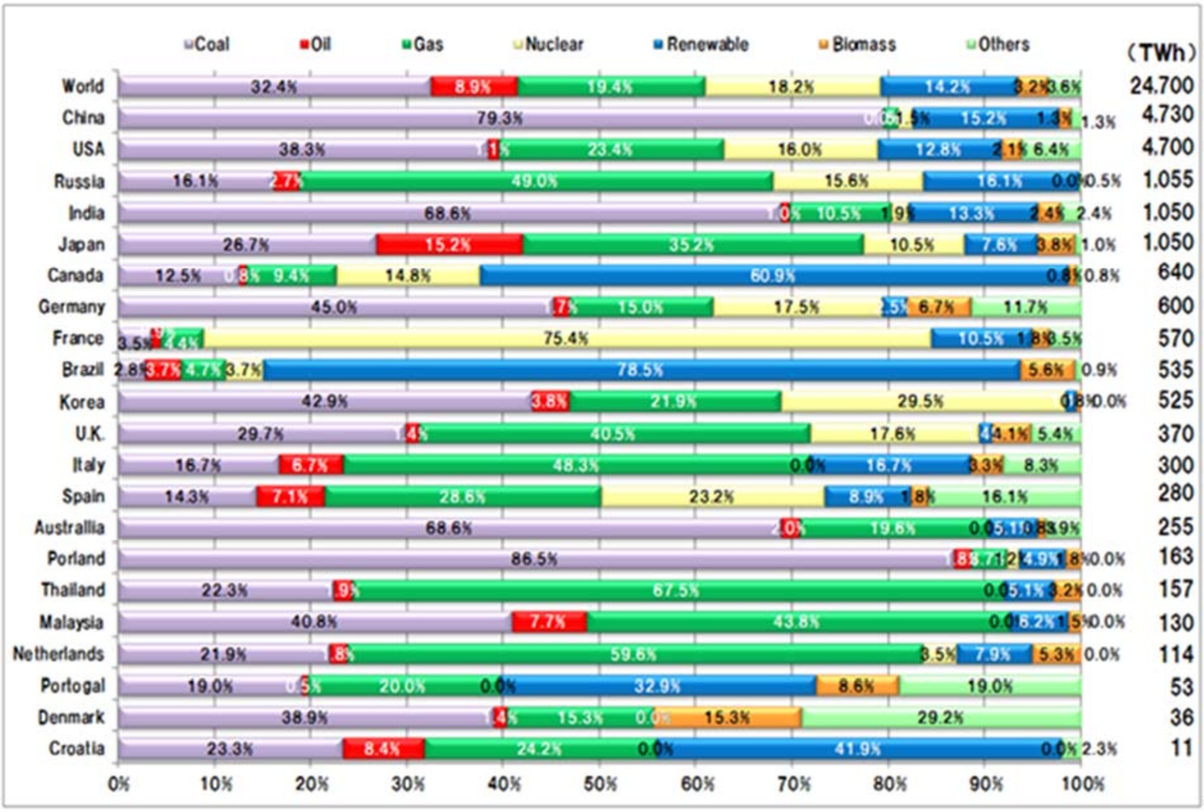


Fig.1 Energy Share in Power Sector

Fukushima nuclear accident has increased the awareness of promoting more renewable energy, and further increased awareness of energy conservation in some OECD countries such as Japan, Germany where the share of the nuclear power is relatively high.

In Japan as of July 2014, all nuclear power plants are not in operation for the re-examination of safety, the share of fossil fuel fired thermal power is over than 88%. The share of natural gas has also increased from 36% in 2011 to 43% in 2012. Since the natural gas fired power plant

have the advantage of flexible operations, it can correspond not only the base-load demand but also the peak load demand, and natural gas fired CCGT is evaluated for its relatively short construction period.
The re-examination of safety for nuclear power plants by Japanese Nuclear Safety Commission is very severe and it is unclear how many of the existing 54 nuclear power plants will pass the re-running review.
The Japanese government has attempted to accelerate to introduce renewables as an alternative of nuclear power and introduced FIT (Feed In Tariff) program with very high purchase prices of 0.4 $/kWh for the initial introduction.
However, actual introduced renewable power occupied only 1.6% of total power supply in 2013. In terms of the scale of the capacity required to replace the nuclear power, there is no doubt that natural gas fired power plant is the most likely alternative.

In Germany, in July 2011, the government has decided to shut down and abolish 8 old nuclear power plants and also decided to stop of 9 nuclear power plants in operation by 2022.
Instead of nuclear power, Germany has introduced the promotion of renewable energy, since wind power and solar power need backup power plants, the importance of thermal power plants has increased toward 2022. Especially, in order to maintain high purchase price by FIT system, expectation of inexpensive coal-fired power is increased more than the expensive natural gas-fired.

In Italy, national referendum in June 2011 resulted that they completely rejected re-operating existed nuclear power plant and decided not to reconstruct new power plant.
Originally, after Chernobyl nuclear power plant accident in the former Soviet Union in 1986, Italy once decided to abolish nuclear power plants in the referendum. After that, the number of natural gas power plants increased and the natural gas consumption has increased, but it created the high electricity price and it has become the burden on the people.

In Spain and in Sweden, both countries also have nuclear power plants and once decided to become independent from nuclear power plants, but these two countries decided to maintain certain percentage of nuclear power and to replace new nuclear power plants by introducing more renewable energy .

In France and the UK, these two countries keep using the nuclear power as the base load power.

In the USA, nuclear power plants are scheduled to newly install from 2016 to 2020, but the mainstream of the new introduction is the natural gas fired power plant. By the shale gas revolution, in the United States, it is expected that the use of natural gas becomes mainstream, and also natural gas power generation is getting large share in the power sector.

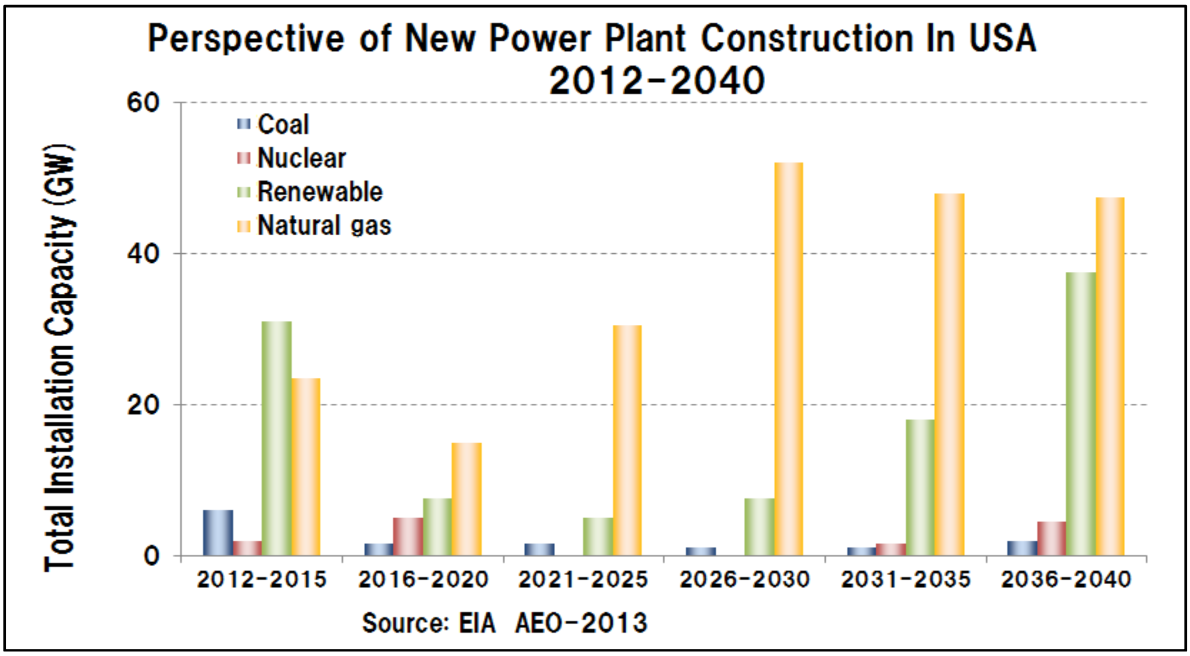
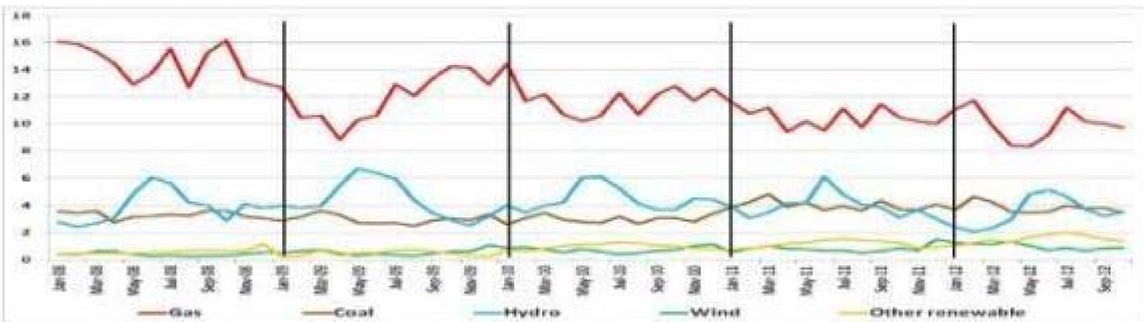


Fig.2 Perspective of new power plant construction in the USA

The shale gas revolution has had a significant impact on the power sector and industrial sector in the USA. Thanks to the shale gas revolution and the tight oil revolution, fuel prices of all fossil fuels including coal have dropped, especially the natural gas price becomes half or 1/4 compared to 5 years ago and becomes even or lower compared to the coal.
Several industries of the USA once have shifted their factories to South East Asia and China and are now returning to the United States again because of the lower fuel prices.
Unlike the USA, not many countries can enjoy the benefit of the shale gas revolution. Even some countries suffered negative impact on the natural gas consumption. Especially in the power sector in the EU, due to the over flow of the coal from the USA, the natural gas-fired power plant has lost its competitiveness to the coal-fired power. For example, in Germany, power generation cost of natural gas is higher than the wholesale electricity price.

In Germany, the rate of the operation of coal-fired power plants increases, relatively more costly natural gas-fired power plants are beginning to stop. Even though coal fired power plants emit more CO2 than the natural gas fired, from the view point of the economics, it is more cost saving to operate the coal-fired power plant with purchasing CO2 credits. As the results, natural gas demand in Germany has been sluggish these 3 years. This situation would not change until 2015.



Source: Author's calculations from ENTSOE's and Terna's data.

Fig.3 Italy's fuel share in the power sector

In Italy, situation is similar to Germany. Toward 2020, Italy has tried to diversify its energy portfolio to reduce the usage of the fossil fuel and increase the use of the renewable energy, however, only the share of natural gas has decreased dramatically while the share of coal has increased slightly.

In addition, about 30% of new planned thermal power plants in Italy are the coal fired plants.

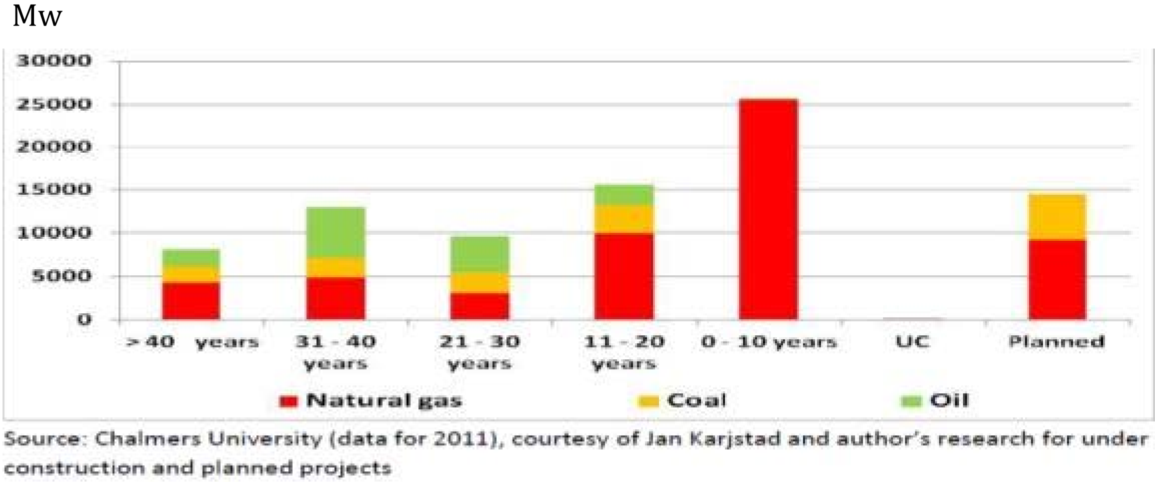


Fig.4 Result and Perspective of power plant construction capacity in Italy

In Asia, especially in the LNG importing countries, situation is more severe.

In Japan, for example, due to the increase of the high price LNG import to replace the nuclear power plants by natural gas-fired power plants, national trade deficits and soaring electricity prices have become a political issue, the government and major power companies have started considering the introduction of coal-fired power plants again. Because the electricity price produced by the coal fired is less than 1/3 of the natural gas fired, even if including CO2 credits cost.

In addition, efficiency of the state of the art coal fired power plant called IGCC(Integrated Gas fired Clean Coal) is greater than 48%. Japanese government and Tokyo Electric Power Company are making plan to construct new coal-fired ultra-high efficiency power plant as the symbol of Fukushima revival and reconstruction.

In a lot of countries outside USA, high natural gas price becomes big problem and natural gas has lost competitiveness to coal in the power sector.

In the industrial sector, traditional oil linked high price LNG and soaring electricity price causes another problem now in Japan. Industrial customers are accelerating to transfer their production sites to the USA and developing countries where energy cost is low and environmental regulation is not severe.

In order to maintain the industrial gas demand in Japan, it is vital to secure low price LNG for the power plants and the industrial use. The shale gas and CBM are new attractive source of LNG, since they are not linked to oil price and produced in politically stable countries outside of Middle East.

Once the benefit of the shale gas revolution widely spread over the world, it is expected that the price competitiveness of natural gas would not be the issue anymore. However, it may take some time to come true.

Since the nuclear power plant has lost its credit as the main power generator and renewable energies are still not sufficient to replace the nuclear power, in order to establish low-carbon society, it is necessary to introduce more natural gas in the power generation sector as well as industrial sector.

For this purpose, fuel switching to natural gas from other fossil fuel is important, however, it is not so simple. It is of course required that natural gas price should maintain reasonable price competitiveness and furthermore, the introduction of state-of-the-art technology and the most efficient technology which can achieve significant energy savings are indispensable.

Why do we carry out the "Fuel Switching" from other fuels to Natural Gas?

1. Why do we carry out fuel switching from coal and oil?

Natural gas is the most effective fuel to reduce CO2 emission and prevent global warming. Particularly it is very effective to carry out the fuel switching from oil and coal in the industrial sector where fuel consumption is large.

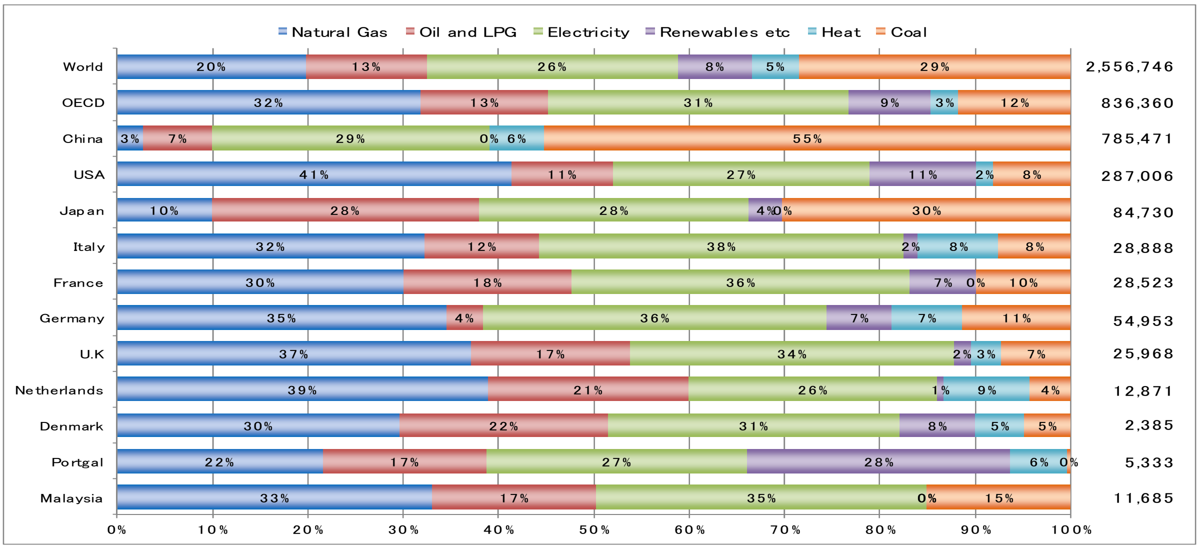


Fig.5 Energy share of the world and major countries in the industrial sector

The energy share of the world and of the major countries in the industrial sector is shown in Figure5. Natural gas share is about 32% in the total OECD countries, but coal and oil also have also secured a certain share.

Looking at individual OECD countries, France, the United Kingdom, and the Netherlands, the ratio of oil accounts for 17-21%, the ratio of coal also accounts for over10% in Germany and France and even in the USA, the ratio of oil is still over 10% and the ratio of coal is 8 %.

Especially, in the USA and Canada, thanks to the "Shale Gas Revolution", the price of natural gas is as low as 1/4 to 1/5 of oil in the industrial sector and in many EU nations, natural gas price is 1/2 to 2/3 compared with oil price. In these countries, it is easy to carry out fuel switching from oil to natural gas because investment recovery period is very short.

On the other hand, LNG importing countries such as Japan, the ratio of oil and coal is around 30% whereas the ratio of natural gas is 10%. In LNG importing countries, natural gas price has been much higher than oil price. Recently, the cost difference is shrinking, but natural gas is still about 10% higher than oil.

Therefore, when performing the fuel switching from oil to natural gas, substantial energy saving is required to reduce energy consumption and total energy cost.

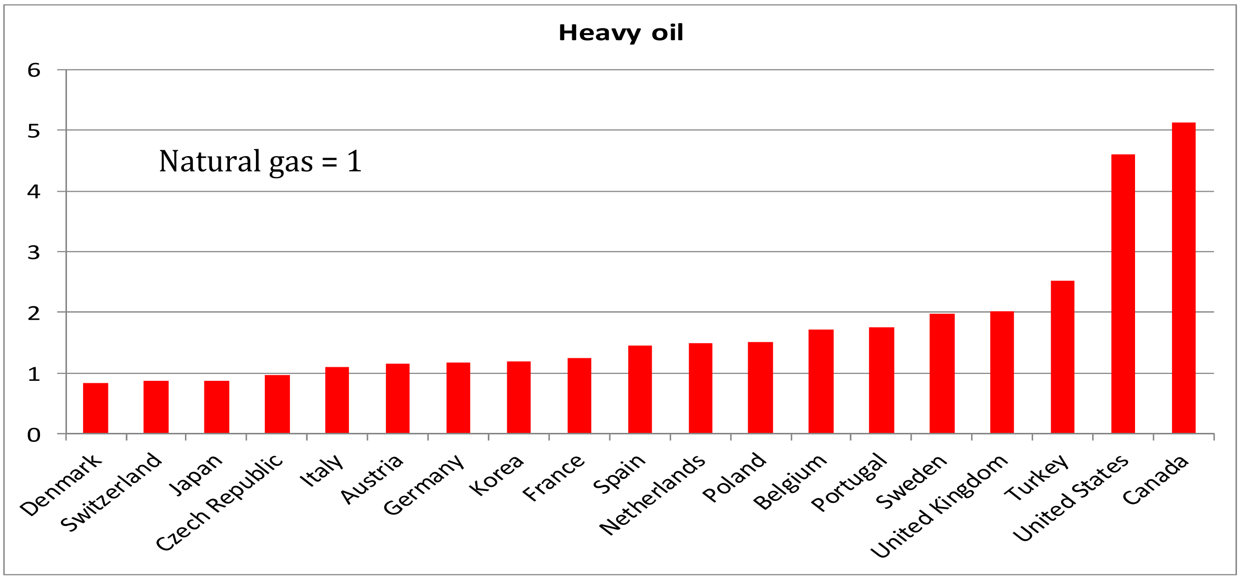


Fig.6 Comparison of the natural gas price and the heavy oil price in major countries in the industrial sector

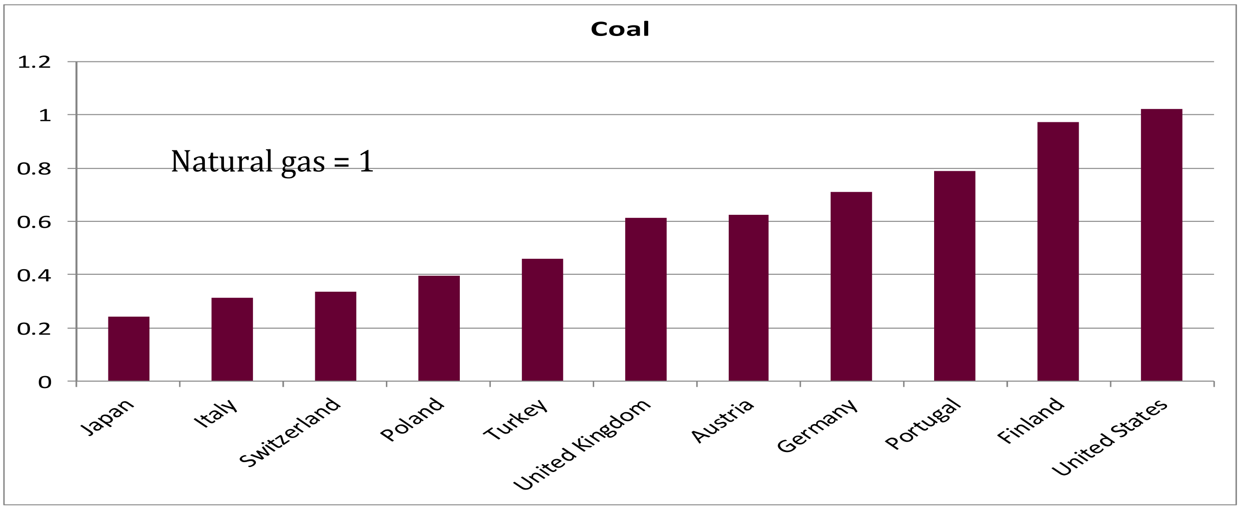


Fig.7 Comparison of the natural gas price and the coal price in major countries in the industrial sector

Carrying out fuel switching from coal is very difficult. Usage of coal for industrial sector is limited to some big industrial customers who use a large amount of steam such as paper industries or chemical industries. They have large scale coal fired boilers and it is very difficult to carry out to switch these boilers to natural gas because of the large difference of the fuel cost. However, it is not impossible to carry out fuel switching to natural gas from coal. For example, if customer has a number of equipment which use steam, central installation type large scale coal-fired boiler system has many heat loss points such as steam leakage and heat loss from long steam transportation piping and heat loss due to partial load operation or stand-by state. It is very rare that all equipment are working at the same time, so central installation type boiler sometimes becomes partial load operation or stand-by state. In this situation, boiler efficiency is low and heat loss is large. On the other hand, gas fired system, it is possible to install high efficiency small gas boilers beside the equipment, and it can be operated respectively under the more efficient state without any heat loss from the pipe. Decentralized installation of gas fired boiler system can achieve massive energy saving.

Advantages and disadvantages of natural gas in the industrial sector and power sector are described as follows.

- <u>Advantages of Natural Gas</u>

1. Easy to reduce CO_2 emission

Natural gas is the least CO_2 emitting fuel among all fossil fuels. Only shifting to natural gas, CO_2 emission can be reduced by20%.from heavy oil and 40% from coal.

2. Easy to achieve massive energy saving

In LNG importing countries, the natural gas price is higher than the heavy oil price, then simple fuel switching is not acceptable for industrial customers, so it is essential to achieve massive energy saving. Even if massive energy saving is achieved; fuel switching from coal to natural gas is difficult for the huge difference of fuel cost. Additionally, low CO_2 emission from natural gas can help fuel switch of coal-fired boiler for some coal-fired customers in air pollution control severe area.

For oil-fired furnace or boiler user, fuel switching is easy, because thanks to the cleanliness and good combustibility, it is possible to adopt the advanced waste heat recovery technologies and to use high-performance burner. Combined these techniques, natural gas can reduce 50% CO_2 emission, in case of fuel switching from oil at the industrial customers.

3. Easy to improve customers product quality and yield of product

Natural gas emits no Sox and fewer Nox, so customer can easy improve their product quality. For example, in the heat treatment process in metal industry, the product surface scale becomes thinner and yield of the product is improved. For the same reason, the texture of the product is improved even in the textile drying and the yield of the product is improved. In almost all industries, by fuel switching from oil to natural gas, their product quality and yield of product is improved.

4. Good affinity with renewable energy

Food industry disposes a lot of food residue and organic waste water. On the other hand, it is recommended to reuse those as a source of energy. In many cases, food processing factories introduce biogas fermenter to recover energy from the waste. Since main component of Biogas is CH_4, biogas is very familiar with natural gas and most effective way to use biogas is mixing it with natural gas.

- <u>Disadvantages of Natural Gas</u>

1. High energy cost

Outside of the USA, as the fuel for thermal power or the fuel for the steam boiler of big industrial customer, the price of natural gas is very higher than the coal. The price of natural gas is twice or 3 times higher than that of coal all over the world outside of the USA.

For the industrial user, compared with the heavy oil, should natural gas 10-30% higher.

2. Huge infrastructure cost

・Gas supply side

LNG terminal construction cost, pipe line installation cost is huge and construction work also needs long period.

・Gas user side

Gas pipeline and auxiliary equipment (regulator, shutdown valve, and gas-meter) installation cost is needed. Oil is needed oil tank, but generally gas auxiliary equipment is higher than oil equipment.

3. Severe ISO standard for gas furnace compared to the oil furnace

   Gas furnaces are needed more safety devices than oil furnaces and the ISO standard for gas is more severe than for oil.

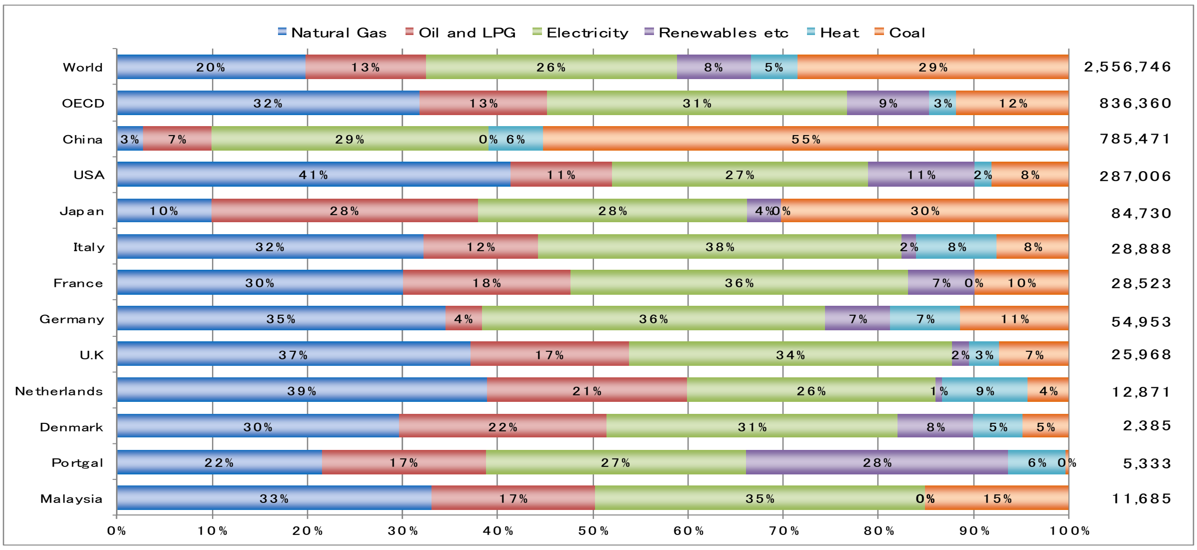
4. Inferior heat transfer characteristics for high temperature furnace

   For the high temperature furnace, such as glass melting furnace, the heat transfer is mainly depending on the radiation. In this case, the flame of natural gas has lower heat transfer than that of oil because of the lower brightness flame of natural gas compare to the oil.

As listed above, natural gas has advantages and disadvantages, but in the industrial sector, most Items of disadvantages are related economic issues such as running costs and equipment costs which can be overcome with massive energy saving .
The greatest advantage of natural gas is to help preventing the global warming.
For this reason, the fuel switching to natural gas from other fossil fuel is significantly important and we must actively promote this fuel switching for ourselves and our future generations.

2. Why do we carry out fuel switching from electricity?

As shown in Figure 5, in the industrial field, in almost all countries around the world, electricity plays the major roll.



This is simply because, besides heating furnace, there are a lot of kinds of equipment which need electricity as power source; such as press machine, milling machine, conveyors, pumps and motors etc.
In these cases, however, installation of gas-fired CHP system can be meaningful to save energy and prevent global warming.

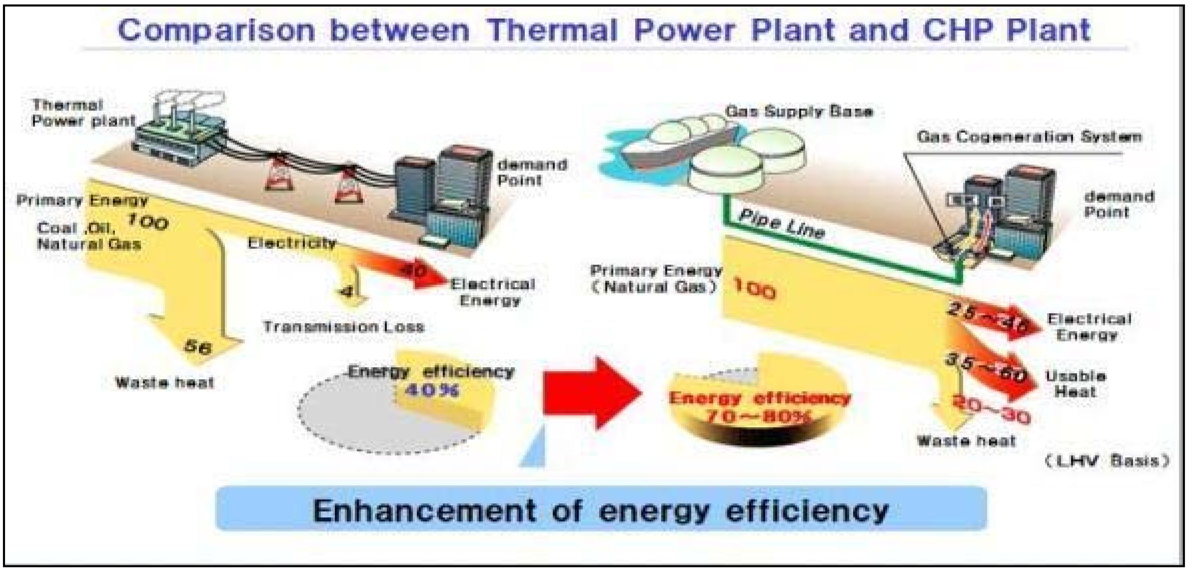


Fig.8 Comparison of central type power station and on-site CHP system

In the world, power efficiency of central type of thermal power plant is about 30-60% (60% is the highest in the world currently for the Gas fired CCGT case).

As shown in Figure 8, if CHP system is installed on-site, the waste heat from power generation can be used in the production process so that total energy efficiency becomes around 70% to 80%. Furthermore, if industrial customers use electric furnaces for producing process, replacing such furnaces from electricity to waste heat can achieve a significant energy saving and cost reducing in many cases. In many countries of the world, generally electricity is more expensive than natural gas.

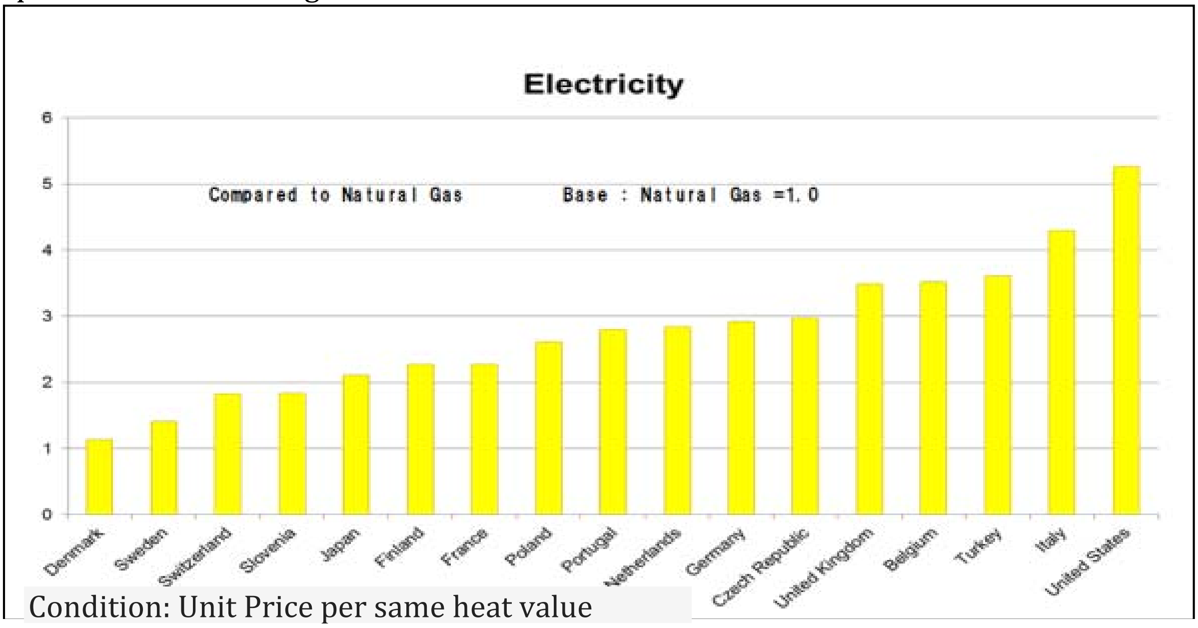


Fig.9 Comparison of the unit price between electricity and natural gas

As shown in Figure 9, in the most countries, the unit price of electricity is more than twice the unit price of natural gas. If heating efficiency is same, customers can reduce running cost to half without any energy saving technologies. However, it is necessary for the natural gas fired furnace to discharge the combustion exhaust which is not required for the electric furnace, as the result, the heating efficiency of electric furnace is higher than that of gas fired furnace. In

particular, in the case of high-temperature furnace, since the energy loss of exhaust gas is large, the gas furnace is required installation of the exhaust heat recovery device.
As shown in Figure 1, since electricity in the most countries of the world derives from fossil fuels, then total efficiency of electricity is low. In the long run, natural gas fired furnaces can reduce CO_2 emission compared to electric furnaces.

The advantages and the disadvantages of natural gas compared to electricity are described below.

- Advantages of Natural Gas

1. Low running costs in product manufacturing
2. Low total equipment cost
   Total equipment cost of electric furnace is higher than the natural gas furnace because electric furnace needs the expensive power receiving equipment, whereas gas furnace needs chimney or exhaust duct and gas regulator etc.

Ex.	6.6kV 2000kW power receiving equipment	around	500,000 $
	Gas meter and regulator 300 m3/h (45MJ/M^3)	around	40,000 $
	Chimney and exhaust duct	around	10,000 $

3. Easy to reduce CO_2 emission

Ex.	Electricity	6.6Kv 2000kW	920kg-CO2/ 2000kwh
	CO2 emission	Intensity	0.46kg/kWh(2010 Germany)
	Gas	300m3	687kg-CO2/300 m3
			2.29kgCO2/m3 Gas (45MJ/m3) ▲25% CO2 reduction

- Disadvantages of Natural Gas

1. Poor product quality at high temperature furnace
   Product scale loss of the forging furnace, compared to the electronic induction heater
2. Difficulty to realize super high temperature heat treatment
   Ex. Vacuum metal heat treatment furnace
3. Limitation on location of furnace
   Chimney or exhaust duct is needed for gas furnace
4. Complicated operation
   Operation of gas furnace is more complicated compared to the electric furnace
5. High furnace cost and heater
   Generally gas furnaces and gas burners are expensive compared to electric furnaces and electric heaters

Potential of fuel switching

As shown Figure 5, in the industrial sector, there are much potential for natural gas to fuel switch. The main target is the fuel of oil, coal and electricity used for furnaces.

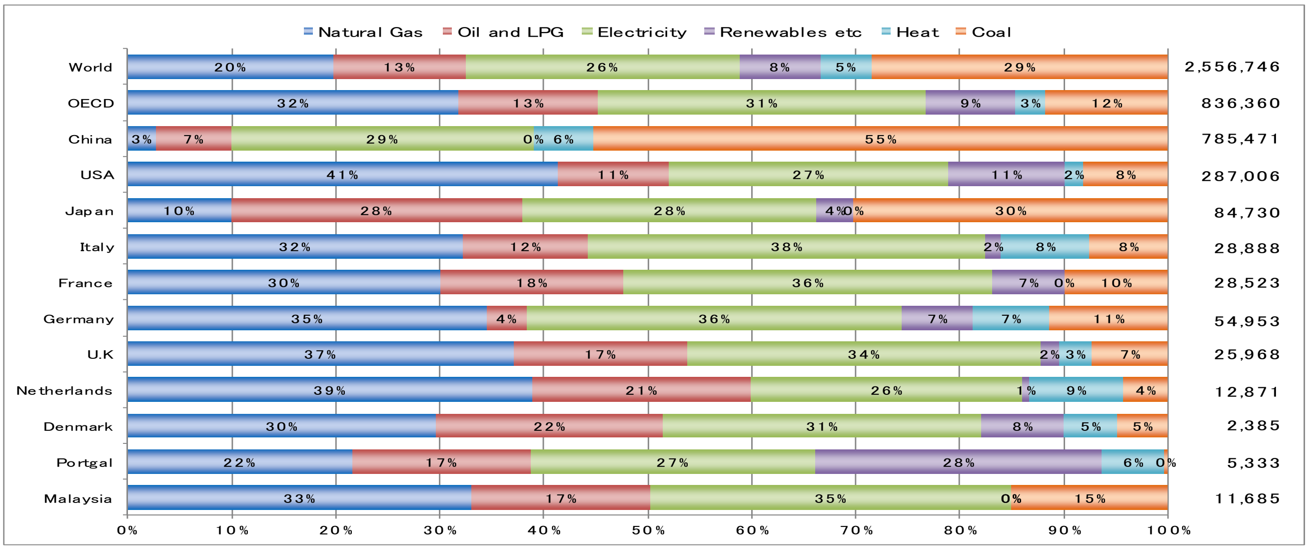


Fig.5 Energy share of the world and major countries in the industrial sector

The aim of fuel switching by natural gas from other fuels is obviously to expand the usage of natural gas, however, by taking advantage of the environmental friendliness of natural gas, there is a great expectation of the outcome of the fuel switching by natural gas, which is to reduce the impact on the global warming.

It is needless to say that replacing oil or coal by natural gas surely reduces the amount of the emission of CO2, NOx and SOx. Replacement of electricity by natural gas seems to increase the emissions at a factory, however, in the most of the countries, electricity is mainly generated by oil or coal at between 30 to 40% of the efficiency, then unless the efficiency of electricity appliances is more than 3 or 4 times of the natural gas appliances, fuel switching by natural gas from electricity is also contribute to reduce the impact on the global warming.

Furthermore, with its cutting edge technologies, natural gas can achieve higher efficiency and reduce the energy consumptions. If the amount of energy to be used is reduced, it results of reduction of the emission of CO2, NOx and SOx.

Thus, development of the fuel switching by natural gas contributes not only for natural gas market enhancement but also for the global environment.

Technologies of "Fuel Switching"

Natural gas is the least CO2 emitting fuel for the same amount of heat among all fossil fuels. If the heat requirement in the industrial furnace is the same after conversion from the other fuel, only by shifting to natural gas, CO2 emission can be reduced by 25% from heavy oil and 40% from coal.
In 2008 at the G8 summit, the developed countries have pledged to aim to reduce CO2 by 80% in 2050. This goal is too high to be achieved only by simple fuel conversion, but by introducing highly efficient gas system with cutting edge technologies. Especially, for high-temperature furnace, the flame intensity of natural gas is lower than that of heavy oil then the simple fuel switching to natural gas will increase the energy consumption by 3-10%.
Furthermore, the equipment change cost on the fuel switching to natural gas is also large, in order to create enough benefit to the customer, the fuel switching is required to achieve significant energy saving.

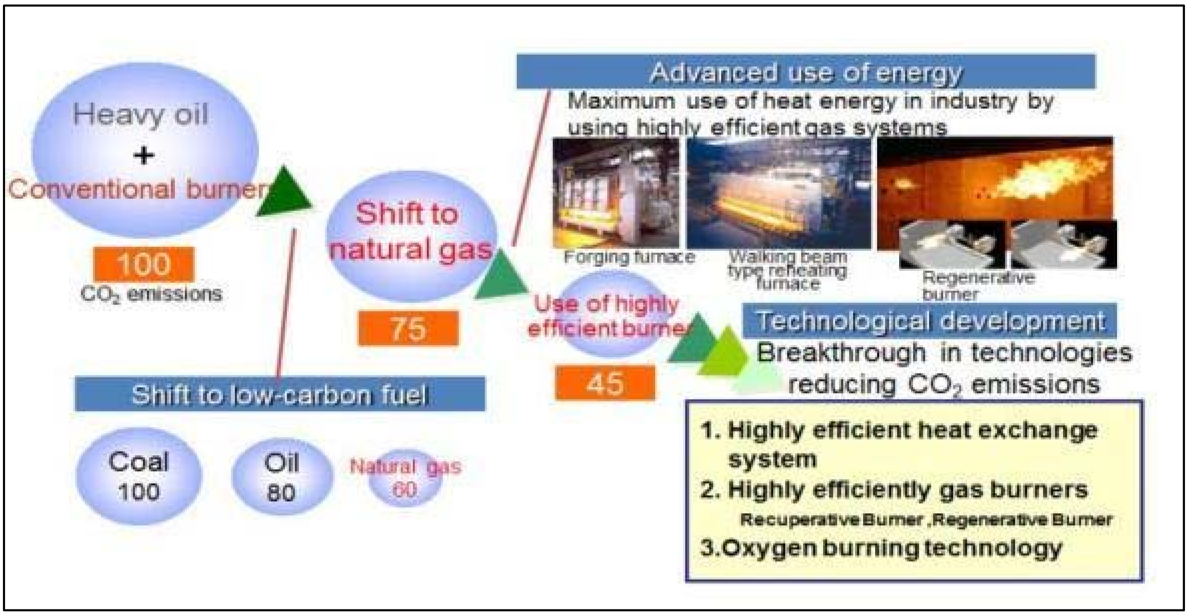


Fig.10. Massive CO2 reduction by natural gas

1. Typical industrial furnaces

There are various types of furnace that are used in the industrial sector and operated under the different conditions, such as the temperature region, the heating atmosphere, etc. Thus, the method of energy saving for each furnace is different. Fig. 11 shows typical industrial furnaces.

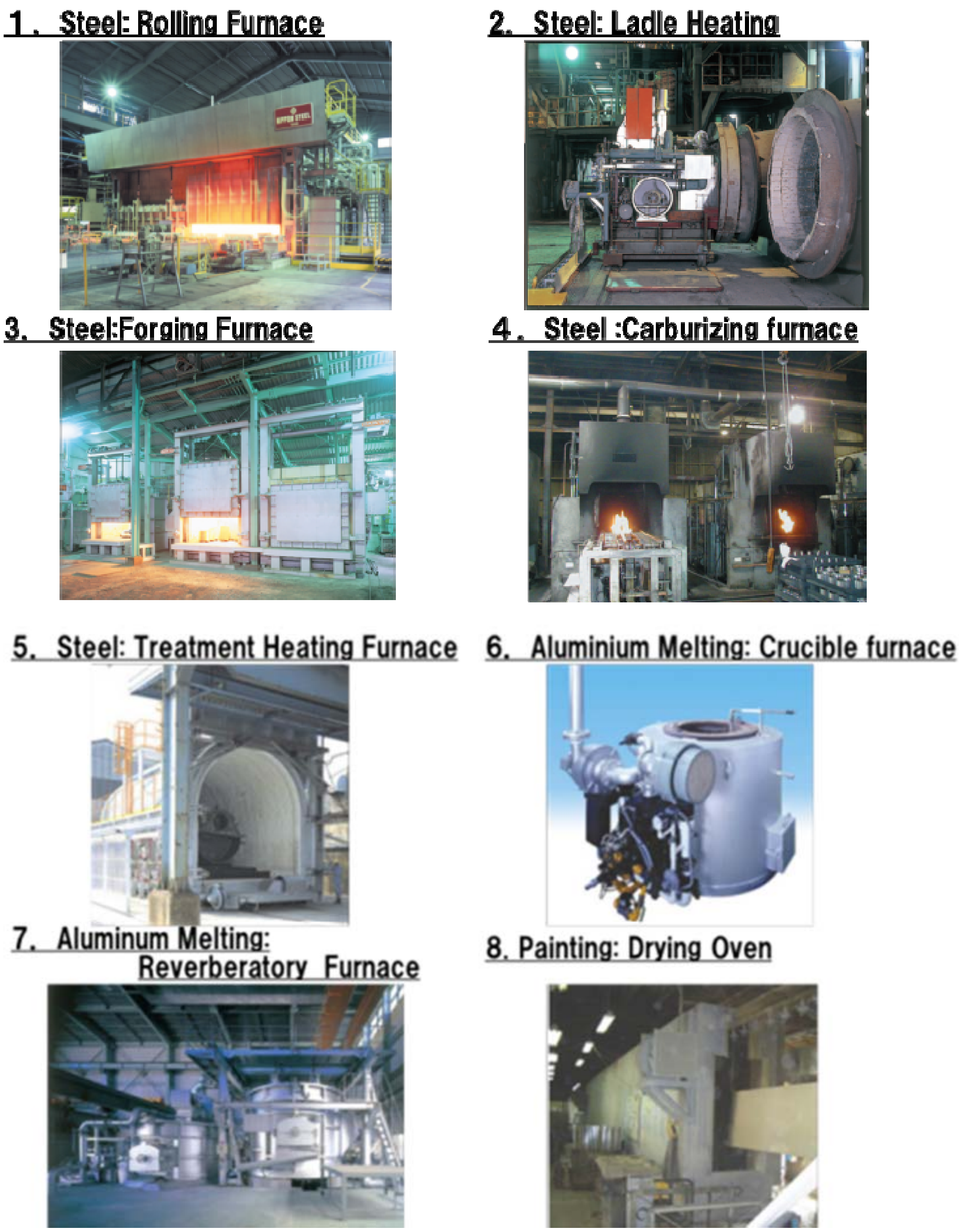


Fig.11 Typical industrial furnaces -1

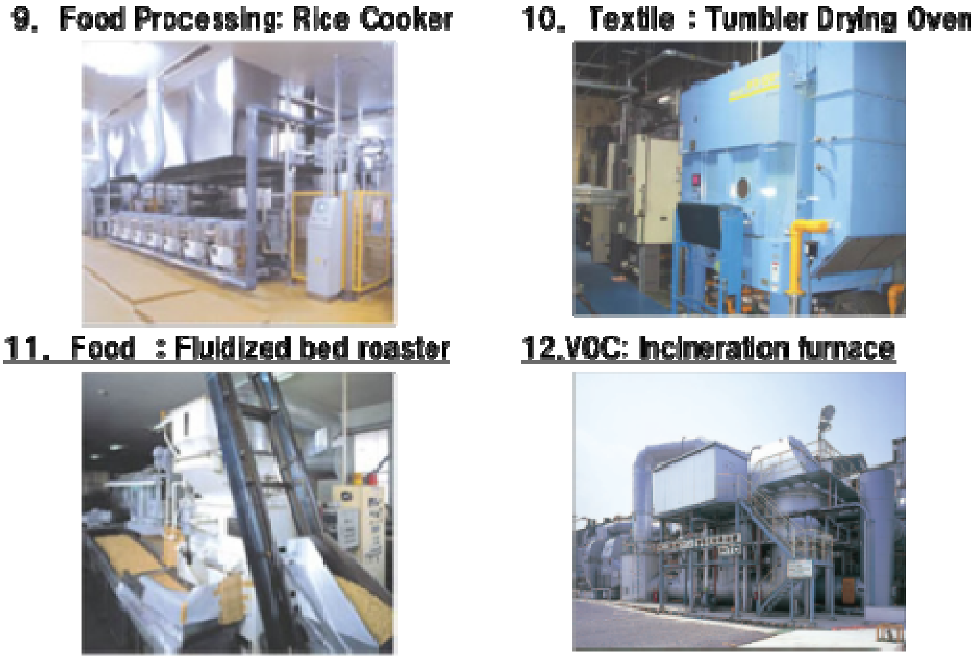


Fig.11 Typical industrial furnaces -2

2. The procedure of energy saving

Heat loss is the biggest factor which reduces the efficiency of the industrial furnaces, so reducing the heat loss is the best way to save energy.

Since there are various heat losses when manufacturing an industrial product, there is a big difference between the quantity of heat required for a product and the quantity of heat to supply.

To reduce heat losses, there are 3 steps as shown in the Figure 12. The total amount of expenses and the effect of energy saving differs from every step.

1. Simple energy saving without expenditure except natural gas burner installation and re-adjustment of combustion condition.
2. Introduction of cutting edge technology
3. Change process or system etc.

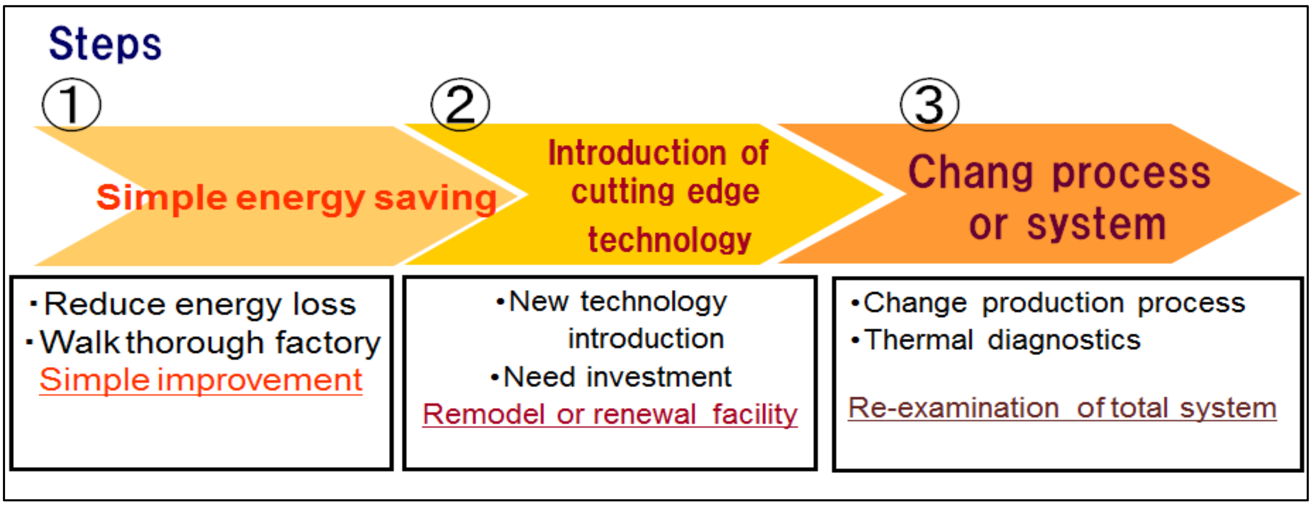


Fig.12 Steps for energy saving

Key point of energy saving to reduce heat losses are shown in Figure. 13

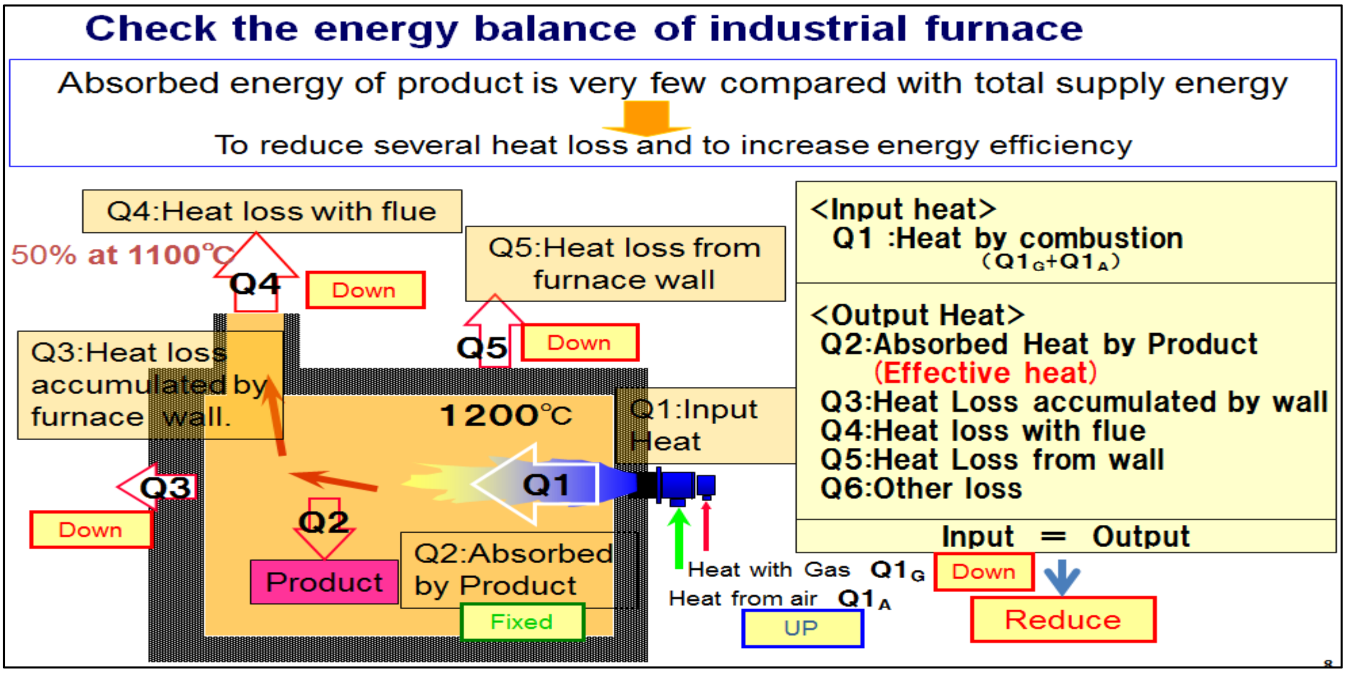


Fig. 13 Key points of energy saving

1. **Simple energy saving**

First step is to reduce these heat losses.

Only by reducing these heat losses, significant amount of energy can be saved without large expenditure. For example, the heat loss of flue gas, Q4 in Fig13, can be reduced massively only by changing from the oil burner to the gas burner. Because as for the oil combustion, in order to obtain good combustion, it is necessary to supply more excess air to the theoretical combustion air compared with natural gas combustion In the case of gas combustion, 1.05-1.2 times as much excess air as theoretical combustion air is need whereas in oil combustion, the 1.3-1.5 times as much excess air is needed as theoretical combustion air.

Especially when the furnace temperature reaches a regular operating condition, the required quantity of heat becomes the minimum and supplied fuel flow rate becomes minimum, in the case of gas combustion, about 1.2 times may be sufficient as an excess air ratio but in oil combustion, it becomes 1.5 or more times.

As a result, the exhaust gas loss in oil combustion increases more than that of gas combustion considerably.

Moreover, in case of oil combustion, oil atomization is needed for getting good combustion, so it is not possible to reduce significantly fuel flow rate. If flow rate is reduced less than 1/3, the pressure of oil and air spraying becomes less than 1/9 and atomization condition becomes worse to keep good combustion. For this reason, oil burner's turndown ratio is limited to about one-third, whereas gas burner's turn down ratio is 1/10.

When furnace temperature reaches a regular operation state, in case of gas combustion, the continuous combustion at minimum fuel flow rate is constantly possible, but at low combustion condition, minimum flow rate of oil combustion is higher than that of gas, the on-off combustion is repeated in case of oil combustion.

Air purge is always performed at the time of burner ignition in case of the on-off combustion, an exhaust loss increases remarkably..

The supply amount of air required for combustion of the normal gas burner is said to require 1.1-1.2 times for the stoichiometric quantity of combustion air, whereas in case of oil, it is necessary 1.3-2.0 times for the stoichiometric quantity of combustion air.

As for the batch type of high-temperature furnace, such as the metal heat treatment, the furnace temperature at 1000 degree C or more, only simple fuel switching to natural gas from oil can attain massive energy saving.

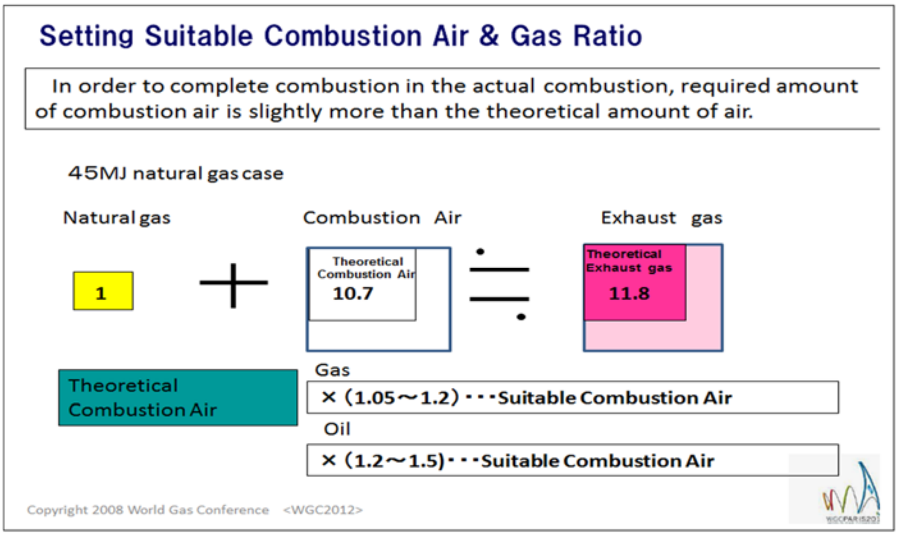


Fig.14 Excess combustion air ratio

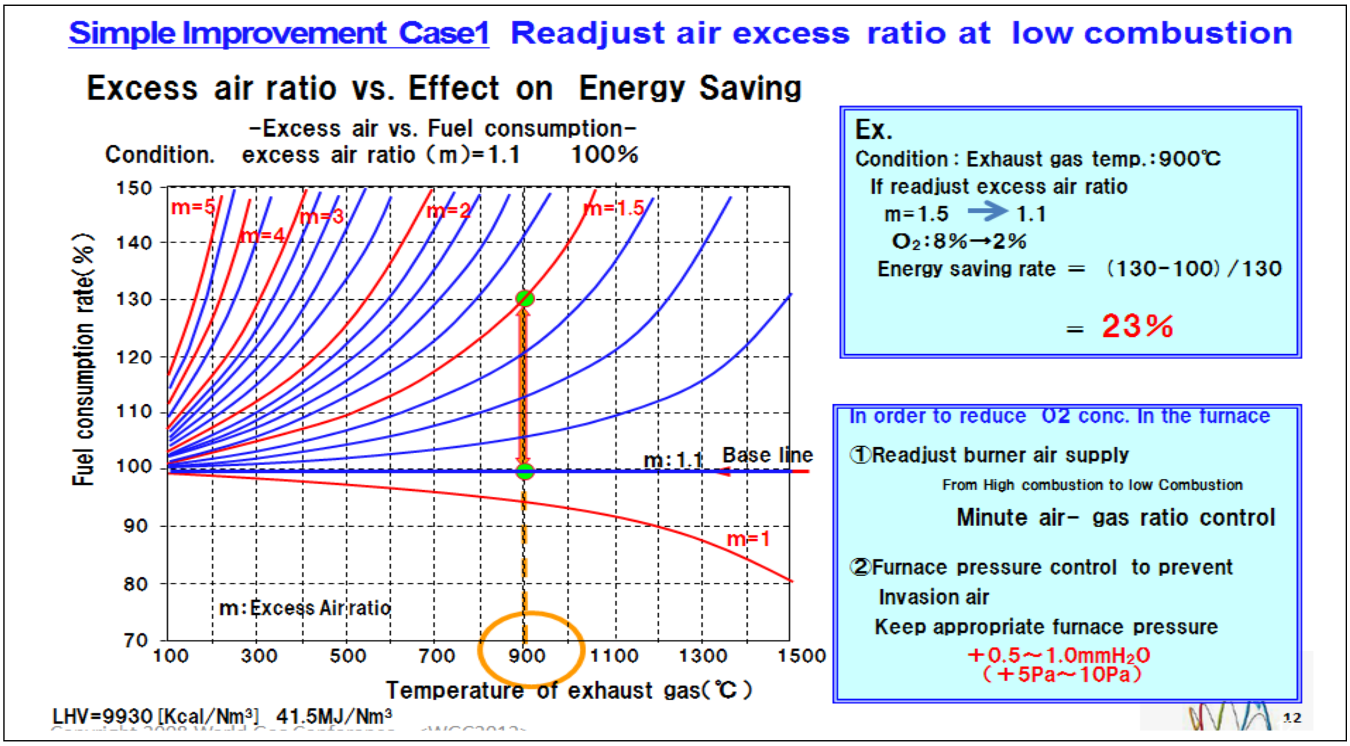


Fig.15 Energy saving by Improvement of Excess Air ratio

In case of simple fuel switching from oil to gas and re-adjust excess air ratio from 1.5 to 1.1, about 23% of energy can be saved and CO2 emission is reduced by 50%. Even if excess air ratio can't be improve and fuel consumption is as same as before, after conversion from heavy oil Bunker A to natural gas, CO2 emission can be reduced by 24.3%.

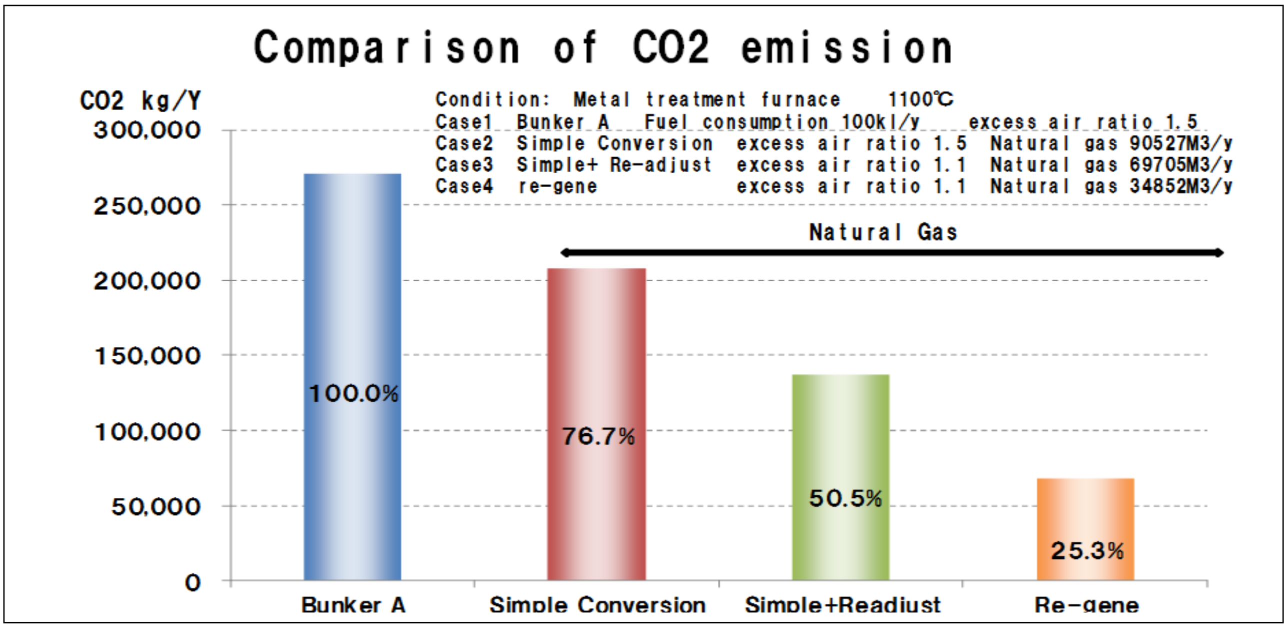


Fig.16 Comparison of CO2 emission by each type of conversions

If adopting the cutting edge technology such as the high performance re-generative burner, fuel switch to natural gas can reduce CO2 emission by 74.7%.

The calculated results of the payback time of fuel conversion from heavy oil to natural gas in OECD countries are shown in Figure 17. The data for this calculation of the payback period is based on the industrial users' fuel unit price listed in the "Key World energy Statistic 2013" issued by IEA

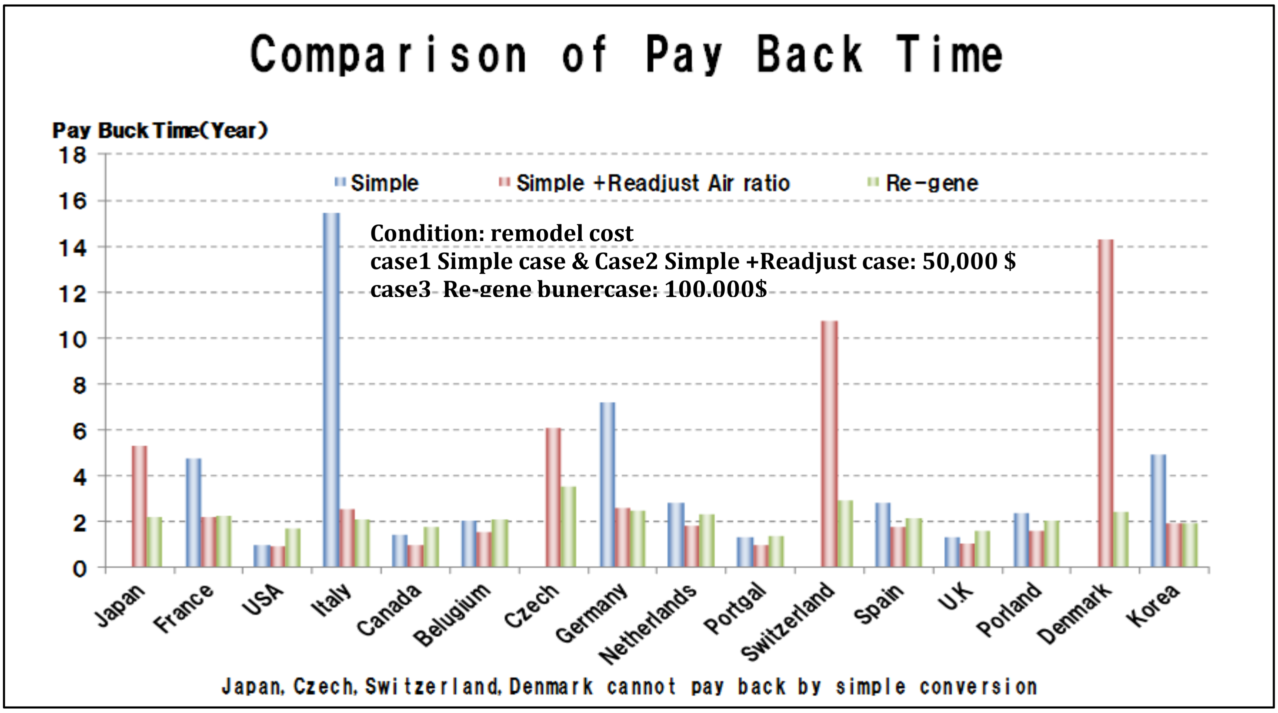


Fig.17 Payback time of fuel conversion in each country

It is obvious that it is very easy to pay back by only simple fuel conversion in the countries such as USA, Canada, Portugal, U.K, where heavy oil is expensive and natural gas is very cheap.
But, in the countries such as Japan, Czech, Switzerland and Denmark where heavy oil is cheap and natural gas is expensive, it is not possible to carry out fuel conversion only by simple fuel switching and improving excess air ratio.

2. **Introduction of the cutting edge technology**

When converted from heavy oil to natural gas, adopting the state of the art technologies such as re-generative burner system can play an important role to recover investment cost. Not only for the economic benefit, but also industrial customers can save energy by more than 60% and reduce CO2 emission by 75% by adopting the gas fired re-generative burner system. (See Fig 16)

In the USA, Canada and Portugal, the payback time of the simple conversion is shorter than that of re-generative burner system, but total economic benefits of industrial customer by re-generative burner system is much more than that of the simple conversion.

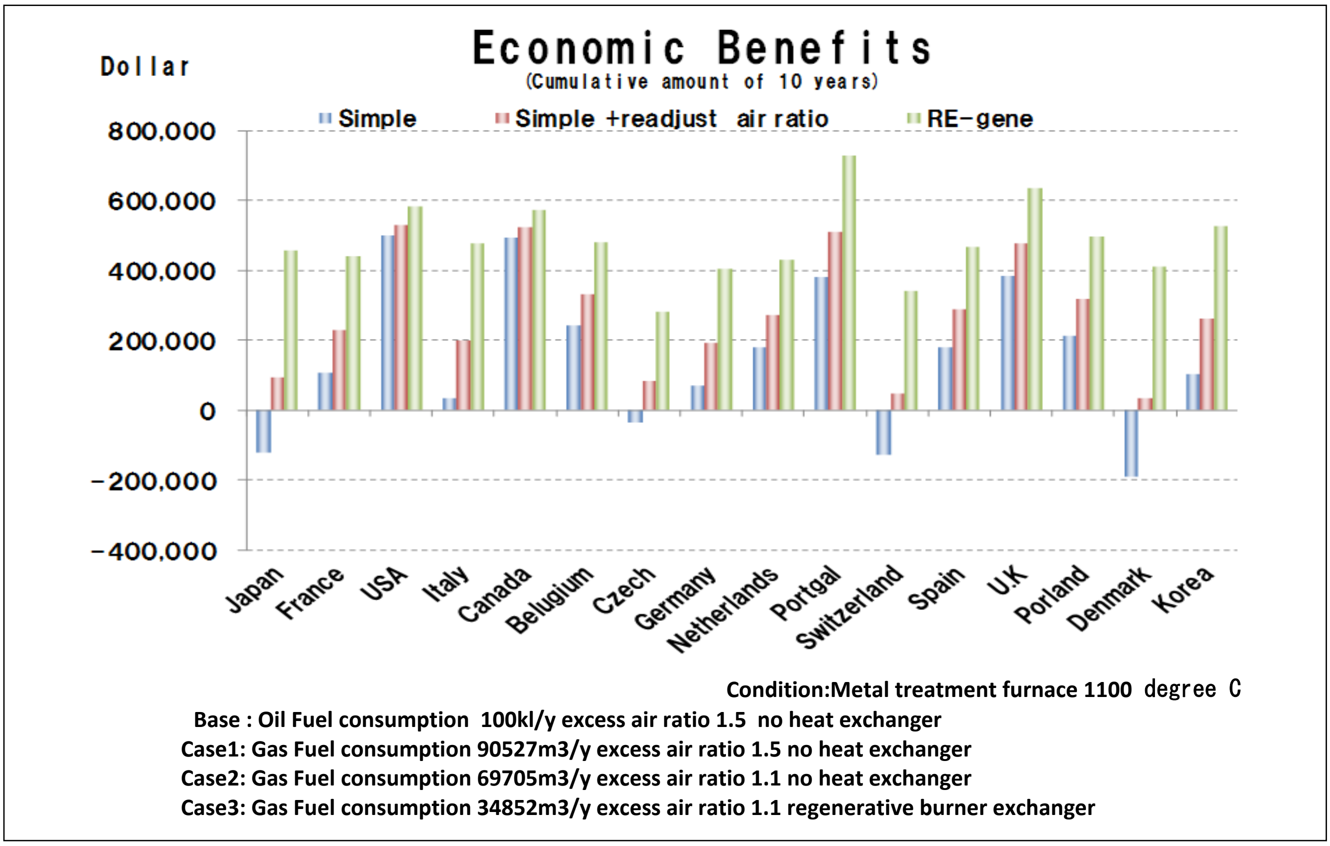


Fig.18 Economic Benefit of fuel switch in each country

	Heavy fuel oil for industry (MWh)	Nat. gas for industry (MWh)	Steam coal for industry (MWh)	Electricity for industry (MWh)
Austria	67.4	58	36.3	..
Belgium	61.57	35.99	..	126.61
Canada	61.0	11.9	..	..
Czech Republic	47.42	48.82	c	144.87
Denmark	77.5	92	..	104.15
Finland	..	45.75	44.5	103.89
France	63.8	51.14	..	116.33
Germany	60.18	51.04	36.3	148.71
Italy	74.28	68.0	21.4	291.79
Japan	80.51	92.05	22.24	194.27
Korea	77.8	64.80	..	88.64..
Netherlands	57.9	38.62	..	109.51
Poland	66.7	43.96	17.36	114.59
Portugal	92.68	52.70	41.52	147.30
Slovenia	..	64.38	..	117.77
Spain	63.66	43.97	..	..
Sweden	124.8	63.32	..	89.19
Switzerland	62.3	71.71	24.15	130.24
Turkey	104.1	41.15	18.89	148.22
United Kingdom	77.9	38.45	23.53	134.17
United States	58.66	12.74	13.02	66.98

(a)Prices are for 1st quarter 2013 for oil products, and annual 2012 for other products.
(b)Low sulphur fuel oil, high sulphur fuel oil for Turkey and the United States.
(c)For commercial purposes.
(d)Unleaded premium (95 RON);unleaded regular for Japan.
(e)Gross calorific value.
(f)Brown coal for Turkey.
.. Not available
x not applicable
c confidential

Source: "Key World energy Statistic 2013"

Fig, 19 Fuel prices of OECD countries

Simple fuel conversion is easy only in a country where natural gas price is very cheap, but also it is possible for every country to carry out natural gas conversion by adopting the advanced technology , which can achieve energy saving and significant CO2 reduction .

At the same time, adopting advanced technology brings significant economic benefits to industrial customers.

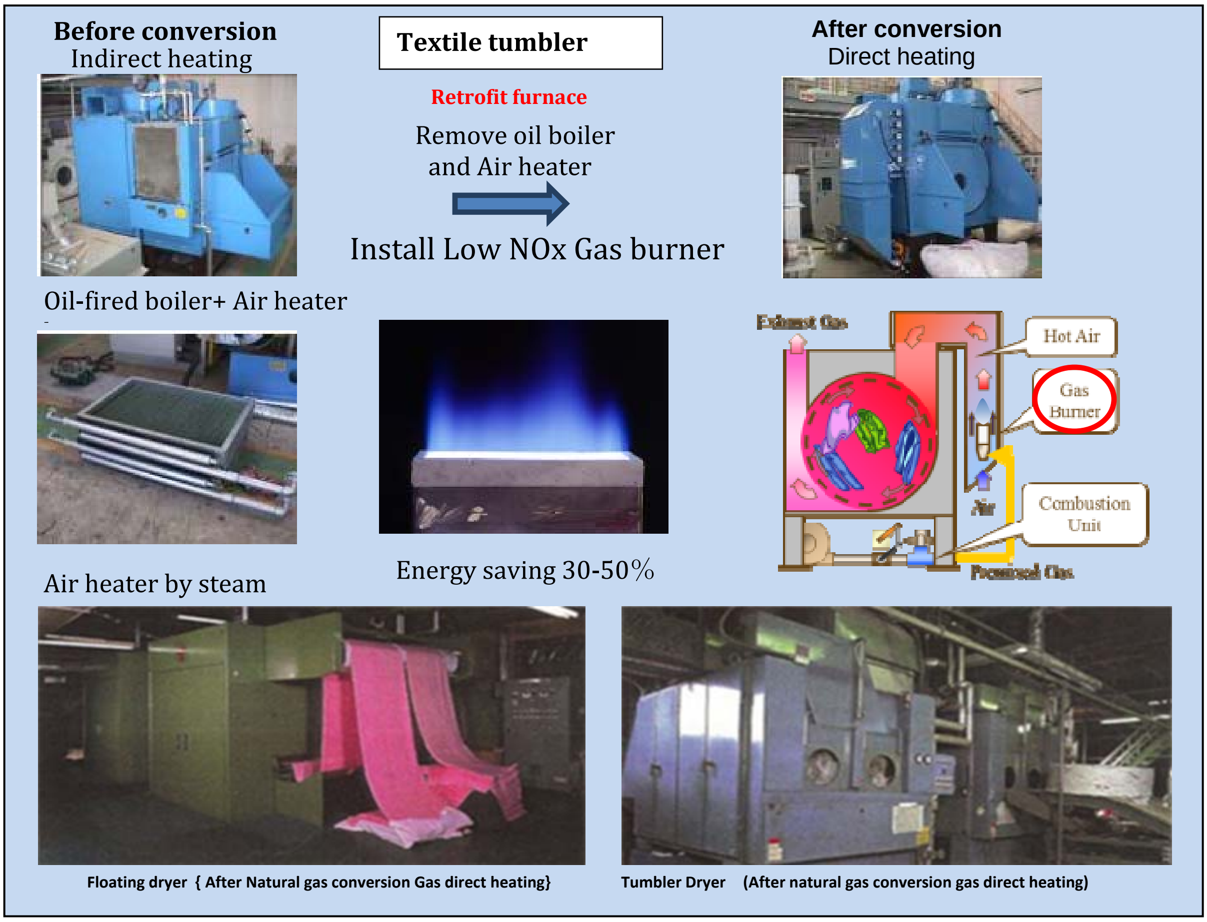
3. Changing process or system associated with the natural gas conversion

If an industrial customer has a high efficient oil- fired boiler, simple fuel switching is very difficult, especially in the county where natural gas is imported as LNG and gas price is very high. In this case the changing process is the effective solution to carry out fuel switching from oil to natural gas.

For example, in a textile drying industry, the customers use oil-fired steam boilers and generated steam and using this steam to generate hot air by heat exchanger for drying textile.

In this case, simple fuel switching such as only replacing oil-fired boiler to gas fired boiler is very difficult due to the efficiency of the oil fired boiler and gas fired boiler are not so different. In this case, changing indirect heating to direct heating is very effective to take the advantage of natural gas.

Because exhaust gas of oil fired burner is dirty and contains high level of NOx or SOx and a little particulate material such as soot, on the other hand, exhaust gas of natural gas is very clean, so it is possible to generate hot air using this exhaust gas directly. In case of indirect heating system which uses oil boiler to produce steam and hot air produce by such steam, there are many points to create losses during the system flow; such as drain loss, heat exchanger loss and so on. On the other hand, direct heating system is quite simple and there is no chance to create heat loss. This changing process from an indirect hot air generation system to direct hot air drying, it is possible to reduce the energy consumption by around 30-50%. Changing the process can create more benefit to customers such as reducing labor costs due to free from boiler management or maintenance work and improving productivity because of increased hot air temperature.



Fig, 20 changing process

Case studies

Fuel switching by regenerative burner

In the industrial sector, especially in the field using high temperature heating furnaces, such as metal heat treatment and forging, a lot of energy is consumed and many oil fired burners are still used.
When promoting fuel switching from oil to natural gas in these fields, one of the most important technologies is the re-generative burner system.
In this section, fuel switching by regenerative burners and its case studies are described in more detail.

1. **Types of re-generative burners**

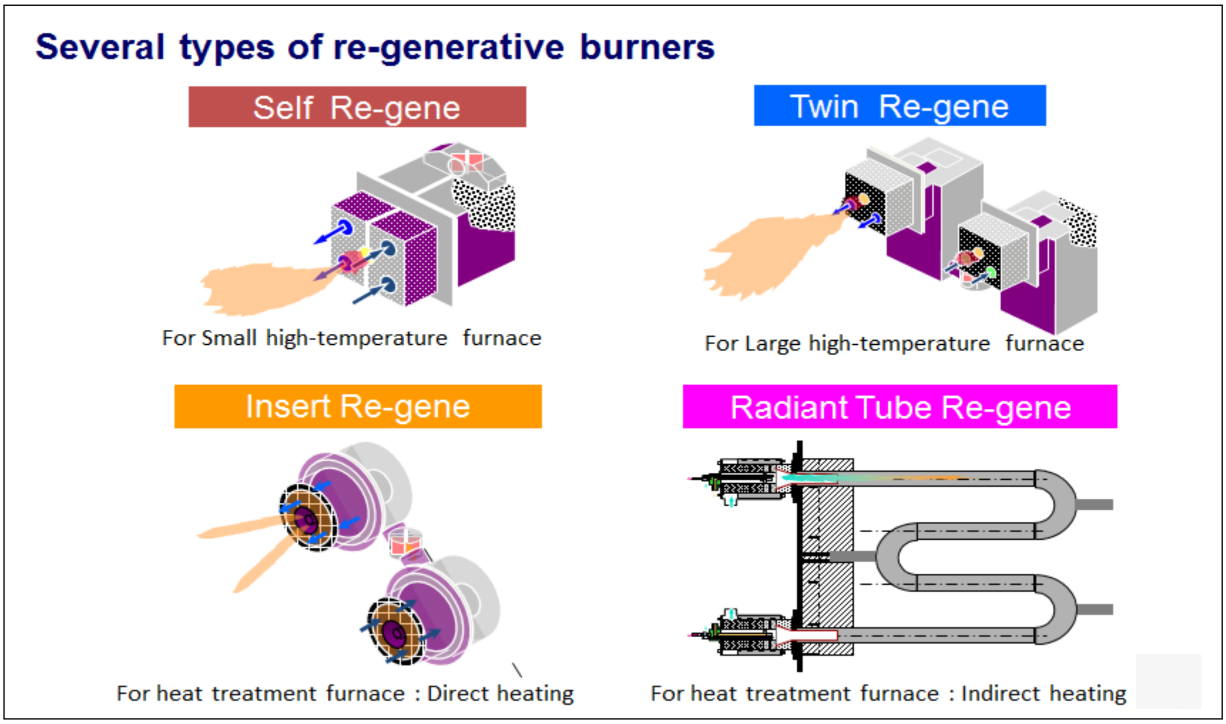


Fig.21 Types of regenerative burner

2. **The energy-saving effect by the regenerative burner system**

For energy saving of high temperature field, the heat recovery of exhausted gas is indispensable.
The heat exchanger made of stainless steel, of which installation cost is low, is used in the temperature range from 800 degree C to 900 degree C, and in the temperature range over 1000 degree C, regenerative burner system is to be used.
In the temperature range of more than 1000 degree C, energy saving of 30-50% can be achieved by adopting regenerative burner system shown as Fig.22.

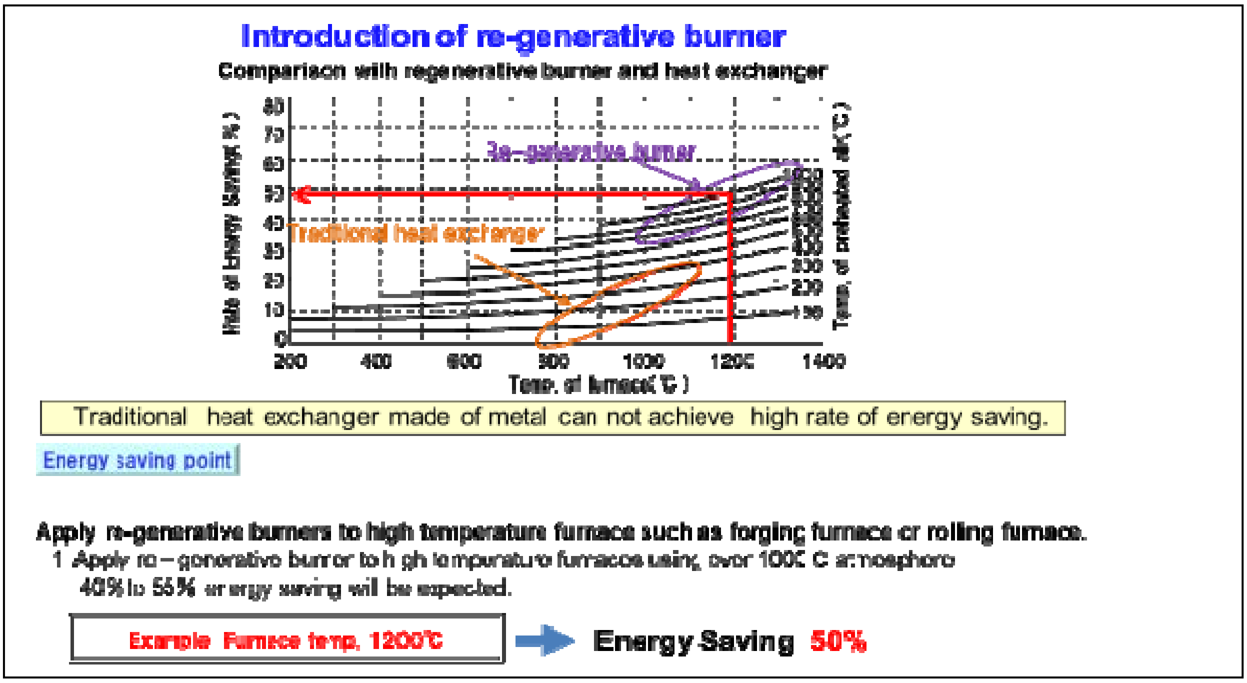


Fig.22 Energy saving effect of introduction of regenerative burner system

3. Components of regenerative burner and mechanism of regenerative burner system

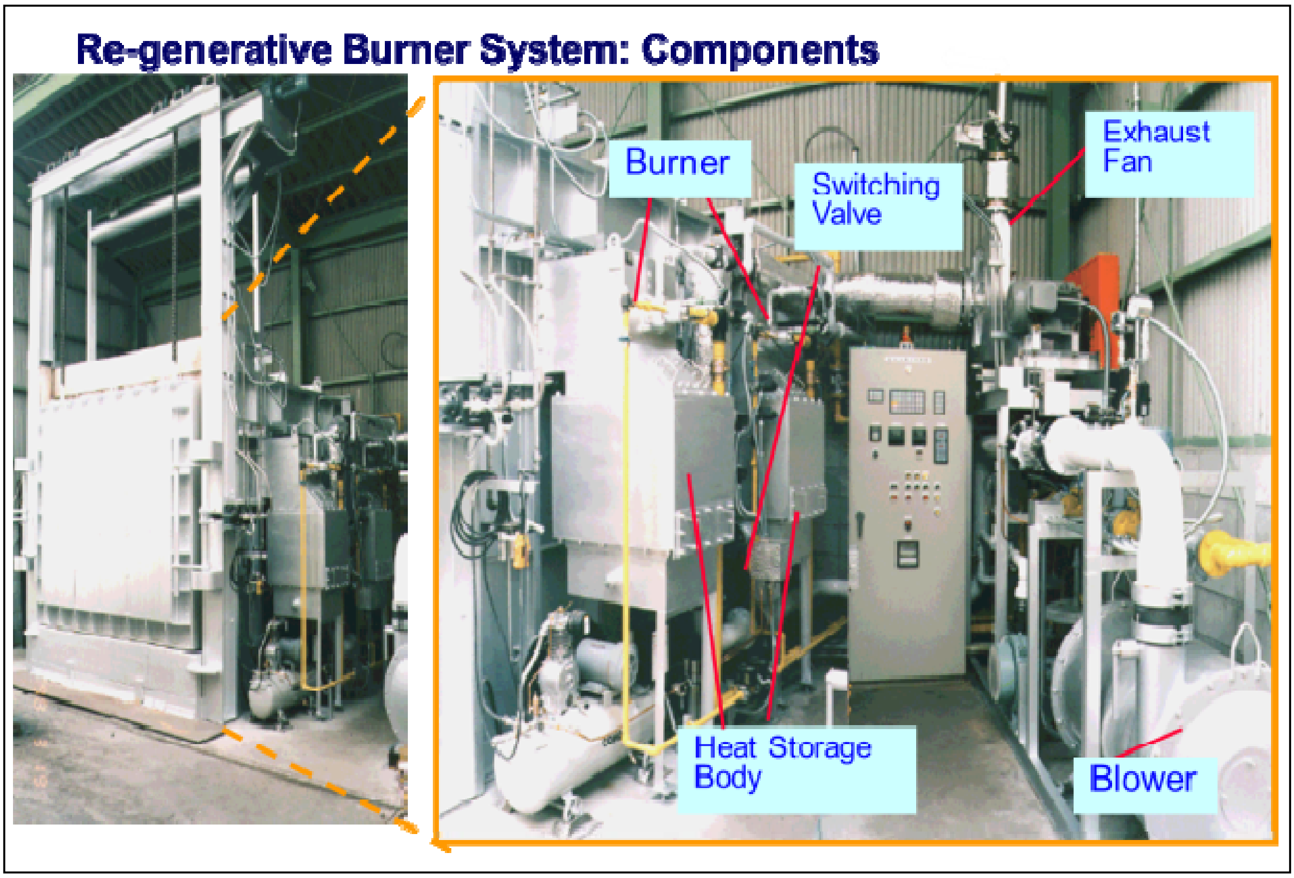


Fig.23 Components of Regenerative burner system

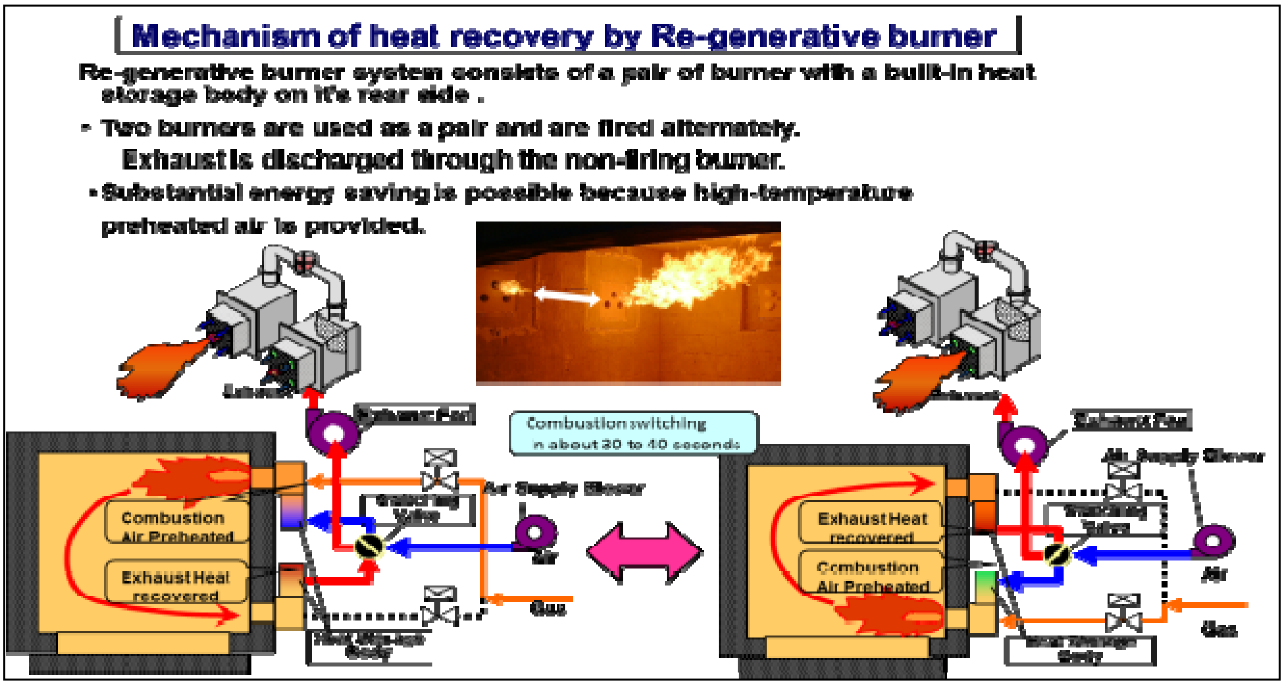


Fig.24 Mechanism of regenerative burner system

As shown in Figure 23, the heating system is basically composed by a pair of burners, and each burner has a box which contains the heat storage material made of ceramic.

While one of the two is burning, another burner plays the role of waste heat recovery.

The heat storage material recovers waste heat from the exhaust gas. As the result, the temperature of the exhausted gas at the inlet of the heat storage material is about the same temperature of the inside of the furnace temperature, but the temperature of the exhausted gas at the outlet of the heat storage material is around 200 degree C to 300 degree C.

After about 30 seconds, the direction of the combustion air supply valve is changed, then outside fresh air is introduced to the heat storage body which recovered waste heat, heated more than 1000 degree C, and supplied to the burner nozzle.

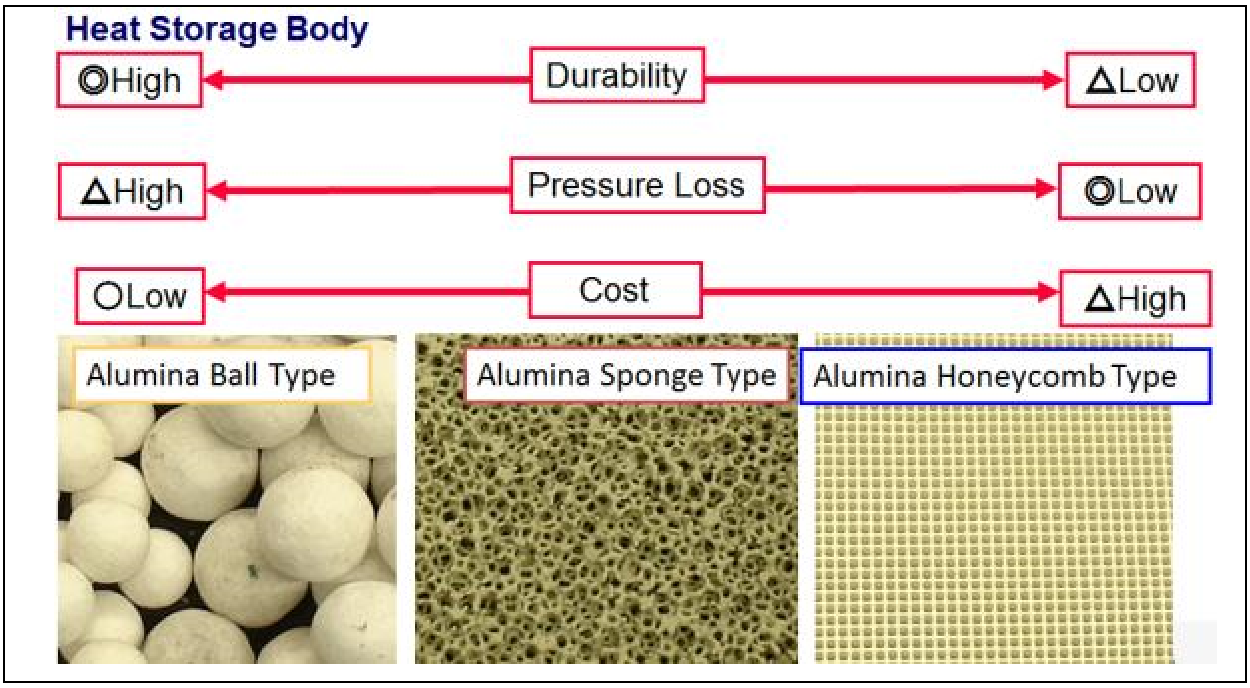


Fig.25 Several types of the heat storage material

There are 3 types of the heat storage material, and the most popular type is Alumina ball type.

4. Actual installation cases of the regenerative burner system

Examples of fuel switching to natural gas are shown below.

1) Twin type regeneration burner system for Batch type forging furnace

Fig.26 Twin type regenerative burner system for Batch type furnace

2) Twin type regeneration burner system for continuous type forging furnace

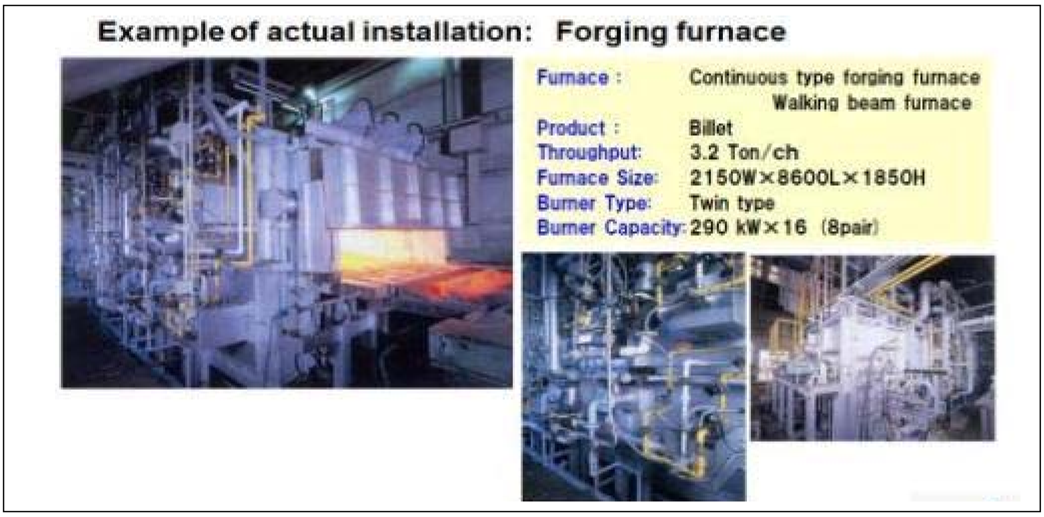


Fig.27 Twin type regenerative burner system for Continuous type furnace

3) Insert type regeneration burner system for Metal treatment furnace
(Hardening furnace and Annealing furnace)

Fig.28 Insert type regenerative burner system for Heat treatment furnace

4) Self regenerative burner for Aluminum melting crucible furnace

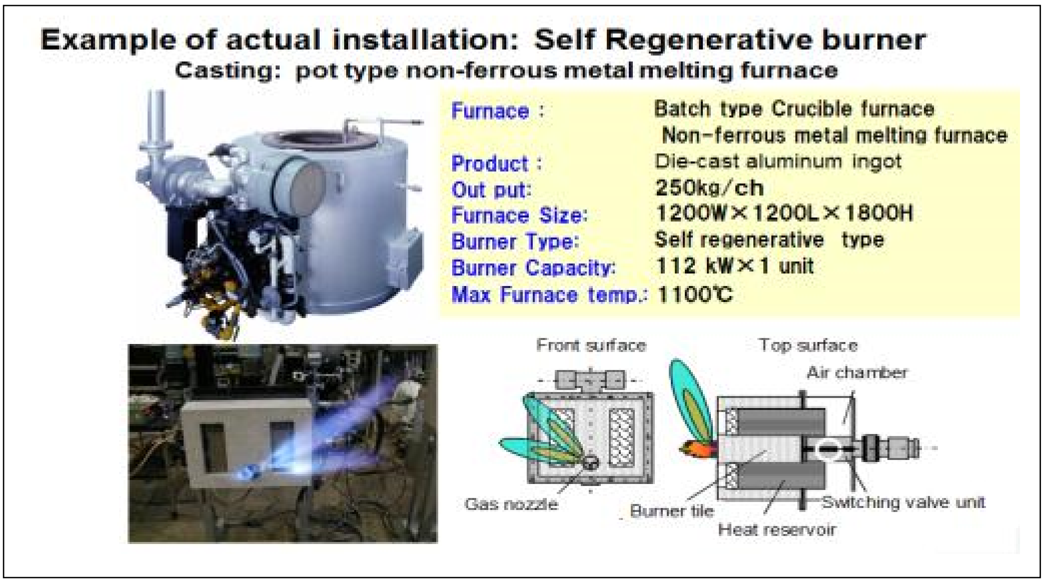


Fig.29 Self regenerative burner system for Aluminium melting crucible furnace

5) Regenerative radiant tube burner for carburizing furnace

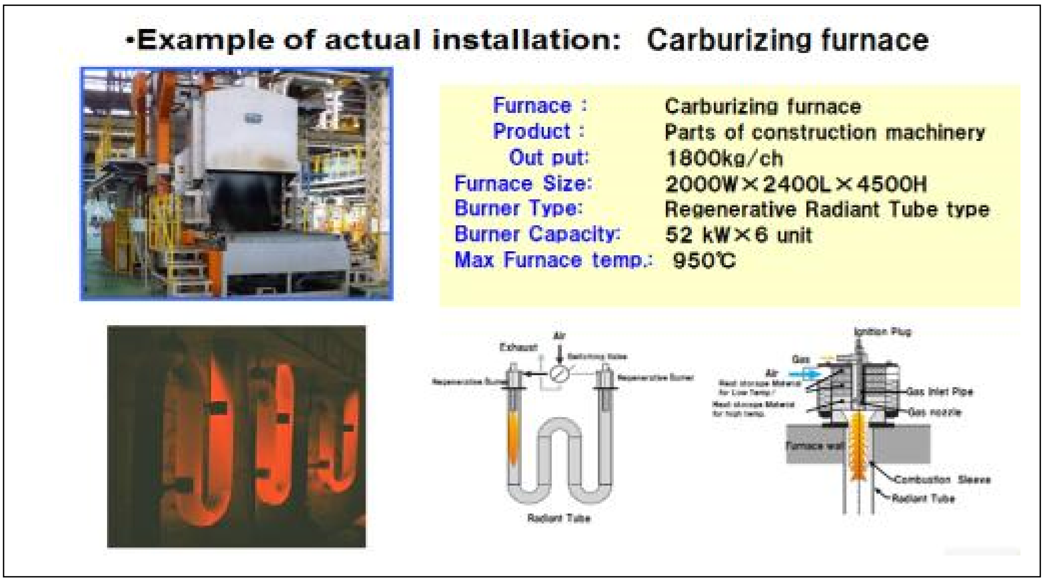


Fig.30 Regenerative radiant tube burner system for carburizing furnace

Examples of fuel switching

In this section, more detail case studies of fuel switching from electricity to natural gas and heavy oil to natural are described.
As for changing into a gas furnace from other fuels, it is the most effective opportunity to replace the equipment when the equipment becomes aged and required to renew. It can save time and effort most, then the fuel switching cost is reduced to the minimum.
However, if burners or heaters properly maintained, furnace body itself does not need to be replaced more than 10 -20 years.
However, there are many cases industrial customers get a great economic and an environmental benefit by converting other fuels in actual use into natural gas furnace described below.

1. Example of detailed case study fuel switching from electricity to natural gas

- **Target furnace : Carburizing furnace by electric heater**
- **Remodel method:** Removal electricity heaters and Installation of gas regenerative radiant tube burner. The outline of a remodeled target furnace is shown in Fig. 31.

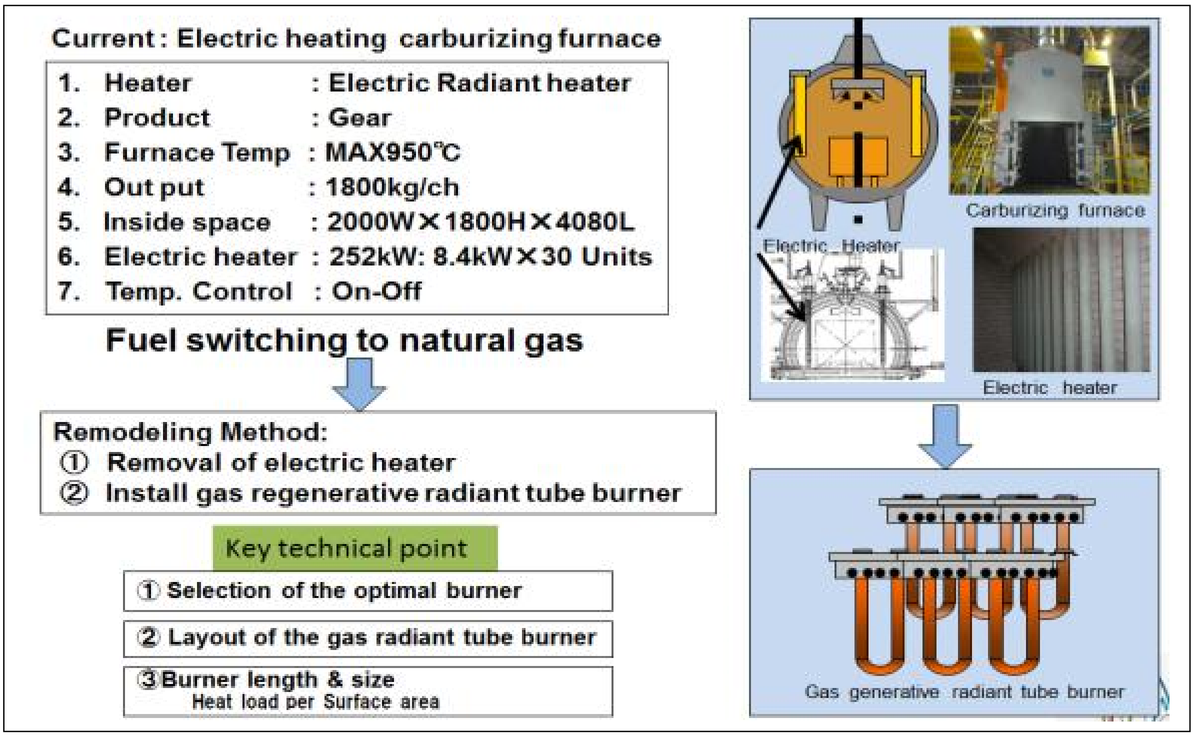


Fig.31 Target furnace for fuel switching

- **Detail study procedure and items**

1. check the structure of furnace and electric heaters capacity of electric heaters.
2. check the total capacity of heaters (kw) and the actual consumed amount of the electricity(kwh) and (kw) , and get the operation data such as the heating pattern.
3. Check the select suitable burners. :Calculate the gas burner capacity and decide the unit numbers
4. Study tube burner layout
5. Check compatibility :Check all detail items
6. Evaluation: Payback time Co2emission etc.

Study flow is shown in Fig 32.

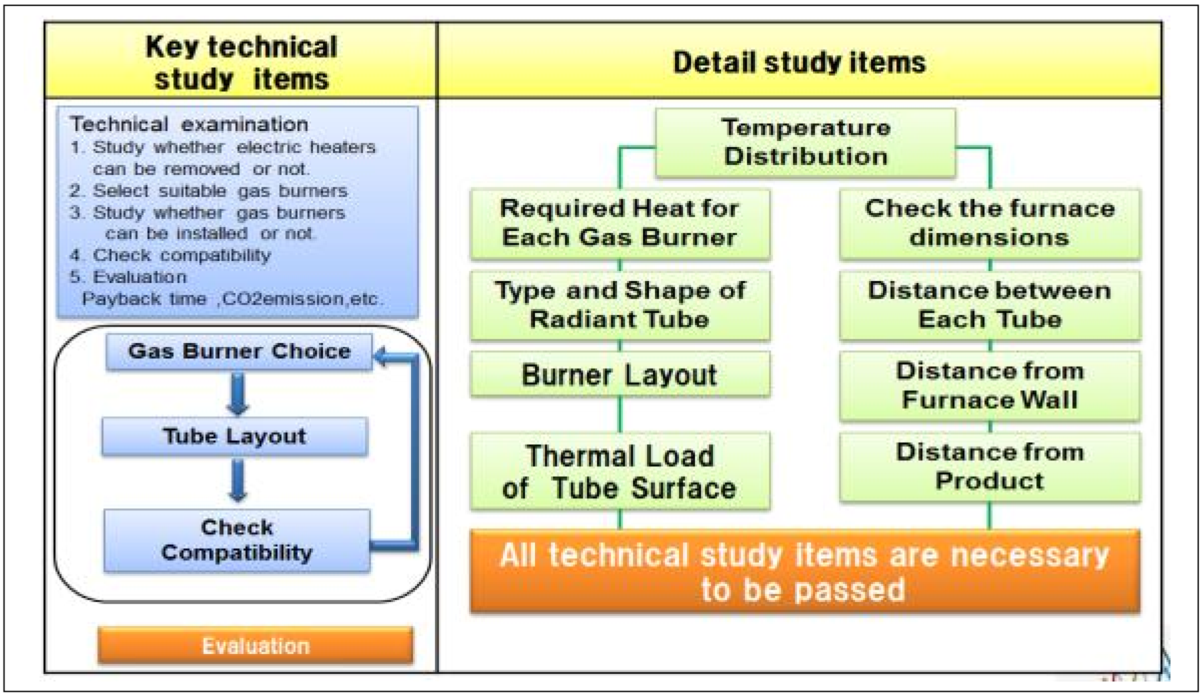


Fig.32 Detail study procedure and items

- **Operation Data**

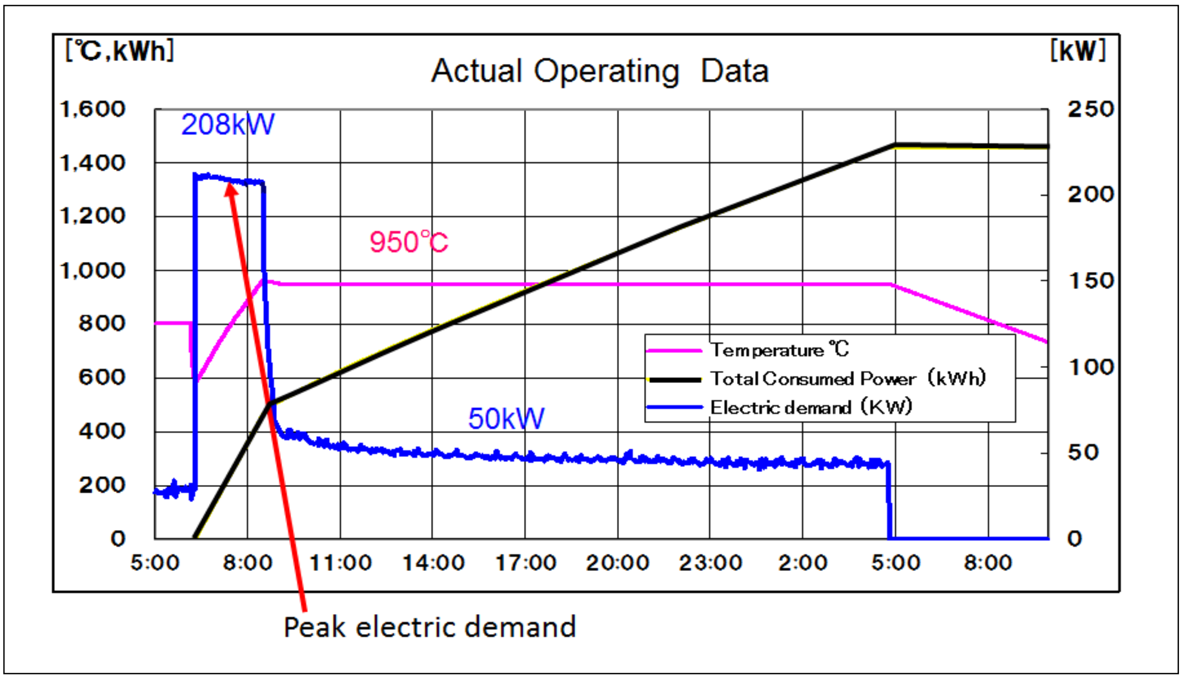


Fig.33 Detail study procedure and items

- **Result of detail study**

According to the calculation result of burner capacity and analyzing the actual operating data, the suitable gas burner is to be selected and the layout of burners is also to be checked.

Gas radiant tube burner has some requirements of its layout in the furnace.

Such requirements are shown in Fig34.

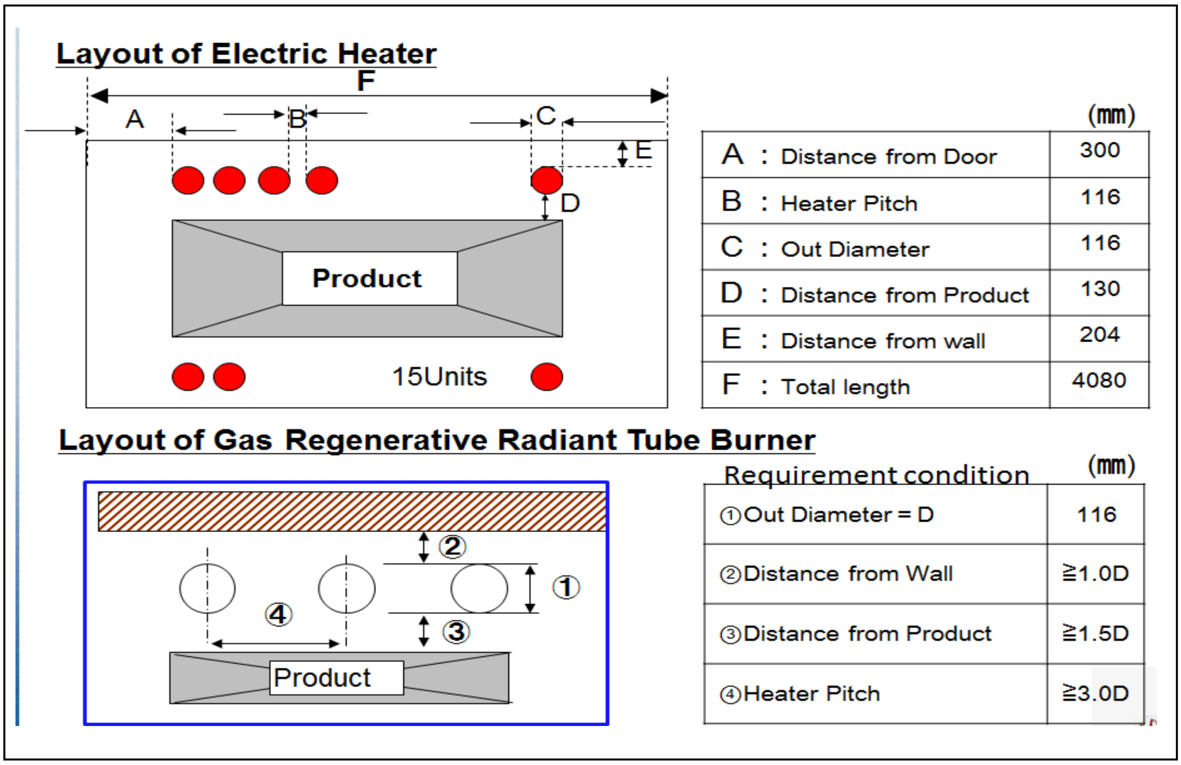


Fig.34 Requirements for gas radiant tube burner

Result of Study of remodeling by Gas Regenerative Radiant Tube burner

		Electric Heater	Gas Regenerative Radiant Tube
Heater size (Diameter)	mm	100	100
Heating Capacity	kW	8.34	52
Unit Number	units	30	6
Total Heater Capacity	kW	250	312
Heating Efficiency		1	0.8
Required heat	kW	250	249.6
Required Length mm	mm	2,615	3,787
Total length of heater	mm	1,130	4,467
Cross-sectional area	m2/m	0.36	0.36
Thermal Surface Load	Kcal/h·m²	19,691	27,809
Heater Pitch		2D	3.0D

Current condition

		Electric Heater
①	Diameter	116
②	Distance from wall	204≧1.0D
③	Distance from product	175≧1.5D
④	Heater Pitch	232≧2.0D

Remodel Study

:by Gas Regenerative Radiant Tube Burner

	Gas Regene100A
Distance from wall	140≧1.0D ○
Distance from product	175≧1.5D ○
Heater Pitch	389=3.35D≧3.0D ○
Thermal Surface Load	27809 ≦30000kcal/m²·h ○

•

Fig.35 Result of Detail study

Payback time 6.4 years

Running Merit of Customer 53,000 $/Year Remodel cost 340,000$

Electricity 0.19$/kWh Gas 0.88$/m3

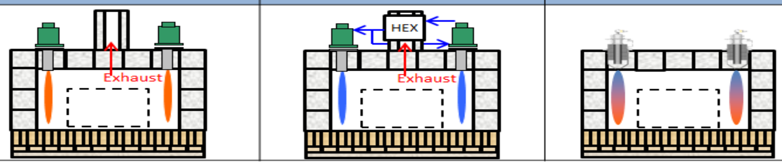
- CO2 Emission reduction 68% compered electric heater

Condition: CO2emission intensity electricity 0.69kg-CO2/kW

Intensity of gas 2.29kg-co2/M3

2. Example of detailed case study fuel switching from heavy oil to natural gas by regenerative burner system at the time of furnace replacement

In this section, case study of fuel switching at the replacement time of aging old furnace from heavy oil to natural gas is described.
As described in the previous section, if the furnace temperature is more than 1100 degree C, because of the high effectiveness of the heat recovery, it is relatively shorter to recover the remodel cost. However, if the temperature of furnace is below 900 degree C, due to the low effectiveness of heat recovery and small fuel consumption, even if regenerative burner system is applied, it is not so easy to recover remodel cost.
Only if a customer renews its aging old oil-fired furnace, it is easier to recover remodel cost incurred by natural gas-fired regenerative burner.



	Target furnace Heavy oil: Bunker A	Remodel By Heat exchanger	Remodel By Regenerative burner
Common condition	Furnace temperature : 880℃、Burner Maximum capacity : 200,000kcal/h Operation times : 3ch/day Operation days 250 days/ years		
Heat recovery	No	Heat Exchanger	Regenerative Burner
Condition of Exhaust	Air Ratio:1.4 Exhaust Temp.: 880℃	Air Ratio:1.4 Exhaust Temp.: 700℃	Air Ratio 1.2 Exhaust Temp.: 250℃
Exhaust loss	51.6%	40.2%	15.2%
Energy Saving	Base	19%	43%
Energy Consumption	62,900L/y =56206 m3/y Bunker A Gas45MJ/m3	45,600m3/y 45MJ/m3	32,000m3/y 45MJ/m3
Running Merit	Base	12,420$	2,4660$
Remodel Cost	Renewal by aging 200000$	250,000$	280,000$
Initial Cost Difference	Base	50,000$	80,000$
Payback time	Base	4.0 year	3.2year
Temp. distribution	SP±15℃	SP±15℃	SP±7.5℃

Fig.36 Case study from oil to natural gas furnace replacement case

6.Example of fuel switching Oil boiler to gas boiler

Example 1

Industrial sector: organic solvent recycle
Fuel consumption: 20 kilo-liters per year
Boiler specification

	Before fuel switching	After fuel switching
Evaporation amount	750kg/h	1,000kg/h
Number	2	2
Efficiency	85%	93%
fuel	Heavy oil	Natural gas

There are high efficiency gas fired boilers, but the efficiency differences between gas and oil are so small that many customers will not change their fuels.
In this case, Increasing feed water temperature was the key factor for fuel switching.

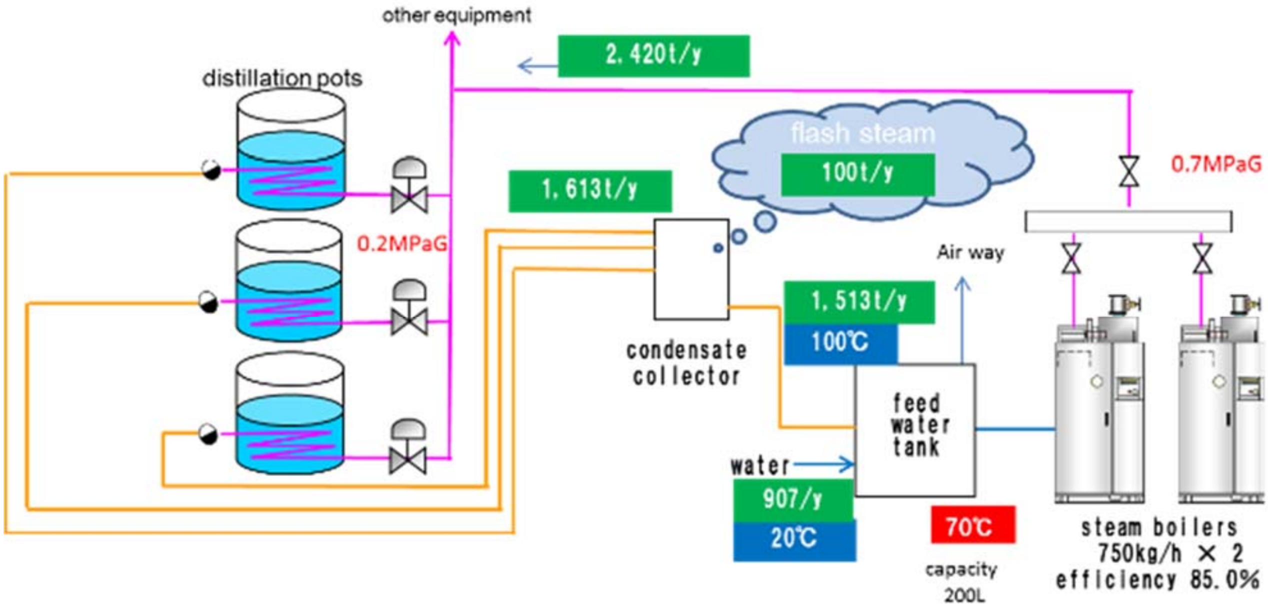


Fig37 system flow: before fuel switching

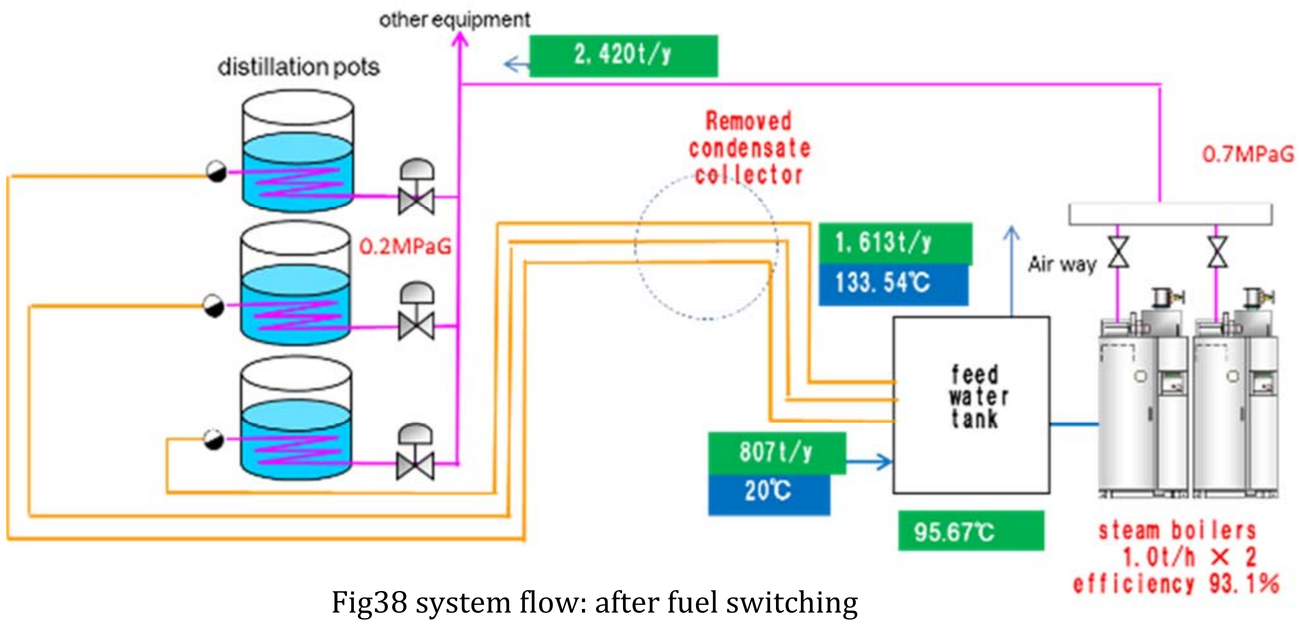


Fig38 system flow: after fuel switching

There was a lot of flash steam from the condensate collector.
Saving energy steps were as below.

1. Removed the condensate collector
2. Remodeled feed water tank to increase the water temperature by the flash steam.

By these methods, the feed water temperature was up to 95.7℃ from 70℃.
And the energy saving rate was 4%
By adopting the high efficiency boilers and these methods above, the energy saving rate became 12%. And our customer decided to change the fuel from heavy oil to natural gas.

example2
Industrial sector: reagent, amino acid

Fuel consumption: 443 kilo-liters per year
Boiler specification

	Before fuel switching	After fuel switching
Evaporation amount	2,000kg/h	2,000kg/h
Number	4	4
Efficiency	89%	95%
fuel	Kerosene	Natural gas

In this case, the site is so huge that it is not easy to recycle the steam condensate. Instead of increasing feed water temperature, steam condensate energy was used to pre-heat raw material, and the steam consumption at the process was decreased.
Steam condensate collector was remodeled as fig39 to pre-heat raw material.
And another process drain line was changed to flow into this steam condensate collector.

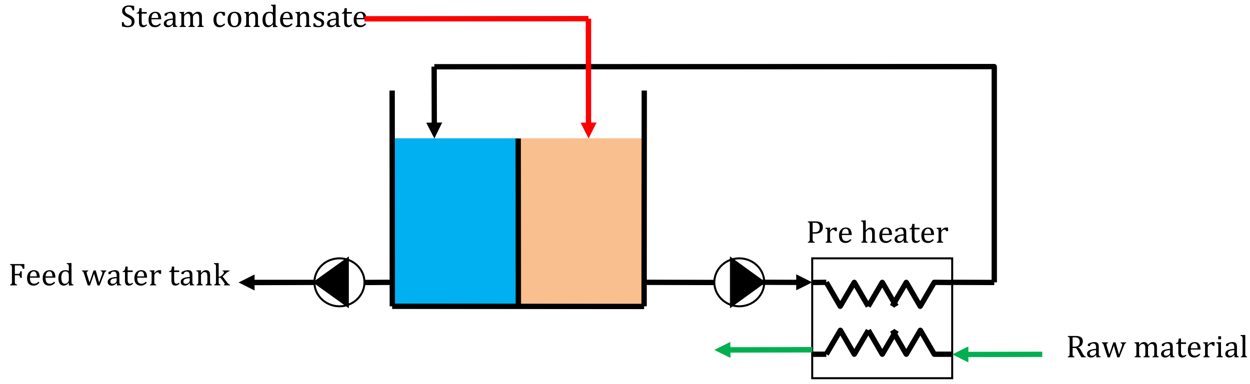


Fig39 raw material pre-heater

By these improvement, feed water temperature was up to 56℃ from 47℃.
The flash steam at the process B vanished and steam consumption at the process B was decreased by 0.55 ton per day.
By adopting the high efficiency boilers and these methods above, the energy saving rate became 13%.

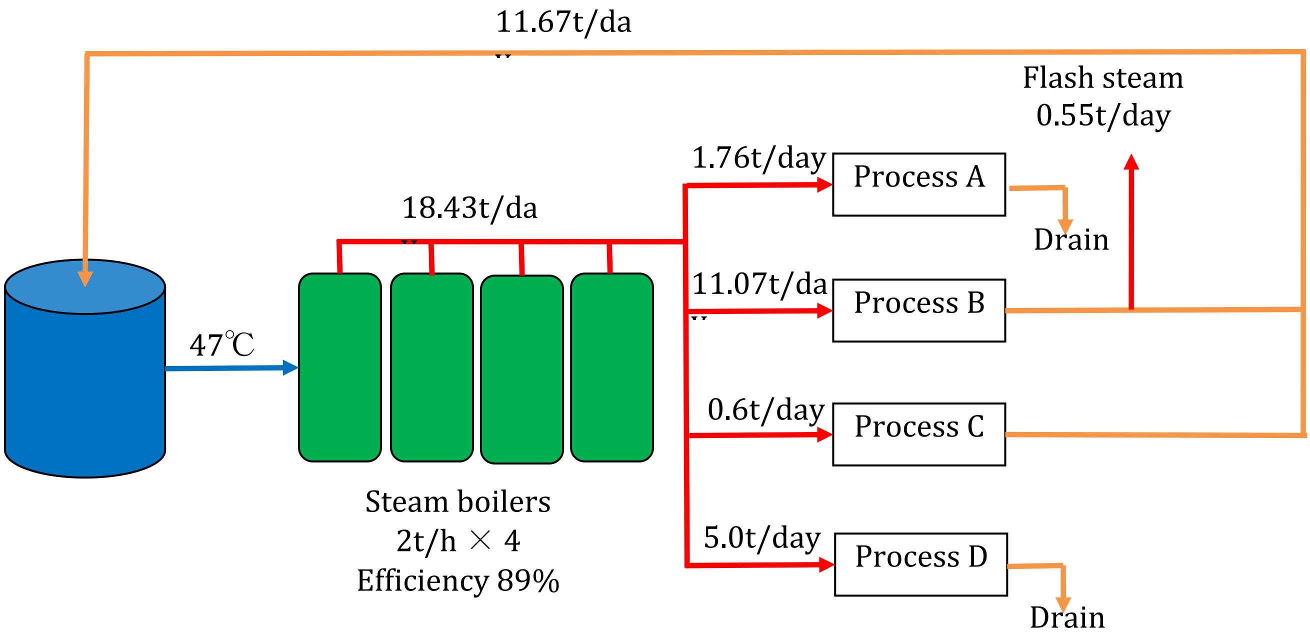


Fig40 System flow (before the fuel switching)

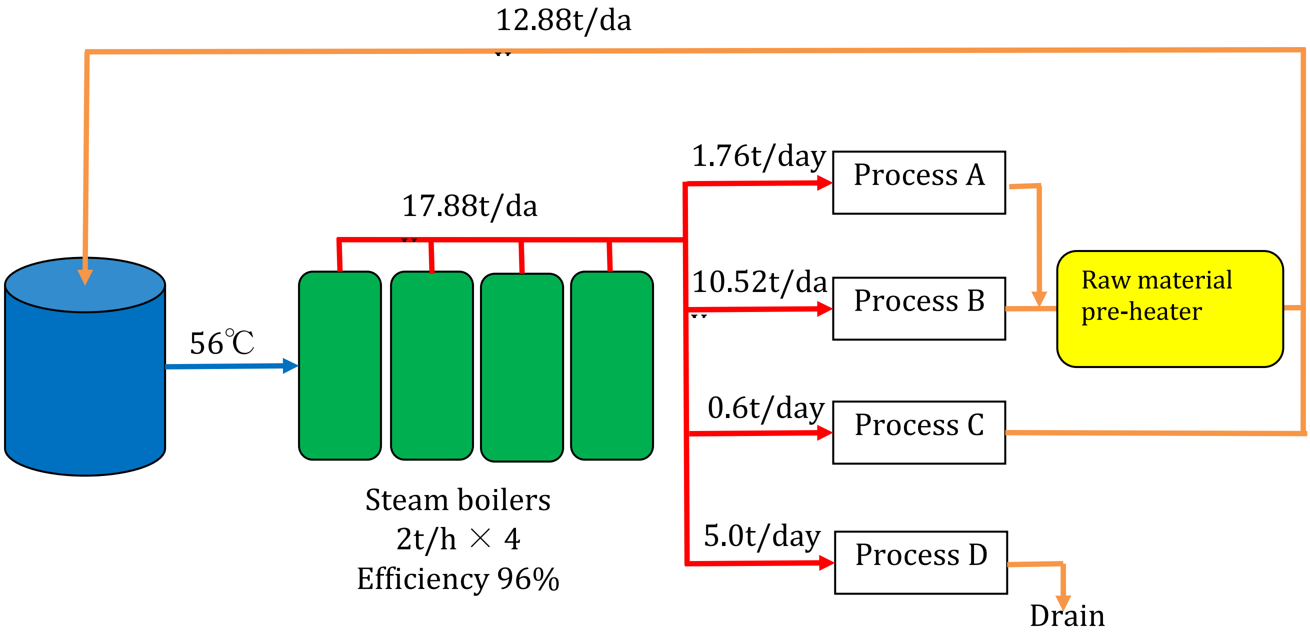


Fig41 System flow (after the fuel switching)

Obstacles/Government Support of "Fuel Switching" in the industrial sector

Natural gas is the cleanest fuel among all fossil fuels and relatively cheaper than oil, however the share of natural gas in the industrial sector is about 20% in the world (See in Fig5) and 32% in the OECD countries.
Promotion of natural gas in the industrial sector is the most effective measure for the prevention of global warming, but the share of natural gas is not quite increased because there are several obstacles to its widespread use.

・**Obstacles**

1. Lack of infrastructure of gas supply.
2. High Auxiliary Equipment Cost
3. Severe exhaust gas emission regulations (Compared with electricity and in some cases)

Probably the most significant obstacle for promoting natural gas in the industrial sector is the lack of infrastructure of gas supply.
Even in the OECD countries, the power plant or the factories that use gas in the industrial sector, are concentrated in the area near a gas supply trunk pipeline network, introduction of natural gas to the factories in the area without a gas pipeline network has been delayed.
Industrial customers in the area without a gas pipe line network still use oil, electricity or coal. Since the construction cost of gas supply pipeline is huge, industrial customers can bear the cost of the modification of furnaces and changing burners, they cannot bear the cost for gas supply to their factories normally.
Although a lot of governments offer great support to renewable energy introduction in many cases, but there is few support by governments for the construction of natural gas pipeline network for the industrial customers and power plant.
It seems that natural gas conversion will be further accelerated if the government support for the construction of pipeline network to the factories in the industrial sector or power plant and CO_2 emission will be most effectively decreased.

The second obstacle is the high auxiliary equipment cost compared to oil and electricity.
Since energy density of gas is low as compared with oil, fuel supply pipe to the burner and fuel shut valve, etc. become larger. Moreover, safety standards for gas furnace are stricter than that of oil, they require measures at the time of ignition, fuel leakage measures from pipes, safety valves and so on, and then total equipment cost for the gas furnace is higher than that of oil.
For the same reason, total equipment cost for the gas furnace is very higher than that of electric furnace. The electric furnace basically emits no exhaust gas, so there is a merit that the duct and chimney for an exhaust gas is unnecessarily or very small for the electric furnace.
For the electric furnace, it is not necessary to equip the safety devices such as flame detector and ignition device.

The third obstacle is severe gas emission regulations.
First one is the regulation for CO_2 emission. In some countries, the national government or the local government has made a request for the big factories to reduce CO_2 emission, and in accordance with this request, some companies change the fuel from gas to electricity.
Second one is the regulation for Nox. In some countries, especially in the developed countries, the national government or local government enacts the law about total amount of NO_x emission from all furnaces of the big factories in a big city or its neighborhood. For this reason, in some cases, this regulation is the major obstacles to carry out fuel switching from electricity to natural gas.
Furthermore, the regulation for NO_x value itself has been an obstacle at the time of carrying out. When carrying out fuel switching from oil to natural gas, there is also a case which cannot

adopt a re-generative burner or heat exchanger, for the reason of this severe regulation of NOx value itself.
It is known well that a NOx emission value will go up if combustion temperature goes up from the combustion theory. Then, with its high combustion temperature, NOx emission value of the re-generative low NOx burner is higher than that of traditional low NOx burner.
But actually, total amount of NOx emission is reduced, thanks to the massive energy saving and reducing total exhausted gas by adopting re-generative burner system.

・**Government Support**

Toward 2030 or 2050, in the power sector, in order to reduce CO2 emission drastically, it is necessary to increase the natural gas-fired power plant by CCGT. For this reason, national government support for the gas pipe line laying is essential, such as strong support to the acquisitions of land for gas pipeline laying and the establishment of subsidy.
For the industrial sector, due to the globalization, there is a competition between countries to invite factories and strong environmental regulations could be the disadvantage.
It is necessary to reduce the gas emissions, however, for natural gas, the most environmental friendly fossil fuel, it is also unavoidable for natural gas to emit gas from its combustion. So it is necessary for governments not only to restrict the emission by the regulation but also to encourage reducing the emission by subsidies of tax incentives.

For our future

There is no doubt that natural gas has the lowest impact on the global environment among the fossil fuels, however, it is not the perfect reason for natural gas to take the major share of the energy used in the industrial sector. There are some obstacles for natural gas to enhance its share; such as necessity of huge infrastructure, high equipment costs, or restriction for gas emissions. However, looking at from the different angle, it is also true that there are room for natural gas to increase its share and potential to contribute to prevent the global warming.

In order to do so, natural gas needs to replace oil, electricity or coal in the industrial sector; the "Fuel Switching".

In this paper, it is shown that the reason why the fuel switching is necessary, how the fuel switching can be realized and technologies for the fuel switching with case studies. Even there are obstacles, there are ways to overcome them and it is our duty to continue to enhance the usage of natural gas in the industrial sector for our industry, our society and our planet.

We hope this paper can be a help to accelerate the fuel switching, then improve our environment.

3. ENERGY EFFICIENCY IN THE INDUSTRIES: OPPORTUNITIES OR RISK FOR NATURAL GAS APPLIANCES

IGU-"Utilizations" - SG 5.1 Philippe Buchet(GDF SUEZ); Egidio Adamo (ENI)

Executive Summary of this chapter

In a context of reduction of availability of fossil energies, increase of volatility of the energy prices, reduction of carbon emission and economical crisis the most important challenge for this century for industrial market will be to reduce drastically their energy consumption in order to increase the profitability of their industrial processes. As shows it, all the international studies made to define the energy directives or the energy strategies of the countries, the first stage of this commitment type, is the implementation of an energy efficiency approach and energy audit.

In this frame of global reduction of fossil energy consumption, what could be the opportunities to promote natural gas appliances and what new business opportunities available for Gas Companies to answer to this industrial demand.

In this article, after a short review of the global context and example of regulations or initiative push by different countries, to promote Energy efficiency, we will try to demonstrate through some case studies the interest of the natural gas solutions and associated technologies to answer this important challenge which is reduction of the energy consumption in the industry. The goal of the report will be to do a kind of technology guide on "How to promote, in the frame of energy efficiency approach, the development of natural gas appliances through the implementation".

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Introduction

In a context of high and volatility of energy prices, strengthening of environmental regulations, implementation of national strategic energy plans, including drastic reduction of energy consumption (ie: CO2 reduction) in order to fight against climate change; Energy Efficiency is becoming the most important issues for the competitiveness of industrial plants.

In another way development of ISO 50001 standards on energy management, will reinforce the necessity for industrial plant to do energy balance of their plans and define progress plan on energy & environmental efficiency and CO2 emissions.

The consequence is commitments for many large industrial plants (Chemical Indus., Steel Indus. Glass.; Paper mill….), to implement improvement plans, including targets on reduction of CO2 emissions, improvement of specific energy consumption ratio of processes, and action plan including:

- Energy efficiency audits ;
- Study and implementation of high energy efficiency processes lines
- Decentralized power production
- Re-engineering of energy master plan of the industrial plants.

This context represents very large range of opportunities to natural gas world to extend the use of Natural gas, the development of innovative and high efficiency technologies in order to provide to industrial customers added value solutions and high level of energy efficiency.
In this article we will try, through a propose energy efficiency methodology and examples of innovative projects or case studies, to show that in this context, natural gas technological solutions can be a good compromise to achieve the energy efficiency objectives of industrial companies while offering opportunities to extend natural gas uses in the industrial markets.
Examples analyzed will be:

- Energy audits and Natural gas solutions ;
- Improvement of energy efficiency of industrial process lines ;
- Heat recovery implementation;
  - Natural gas solution for heat recovery on high temperature heat losses
  - Natural gas solution for heat recovery on low grade heat losses ;
- Decentralized production of power through heat recovery
- Re-engineering of energy master plant – For a better energy mix with NG uses

For each project and/or case study a description of the technical solution will be done; advise on industrial activity concerned and some technical and economical ratios will be provided if data available.
In conclusion the report will propose a road map to go from energy audits to Eco-Design plant (very Low carbon foot-print plants).

Acknowledgements

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Context

1. **Introduction on new energy and regulations context**

- The fight against climate change has become a major concern of many industrial countries or pre-industrial world including the European Union. Many scenarios have been studied to limit or stabilize the amount of greenhouse gases in the hearth atmosphere. As part of these scenarios, including those developed by the IEA (International Energy Agency) to stabilize the CO2 content of the atmosphere, it appears that the three main positions to reduce global CO2 emissions are:
  - Energy efficiency in buildings, industry and transport,
  - Implementation of Energy integration (Optimization with Pinch analyze, High level of Heat recovery,...) on Industrial Plant
  - The introduction of renewable in the energy mix and use of bio-fuels (see fig. 1)

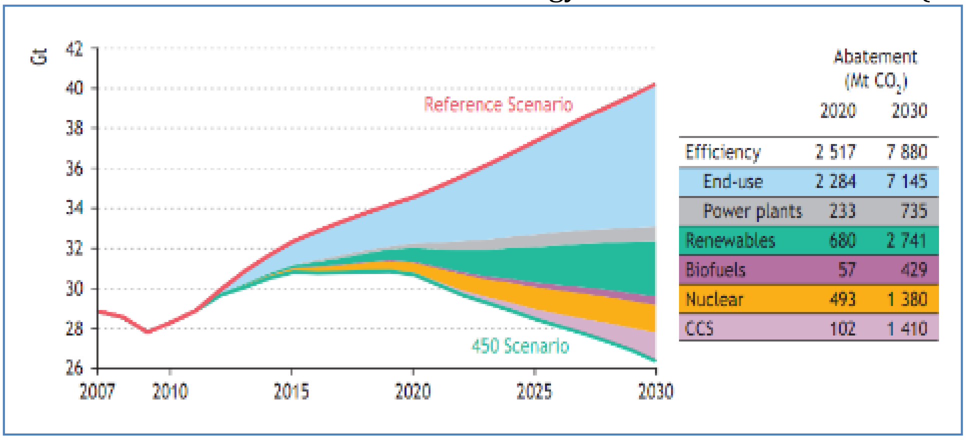


Figure 1: Scenarios of CO2 emissions in the hearth atmosphere regarding solutions

(Source: International Energy Agency, World Energy Outlook 2009)

Likewise a common European energy has been defined through the Climate and Energy Package.

An action plan focuses on three objectives for 2020 has been defined:

- 20% reduction in energy consumption;
- Decrease of 20% in greenhouse gas emissions (GHG);
- Increase of 20% share of renewable energy.

Common EU policy which is now the subject of a European Directive, is declined in each of the 27 member countries and associated countries through the commitment of states to reduce their emissions, implementation of energy regulations specific to the context of each country regulatory and incentive tools, tax and regulatory (Ex: White certificates ; Standards for energy & Environmental management EN 16001 and ISO 50001).
These plans offer an essential overview of Member States' strategies (support mechanism, technology choices, planning reforms, required investments, etc.) for the period 2011-2020.

Thus we see that, even if natural gas is the fossil fuel that contains less carbon (See fig. 2), the main challenge of the gas companies for this new century, will be to respond to these requests and to include regulatory and tax growth in this new global energy context. A major challenge for the gas companies will be in particular to develop innovative solutions for Energy efficiency; support the integration of new industrial energy master plans (including high level of heat recovery & valorization of process gas), and gas renewable fuels such as biogas, bio-methane from energy conversion biomass and to a lesser extent, at least initially solar energy as direct thermal or hydrogen.

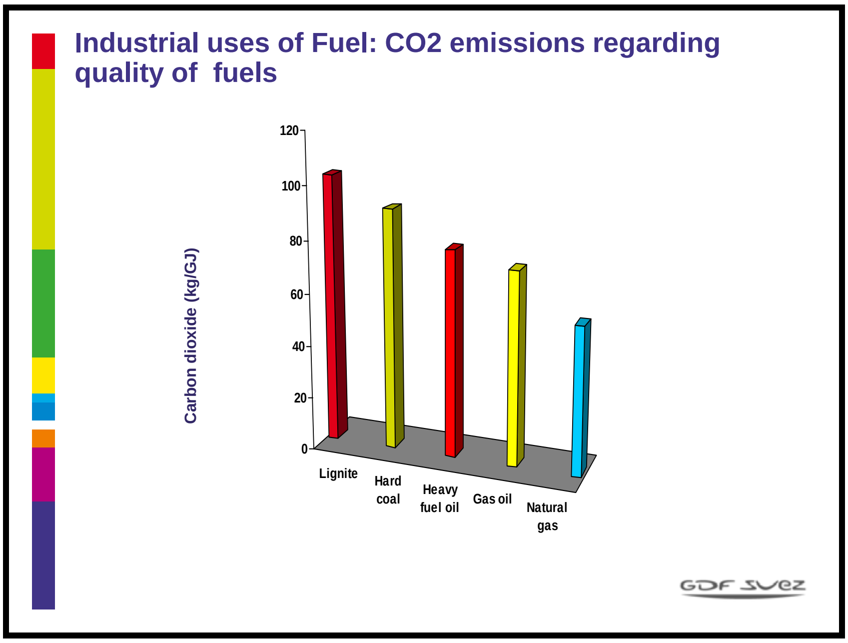


Fig 2: relative CO2 emissions of industrial fuels

2. Energy efficiency in industrial markets: Mechanism and regulation

Energy productivity improvements since 1990 have helped avoid consumption of 3.6 Gtoe of primary energy and CO2 emissions of 8 Gtoe by 2008. Energy consumption is growing less rapidly than the economic activity in all world regions, except the Middle East. This decreasing trend for the energy intensity (energy consumption per unit of GDP) accelerated since 2004 because of higher oil prices and the introduction of new energy efficiency policies: 1.9% per year between 2004 and 2008 compared to 1.4% per year between 1990 and 2008.
In 2009, because of the economic crisis, the trend development was generally slower except in North America and OECD Pacific. More than two thirds of the countries in the world have decreased their energy intensity and 50% of them by more than 1% per year. Energy productivity improved significantly, by more than 3% per year in 30 countries. Significant potential for further energy intensity reductions exist in many world regions, large differences exist also between world regions in their energy intensity levels, even after conversion of GDP to purchasing power parities (For example the energy intensity in the CIS is 2.7 times higher than in Europe, the region with the lowest value; and about twice as much in China, The Middle East and Africa. In North America, India and other Asia the intensity is about 50% above the European value.
This shows significant potential for reduction in the future. OECD Asia and Pacific and Latin America however are only 10% above Europe.

Apart from Europe, energy productivity gains are greater for final consumers, by 20% at world level.

The increasing use of electricity by final consumers has resulted in greater losses in power generation, as most of the electricity is produced from thermal or nuclear power plants.
In Europe, there is an opposite trend: the primary energy intensity is decreasing more rapidly than the final energy intensity due to the increasing share of gas turbine combined cycle, wind and cogeneration in power production and improvement in energy efficiency in process; insulation and heating systems for buildings and transport.

Energy efficiency of thermal power generation is still low (30% to 40%) in most emerging and developing countries, resulting in a significant potential of energy savings Energy Efficiency. For industrial processes roughly the same trends even if large progresses was done in years 90th, especially in Europe and USA countries.

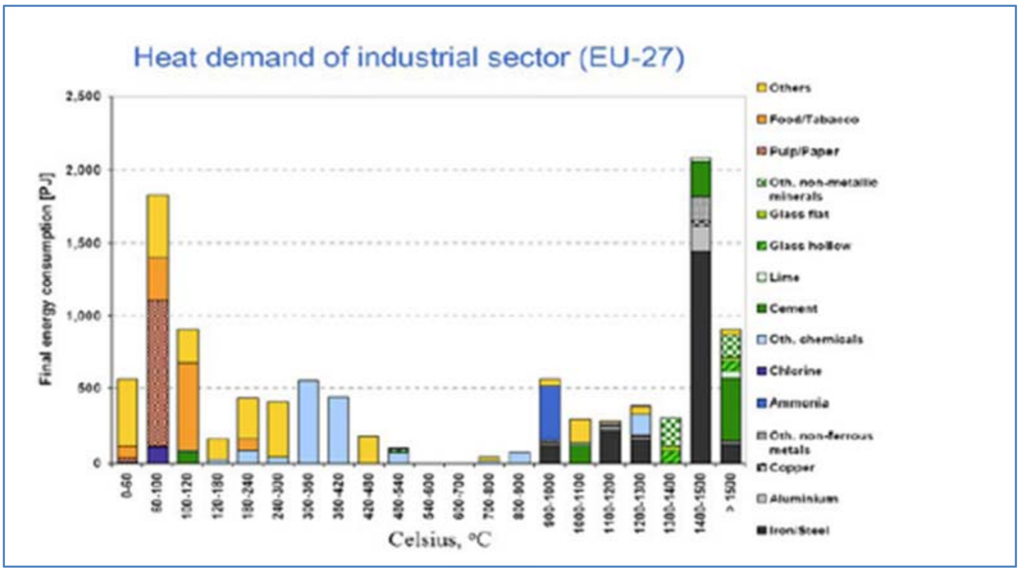


Figure 3: European industrial heat demands

For example: In Europe and in France significant progress have been made in energy efficiency of industrial processes, during eighties and nineties particularly because of the energy crisis. In France, due to this progresses and hard economical crisis in Europe, the annual energy consumption in the industrial market (except power production) is roughly 300 TWh per year (Fig 3). In this countries we can estimated that the average thermal efficiency in industrial processes (Excepted Power production) between 50 and 60%. In consequences fatal Heat losses represent 140 to 150 TWh per year and therefore equivalent potential for energy recovery (or reduction of final energy consumption).

These industrial heat discharges, called (IHW - Industrial Heat Wastes) consist of:

- •Losses associated with fatal processes heat losses themselves (losses to the walls, cooling systems...) on which there are few opportunities for energy recovery;
- •The so-called (IHW) Industrial Heat Wastes at high temperature (> 300 ° C - eg Waste gas furnaces; steam discharges...), mainly in gaseous form, for which there is a high potential for energy recovery;
- •The so-called (IHW) Industrial Heat Wastes at low temperature (<250 - 300 ° C), in liquid or gaseous form, which are often unexploited and where energy recovery is possible.

With regard to France alone, Studies shows a potential for reducing energy consumption (heat recovery) in the industry of about 110 to 120 TWh per year (90 - 100 TWh at high temperature level and 30- 40 TWh at low temperature level- (Fig 3). So many projects are presently launched to implement innovative solutions to recover this loss energy.

For Europe, it can be the first approach estimated a potential of about 8 to 10 times higher. In the world, given that the average energy efficiency of the processes is much lower (~ 30%), particularly in developing countries, the potential for increasing energy efficiency by energy recovery is huge.

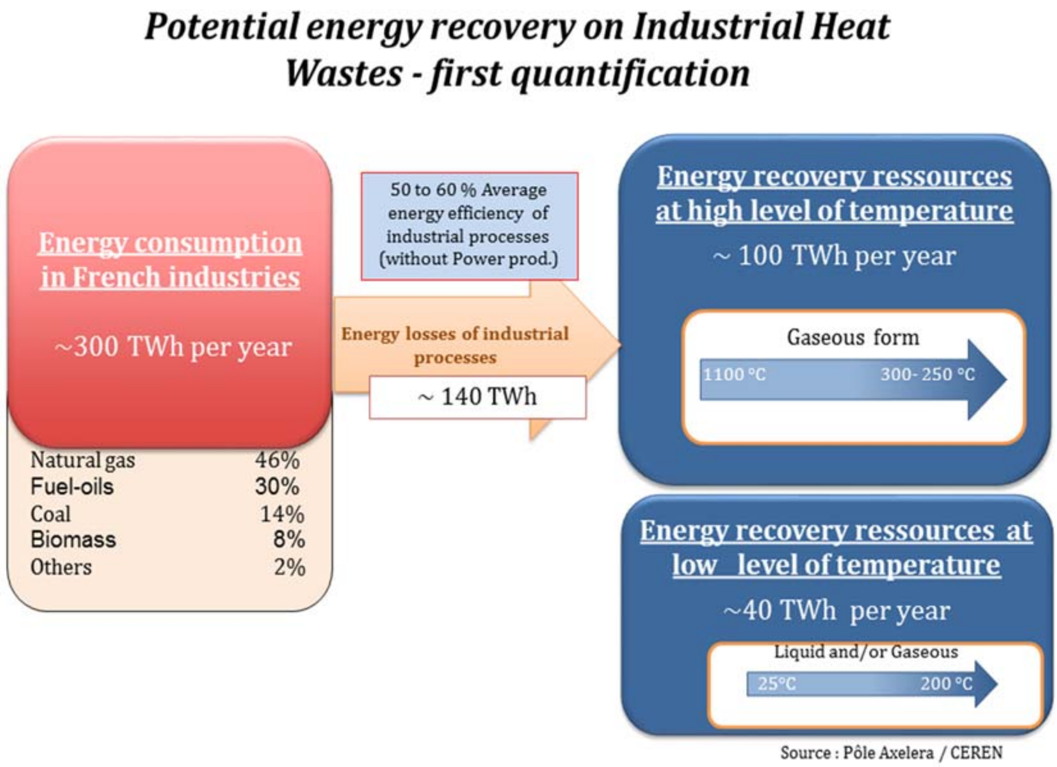


Fig 4: Estimation of industrial heat losses in France

Energy efficiency is therefore the first step to reduce energy consumption (ie : CO2 reduction) in the industry and thus allow the economic sustainability of these activities.

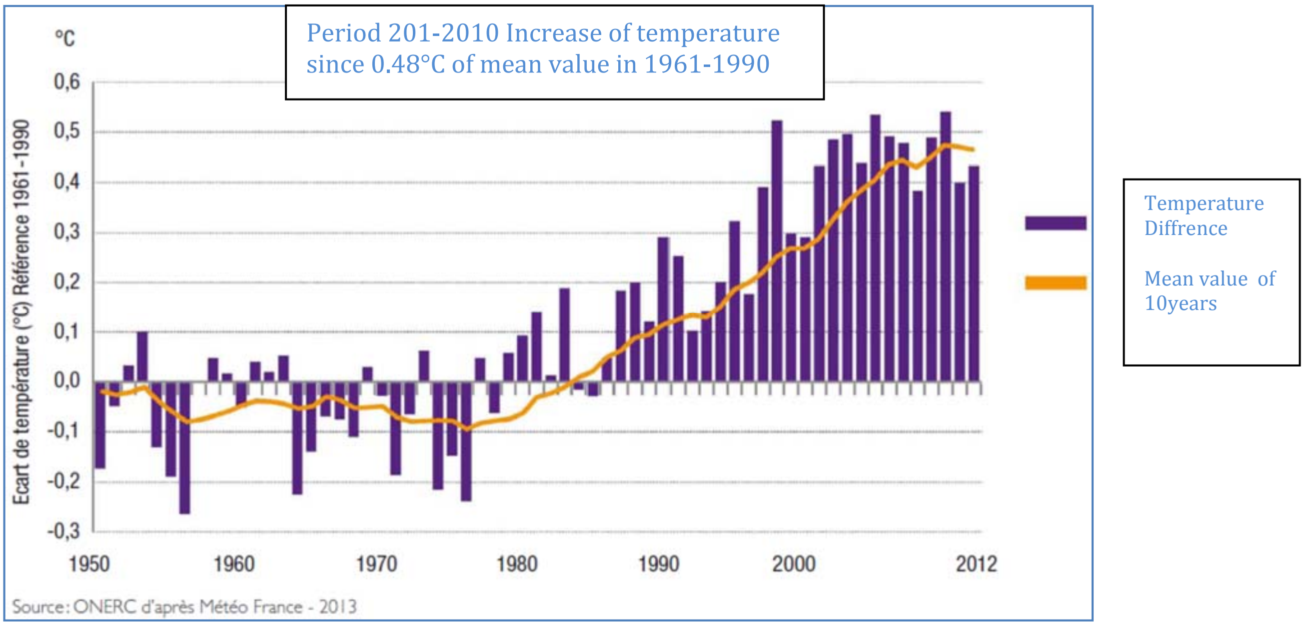
But given the challenges and commitments made by countries in terms of drastic reduction of greenhouse gas emissions, it will be not enough and will have to be complemented by the development of hybrid solutions integrating / combining renewable to fossil fuels in processes and energy master plans of the industrial plants.

3. Synthesis of Energy Directive regulations in Europe

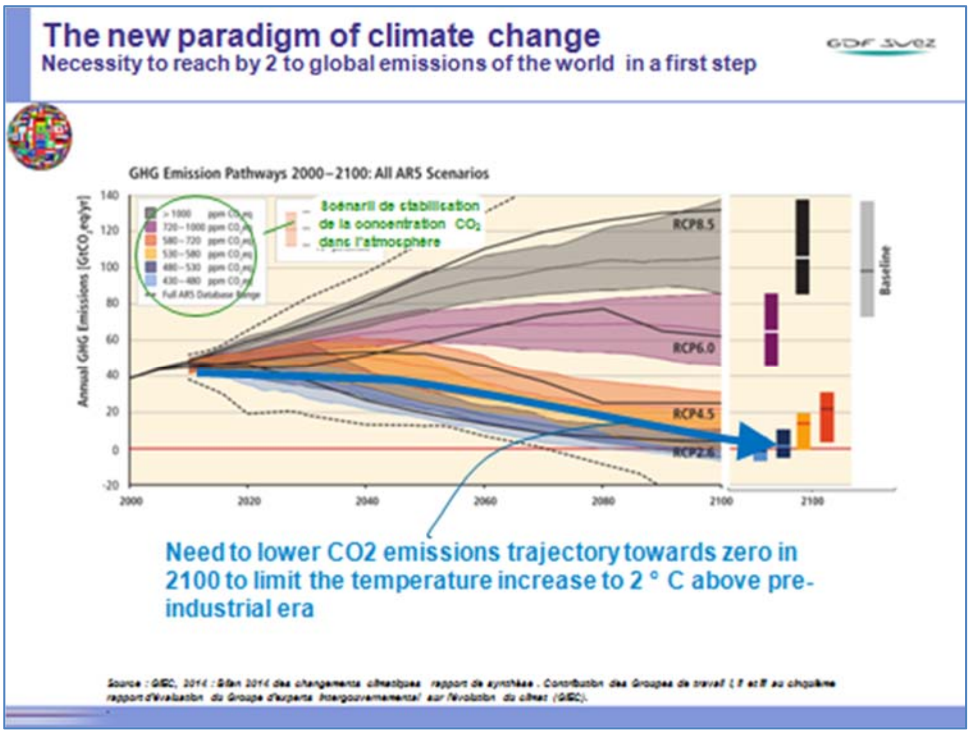
Climate change is the new paradigm in the sense that even if the price of fossil fuels were to collapse as in 1986, climate constraints remain. So was there a perennial supporting factor for energy optimization. Regarding the issues of climate change, recent anthropogenic activity, change deeply and quickly the climate. The rapid accumulation of CO2, the main representative of greenhouse gases in the atmosphere amplifies the greenhouse effect and warms the climate. The IPCC, the Intergovernmental Panel on Climate Change's mandate is to evaluate and synthesize on the basis of consensus, objectively, the information available in relation to the issue of climate change of human origin. The IPCC is a United Nations offshoot and was created in 1988 at the request of the G7 (now G20). The IPCC is not a research organization, but a place of expertise to synthesize the work in laboratories around the world.

The observations made and the works have led experts to formulate the following recommendations and practical conclusions:

- Towards decarburization of economies;
- Limiting warming to 2° C compared to 1750 year;
- Stabilization at 450 ppm CO2 equivalent GHG ;
- Path to zero emissions in 2100.



Do not exceed the threshold of 2 ° C implies a reduction by factor 2 of global emissions of greenhouse gases by 2050, and since it is matter of course, important goals are also needed to time horizons closer to us. This goal led to a division by 2 global GHG emissions by 2050, seems to divide by Four the emissions of industrialized countries by 2050 in order not to jeopardize the transition countries' development prospects and developing. This is the well known “objective factor 4".



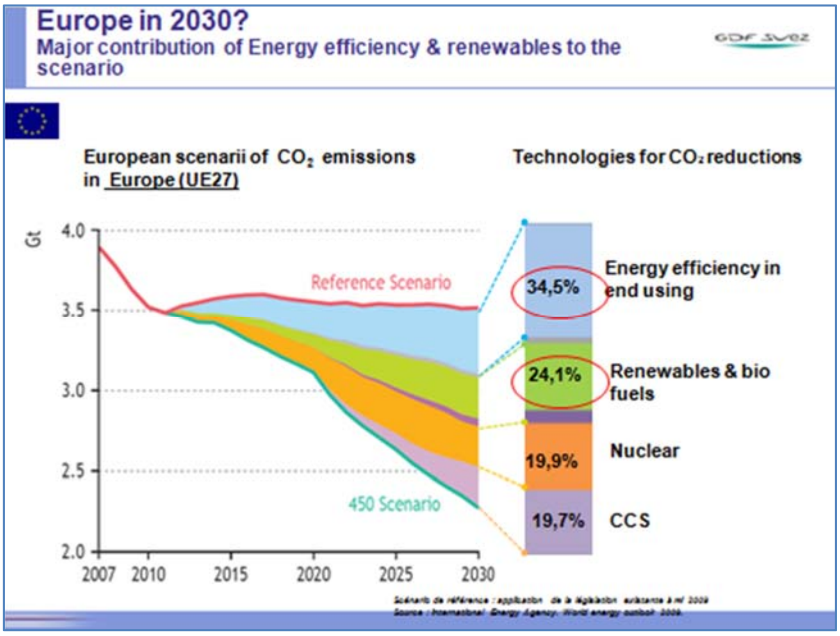
The strategy is the base of the Energy Directives developed in different parts of the world, and especially in Europe. The climate change-related regulatory pressure has increased in recent years with Europe (and France) proactive despite uncertainties on international commitments beyond 2012. The first strong international commitment was established by the Kyoto Protocol. By ratifying the Kyoto Protocol, the EU-15 is committed to an 8% reduction, emissions of greenhouse gases by 2012 compared to 1990. To fulfill these commitments, countries have the possibility of recourse to mechanisms "flexibility" as the exchange of emission permits between industrialized countries.

The Kyoto Protocol is, however, expired in 2012 and a new international agreement had to be reached to continue gas reduction efforts greenhouse. To do this, 193 states met in Doha in 2012 as part of the annual meeting of representatives of countries that have ratified the United Nations Framework Convention on Climate Change. Then it is the 18th such meeting (COP 18). At the conclusion of the Doha conference, the Kyoto Protocol is extended narrowly until 2020, but the countries participating in the second phase of the act (2013-2020) represent only 15% of global gas emissions greenhouse (GHG) in the world. This is the European Union, Iceland, and eight other industrialized countries, including Australia, Norway and Switzerland.
In late 2008, to support its international commitments in the fight against climate change, the European Union has worked for a comprehensive and ambitious legislative package.
This package called "climate and energy" is an action plan to implement a common energy policy and the fight against climate change. Its full realization will, in the EU to achieve by 2020 the ambitious goal of "3 times 20 rule":

- 20% reduction in greenhouse gas emissions,
- 20% renewable energy in EU energy consumption
- And 20% improvement in energy efficiency.

Only the first two measures were binding in the first instance, the third had an indicative value, until the adoption by the EU Directive on energy efficiency in 2012 given the insufficient progress made in the field of energy efficiency.
In October 2015 the EU reached an agreement for 3 new targets for 2030:

- 40% reduction in emissions of greenhouse gases compared to 1990 levels,
- Increase the share of renewable energy to 27%,
- Reaching 27 % energy saving.



Specifically on the European and French regulations on greenhouse gases, the coming period to 2020 is characterized by a new allocation methodology based on European benchmarks and a broader scope in terms of sectors activity and greenhouse gas emissions. The context of the international commitments of the European Union Directive quotas in 2003, amended in 2009, is introduced. This is to set up a system of exchange of emission quotas for greenhouse effect. The activities concerned were initially large industrial glass, paper, steel, cement, tiles and bricks, lime, ceramics and Large Combustion Plants with more recent extension to other combustion plants, the chemicals sector and that of non-ferrous metals. The implementation of the European exchange market has three "phases". The first period covers the years 2005 to 2007 and was designed to calibrate the method for calculating and adjusting the allocations for the next five-year period (2008-2012). The third phase covers the period 2013-2020. From 2013, the principle of allocating allowances will be that of the auction with more or less progressive:

- The allowance will be free to 80% in 2013 and decline linearly to 30% in 2020 ;
- The allocation is now done, when it's possible, by product benchmark and on the basis of the 10% most efficient installations in the European Union to make the product in question. It's a system that rewards the virtuous facilities since the past allocation was based on historical emissions ;
- The non-free allocation is done mainly by auction ;
- The allocation is 100% free for sectors exposed to carbon leakage ;
- There is no free allocation for electricity production. There are for the heat cogeneration and district heating

Obviously, there is every activity that develops around the counter and art and how to count CO2 are explained by the EU Regulation 601/2012, which defined for the period 2013-2020 technical procedures to verify and quantify CO2 emissions. It is implemented in France by the decree of 31 October 2012 which repeals the 31 March 2008. Especially, the Directive 2006/32 / EC of 5 April 2006 on energy end-use efficiency and energy services, define: → DIRECTIVE 2012/27/UE

- The Indicative Target: 9% energy savings by 2016. Target not repealed;

- The necessity of an action plan for energy efficiency to be submitted by States (EEAP) every 3 years.*Second NEEAPs submitted by France to the European Commission on 17 June 2011*.
- Development of Cogeneration plant and district heating systems ;
- Obligation to do Energy Audits for large industrial plants before end of 2015 and every each 4 years ;
- A reinforcement of obligation mechanism, high efficiency technologies and cogeneration appliances, like :
  - Article 7: obligation mechanism
    Energy saving minus 1.5% / year with end customers for energy sellers.
    And / or public policies with equivalent results.
  - Article 14: Promotion of efficiency in heating and cooling.
    Evaluation by the potential of States for high-efficiency cogeneration and efficient networks of heat and cold
  - Article 15: Promotion of energy flexibility as a measure of energy efficiency ;
  - Article 24: National action plans for energy efficiency every 3 years ;
  - Article 28: Transposition later than June 5, 2014 ;
  - Article 25: Online platform for the exchange of experience:
    http://ec.europa.eu/environment/resource_efficiency/index_en.htm

Case study: Transposition of Energy efficiency directive - Energy efficiency action plan in Slovenia.

Like many European countries Slovenia has developed an action plan for energy efficiency based on the transcript of the European Directive. Today the situation of the Slovenia versus mean European countries is relatively good. Energy efficiency is improving slightly faster than EU-27 in the period from 1995 to 2012. However, the energy intensity is still higher comparing with EU-27 in the absolute terms.

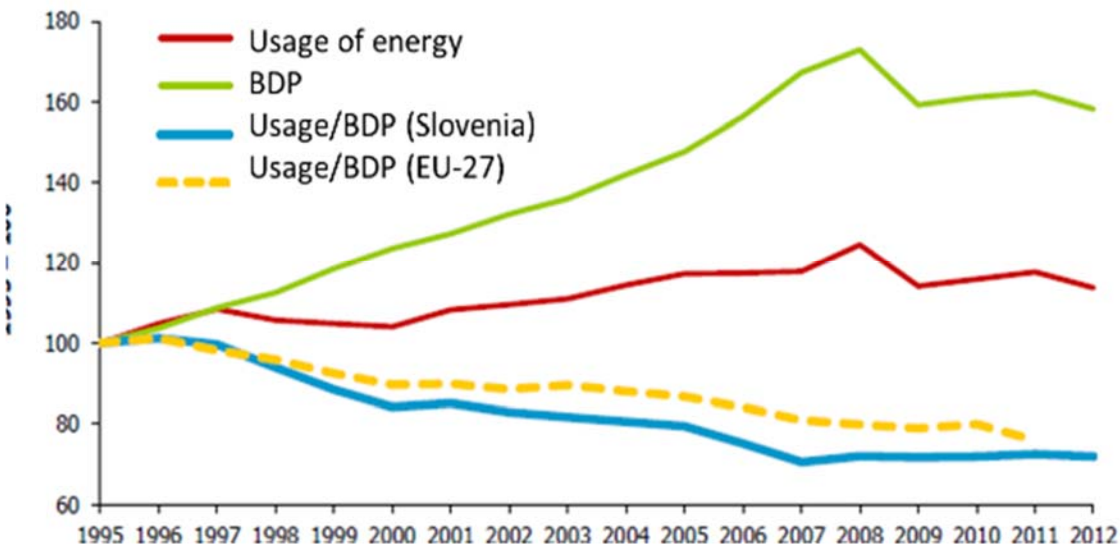
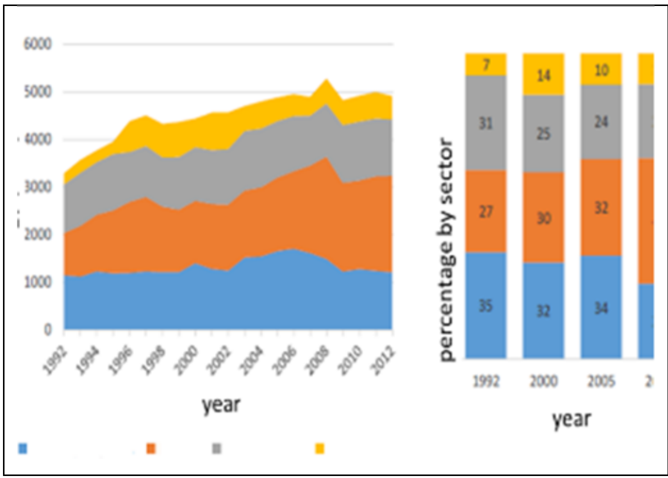
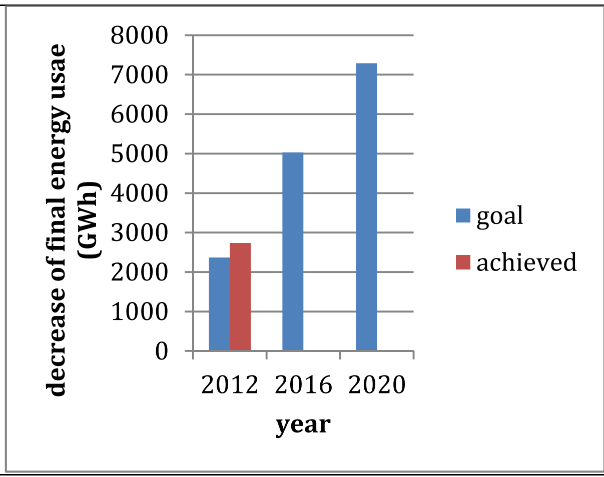


Figure 5: Evolution of energy efficiency vs GDP in Slovenia

With transportation activities, industrial activities are one of the major consumers of energy in Slovenia. So action plan of energy efficiency and strategic goals for energy reduction has been defined up to 2020.



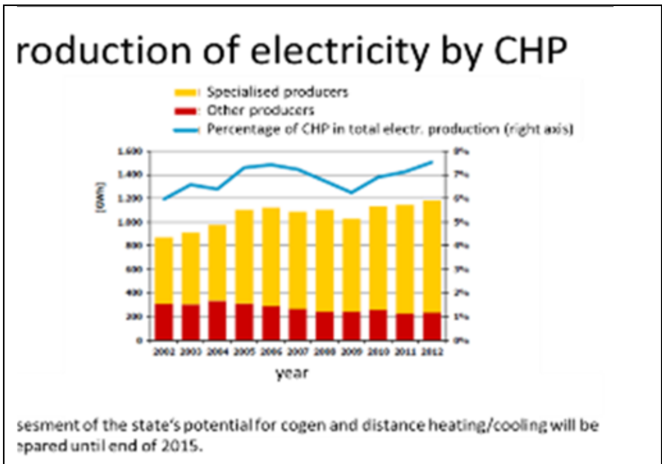


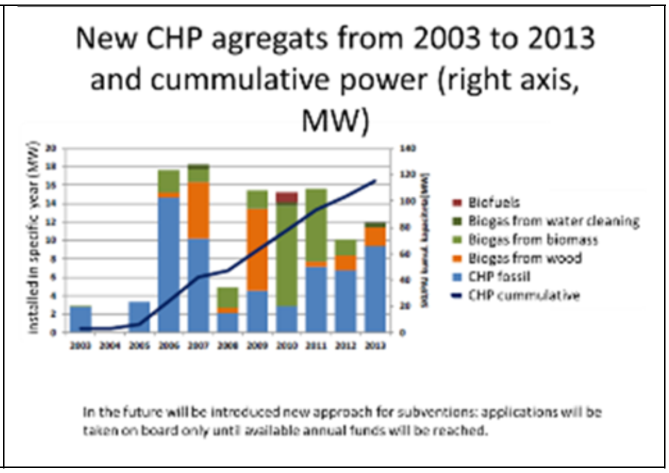
The Energy efficiency action plan includes different measures for energy consumption and implementation of energy management plan. This action plan concern:

- Industrial sector activities with : subsidies for energy revisions, energy management and energy consultancy services;
- Public sector with : definition of public entities which will be obliged use energy management; promotion of energy accountancy and energy revisions, optimisation of energy systems;
- And more generally for large companies: obligatory to do energy revisions every 4 years.

More specifically for industrial sector, the energy efficiency action includes measures on :

- Introduction of energy management systems: (education of employees, energy measurments, IT support, introduction of ISO 50001 standard);
- Increase of efficiency of use of electricity: enhanced electromotors, illumination, regulation;
- Decrease of usage of heat, usage of waste heat, use of renewables;
- Increase of co-generation and power generation from renewables: co-gen specially in process-intesive industries (paper, chemical, rubber…). CHP on natural gas and renewables. Increase of power generation by hydro, wind and solar generators;
- Development and production of sustainable products.



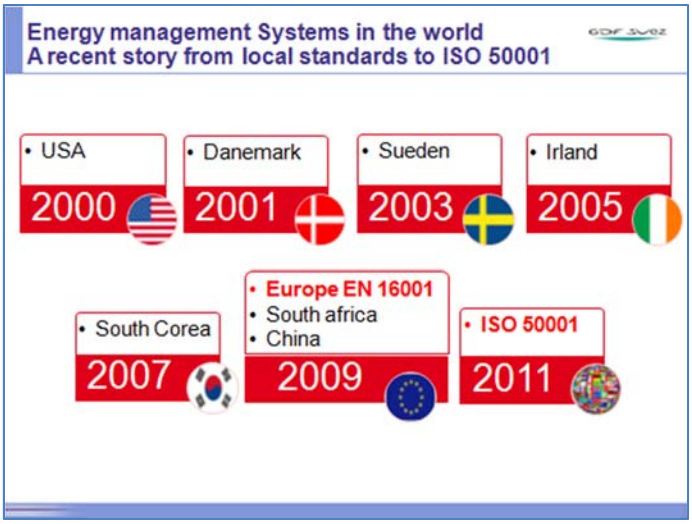


4. Synthesis of ISO 50001 (Energy management standard)

The objective of ISO 50001 is to help all types of organizations to establish the systems and processes necessary to improve energy efficiency continuously. The standard doesn't define standard energy- performance criteria: 2 identical plants can meet the requirements of the standard (and therefore comply) while having very different energy performance.

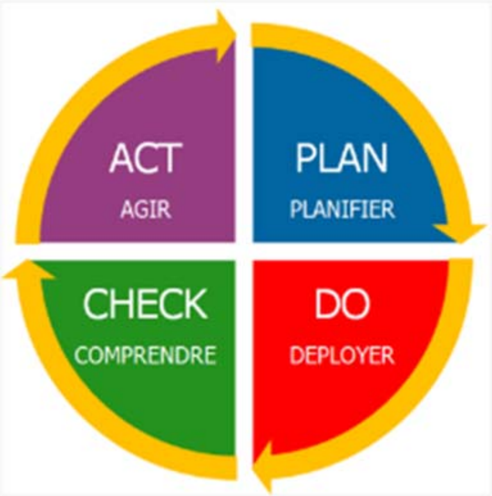
Energy optimization covers many topics and for large industrial companies that may be primarily a question of organization and establishment of the conditions for improvement. Standardization instances are mixed and there since mid-2009 a European standard EN 16001 which was the base of discussions and definition of the international energy management ISO 50 001. This standard provides requirements of a system and processes that improve energy efficiency sustainably. It has the same logic as the ISO 14001 standard for environmental management, so that it probably be included cheaply, in addition to an existing management system.

Standardization of energy management is recent. In Europe, Denmark is considered a pioneer in 2001 with the publication of a national standard. It was followed by Sweden, Ireland and Spain in 2009 to converge towards a European standard EN 16001 and now ISO 50001. The interest in Europe is found internationally and has naturally led to launch a project of international standard. ISO 50001 was published in June 2011 and replaces the European EN 16001.



ISO 50001 is based on the methodology PDCA (Plan-Do-Check-Act). This principle of continuous improvement loop "Plan - do - check, act" makes the ISO 50001 compatible with other management system standards, including ISO 14001.

It is therefore easier to integrate into an existing EN 16001 quality management system, but it is not a prerequisite. One of the prerequisite is the nomination of a energy head manager in the company. The strong compatibility between ISO 14001 and ISO 50001 justified, the ENVIRONMENT head manager could be also responsible ENERGY.



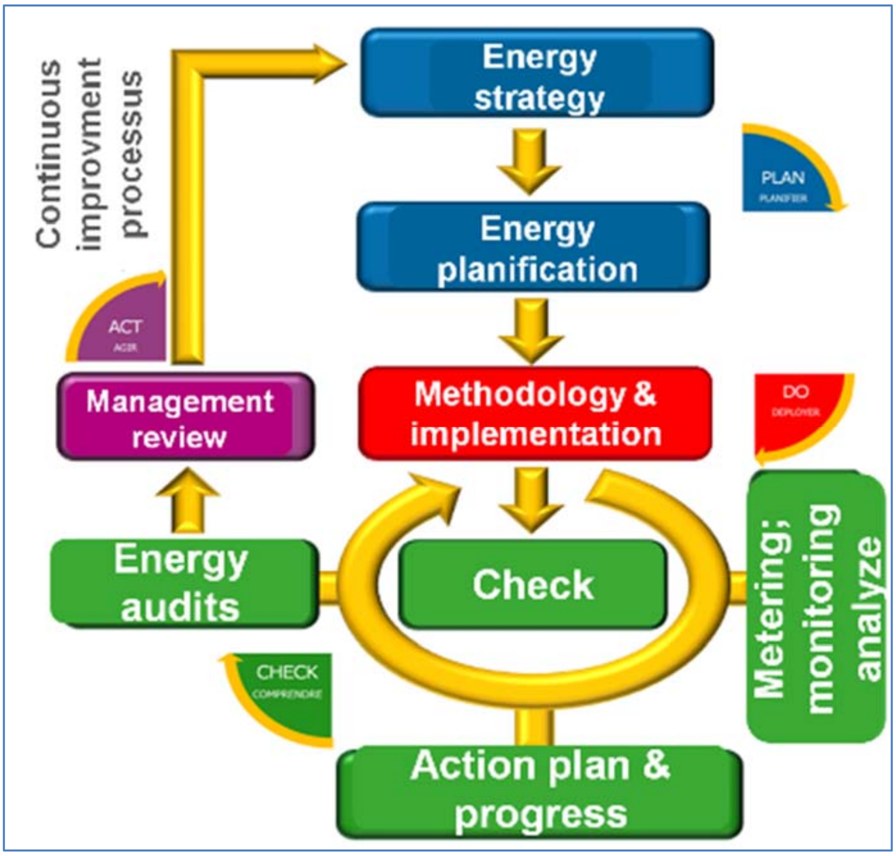


Figure 6: Synthetic diagram of ISO 50001 methodology

A successful energy management program starts with a strong management commitment of the organization to the continuous improvement of energy efficiency. In particular it is the responsibility of the Head Management staff:

- To define the scope of the EMS ;
- To appoint a representative and approving the formation of a team that will depend on the size of the organization ;
- To communicate the importance of the EMS to employees ;
- To define and maintain a clear energy policy.

An action plan has to be established with measurable objectives, definition of resources, time and responsibilities. The energy review is the data analysis process and the steps by which one identifies opportunities for improving energy performance. It is this process that allows to establish and update:

- The energy baseline ;
- Energy performance indicators ;
- The objectives and Targets ;
- The Action Plans ;
- Regulatory requirements and those to which the organization subscribes are identified and addressed.

The term energy audit is not included in the ISO 50 001 standard, but it's the principle of what is define through "energy review". Implementation and operation of ISO 50001 require the achievement of an organization for the effective functioning of the management system and the implementation of improvement actions. More than in other management systems, **energy** requires awareness and training. The high energy impact operations meet energy policy with typically:

- Establish criteria for the operation and maintenance of facilities ;
- Ensure consideration the energy aspect in the acquisition and purchasing of equipment, raw materials and services ;
- Evaluate the energy consumption during the study, modification or renovation of properties, including buildings of the company.

Audit phases and action plan designed to ensure the compliance of consumption compared to forecasts, ratios and indicators, regulatory compliance, and for understand and correct any anomalies. This implies the existence of a metering plan and implementation of energy and/or plant dashboard.

Feedback of ISO 50 001 implementation:

The feedback precursor's countries (national standards) allow a number of lessons:

- The penetration rate of energy management systems is high when accompanied by an incentive public policy. For example; the United States has set a standard in 2000, but the lack of incentive leads to a low penetration rate (<5%). However, it is 60% in Denmark and 25% in Ireland because these countries have public policies that encourage the adoption of standards.
- These proactive policies based on the granting of subsidies, exemptions or tax reductions through long-term commitment between the State and the company. For example :
  - Denmark : ISO 50001 implementation vs voluntary reduction of taxes, subsidies ;
  - Sweden: energy efficiency program commitment vs reducing taxes on electricity ;
  - Netherlands: ISO 50001 vs long term commitment grants;
  - Germany: Reduction in price of electricity transmission;
  - France : Increase of value of Energy efficiency certificate and subsidies

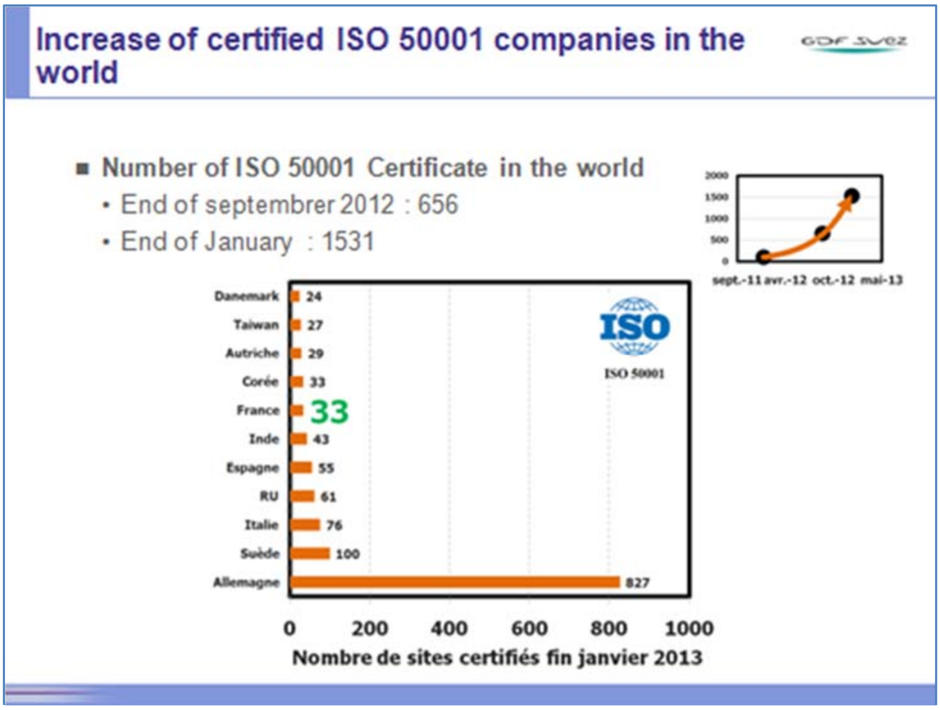


Figure 7: Evolution of ISO 50001 Companies number

5. Synthesis of European standards on Energy audits EN 16247

For compliance to the expected EU Annex VI Energy Efficiency Directive, European industrial large companies need to perform energy audits in 2015. The first audits must be completed before end of Q4, 2015.

The EU Directive 2012/27/EU requires that large companies do an energy audit every 4 years. The audit conducted by qualified auditors must comply with the standard EN 16 247. This energy audit will include an energy review, to establish the baseline energy consumption, significant energy uses, energy performance indicators, progress action plan.

This energy audit has to help the industrial companies to identify realistic energy economies, immediate & intermediate improvements. The energy audit results have to include proposals of improvements, which should allow to build a structured action plan to reduce energy consumption. The proposals have to be prioritized according to the level of investment required and the potential ROI associated and specific to industrial company criteria. A distinction has to be made between:

- The good practices: behavior, production management, maintenance, operation of facilities ...
- Economies needing significant investments :
  - ✓ Immediate action: low investment ROI <1 year,
  - ✓ Priority Action Short term ROI <2 years,
  - ✓ Structural Actions ROI> 2 years.

The objective of standard EN 16 247, is to warranty the quality of the energy audits, through the definition of a methodology to realize the energy audit and give for each step of the process the requirements and information to take into account and to analyze and also the expected results.

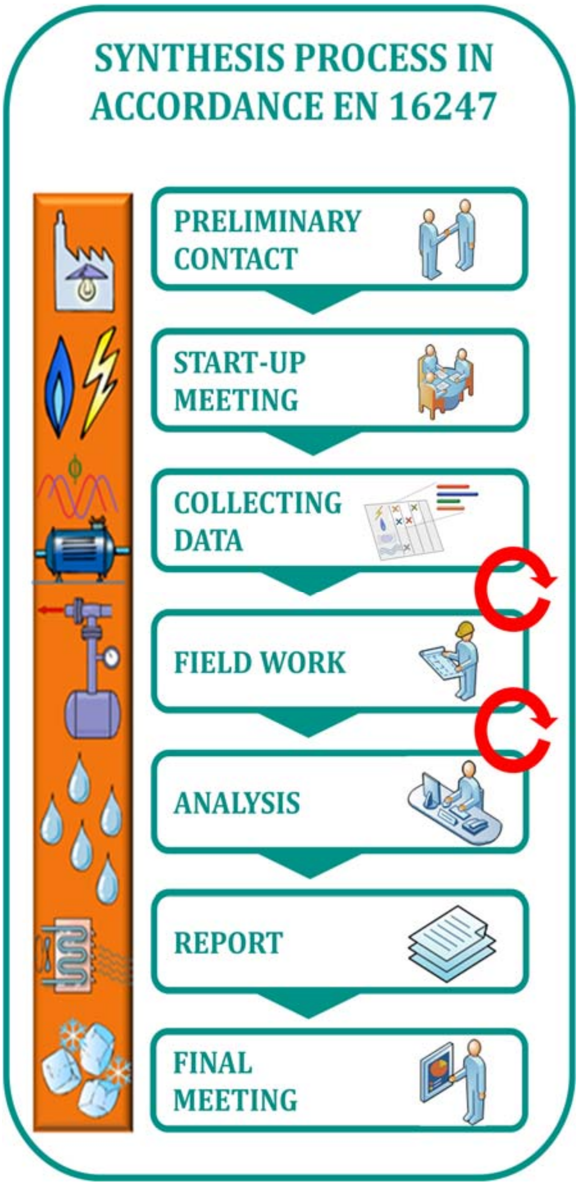


Figure 8: Synthetic scheme of EN 16 247 standard

The process include seven steps and start by a preliminary contact between the qualify auditors and the customer. This could be done through a pre-site visit (contact & kick-off meeting). A conference call or Webex could however be possible depending on the preference of the site. A detailed agenda have to be provided to prepare this meeting. The kick off meeting is very important to understand the needs of the customer and define clearly the perimeter of the energy audit.

Data collection has to be initiated with a questionnaire to be sent to the site prior to fieldwork. Available data must be sent prior to the step of fieldwork. Discussions have to be done with customer to implement complementary metering for non available data.

The most important steps of energy audit process are: Definition of the perimeter, Data collection, Fieldwork, which is an obligation, analyze and report.

The analysis phase can be summarized below according to the requirements of the standard EN 16 247:

General requirements
Assess the reliability of the data and draw attention to defects or anomalies
Appropriate and transparent method of calculation
To document the methods and assumptions
Process of verification and validation
Take into account the particular regulatory constraints associated with potential ways to improve energy efficiency

Existing situation of the energy performance
Breakdown of energy consumption by use and energy type
Energy flow and energy balance of the audited object
Energy flow and energy balance of the audited object
Link between energy consumption and adjustment factors
One or more Key Performance Indicators of energy consumption adapted to the object studied

Identifying opportunities for improvement
The financial savings
The investments
ROI or other economic indicator
Non-energy gains
Comparison of various improvement measures
Technical interactions between different measures

The EN 16 247 standard describe the type of data collection to be provided for the energy audit to contribute to the success of the approach taken. The industrial company has to be committed to providing the technical available elements required and necessary for the study, as for example:

- Description of the plant, the existing process and process diagrams,
- Production data and energy consumption over the last three years and specific ratio (specific consumption, annual production. ...) on a monthly basis,
- Energy consumption (electricity, natural gas, fuel oil, ...), for the last years (generally 3 years to take account of production variations)
- Data for comparison of process energy consumption and weather consumption (heating, DJU, ...),
- Energy Balances and/or dashboards, if existing,
- Schemes of Energy & production to establish an overview of energy between the energy consumption and the production (quantity, time, teams who products ...).

For a given industrial plant the Analyze phase of the energy audit has to include:

A complete balance of actual energy performance of the plant

- Balance of energy consumption per usages and type of energy
- Energy flux and energy balance of the production line & utilities.
- Evolution of energy demand during year or different specific steps .
- Ratios or correlations between energy consumption and different criteria (ex: specific energy consumption …..)
- Specific criteria of energy efficiency adapted to specific case studied .

Depending of audit objectives & analyze deepness

- Definition of complementary data to be collected .
- Definition of analyze deepness needed .

Results : Identification of progress solutions and action plan

- Estimation of energy saving & Economical figures .
- Level of CAPEX for each proposal.
- Estimated ROI or equivalent criteria.
- Costs saving associate (ex : maintenance, productivity…)
- Benchmark of proposed solutions.
- Impacts & correlation between different proposals.

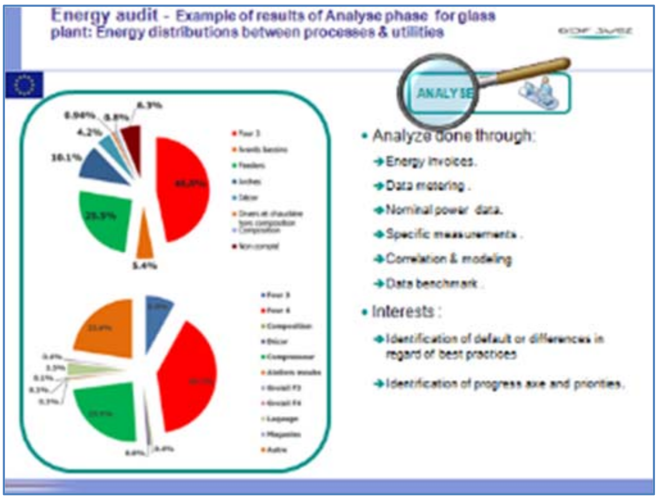
Exigences générales

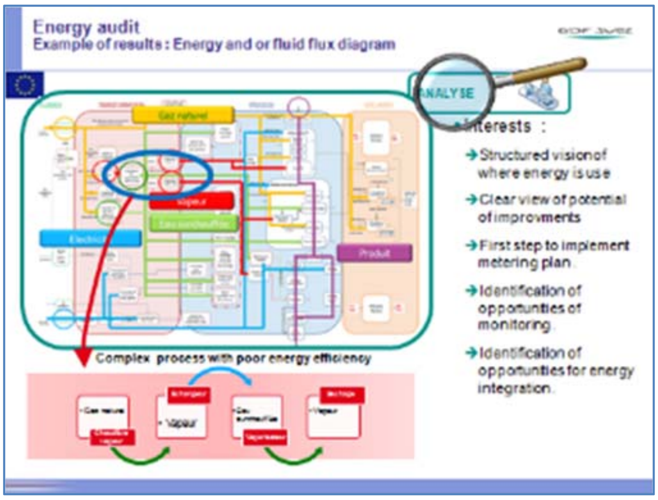
- Assess availability of the data collected and give warning on default detected .
- Use clear and explicit calculation methodologies in ther report.

- Give all information and figures use or necessary to explain hypothesis taken and calculation methodology.
- Explain assessment methodolgy of hypothesis taken.
- Take account of regulation constraints or specificities of the plant /company for proposed progress solutions.

Example of results provided after Energy audit with EN 16247 standard method:

- Energy balance and energy flux diagrams





- Different improved solutions studied (Example: Valorization of heat losses after furnace or boiler)

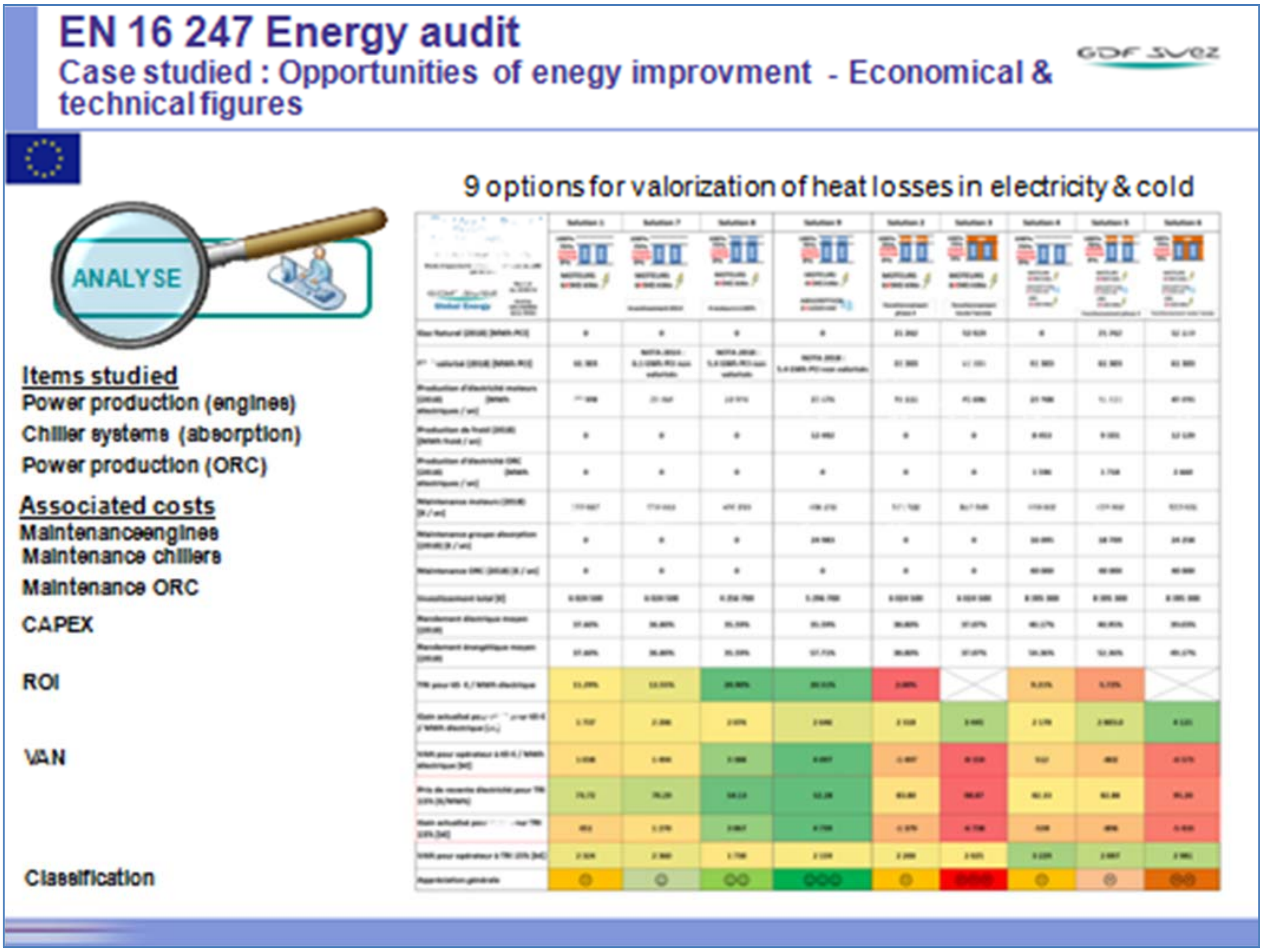


Figure 9: example of expected results after EN 16 247 Energy Audit

6. Example of Energy efficiency regulation & CEE certificates : France

France will be facing in the coming years with major energy issues: control its overall energy use, secure supplies in the face of fossil resources are not unlimited and divide by a factor of 4 to 5 2050 emissions CO2 to limit global warming. To achieve these goals, a strong and immediate recovery of energy saving becomes imperative, particularly in sectors of everyday use (residential, offices, industries ; shops and transport) today strong growth and which contain large deposits of economy. The program law setting the guidelines for energy policy requires reduction of 2% per year by 2015 and 2.5% in 2030 final energy intensity, that is to say the ratio between energy consumption and economic growth. On the other hand, the law of programming for the implementation of the GRENELLE Environment sets a goal of improving energy efficiency by 20% by 2020.

Significant savings potentials exist, sometimes profitable very quickly but lack of awareness on the issues, information on how to achieve these savings and financial incentives, the French are reluctant to take action.

In a market economy, certificates of energy savings created by the Energy Act are a way to educate and empower civil society, while limiting public spending. This device complements the existing instruments (regulations, taxation ...) and added to a sartorial approach which, by

nature, focuses on the most concentrated deposits (eg energy consumption in industrial processes).
ADEME also conducted in 2004, at the request of the Government, a large national mobilization campaign over three years with the slogan "Energy saving, quick do, it heats" with the support of many national and local partners. The principle of bonds and certificates of energy savings was defined.
The proposed measure is based on an obligation to achieve energy savings required by the authorities over a given period to the power sellers (electricity, gas, heat / cold, heating oil and motor fuels) as EDF, Gaz de France the CPCU, Total, SIPLEC, supermarkets...

Freedom and creativity are left to the power sellers to choose the actions they will undertake to meet their obligations. They can bring their customers achieve energy savings by providing them with information on how to implement, with financial incentives related manufacturers or distributors: premium for the acquisition of equipment, aids work, pre financial service, free diagnosis.
The scope of initiatives proves wide and open. In consideration of the findings of investments made by consumers through these actions, the power sellers receive certificates based packages in kWh (kWh Cumac) calculated by type of action. They also have the opportunity to achieve energy savings in their own buildings and facilities, provided that these sites are not already subject to requirements under the regulation of gas emission quotas for greenhouse.
However, the power sellers can choose to purchase, if it proves less costly energy savings certificates from other stakeholders such as local authorities and / or social landlords (called "eligible") that may, under certain conditions, also obtain certificates.

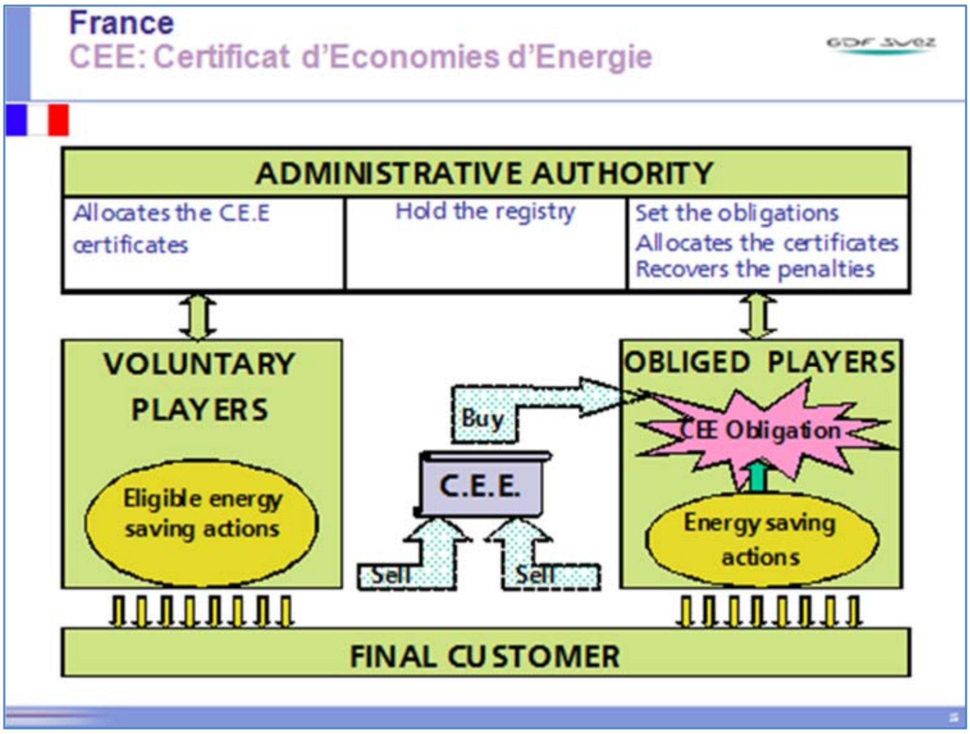


Figure 10: processus of French energy certificates

Many actions to achieve economies demonstrably may initially enter the certificates: field lighting, heating, insulation, etc.
For this, the Directorate General for Energy and Climate, ADEME and ATEE (Energy Environment Technical Association) **developed a** public catalog of standardized **calculation** sheets describing the various actions eligible for the issuance of certificates (available on the website internet DGEC, see cons), in the areas of residential, commercial, industrial,

transportation, agriculture, and networks. Moreover, the benefit of the device is expanded renewable energy for heating in buildings, under specific conditions, when they come to substitute for fossil fuels.

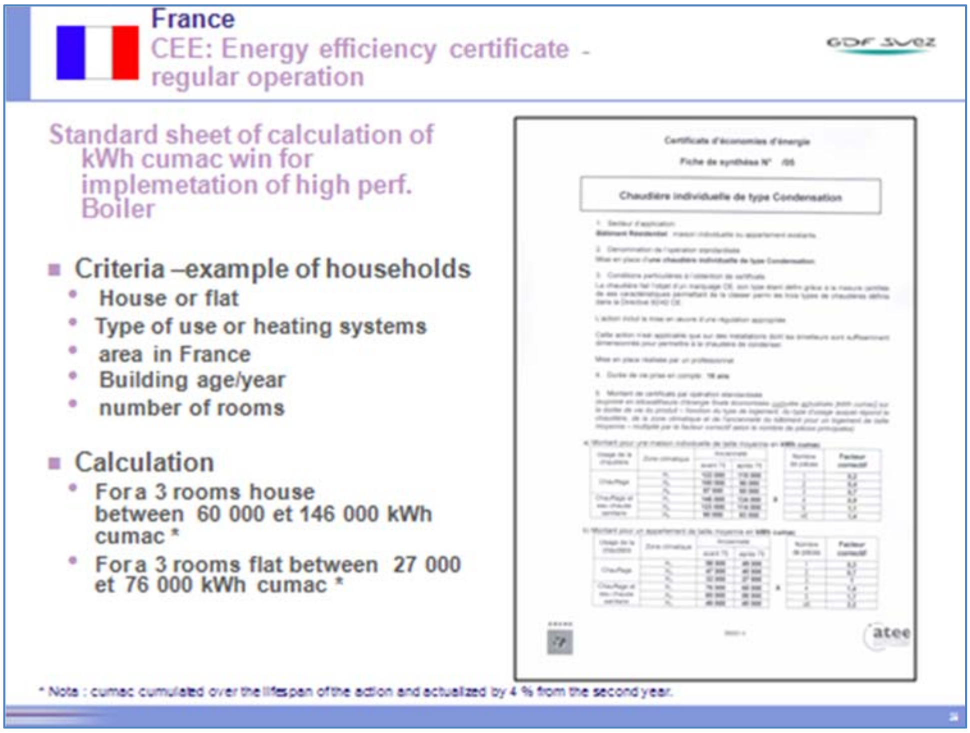


Figure 11: example of energy saving regular calculation sheet

The establishment of the overall device has been progressive: after an initial trial period of 3 years (July 2006 - June 2009), it is the law National Commitment to the Environment (July 2010) that defined the establishment of a second period of the device, from 1 January 2011 until 31 December 2013.
The bonds selected for this second period are 345 TWh cumac be 6.4 times the requirement of the first period (54 TWh cumac) whose 90 TWh for cumac fuel dispensers that become new forced the device.

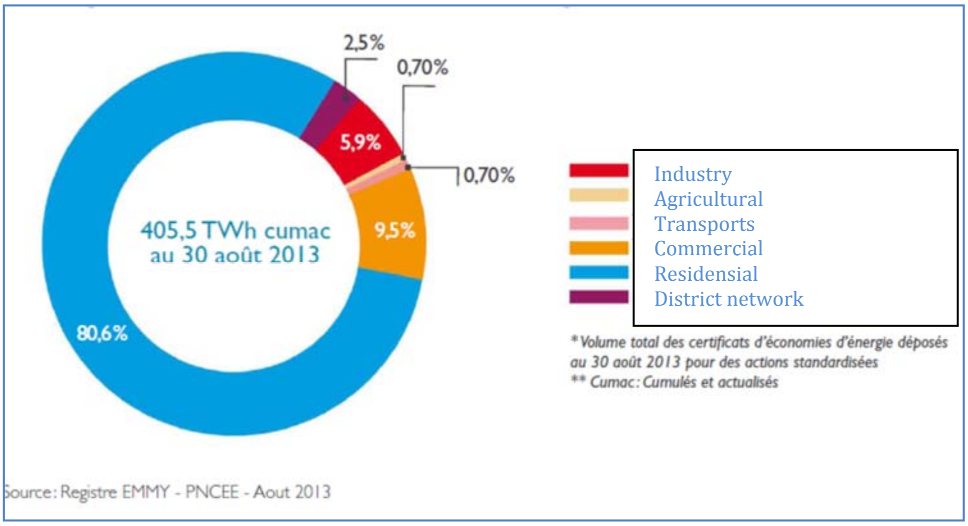


Figure 12: CEE distribution TWh cumac by sector in France

To meet their obligations, energy suppliers encourage consumer clients to invest in energy efficient equipment. This incentive, prior to the implementation of the action can take the form of technical support, assistance in financing, etc. Furthermore, the creation of a certificate market should enable the realization of actions at least cost to the power sellers, they have every interest in achieving the lowest cost actions when in financing part. In addition, they can use the special relationship that binds them to their customers to convince them to act. In total, the information is more effective because it directly affects the consumer. Assisted in its approach, it will be easier to modify their behaviour to save money and protect the environment.
This device provides funding very diffuse energy savings, including those made by individuals in their habitat. These actions are, in general, difficult to cause large scale and in this case difficult to finance. Certificates of energy savings are intended to provide a solution to this problem without creating an additional burden on the state budget.
Objective of the 3-year period set by the authorities. The energy savings can be realized by each supplier of energy in all sectors (residential, commercial, agriculture, industry, transport ...)

At the end of the period of 3 years, each energy supplier must demonstrate the fulfillment of its obligation to provide the corresponding amount of white certificates.

During the first period of implementation in France, the mean sale price of Energy Efficiency Certificate was 0,003 € / kWh cumac. During the second period the sale price was between 0,0035 et 0,0043 centimes d'euros le kWh cumac (ie 3,50 € à 4,30 € par MWh).

In total, they have 540 received at least one of the 2,495 decisions to grant Energy Saving Certificates. 1780 it was observed of them were granted to 263 forced, while 715 277 decisions concern not required. This equals the amount of energy saved 109.6 TWh and 7.5 TWh, for a total of 117.1 TWh of energy saving . These certified energy savings are divided between four areas:

- 83% was done in Residential area
- 7% in Commercial area
- 6% in industrial area
- 4 % in district heating

If energy salespeople fail to fulfill their obligations within the time**, they will have** to pay a discharge penalty to be paid to the Treasury.

7. Example of Energy efficiency regulation & White certificates: Italy

As for the other European Countries, also for Italy energy efficiency represents the first source of "renewable energy" and the "cheapest source of energy". The lack of traditional natural resources has stimulated in the years the adoption of technologies and behaviors that can achieve energy savings.
Nowadays national regulation about energy efficiency is working in the frame of European Regulation.
All regulations have been inspired to the target of 20-20-20 formula, defined in 2008, meaning the achievement of 20 % of power generation by renewable, 20% of reduction of CO_2 production by 2020 with respect to 1990. Primary energy consumption reduction of 20% was considered a wished but not binding target; anyway, the achievement of both the two previous

targets is strictly connected with the enhancement of energy efficiency (reduction in traditional source energy consumption).

It is thought that effort done to achieve emission reduction will give results also afterword's, with a reduction of 40% within 2050. Moreover the objective on renewable contains an objective of 10% of biofuels.
In this frame, Italy adopted this plan, with the following objectives at 2020:

- 18% of green house emissions, divided in to 21% for ETS sectors (Emission Trading System, especially power generation) and 13% with reference to 2005 for the other sectors;
- A binding objective of 17% of Energy produced from renewable sources;
- Italy adopted also a commitment to reduce of 20% primary Energy consumption.

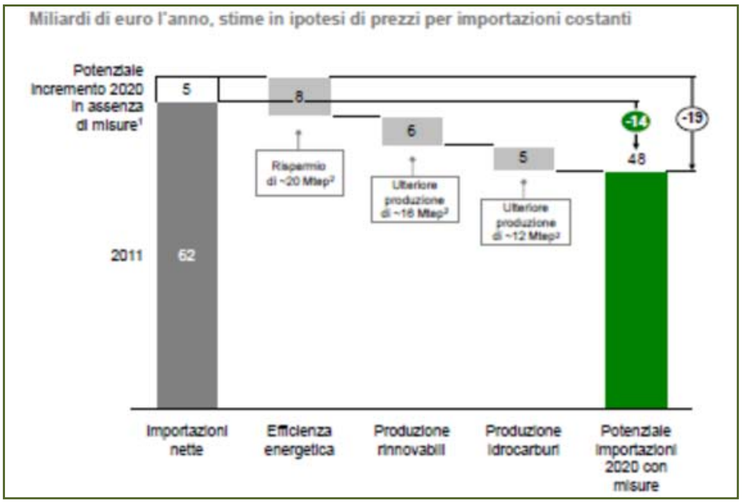
The previous European Directive on Energy Efficiency – 2006/32/EU - had been adopted in Italy in 2008 with the Decree no. 115 of 2008.
Meanwhile a lot of debate has taken place in Italy on the ways to improve energy efficiency which carried to the publication in autumn 2012 of a document of Italian Government called SEN "Strategia Energetica Nazionale" or "Italian National Energy Strategy", which represents a reference documents for Italian actions in energy utilization.
National Energy Strategy is based on four main objectives:

- To reduce significantly the gap of Energy cost for enterprises and citizens, with respect to other European countries;
- To reach and overcame Objectives defined by European Package 20-20-20
- To continue in improving security of supply, especially in gas sector ;
- To enhance sustainable economic growth of the country through the development of energy sector, stimulating also growth of industrial sector.

Energy Efficiency is one of the seven drivers described to reach these objectives, representing a way to achieve environmental benefits and sustainable industrial growth.
In detail, it is expected to achieve + 25% Energy saving with respect to european reference scenario, with a saving of about 20 MTEP of primary Energy within 2020, avoiding the emission of about 55 Million of CO2 per year.
There are several technological opportunities, many of them with positive pay back, but their introduction and use is very difficult due to many barriers (different for any specific sector). So government is willing to adopt a series of solutions to overcome these barriers, e.g.:

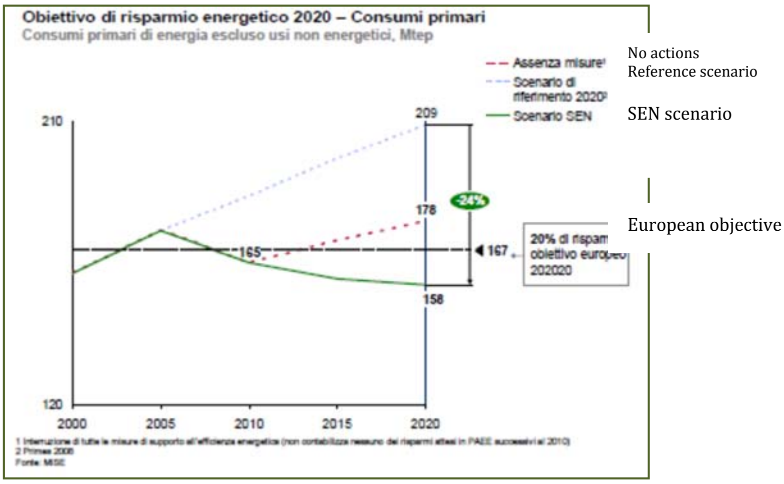
- enhancing minimum standard and regulation (for transportation and buidings)
- adopting fiscal exemptions, mainly for building and residential sector;
- the use of direct incentivation for public administration, which cannot use fiscal incentives;
- the enforcement of White Certificates System (which will be analyzed in the following part of the document).

In the frame of SEN, also the enforcement of ESCo . Energy Services Companies is expected.
Moreover, a specific phenomenon is underlined: the evolution and growth of electricity consumption (e.g in heating with electric heat pump and in transportation). This trend is visible in various studies and has to be investigated both for the evolution of energy efficiency technology and to better underline and enhance, on the other hand, the role of gas.
The following figure represents the evolution of energy importation in Italy at 2020 without and with actions.

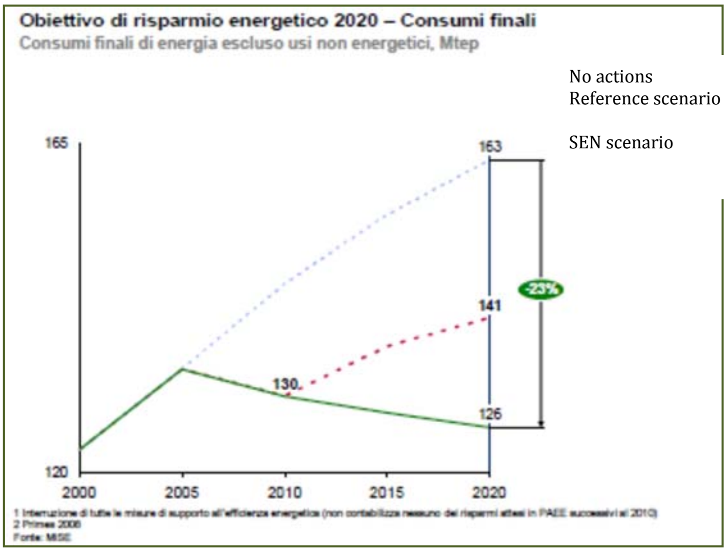


Source SEN – 2012

The objectives at 2020, in terms of primary energy and in terms of final energy are showed in the following two figures.



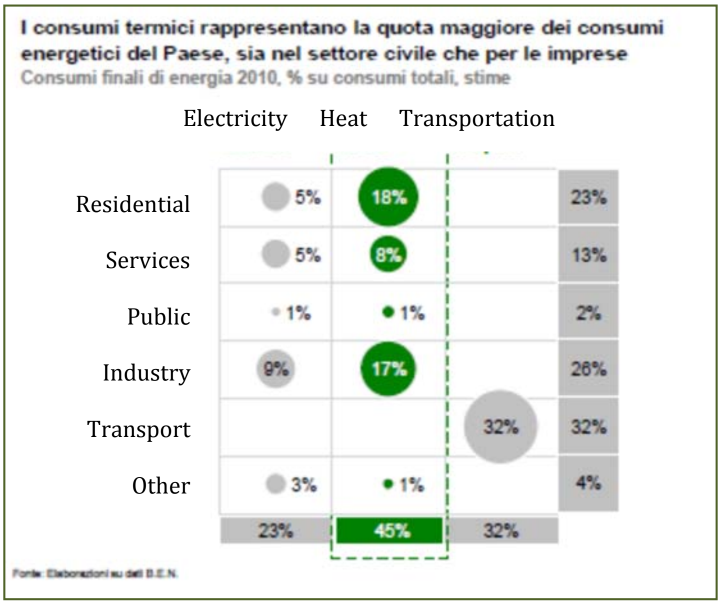
Scenarios on primary energy consumption in Italy - Source SEN – 2012



Scenarios on final energy consumption in Italy - Source SEN – 2012

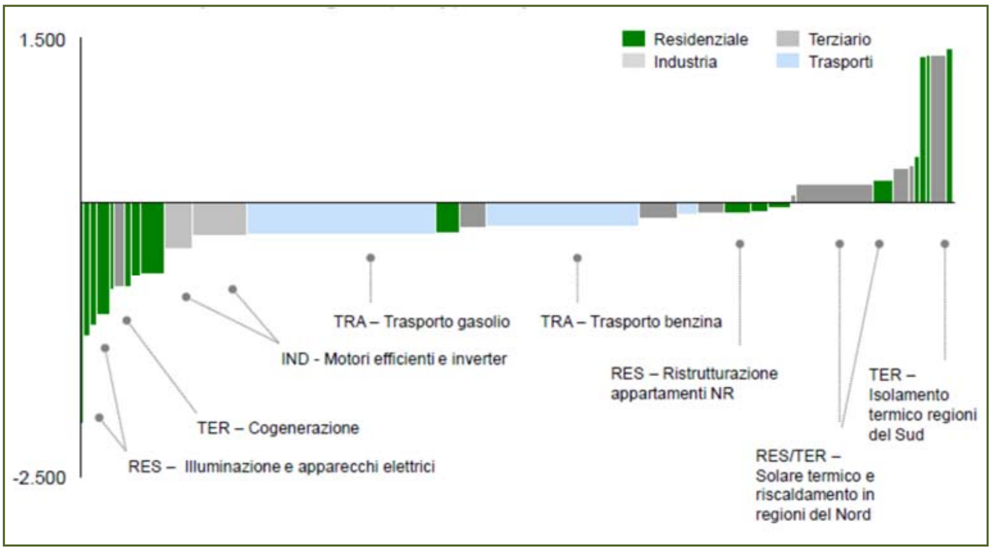
Italy shows already high performances with respect to other European countries. Anyway, many actions can be done to improve energy conservation and rational use of energy, adtopting technological solutions which have positive pay backs.

Present final Energy consumption in Italy is roughly 130 MTEP, of which heat represents main part of this (45%). Industrial use of energy is about 26% (transportation about 32%, residential 23%, services 13%, public administration 2%).



Percentage of energy consumption for different sectors and energy vectors

In the last year many results have been achieved, based on the last PAEE (Action plan for energy efficiency).. Roughly 4 MTEP of final energy and 6 MTEP of primary energy per year have been saved at 2010 (objectives were 3,5 MTEP)
In the following figure, the curve of cost is showed. For many solutions, cost is negative which means cost of investment is paid by energy efficiency.



Various energy efficiency solutions, with cost of energy savings (€/TEP)

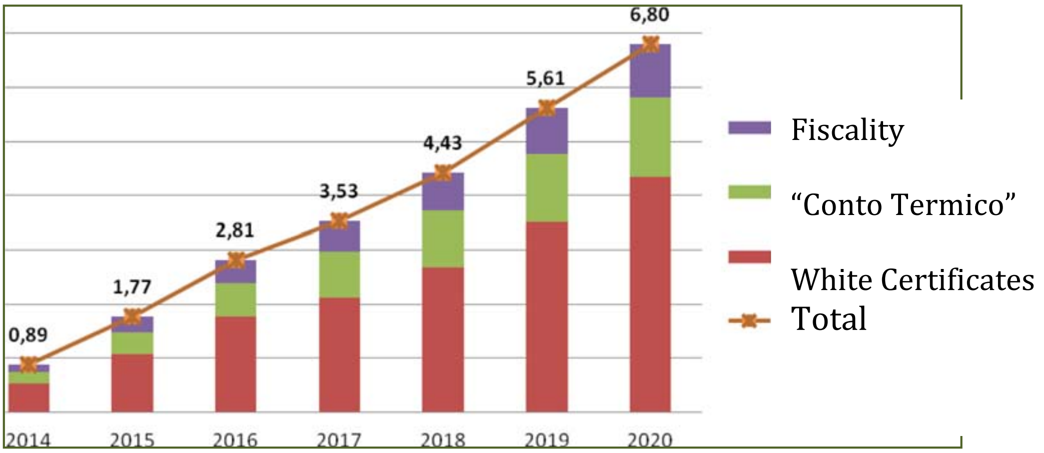
The last European Directive on Energy Efficiency 2012/27/EU has been adopted in Italy on 19 July, 2014 with the Decree n° 102 of 4th July 2014.
Such decree establishes many actions to support energy efficiency. Among this:

- white certificates is the main mechanism to support energy efficiency and it is adopted as official "mandatory scheme of energy efficiency obligation". It will assure 60% of the entire objective of energy efficiency

- energy audit will be mandatory for big industries and will be sustained for SME
- Certification of ESCos and of energy auditors is enhanced

White Certificates Scheme ("Titoli di Efficienza Energetica" or "Certificati Bianchi")

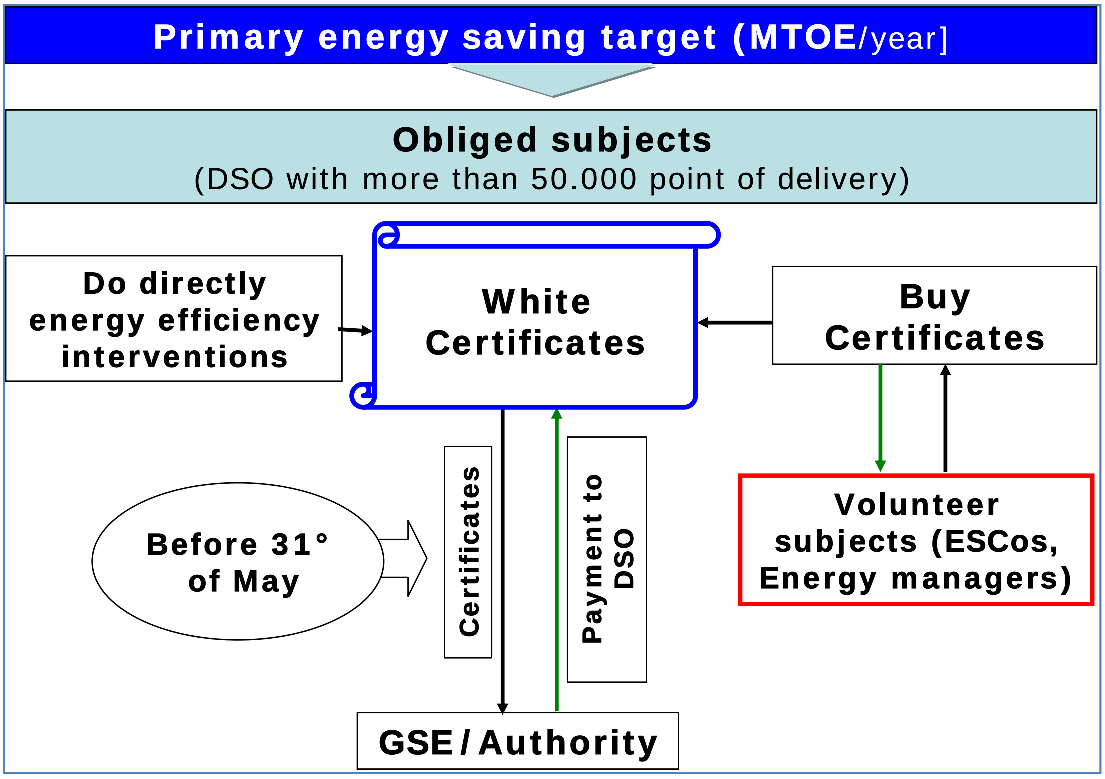
Various mechanisms have been adopted in Italy to promote Energy efficiency.
Among this, White Certificate System is one of the most successful and in 2014 it reached its first 10 years of life.
As mentioned, White Certificates Scheme is responsible for about 60% of the Italian energy efficiency objective.



Source – GSE (Gestore Servizi Energetici)

In 2004 two Ministerial Decrees established in Italy the **White Certificate system**. It is basically a market mechanism for energy efficiency, which aims at reaching yearly objectives in terms of saving of primary energy at the minimum cost.
DSO (distribution system operator, both for gas and electricity) have been selected as subject obliged to achieve energy efficiency targets every years. They can achieve such targets through their own projects or buying "Energy Efficiency Certificates" (TEE) also called "White Certificates". White Certificates are tradable titles recognized to projects achieving energy efficiency, which can be obtained by ESCo, energy managers or DSOs. Trading of certificates can be done on a specific exchange market or by bilateral contracts. At the end of the chain, DSO receives contributions after reaching the obligation target.

In the following figure, mechanism is showed.



Italian White certificate mechanism

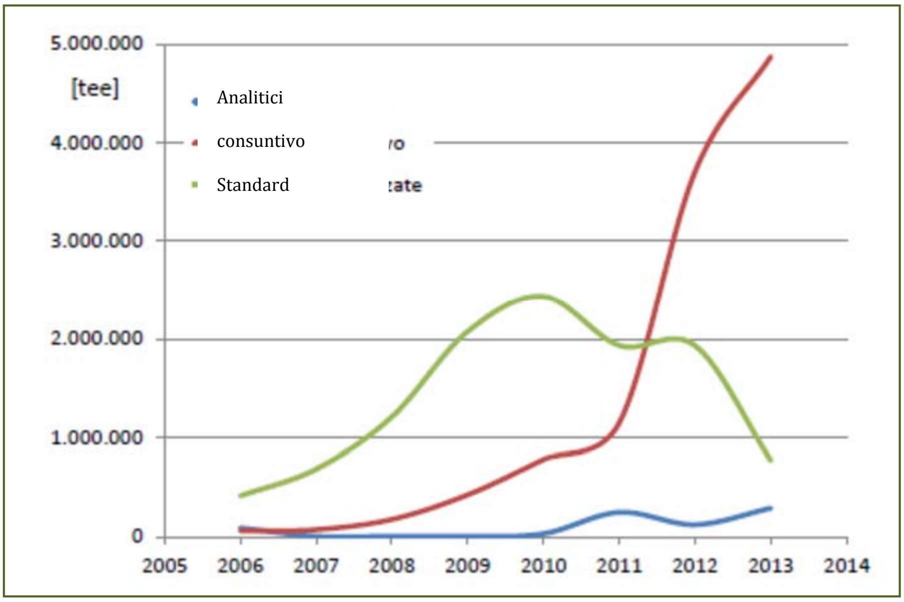
The Authority responsible for the management of the mechanism is GSE – Gestore dei Servizi Energetici.

The ways to measure energy savings are basically three:

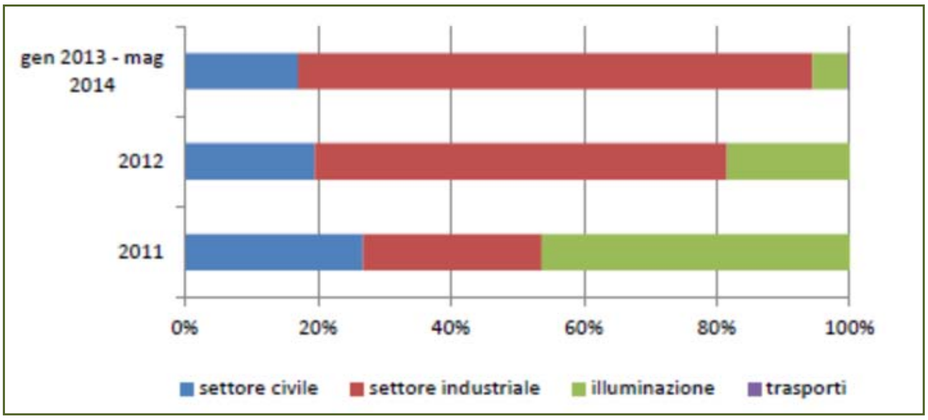
- standard: it means that saving are calculated on estimated rates based on type and size of specific projects;
- analitici: savings are calculated using pre-defined formulas and metering some parameters;
- “a consuntivo”: algorithm to measure and calculate energy savings are proposed by subject which propose the projects and needs specific approval. Savings have to be measured with specific meters.

Standard and “analitico” are mainly used for civil and residential sectors; the last method is used every time that pre-defined formulas are not available and it is the mainly adopted method in industry.

From the beginning of the mechanism until May 2014, approx. 27,3 Million of White Certificates (Source AEEG). It is important to underline that White certificates take into account savings related to conventional life of projects, on the other hand, certificates are recognized only to savings additional to savings that would have been achieved owing to normal technological evolution.
In the following graph, number of Certificates released is showed.



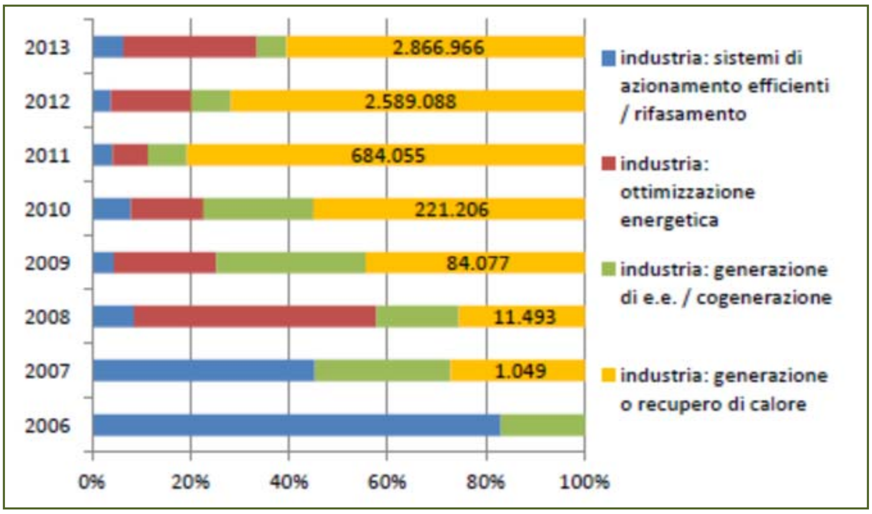
Amount of Certificates (Source GSE April 2014)



Residential and commercial Industry Lighting Trasportation

Percentage of White Certificates for sectors (Source GSE)

Heat recovery and thermal intervention are becoming the main source of energy savings in industry.



Percentage of White Certificates for type of intervention in industry (Source GSE)

8. Example of Energy efficiency program in Algeria

The energy efficiency program is governed by ALGERIA's commitment to promote a more responsible use of energy and to investigate all the ways to protect the resources and systematize (explore all possible avenues for conserving resources and systematizing) efficient and optimal consumption.
Energy efficiency aims to produce the same goods and services by using least possible energy (the less possible energy). The program provides for measures that favour forms of energy most suitable for different uses and require behavioral change and improved equipment.

The energy efficiency program is defined as follows:

- **Thermal insulation of buildings :** In Algeria the construction sector is the most energy intensive sector. It uses more than 42% of overall energy consumption. Proposed measures to achieve energy efficiency in this sector include the introduction of thermal insulation of building , which will reduce energy consumption related to home heating and cooling by about 40%
- **Solar Water heating development :** The penetration of solar water heaters in Algeria remains undeveloped but the potential is significant. They are plan to develop the implementation of solar water heating systems to gradually replace conventional heating system.
- **Spreading the use of low energy consumption lighting systems:** The objective of action strategy is gradually prohibit the marketing of incandescent lamps on domestic market to reach a total replacement by 2020. In parallel there are plans to put several million low energy bilbs on the market. Furthermore, local production of low consumption lighting systems will be encouraged in particular through partnerships between local and foreign producers
- **Promoting energy efficiency in the industrial sector** : The industrial sector accounts for about one fourth of country's averall energy consumption. For energy efficiency there are plans for:
    - Co financing Energy audits and feasibility studies that will enable industrial companies to precisely define technical and economical solutions best suites to reduce drastically the energy consumption
    - Co financing additional costs linked to the introduction of energy efficiency into technically and economically viable projects
- **Promoting liquefied petroleum gas fuel** : There are plans to increase by 20% the market share of liquefied petroleum Gas fuel (LPG/F) in automobile fleet by 2020. This will be accompanied by the provision of direct financial assistance tio individuals wishing to convert their vehicles to LPG
- **Promoting Natural gas use/fuel** : at early beginning of 90s year, a R&D program was initiated to convert vehicles using diesel fuel to natural gas compress fuel. Station were developed by SONELGAZ to distribute natural gas fuel to experimental fleet . In 2013 it was planned to convert several tens of district buses to natural gas fuel in the city of ALGIERS and to extend this operation to others large city before 2O20.
- **Introduction of key technologies for solar air conditioning** : Solar energy for air conditioning is a technology that should be promoted particularly in south of the

country , as far as needs for cooling mostly coincide with the availability of solar radiation. Moreover solar collectors may also be used for hot water production and room heating during the cold season. The overall performance of a solar cooling system is therefore of a great interest. By 2013 studies will be launched to acquire and harness solar cooling technologies and choose the system best suited to the Algerian context. Two pilot projects for air cooling using absorption and adsorption chillers will be launched for cooling of buildings in south of the country

9. Methodology propose

- ✓ ***Energy optimization: A methodology in four steps (schemas - France)***

The realization of an energy optimization approach for an industrial site is a complex problem because it includes a wide variety of technical devices (various specific production processes - various type of Furnaces, chemical reactors, drying systems and curing processes...); associated industrial utilities (Compressed air production systems and distribution grids ; boilers for production of steam or superheated water and associated distribution grids…); systems using the driving force (Fans, transport tables, rolling mills, roller tables, robots....) and specific buildings dedicated to manufacturing lines, storage and offices, which also use air conditioning systems, heating or cooling systems , and lighting systems. Furthermore, regarding the type of processes versus the industrial plant implementation(Countries) the energy mix of an industrial plant included also a wide range of energy used (Electricity; natural Gas ,Fuel-oil, Coal, Process gas, Biomass, green gas…).
So the implementation of this type of approach and audit energy industry therefore requires a structured approach, systemic and a wide range of more or less specific technical expertise. For that, many works has been carried out since nineties years, with the help of research Universities, by different energy agencies in many countries (eg: ADEME -FRANCE; CARBON TRUST - UK or Ministère de l'énergie et des Ressources naturelles – Québec ;…) and Energy Utilities and ESCOs as GDF Suez. To illustrate this, we will explain, in the following, an energy-efficient approach, base on the energy efficiency regulations and standards set forth above, and implemented by GDF Suez to provide energy optimization services to industrial customers in Europe.

10. GDF Suez- Research division – Research center CRIGEN – Methodology

In a context of high and volatility of energy prices, strengthening of environmental regulations, implementation of national strategic energy plans, including drastic reduction of energy consumption (ie: CO2 reduction) in order to fight against climate change; Economical crisis and hard economical fighting between countries:

- Energy & Environmental efficiencies are key criteria of profitability of industrial activities;
- Energy & environmental directive reinforce drastically the needs of reduction on Energy consumption & pollutant emissions;

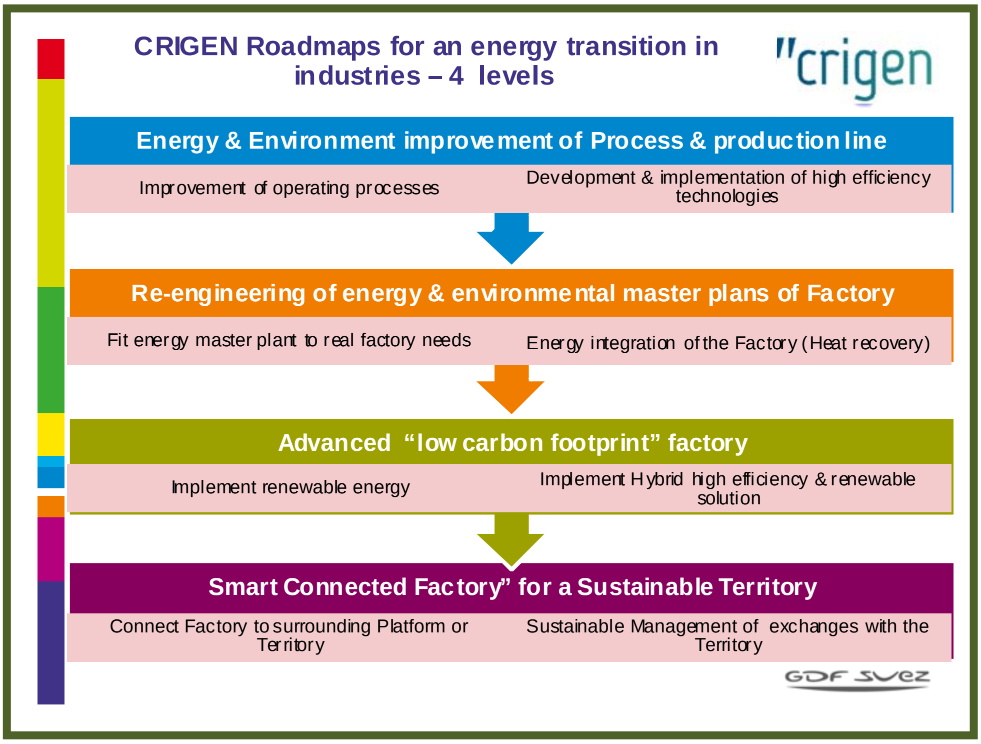
In an attempt to respond to these new industrial challenges, it appears important to implement coordinated and strategic approach of Energy Efficiency including:

- Energy & Environmental efficiencies trough Energy & Environmental audits;

- Energy integration approach for Processes ; production lines and whole factory plant through reengineering of Energy Master Plant (EMP)

- Integration of new concepts, like renewable energies, to move toward to innovative concepts of "Eco-design or low carbon footprint Factories"

These trends needs to think with new **systemic approach & "territory optimization"**
To implement that a four-step approach can be proposed and summarized in the following graph.



- **Step 1: Optimization of Energy Efficiency of processes & production lines**

This first step in the process, which started with the implementation of energy audits and possibly environment audits, will be focused not only on the analyze and studies to improve the performance of production processes, but also on the study of improvement of the operating conditions of the processes and implementation of good practices for process operation and maintenance of the systems analyzed. Several items could be analyzed:

- Improvement of combustion efficiency and combustion systems
- Improvement of performance safety and reliability of energy providing facilities (Fuel-oil; natural gas, process gas; biogas…) and associated distribution grids
- Improvement of performance; heat transfers and energy uses in thermal processes
- Improvement of performance safety and reliability of steam/hot water facilities and associated distribution grid

- Improvement of performance and reliability of Compress air systems and associate distribution grids
- Improvement of performance of eclectic devices
- Improvement of safety and reliability of electric devices and electric distribution grids
- Improvement of control-command systems, set points & transient phases

- **Step 2 : Reengineering of energy master plan : Fit energy needs and Energy integration of production line & processes**
  - ✓ Re-engineering of EMP: Fit energy needs of the factory
    - – **Decentralized electricity production :** (Auto consumption, Rankine cycles & Organic Rankine Cycle (ORC), New thermodynamic cycles , cogeneration …)
  - ✓ Topic : Re-engineering of EMP: Energy integration of the processes lines
    - – Heat losses recovery : valorization of heat losses
      - **Heat recovery on high temperature heat losses**
      - **Heat recovery on low temperature heat losses**
    - – Heat losses valorization through electrical conversion
      - Conversion to electricity: Steam turbine, ORC
- **STEP 3: Advanced low Carbon footprint Factory**
  - – Integration of renewable energies in the energy mix
  - – Implementation of Hybrid energy solution
- **STEP 4 : Energy integration of Industrial plant in Territory**
  - – Connect the factory to the surrounding territory
  - – Sustainable integration of the plant into the territory

Natural gas appliances & energy efficiency: Case studies & industrial references

In this paragraph, after a short review of the global context and example of regulations or initiative push by different countries, to promote Energy efficiency, we will try to demonstrate through some case studies the interest of to implement energy efficiency program and the opportunities for the natural gas solutions and associated technologies to answer this important challenge which is reduction of the energy consumption in the industry.

11. Topic: Optimization of Energy Efficiency of processes

Case study: Implementation of high efficiency NG boilers & reengineering of steam production systems: Best practice for production of steam or hot water:

A very large number of industrial processes are using steam and hot water as main energetic vector. It's typically the case of industrial food processes, chemical and petrochemical processes….. In these industrial cases, knowing and control the correct cost of steam is very important, and in the present economical world situation, all of these industrial companies have to do with improving the company's bottom line in order to:

- ✓ Properly evaluate the economics of proposed process efficiency or production capacity-improvement
- ✓ Prepare new projects; if the calculated cost is not accurate, many good energy projects may be missed or rejected, and bad projects may be approved for implementation
- ✓ Serve as a basis for optimizing the steam generation system, and minimize costs
- ✓ Ensure more effective negotiations with the utilities or third party Independent Power Producers
- ✓ Properly evaluate steam needs for proposed cogeneration projects.

Steam is used for a variety of applications in commerce and industry:

- Process heating (cooking, heating chemical reactor, drying, distillation,…..)
- Produce Vacuum trough use of Vacuum jets systems (ex: Steel industries or health industries…)
- Mechanical power production (Shaft work for mechanical drives)
- Power generation
- Production of heat and/or hot water for HVAC or Cooling systems.

In the industrial manufacturing facilities, use of energy trough production of heat, accounts for an average of more than 60% of thermal energy use, predominantly in the form of steam. Process heating also accounts for a significant portion of controllable operating costs (15 – 30 % of the production costs). So it's one of the few areas of opportunity where management can reduce operating costs and improve profits.

In most companies, the reported cost of steam is the average cost of generation at a particular production rate. The total operating costs—fuel, power, water, chemical additives, labor, maintenance, depreciation, interest, and administrative overheads—are divided by the total amount of steam produced. This may be a convenient corporate financial benchmark, but is not particularly useful for managing the steam production system to minimize costs. For that, we need a better method for steam cost accounting.

One of the issues is that the cost of steam depends on the generation rate, especially in complex multi-boiler multi-fuel plants that also have steam turbines. To most people, this is not intuitively obvious.

So the first things to do when a company want improve the energy efficiency of the boiler house is **to do a detailed energy audit with a methodology for improvement of boilers houses base on 5 major steps :**

- **First steps : The necessity to think or do reengineering of the system in order to adapt the design to the real actual needs (techniques, power, energy level, reliability, flexibility)**

Many of industrial production steam system (Boiler house & steam networks) have been designed at the early beginning of the factories, when conditions of production, technologies and market energy price were very different. Also, especially in Europe or USA, many industrial plants have been restructured and big plants divided in several industrial plants. In these cases we often see large discrepancy of the actual design of the steam production plants and distribution network and the real steam needs of the plant.
Also in these cases the first thing to do reengineering of the present design, like:

- What is my real needs ? (eg, have I really need of steam rather than hot water? ; The amount of steam produced or the number of boiler running is not it too much ? Which are the charging rate of the boilers (10%, 40% ,60%.......)
- What is the efficiency of the running boilers?
- How many time during a year Steam traps are checked?......
- What is the level of steam leaks?
- What is the condensate rate return?
- Do I need to produce power and thermal heat?....

Adapt the design of the boiler house to the real needs for a complex steam production and distribution system is a complicate task but necessary to reduce drastically the steam production costs.

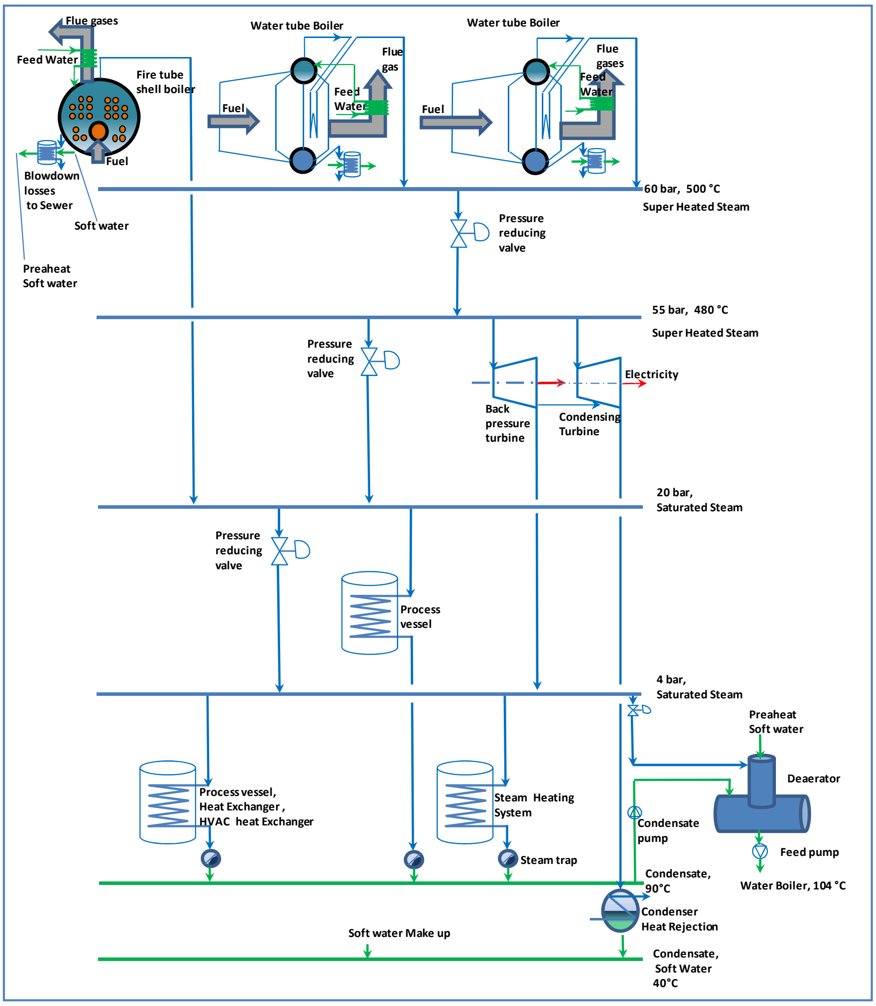
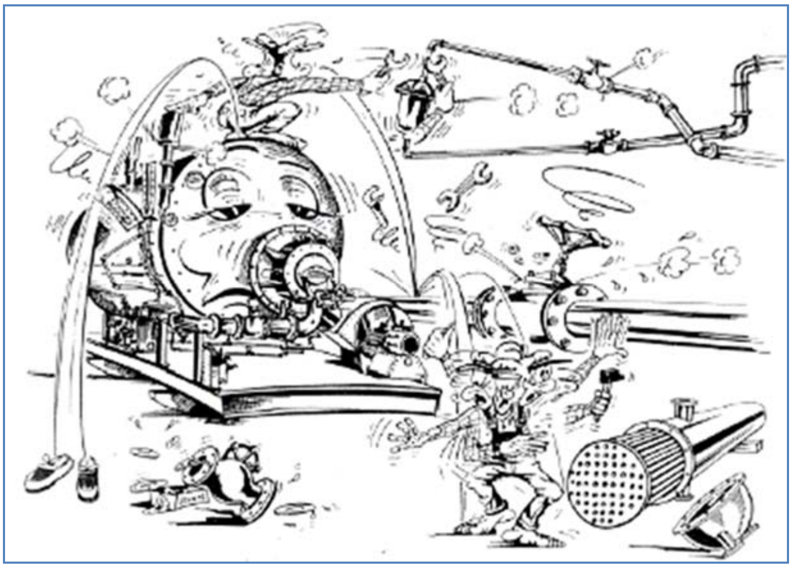


Figure 13: Example of complex and non optimize steam production and distribution system

- **Second steps: Necessity of training staff to improve the skill of the staff and the developers**



As we explain before steam production and distribution systems are complex system, coupling several industrial processes and sometimes also power production system. As it's a mature and often semi- automatic controlled systems in lot of factories, staff dedicated to his daily optimization is poor. This is a big mistake which generates worth running and rapidly costs losses.

- **Third step: Control the Efficiencies of boilers and use high efficiency boilers**

The steam production boiler is a well known and mature thermal process. Even though, due to the regulation obligations on energy efficiency and NOx emissions, many boilers manufacturers have improved their technologies and now a best available boiler need to have energy efficiency up to 98 %.

Specifically, with Natural gas technologies many manufacturers have developed High efficiency boiler and associated burners, like Condensing boilers; so it's very easy to find high energy efficiency NG boiler with efficiency from 98% up to 110% of net calorific value) .

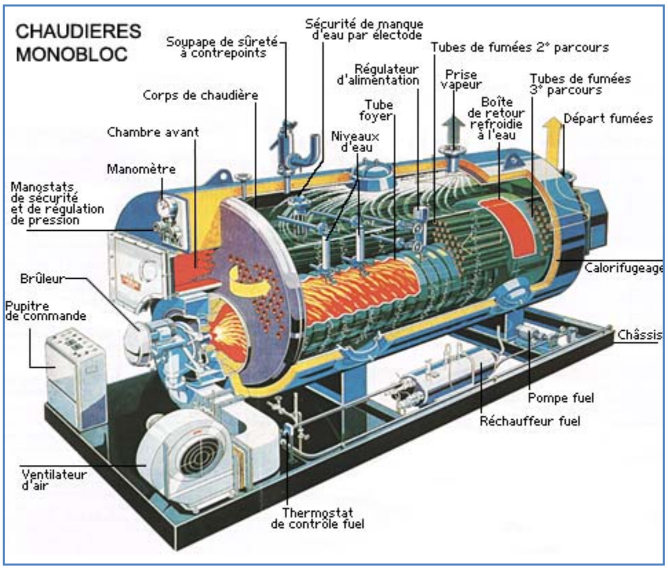
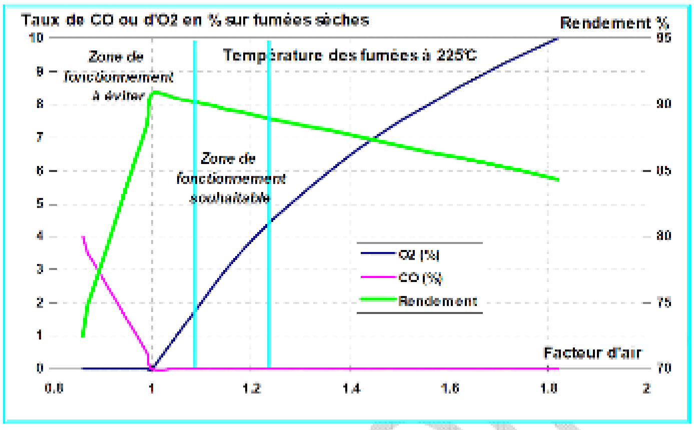


Figure 14: Modern high efficiency boiler

Nevertheless, to be sure to keep the nominal high energy efficiency it is very important to pay attention to the following points:

- ✓ **Flue gas heat losses** : trim control – Control in a continuous way the operating parameters of the boiler/ steam production in order to reduce fue gas heat losses at all production level



- ✓ **Reduce flue temperature output gas:** Improve the overall energy efficiency of production system by implementing high level of heat recovery on fue gas heat losses. Many systems are proposed by boiler manufacturers to do heat recovery to preheating of combustion air, preheating of feed water …..

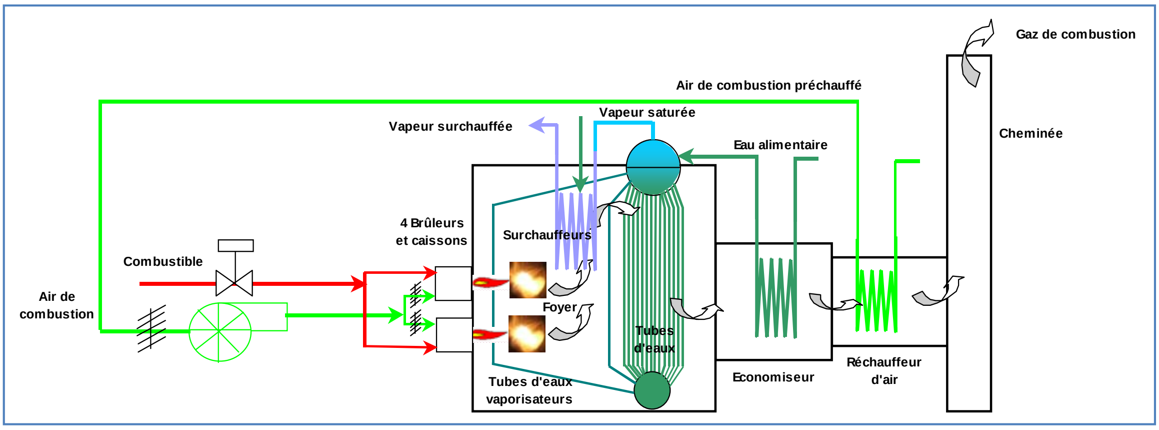


Figure 15: Implementation of economizer and air preheating systems on NG boiler

✓ **Improve combustion**: Control the quality of the combustion is a major points to warranty a high level of energy efficiency (air /fuel ratio, excess air …..) . Continuous measurement of fuel flow and O2 / CO contents in the flue gas are minimal of controlled parameters. Staff training to combustion quality is also a best practice.

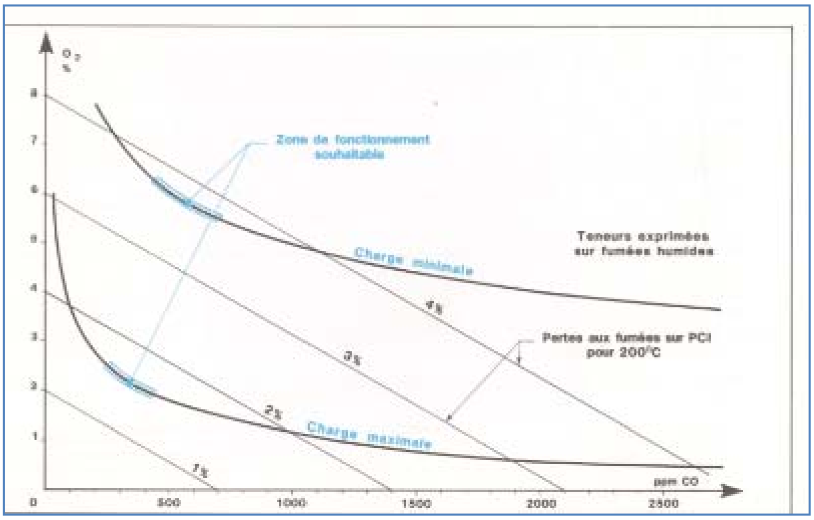


Figure 16: Evolution of heat losses vs excess air

Conclusions

The following board give some example of Energy saving which are possible trough implementation of High efficiency NG boiler and associated progress actions after energy audit.

Technique Method	Energy Saving Potential
Implementation of NG high efficiency boiler	Up to 10%
Implementation of NG condensing boiler	Up to 15%
Implementation of Economizer heat exchanger	Up to 5 %
	Up to 1-2 %

Combustion air pre-heating	
Boiler and burner management systems, digital combustion controls and oxygen trim	Up to 3 %
Improved operation and maintenance of boilers	Up to 5 %
Radiation losses : minimize by insulation and plant scheduling	Up to 1 %
Improved water treatment and boiler water conditioning (Heat transfer gas and water side)	Up to 2 %
Total dissolved solids (TDS) control and boiler blow down and minimize by water treatment	Up to 2 %
Implementation of Blow down heat recovery system	Up to 3 %
Variable speed drives (VSDs) – for combustion air fans and pumps	Up to 1 %

12. Topic: Heat recovery: valorization of heat losses

After optimization of the efficiency of industrial processes, the second step of improvement is to implement or improve the level of Heat recovery on fatal heat losses. The industrial heat losses are essentially made of the exhausted flew gas coming out from Furnaces and boilers; residual steam and oil or water cooling. They can be classified in two main categories:

- High temperature Heat losses exhausted with a temperature (250°C<T < 1300°C) They are mainly composed with hot exhaust gas from furnaces and boilers and residual steam coming out from steam turbines.

Low temperature Heat Losses (40°C<T<250°C), mainly composed with low temperature exhaust gas; oil and cooling water and process hot liquids. Due to the relative low average thermal efficiency of industrial processes (See Fig 3 - 30% to 60%) the potential for energy recovery on industrial heat losses is very large. It's why one of the main priority in energy audit and after optimization of energy efficiency of industrial processes, is to implement a high level on heat recovery. The heat recovery could be studied for the process itself (ex: Combustion air preheating trough direct heat recovery on exhaust gas, preheating of raw water for a boiler direct heat recovery on exhaust gas, Pre-heating of the load to be heated…) or done by heat exchange between one process/production line to one other part of the factory or surrounding Territory (See example hereafter).
We will in this chapter trying to present some examples of applications of heat recovery on industrial facilities, where natural gas solutions are particularly interesting in regards of technical but also economical point of view.

Example of case study of heat recovery in chemistry industry (E Adamo- ENI)

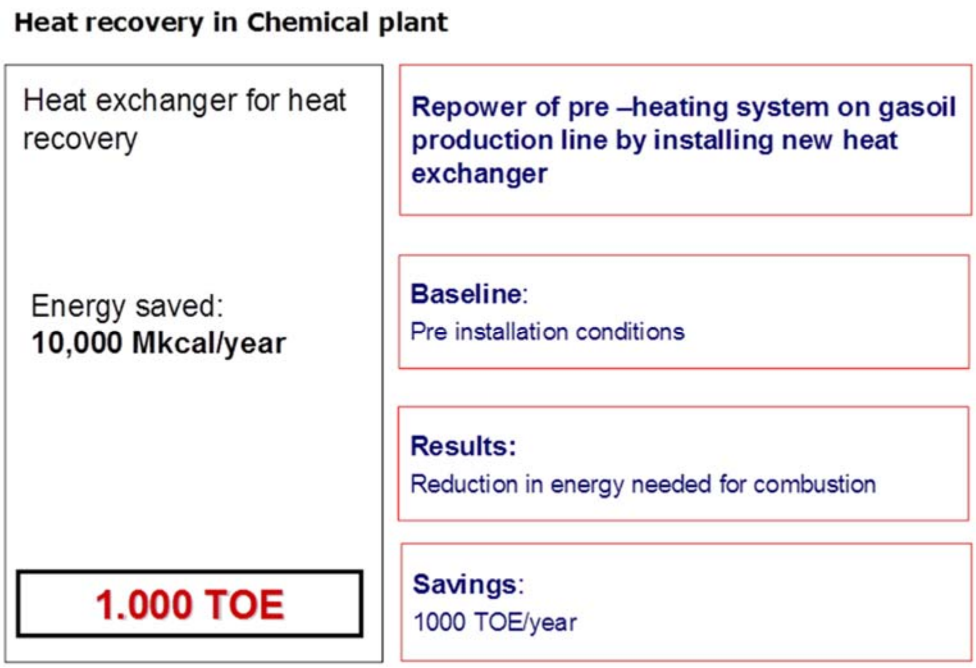


Figure 17: Energy saving by heat recovery on boiler & fuel conversion

12.1 High temperatures heat recovery

Implementation of Flameless regenerative combustion systems in steel industries –GDF Suez CRIGEN (Research Center for Gas and Renewable Energies)*:*

Since now more than ten years, GDF SUEZ has realized in partnership with Steel industries, glass and burner or furnace manufacturers, developments and industrial trial tests for the implementation of Flameless regenerative combustion technologies.
To improve the efficiency of thermal process, the best way to do that is the implementation of Heat recovery systems in order to preheat combustion air before use into the furnace. Different solutions are already existing (Fig 17).

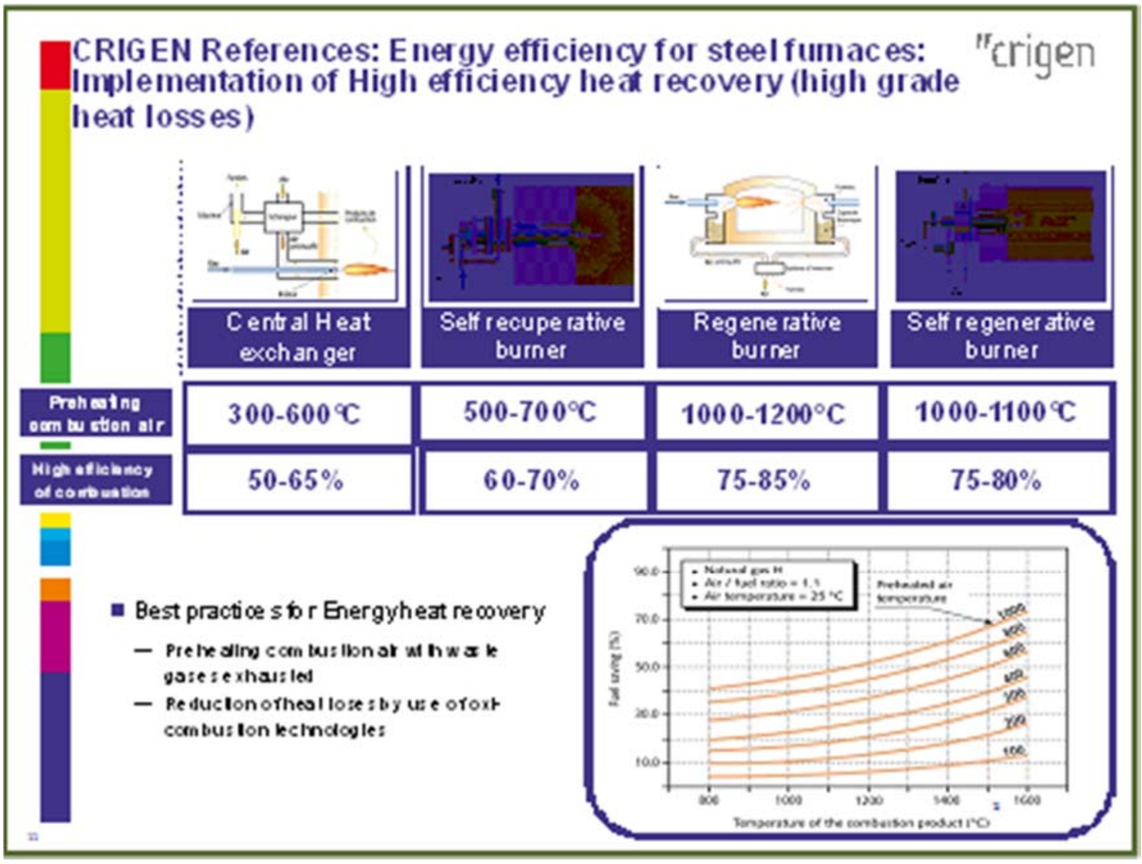


Fig 18: Heat recovery systems on exhaust gas and Combustion air preheating

The Flameless regenerative combustion systems are one of the last systems developed, which is now one of the new Best Available Technologies recognize for Combustion air preheating and high level of heat recovery.

Technology description:

This technology is the combination of very high staging combustion burners, in order to obtain very low level of nitrogen oxides emissions (NOx) , with regenerative heat recovery to reach high level of pre-heat combustion air. The interests of this innovative combustion technology are:

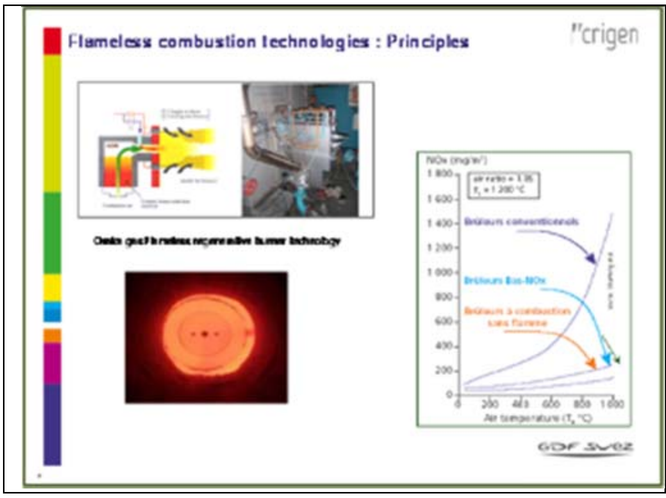
- Combination to high efficiency energy recovery systems ;
- Drastic reduce of NOx emissions

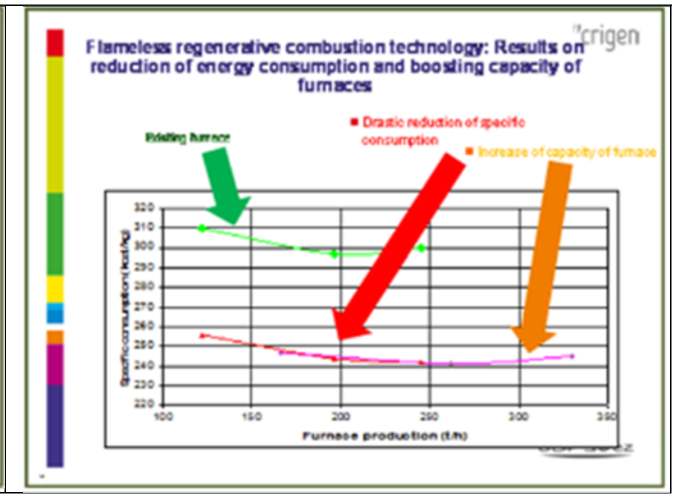
Even if this technology is not dedicated to natural gas, in the main part of the developments or industrial implementations, this technology has been done with natural gas fuel and/or in the frame of energy conversion of thermal processes to natural gas fuel.

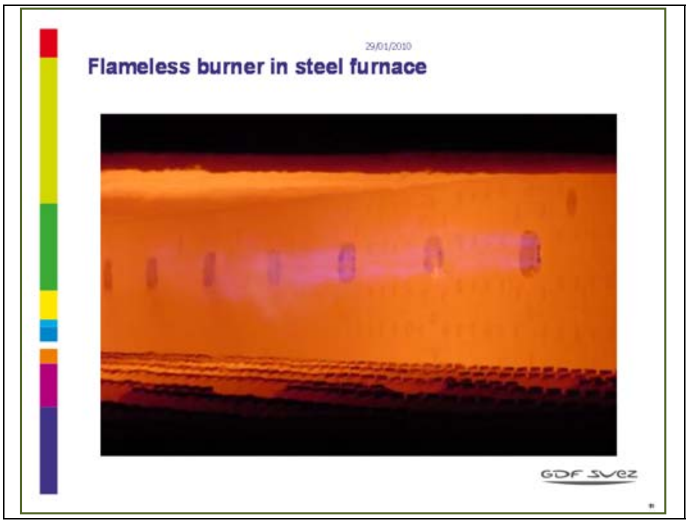
Results obtained:

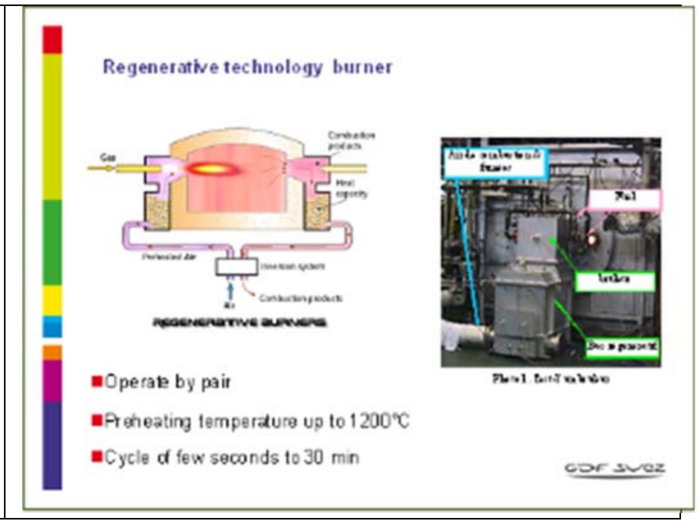
During the development and in the industrial references done the results, on energy & environmental efficiency obtained with this technology could be summarized as follow:

- In regards of NOx emissions this technology is one, which is able to reach new emission standards of the NOx regulation. For example, applied on Steel furnace , working at high temperature of process (T~1100°C -1350°C) ; the level of NOx emissions with Flameless technology is around 300 mg/Std m^3 at 3% of O_2). This reduction represents a decrease about 50 % in regards of standard low NOx burner technologies.





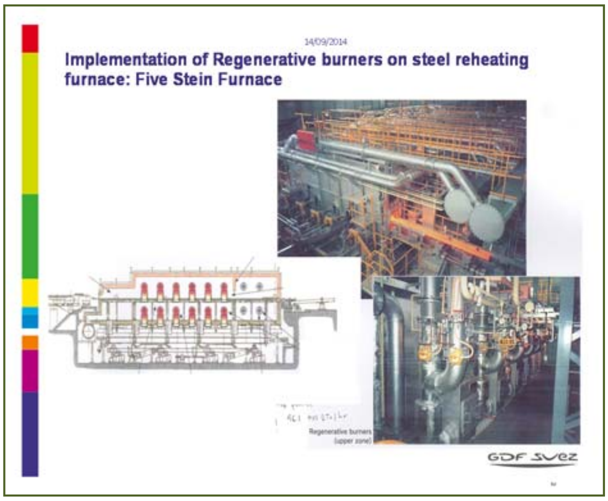


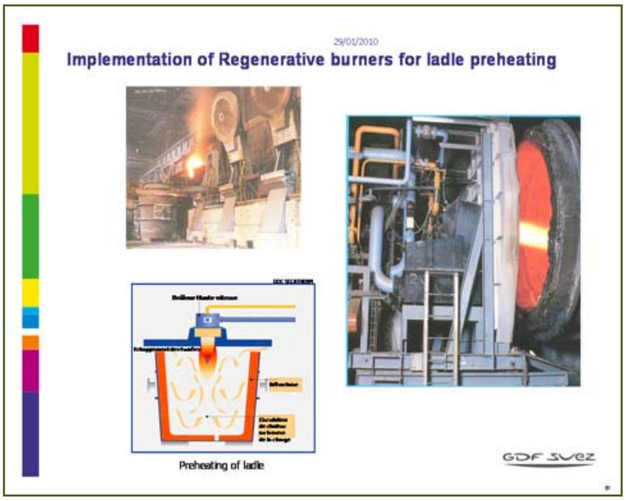


- In regards of thermal efficiency of furnace and increase of heating capacity, implementation of Flameless technology to steel reheating furnace have demonstrated capacity to reduce by about 30% the specific consumption of furnaces and increase by 20 to 30% the production capacity of furnace. these high efficiency performances are that this technology has now become the Best Available technology for Steel reheating Furnace. So many industrial references are already done, several in progress both for small capacity pusher furnaces or High capacity walking beam furnaces.

In most of these industrial references, natural gas has been chosen as fuel for the implementation of Flameless technologies.

Some industrial references





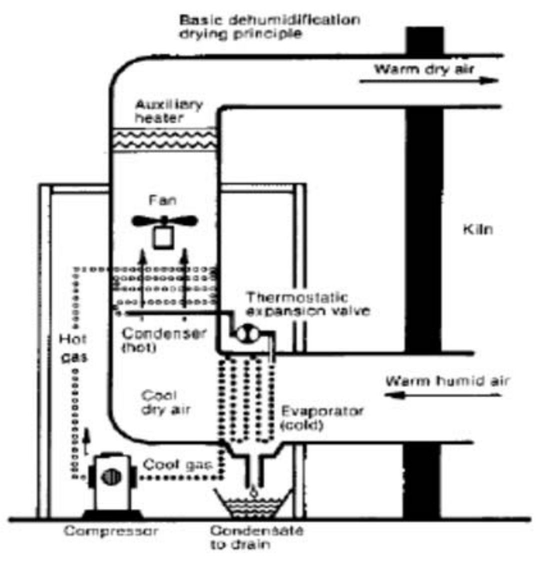
12.2 Low temperatures heat recovery:

Case study : Implementation of Heat Pumps in drying agricultural applications (Gas Technologies institute):

Indirect Drying is a significant natural gas load in North America, 5% of the U.S. commercial and industrial gas consumption. Drying process step can consume between 50-70% of the process energy to deliver finished product in agricultural and lumber applications. The same overall design has been use for over 50 Years, with a nominal efficiency of 35%, with advanced technologies reaching 82-88%.

The industry has explored different other electrical technologies like Vapor Compression systems (VC) heat pump drying (HPD) since 1973, through market impact since has been limited – due to high relative cost of electricity at – nearly 6,5 X that price of natural gas today in US (US DOE -2012).

In this context thermal driven HPD makes good sense , through a simultaneous heating and dehumidification of products with a lower lift than other heat pumps solutions.



USDA Agricultural Handbook AH-188: *Dry Kiln Operator's Manual* (2001)
http://www.fpl.fs.fed.us/products/publications/several_pubs.php?grouping_id=101&header_id=p

To assess the opportunity to use Thermal Driven Heat pumps, GTJ (Gas Technologies institute) has developed and demonstrate, in a frame of a R&D team, a new concept of hybrid Fired Rotary Dryer with solution and with integrated heat pump for Ag Drying California. In California the drying of fruits and vegetables requires 1815 GWh/year. The R&D team includes manufacturers of Drum dryer (GL&V) and burners (FLYNN), HPD technology developer for Ejector Heat Pump (May Ruben thermal solutions); food processer host site (Bean Drying company) and Utility partners.

Technology description:

The technology is based on a thermo –compressor using ejector to compress a low pressure gas or saturated vapor with a high pressure fluid. It's a simple system for compression when steam or waste heat is available on site. This solution is well known, Standard ejectors were used for refrigeration & ice production since 19th century. Standard systems had COP cooling <0,3, small entrainment ratios , not common today .

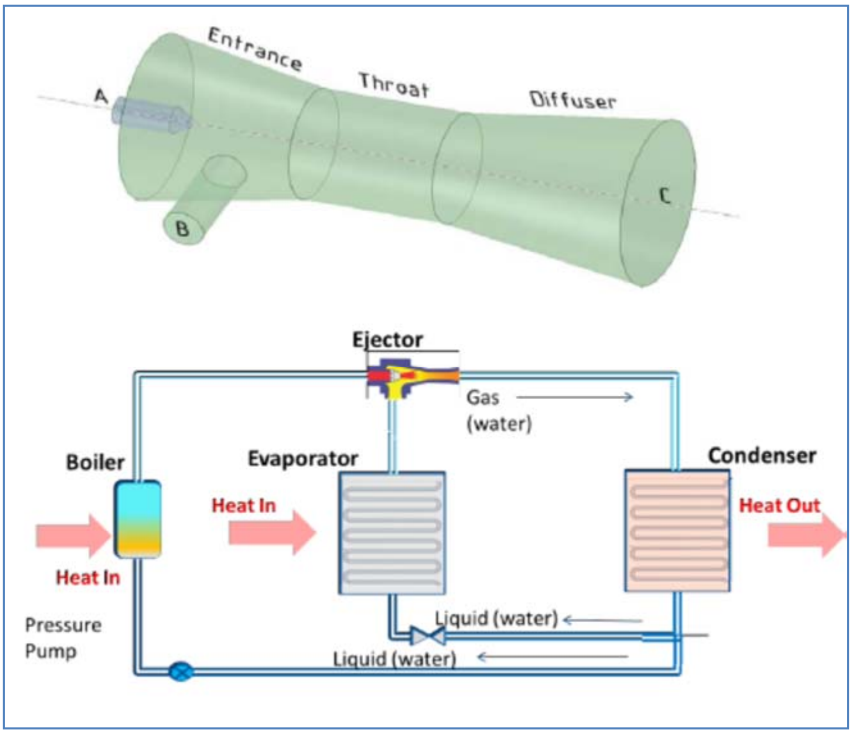


Figure 19: Process diagram of BFE HP GTI system

The two major problems to solve was the limit of ejector performance:

- Single working fluid needed two distinct jobs compromises by doing both poorly:
  - **Refrigeration-** Fluid must have a high enthalpy of vaporization for near isothermal phase change in condenser/ evaporator. Heat transfer efficiency and capacity drop when non-isothermal.
  - **Ejector entrainment capacity** – Fluid must not have a high enthalpy of vaporization to boil easily in the generator, improving the COP.
- Principle method of compressing refrigerant during entrainment phase is the momentum exchange, inefficient turbulent mixing. Pressure exchange is much better with the driving fluid providing mechanical compression.

Finaly the choosen solution was based on new MAY-Ruben solution, the Binary Fluid Ejector (BFE) heat pump for non-incremental improvement over standard ejectors:

- Two fluids engineered for two respective roles
- Novel nozzle designs with vortex columns or, in later possible developments, dynamic oscillating nozzle.

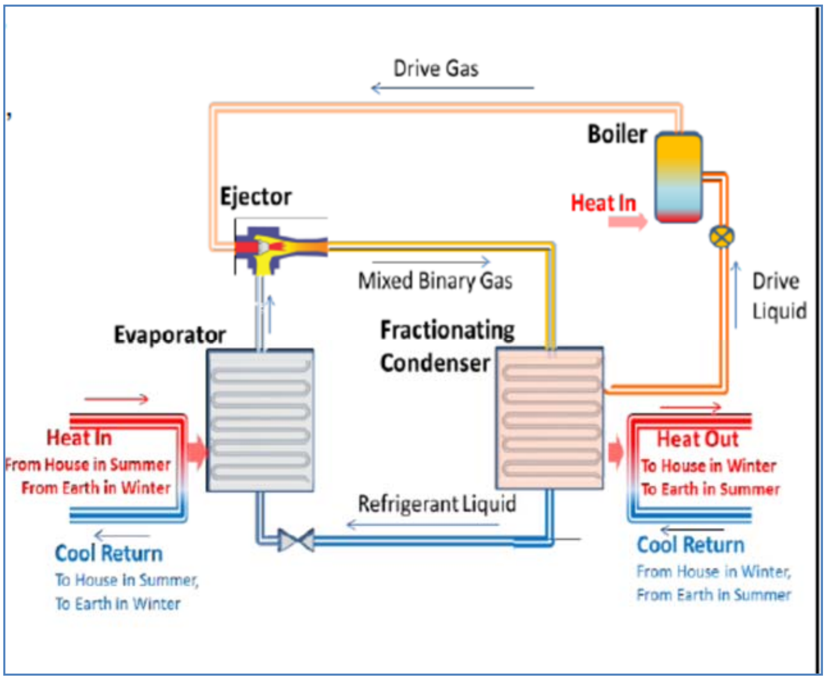
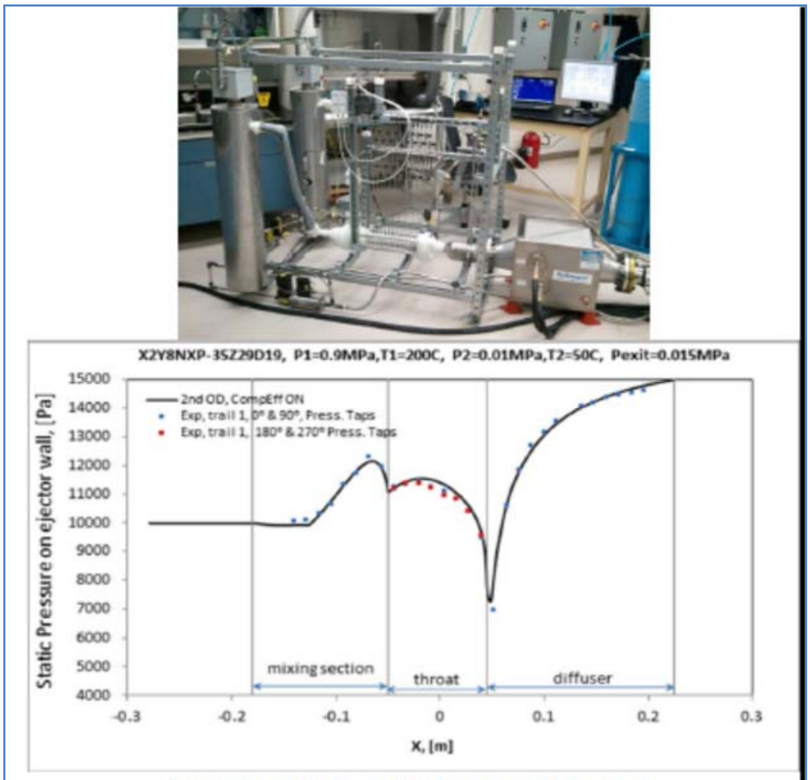


Figure 20: BFE HP concept

Design of nozzle and system was test and modelling with CFD model. Entrainment ratios and estimated COPs, when extrapolated to seasonal temperature lifts, show exceeding heating/cooling COPs of 2/0.9 may be feasible. Depending on ultimate fluid pair selection, operating pressures may be quite moderate (<<10 Psi/0.7 MPa). With quick start-up capacity, ejector may be deployed in parallel for modulation.



Example of CFD model calibration with inert gas

Simplified analysis shows critical impact of binary fluid selection and ejector design, guides optimization process and performance estimates:

- Entrainment ratio (m_R/m_D) is largely a function of the nozzle design and ratio of fluid MW
- Fh is a function of fluid selection and operating conditions

$$COP = \frac{Q_{evaporator}}{Q_{boiler} + W_{pump}} = \omega \frac{\left(h_{s,out} - h_{s,in}\right)_{evap}}{\left(h_{p,out} - h_{p,in}\right)_{boiler} + \frac{\left(P_{p,out} - P_{p,in}\right)_{pump}}{\rho_{avg,in\ out}}}$$

$$COP = \omega \frac{Hv_{Evap} + \overline{Cp_1}(T_{Cond} - T_{Evap})}{Hv_{Boil} + \overline{Cp_2}(T_{Boil} - T_{Cond})} = \omega f_h$$

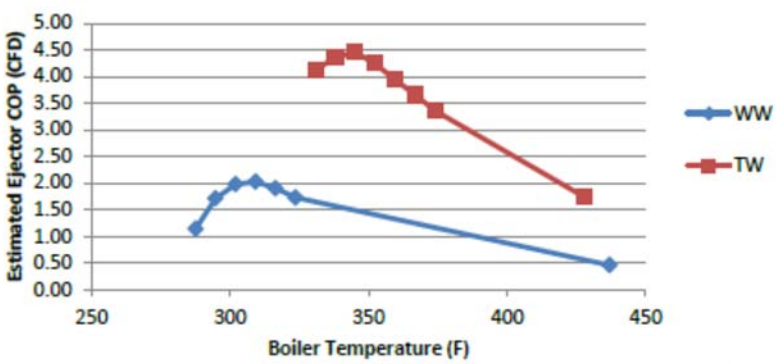


Figure 21: BFE HP Cop calculation

Results obtained:

To complete the R&D works a complete case study was done for an industrial site, and showed promising technical and economical results.

- Energy saving is high versus standard gas drying systems and other heat recovery solutions
- Good capital and operating costs versus existing HPD options

So R&D program has been followed and industrialization ongoing.

Heat Source	Output Energy (MWh)	COP	Input Energy Required (MWh)	Annual** Energy Cost ($)	% Cost Savings vs gas heat	Annual Cost Savings ($) vs gas heat
Direct Fired Gas	1	0.8	1.25	$ 233,235	-	-
Electric HP	1	4.0	0.25	$ 197,100	15%	$ 36,135
BFE HP	1	2.0	0.50	$ 93,294	60%	$ 139,941

***based on natural gas rate $0.22/m3 and electrical rate of $0.09/kWhr at annual operations of 350 days/year*

Table 2: Results of BFE HP case study

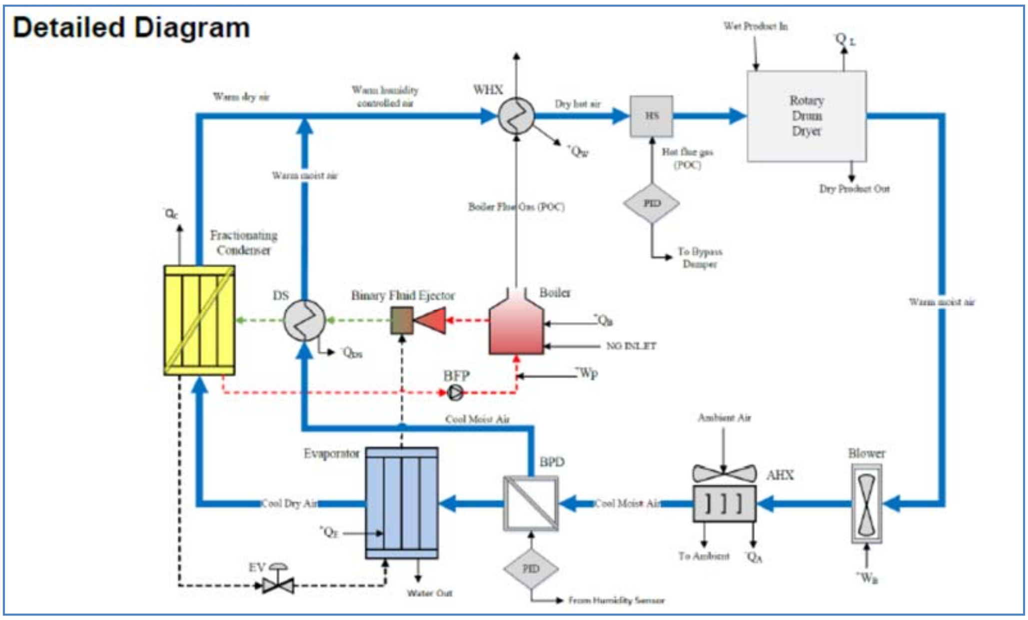


Figure 22: Detail diagram of case study solution

Case study: Implementation of TRANSECO Condenser coupled with Hydro gas accumulator system (Ste lacaze - France)

Context of study:

In a context of research and assessment of high efficiency technology for industrial appliances, Gdf Suez group organized a series of tests to evaluate the performance of a condenser TRANSECO, developed by Lacaze Company to recover much the sensible and latent energy contained in the flue gas from a hydro-accumulator Hydrogaz of the same company. The measurement campaign should help quantify the energy saving achieved against the Hydrogaz yields measured under different taps.

The tests were conducted in the site of the company Delpierre Fécamp (Food industry), where the condenser TRANSECO TR1600-22T recently coupled with the Hydrogaz Maximil 30 (810 m3) which supplies to the plant hot water for operations cleaning and washing industrial food processing machine. The hydro-accumulator has a Weishaupt Monarch G7 NG burner model with a power rating of 880 kW installed at the bottom.

Technology description:

Figure 23: Lacaze hydrogas system with condenser

The Delpierre Company has since many years of Hydrogaz Maximil 30 810 m3 for the production of hot water for the needs of its plant in Fecamp. Like the name is clearly indicated the system is equipped with natural gas burner system (Weishaupt Monarch G7 **NG)**

To reduce the energy consumption of hydro-accumulator, the Lacaze company proposed to his customer to do implementation of a condenser TRANSECO, at the flue gas outlet and near the burner, to value the sensible heat and latent heat of the output flue gas.

The daily consumption is more than 80 m3 of hot water, heated to 65 ° C. The operation peak is mainly on the time slot 21 pm - 4 am. In order to meet this peak demand with a temperature of hot water and stable at constant working pressure, the Delpierre company installed two storage tanks with boosters.

The system of control has an impact on the regularity of the cold water flow coming into the hydro-accumulator and thus the water temperature ensuring irrigation condenser via a pump.

The TRANSECO condensing system uses the principle of exchange against stream between flue gas and water, both circuits being separated by a wall consisting of finned tubes. The fumes from the burner enter the upper part of the machine, down and transfer their heat to the water flowing in the opposite direction, inside the finned tubes. The combustion products are conveyed in the direction of the condensation and to meet as their course, a cold wall promoting the condensation process. The pump is controlled by the operation of the burner. The preheated water is directed to the water feed circuit in the accumulator.

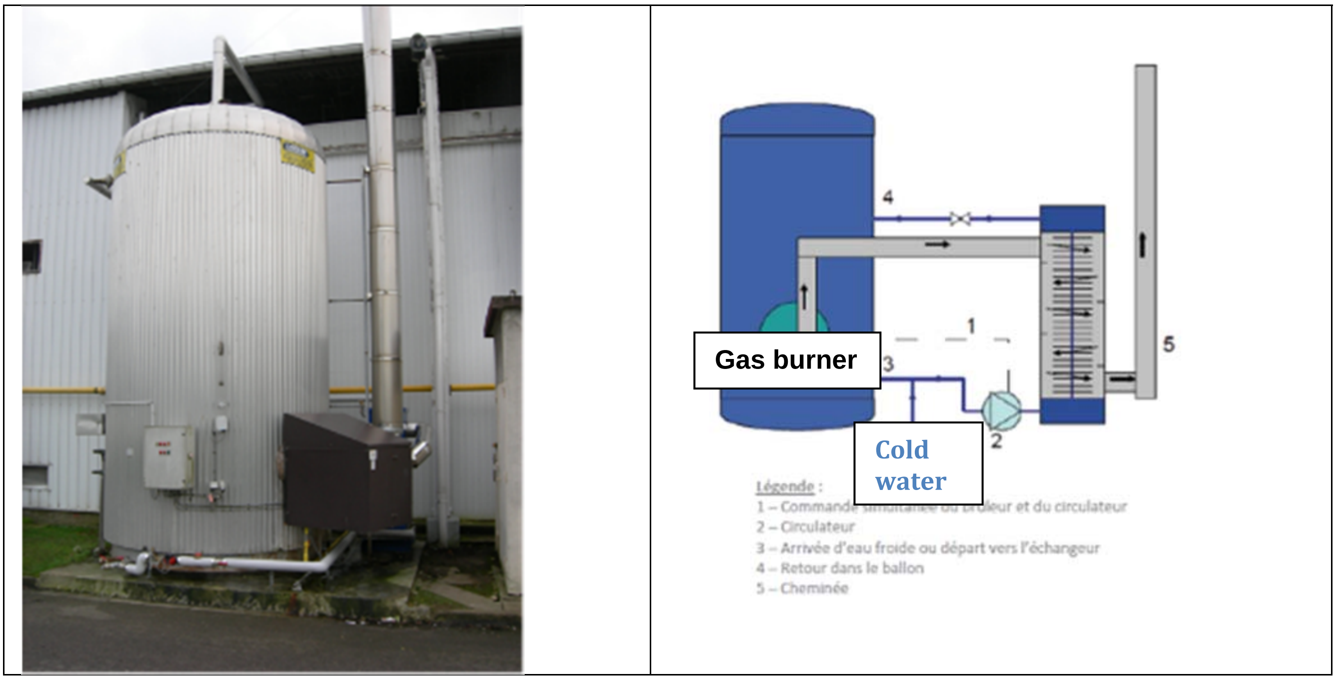


Fig 24: hydro-gas coupled with condenser

Results & conclusions

The energy efficiency of the system has been assessed trough a measurement campaign, with a complete set of measurements in order to do energy balance of the system with 3 configurations:

- **Indirect energy efficiency of the hydro-gas system alone ,**
- **direct et indirect energy efficiency of the condenser ;**
- **Indirect energy efficiency of global du system.**

Yields were calculated for each of the three configurations shown above. To maintain uniformity in the methods and results of calculations obtained, all displayed returns are based on the indirect method, only implemented method for characterizing the Hydrogas. To the condenser, the two methods were used, with a function of the cycles considered, yields differences in most cases of the order of 5%. These differences are due to several factors:

- Uncertainties related to metrology implementation,
- The short duration of some cycles in relation to the inertia of the condenser, not to achieve a completely steady to survey perfectly reliable measurements
- Large fluctuations of temperature of the inlet water flow in the condenser associated with the design of the hydraulic network of the Delpierre society.

These reasons have strongly guided the choice to favor the use of indirect return in the comparative analysis of the situations involved in the characterization of the condenser.
The indirect return of the condenser is given by ratio between Outlet heat amount / Inlet heat amount

Hydro-gas Energy efficiency (% of NCV)	**90,3 %**
Energy efficiency of global system (% of NCV)	**100,8 %**
Condenser Energy efficiency (% of NCV)	**112 %**

Table 3: Performance of the three configurations

The good performance of the condenser coupled to the Hydro-gas allows 10.5% of energy saving in regard of initial output and allows a global energy efficiency of 100.8% of the net calorific value of the natural gas.

13. Topic: Heat losses valorization through electrical conversion

In a context of improvement of energy efficiency of a production line or industrial plant heat recovery in heat losses is now necessary. One of the issues is many industrial processes produce more heat losses than they need (Ex: Steel, glass industries...). So in this case, direct or indirect heat recovery to produce heat to be re-use is not possible.
Given the increase in energy prices, especially for electricity, heat recovery by energy conversion to energy (ie Electricity) becomes economically more interesting. A regularly used solution is to convert this heat into electricity by use of steam turbine (Rankin cycle). This requires a high level of energy available in order to produce high pressure steam for good efficiency conversion. To do this, conventional steam turbines are the most common solution. The heat is used to generate steam which is expanded in the turbine to produce electricity.
However, the limit for the production of steam is defined by the available heat temperature level. It determines the level of overheating and the pressure obtained for the vapor, so that the electrical efficiency is seen as packaged.
For many optimize industrial process level of fatal heat losses his often too low to be able to use this steam turbine technology with a reasonable efficiency.

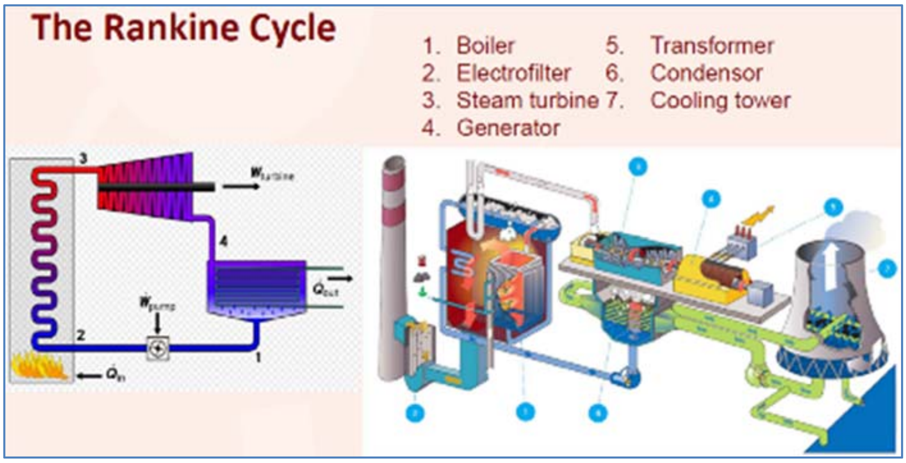


Fig 25: Rankine cycle with steam

Since the energy efficiency purpose focuses on the recovery of low grade heat power, a superheated approach like the traditional SRC -Steam Rankine cycle is not appropriate. Therefore, a small superheating at the exhaust of the evaporator will always be preferred, which disadvantages "wet" fluids (that are in two-phase state at the end of the expansion).

In this case study "dry fluids", with associated ORC (Organic Rankine cycle) turbine should be used, the interests are:.

- Low freezing point, high stability temperature of the fluid
- Unlike water, organic fluids usually suffer chemical deteriorations and decomposition at high temperatures. The maximum hot source temperature is thus limited by the chemical stability of the working fluid. The freezing point should be lower than the lowest temperature in the cycle.
- High heat of vaporization and density
- A fluid with a high latent heat and density will absorb more energy from the source in the evaporator and thus reduce the required flow rate, the size of the facility, and the pump consumption
- Low environmental impact - The main parameters taken into account are the Ozone depletion potential (ODP) and the global warming potential (GWP).
- Safety -The fluid should be non-corrosive, non-flammable, and non-toxic. The ASHRAE safety classification of refrigerants can be used as an indicator of the fluid dangerousness level.
- Good availability and low cost
- Acceptable pressures

The Organic Rankine Cycle uses the same basic components in the cycle than the one based on steam (heat exchanger, evaporator, (recovery), turbine and condenser. However, an organic fluid is used as the working fluid instead of water and specific design of turbine is required.

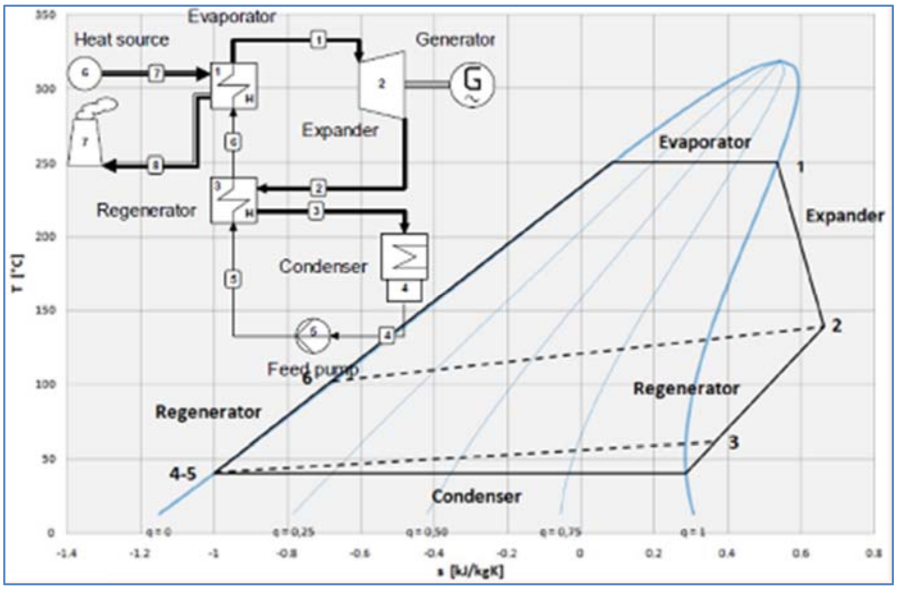


Fig 26: ORC cycle description

Today, the ORC modules are available for power ratings from a few kW to over 3 MW, In a ORC thermo dynamical cycle, the operating pressure is much less than in a SRC. Water has very high critical features. The closer we get to the critical point, the better the efficiency of the turbine.

ORC fluids are characterized by positive slopes from the side of the saturated vapor in the TS diagram, while the "wet" fluids have negative slopes. This causes droplets appear when the pressure drops. Dry fluids do not need to be overheated to enter the turbine, after expansion as the fluid remains in the superheat region. This has a major impact on the life of the turbine and its effectiveness.

Since now several years different appliances of ORC systems has been done and several manufacturers have a range of modules available or still in development. The energy efficiency of conversion depends of the type of appliances done and level of temperature of heat losses to be recovered.

EFFICIENCY	APPLICATION	HEAT CARRIER	HEAT RELEASE
24%	Biomass / Heat Recovery / CSP	Thermal Oil 310 °C	Water 27°C
19%	Biomass (CHP)	Thermal Oil 310 °C	Water 77°C
19%	Heat Recovery	Thermal Oil 277 °C	Water 27°C
16%	Geothermal / Heat Recovery	Water 180 °C	Water 30°C
10%	Geothermal	Water 105°C	Water 10°C
7.5%	Geothermal / Heat Recovery	Water 91°C	Air 16°C

Fig 27: ORC conversion efficiency

Some example of suppliers of ORC heat recovery systems

Many implementations has been done in the industries in the world, in order to increase the global efficiency of production plant by :

- Producing locally power to be seft-consumed or to secure the availability of electricity for the plant
- Produce electricity to be sale to the electricity grid

This kind of technology has already applied in :

- Melting Glass process: Heat recovery on flue gas of natural gas melting furnace

- Steel processes: Heat recovery on flue gas coming from electric arc furnace EAF or natural gas or steel gas reheating furnaces ;

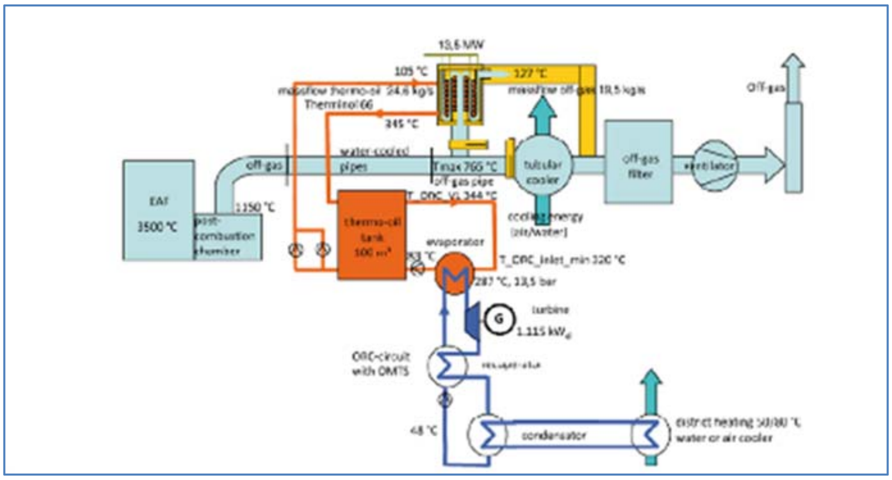


Fig 28 : Implementation of ORC on EAF

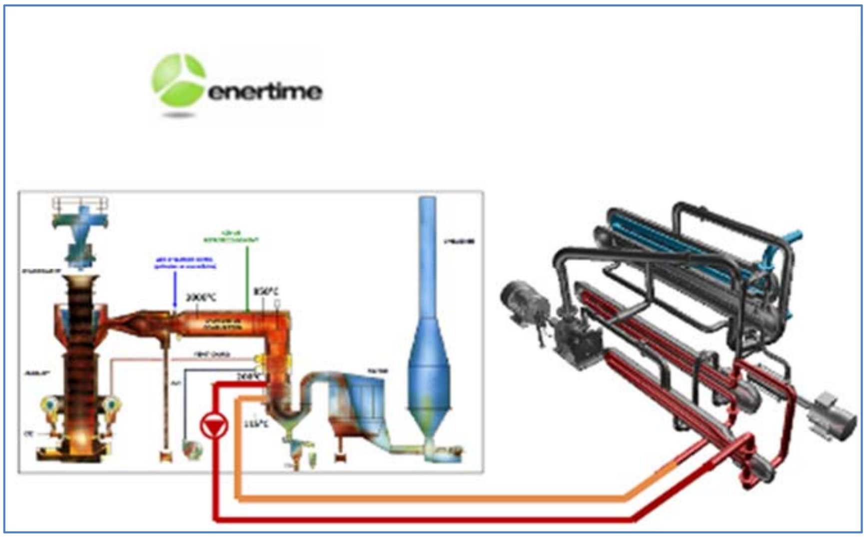


Fig 29: Implementation of ENERTIME ORC on Foundry Cupola (FMGC)

This technologies are good complementary solutions to high performances natural gas technologies (for example furnace equipped with regenerative Flameless combustion systems) to improve drastically the energy efficiency of industrial production lines.

14. Conclusions: From energy efficiency of industrial processes to industrial Ecology

Through this articles all over the world, and not only in the old industrial countries , we have seen that reduction of energy consumption and implementation of energy efficiency is major subject for industrial companies but also for countries. This interest for energy efficiency is due to :

- World economical context with a high volatility of energies in the different part of the world and general context of reduction of reserve of fossil energies
- Commitments of Countries in regards of reduction of GHG emissions and more balanced economical situation

- Implementation of regulation and associated tools (ISO 50001 , EN 16 247) for energy efficiency increases, rational use of energy and energy transition to a better energy mix in the next 25 years

In this context of drastic modification of the energy mix with a mix between low carbon fossil fuel and renewable energies, there is a high level of opportunities for gas companies to develop use of natural gas and development a large range of high efficiency technologies coupled or not with renewable energies.
Some of examples presented in this article show clearly the potential for natural gas solutions to give suitable answer to energy efficiency demand of industrial customers.
In the frame of energy transition, the energy efficiency programs launch by countries or industrial companies will have to be more ambitious and not only think about how to improve the energy efficiency of production line or an industrial plant but think and have a look on what is happening around the industrial plant or in a territory.
The future challenge of gas companies will be to develop new natural gas solutions integrating :

- Renewable energies in the energy mix of the factories (Biogas, Hydrogen, solar , wind..)
- Local production of energy trough valorization of waste , gas process, by-products or heat recovery
- Drastic reduction of energy demand due to implementation of low carbon footprint factories concept
- Flexible energy demand of industrial plants and request of energy hybrid solutions

And to develop technical and economical Services in order to support industrialist to go from energy efficiency of processes to industrial Ecology concept or the territorial Ecology concept
All this new developments give hope that is possible to have on time new solutions when the current fossil fuel sources are used. The next decennium, all over the world, we must work together to work out the innovations ideas or the mentioned examples to good affordable equipments in order to able to provide solution to Global warning climate change.

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4. GAS TO POWER GENERATION

Authors: Ali Zatout, Egidio Adamo et alii

1. Introduction

It is now recognized that the energy security of nations and mitigating emissions of greenhouse gas emissions can only be achieved if a mix is adopted, in order to also diversify supplies. Every region or country is ongoing to analyse, observe and study continuously changing context, looking to correct their prospective visions on the future mix.
In this case all the international organizations (IEA, WEC, IAEA, IRENA …) with sharp tools and experienced experts provides us with perspectives and opportunities in the medium and long term evolution of this mix at regional and world levels. The share of natural gas consumption is well defined in these models and we found that its use for the production of the electricity is increasingly important.
To avoid this issue, the WOC 5 via its group 5.1 in charge of gas utilizations, proposed to examine issues related to the uses of gas and retained an item on the use of gas for power generation (Gas To Power).
Also, this report is proposed to present the current status of natural gas for energy production in the various regions of the world, all in specifying the prior context that brand.
A particular focus in this paper is focused on :

- Power generation perspectives (view of IEA and WEC)
- Case of USA
- Case of Africa
- Case of Asia
- Case of Europe
- Mechanism and regulation
- Technology Status
- Case Study

2. Context

The production of electricity from natural gas evolves in a context marked by two important considerations. Firstly and on the one hand, the supply areas are marked by tensions and perturbations that make consumers reluctant and countries and their energy security subject to vagaries. Secondly and on the other hand, the technical conditions of gas fired power stations that allow rapid intervention if only to overcome the peak loads and ensure the continuity of electricity supply; in this case, we talk about the flexibility of gas fired power plants.
This context is also marked by the protection of the environment that is becoming increasingly vulnerable to atmospheric emissions from fossil fuel power plants. In this case, it is noted that natural gas is the most cleaner for use among these fuels.
But still do not forget that if the context was previously marked by the fear of depletion of natural gas reserves, today it is proved that the unconventional gas comes into power to renew the dry hitherto reserves. This new factor has driven a dynamic among technology providers sharpen their strategies to propose more effective and efficient solutions. Also, their placement and deployment is enlarging in the world.

3. Power generation perspectives (view of IEA and WEC)

3.1 International Energy Agency (IEA)

IEA sees growth of natural gas in power generation slowing over next 5 years

“Natural gas will continue to increase its share of the global energy mix, growing at 2.4% per year between now and 2018, the IEA said in its Medium-Term Gas Market Report (*MTGMR*) issued today. However, this projected growth rate is lower than the IEA’s forecast last year of 2.7%, due to persistent demand weakness in Europe as well as difficulties in upstream production growth in the Middle East and Africa.

At the same time, the report sees gas emerging as a significant transportation fuel: Thanks to abundant shale gas in the United States and amid more stringent environmental policies in China, gas is expected to do more to slow oil demand growth than electric vehicles and biofuels combined.

“Even though we have revised our growth estimates downwards, the ‘Golden Age’ of gas remains in full swing,” said IEA Executive Director Maria van der Hoeven as she presented the report in Saint Petersburg. “Gas is already a major fuel in power generation, but the next five years will also see it emerging as a significant transportation fuel, driven by abundant supplies as well as concerns about oil dependency and air pollution. Once the infrastructure barriers are tackled, natural gas has significant potential for clean-energy use in heavy-duty transport where electrification is not possible.”

While the report foresees the share of gas in the global primary energy mix rising and while total gas demand is expected to rise to nearly 4,000 billion cubic meters (bcm) in 2018 from 3,427 bcm in 2012, gas faces challenges in all the major geographic regions. In the United States, in the absence of policy constraints on coal-fired plants, recovering gas prices will prompt coal to regain some of its share of the power market, putting US greenhouse-gas emissions from the power sector back on a growing track. Europe sees only a weak and partial recovery due to the Euro zone crisis and low carbon prices. Gas exports from the Middle East decline amid runaway domestic demand growth – especially in the power sector.

“The persistent tightness of LNG markets is a major concern as it limits the contribution of gas to sustainable energy security,” Ms. Van der Hoeven said. “’It also highlights the need to tackle energy subsidies and improve energy efficiency in major producing countries as well as to adopt supportive policies for LNG investment.”

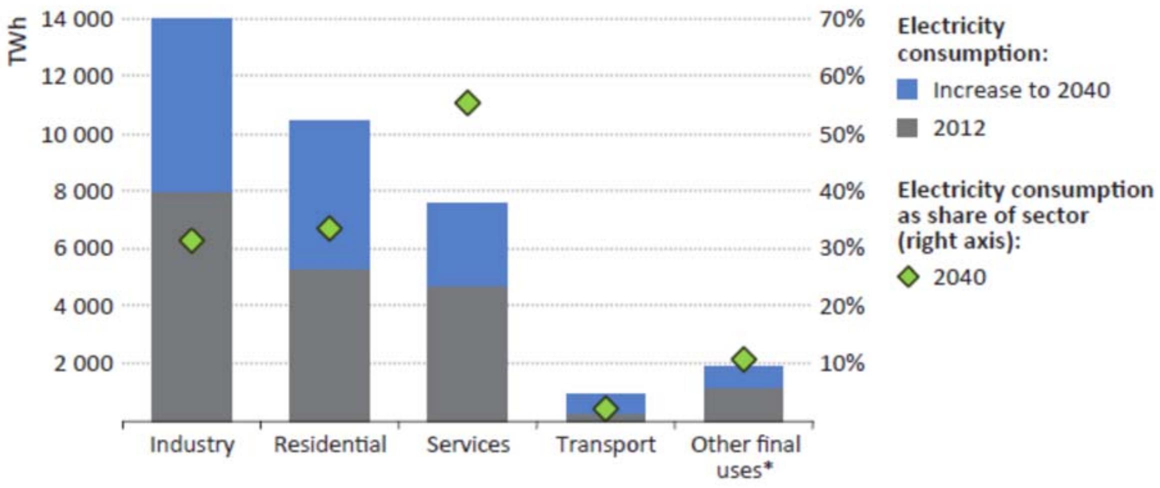
Other key findings of the report include:

- Non-conventional production will remain a North American phenomenon in the medium term. The United States alone represents over one-fifth of the global increase in gas production, benefiting from technological developments and cost-efficient field services. Exploration in other regions continues, but is hindered by geology, infrastructure and environmental constraints as well as lack of social acceptance.
- Natural gas plays a major role in addressing air quality concerns in China. China will account for 30% of the growth of global gas demand. Despite the country’s impressive progress on domestic production, this still puts China on a path of increasing import dependency: In the next five years, China absorbs the entire production increase from Central Asia as well as one-third of the global increase in LNG supply.
- The tightness of LNG supply enables some recovery of Russian exports to Europe. Nevertheless, in the longer term, Russia will be able to maintain its premier position in the world of gas only by developing the resources and infrastructure for large-scale Asian exports.”

Outlook on power generation

According to WEO 2014 of IEA, in all scenarios there taken into account, electricity is the fastest growing form of energy in the final uses, mainly due to variety of services (mechanical power, light, feed of electronic appliances), to cleaness and zero emissions at the point of use. The share of electricity use in the world increases in each sector. As for industry, it remains the single largest end-use sector, with the share of total electricity use rising up from 27% in 2012 to 32% in 2040.

Figure 6.4 ▷ World electricity consumption by sector in the New Policies Scenario



* Includes other energy sector and agriculture.

Expected world electricity consumption (source WEO 2014 – IEA)

Table 6.2 ▷ World electricity generation by source and scenario (TWh)

			New Policies		Current Policies		450 Scenario	
	1990	2012	2020	2040	2020	2040	2020	2040
Total	11 825	22 721	27 771	40 104	28 489	44 003	26 760	35 043
Fossil fuels	7 495	15 452	17 265	22 232	18 264	29 101	16 138	10 635
Coal	4 425	9 204	10 377	12 239	11 271	17 734	9 428	4 606
Natural gas	1 760	5 104	6 056	9 499	6 124	10 806	5 929	5 777
Oil	1 310	1 144	832	494	869	561	781	251
Nuclear	2 013	2 461	3 243	4 644	3 215	3 856	3 293	6 435
Hydro	2 144	3 672	4 553	6 222	4 458	5 862	4 561	6 943
Other renewables	173	1 135	2 709	7 007	2 553	5 184	2 768	11 030
Fossil fuels	63%	68%	62%	55%	64%	66%	60%	30%
Coal	37%	41%	37%	31%	40%	40%	35%	13%
Natural gas	15%	22%	22%	24%	21%	25%	22%	16%
Oil	11%	5%	3%	1%	3%	1%	3%	1%
Nuclear	17%	11%	12%	12%	11%	9%	12%	18%
Hydro	18%	16%	16%	16%	16%	13%	17%	20%
Other renewables	1%	5%	10%	17%	9%	12%	10%	31%

Electricity generation by source (source IEA – WEO 2014)

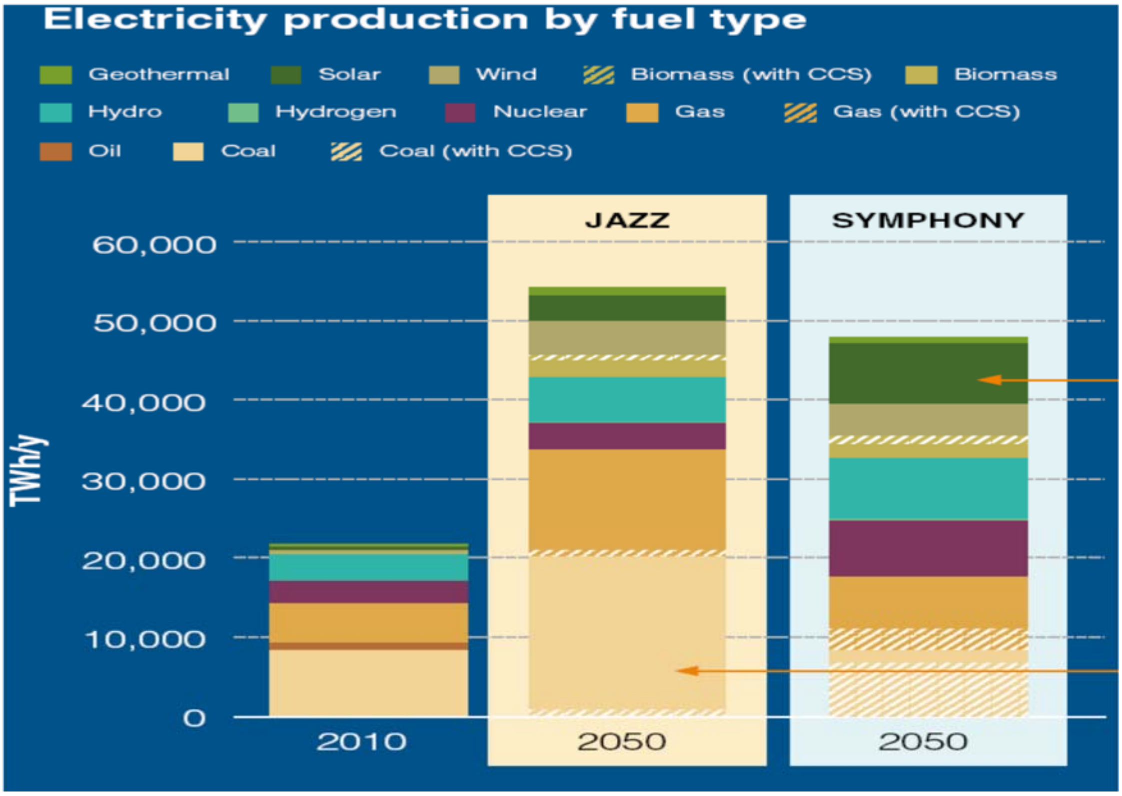
The share of electricity from renewables will grow, but owing to the non predictability of this kind of power generation, new traditional capacity has to be installed to upfront lack of renewable sources (lack of wind or solar irradiation)

In the « New Policies Scenario », installed capacity based on gas passes from 1620 TW in 2014 to 2660 TW in 2040.

3.2 World Energy Council (WEC)

Natural gas is yet another fossil fuel resource that will continue making significant contribution to the world energy economy. The cleanest of all fossil –based fuels, natural gas is plentiful and flexible. It is increasingly used in the most efficient power generation technologies, such as, Combined Cycle Gas Turbine (CCGT) with conversion efficiencies of about 60%.

The reserves of conventional natural gas have grown by 36% over the past two decades and its production by 61%.
Compared to the 2010 survey, the proved natural gas reserves have grown by 3% and production by 15%. The exploration, development and transport of gas usually requires significant upfront investment. Close coordination between investment in the gas and power infrastructure is necessary.
In its search for secure, sustainable and affordable supplies of energy, the world is turning its attention to unconventional energy resources. Shale gas is one of them. It has turned upside down the North – American gas markets, and is making significant strides in other regions.
Source : World Energy Resources – Survey 2013



Source: World Energy scenarios – Composing the future 2050

4. Mechanism and regulation

4.1 USA

Natural gas-fired power plants accounted for just over 50% of new utility-scale generating capacity added in 2013

Most natural gas utilities do not own their own gas wells. Utilities typically operate as distribution-only entities, buying gas from multiple suppliers over multiple pipelines to serve their retail consumers. Like electric utilities under restructuring, most natural gas utilities also allow larger consumers to purchase gas directly from wholesale gas suppliers, and pay the local utility to deliver the gas from the interstate pipeline.

However, unlike distribution-only electric companies, gas utilities typically buy gas from suppliers, then pass the cost through to consumers in rates without any additional markup or "profit" component. It is common for gas utilities to sell "bundled" supply and distribution service to residential and small commercial customers, but sell only "transportation" service to large users, leaving these customers to negotiate gas-supply contracts with marketers and brokers.

Source: RAP : Electricity regulation guide – March 2011

4.2 Africa

During the meeting of WOC 5 in Algiers (April 2014), with a special session allowed to Africa, we discover the experience of African countries in the use of gas.

For Republic of Cameroun, The liquefaction of natural gas in Kribi Town in the South Region brings to the grid an additional capacity of 216 MW (expandable to 330 MW) and a capacity of 2.5 to 3.5 million ton per year bringing the total installed capacity to 1,400 MW Cameroon, operational in March 2013.

The Republic of Gabon has a need of 154 MMSCF of Natural gas to supply the gas fired plants which produce a half of total consumption or Electricity.

In Tanzania, 436 MW is the total gas fired capacity for power generation is installed. New project of 400 MW is in construction actually in southern Tanzania's Mtwara region. Algeria which is leading use of gas in the continent Energy Mix (2013) : Installed capacity: 1.5% hydro, 1.9 Diesel, 97.6 Natural gas

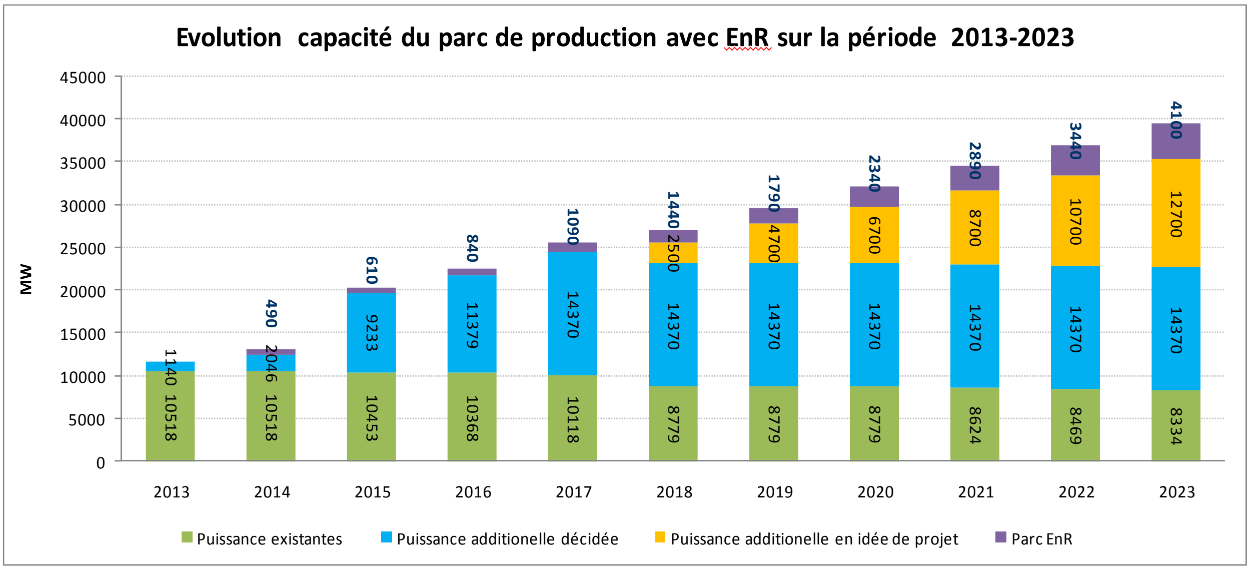
For the republic of Mozambique, 16 % of annual total energy consumption is due to power generation with total capacity of 105 MW. But projected capacity for 2015 is 430 MW.

The republic of Cote d'Ivoire has 70 % of gas in electricity mix generation and 950 MW are planned for short term.

South Africa has a very carbon-intensive economy due to the use of local coal, so the country is looking to introduce natural gas power plants.

Case of Algeria

Average of 98% of electricity generation is produced by natural gas (2013)



- <u>Area of regulatory intervention</u>

According to Act 02-01, only firms that have been granted a concession may build and operate a distribution network. The concession holder, selected after a call for bids, becomes the owner of the facilities. A concession was granted to all SONELGAZ subsidiaries involved in distribution activities prior to entry into force of Act 02-01.
Concession holders are subject to the public service obligations defined by Act 02-01.

Access to the natural gas distribution network can be requested on the basis of a TPA right provided for by Act 02-01. The regime of this TPA is similar to the one regulating access to the network intended to satisfy domestic needs

- <u>Infrastructure financing</u>

The access to the distribution network is regulated by Act 02-01. The Commission is in charge of setting a tariff which will be based on the principles of transparency and non discrimination. According to Act 02-01, such tariffs shall cover all investment costs and allow for a reasonable profit.

- <u>Regulation of TSO revenues</u>

The price of gas intended to fulfill the domestic needs is strictly regulated. This is due to the fact that the gas supplying activity is considered a public service. Only holders of authorizations can undertake gas trading activities. The manager of the domestic transport network cannot buy or sell gas.

In respect of gas intended to be traded abroad, The Act only requires that the sale contract be transferred to ALNAFT in order to enable it to fix the benchmark price. The Act also provides that the gas sale contract shall contain mandatory information, notably the name of the buyer, the total quantity of gas sold, and the duration of the contract or the price.

4.3 European Union

Even if the competitive situation for natural gas means that gas-fired power plants in Europe have found it difficult to make ends meet, gas consumption by Power Generation reached 37.4 % in 2011.

From 1973 to 2012, the average annual growth of electricity generation by natural gas is 4.5 %.

4.4 Russia

Construction of new power generation units in Russia during the period 2012-2015

The period from 2012 to 2015 for Russian power market was a boom of construction of new power generation units, mainly gas-fired.

Below is the overview of project groups that made the biggest contribution to the fast growing number of power generating units.

1. **Capacity Supply Agreements (a.k.a. DPM)**

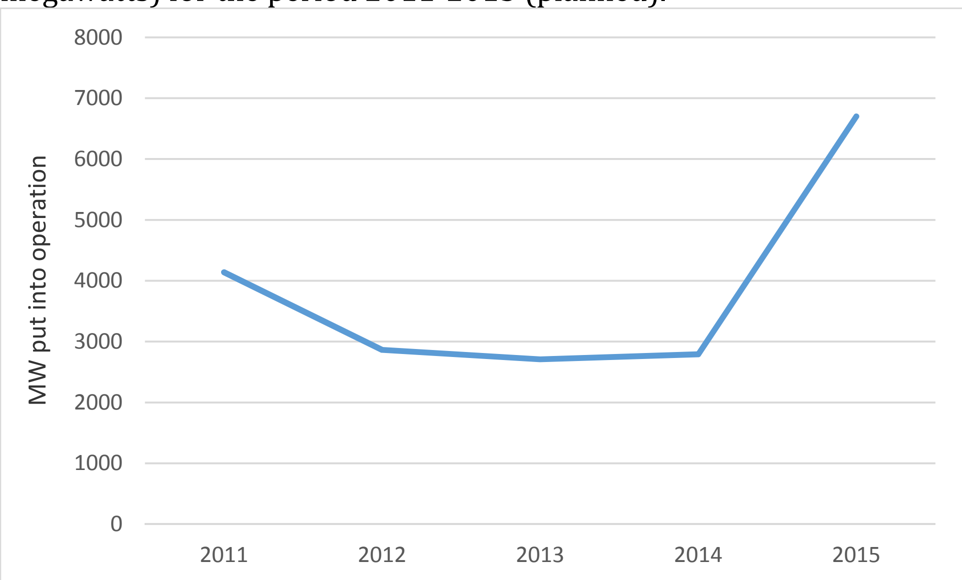
Capacity Supply Agreements (DPM) made one of the biggest contribution to the construction boom of new power generation plants.

According to DPM, the generating companies were bound to put into operation new units with specified characteristics until a certain date. These agreements guarantee the sale of all the power generated by them during the following 10 years, providing the coverage of 70 to 95 percent of CAPEX and OPEX, as well as full compensation for the grid connection costs. With this agreement signed, the generation units will have certain privileges during the competitive capacity outtake (KOM): their power will be sold on the market primarily and they will be qualified on the outtake by default.

The DPM are oriented at fossil fuel generation. The nuclear power plants and hydroelectric plants have similar agreements.

The application campaign for DPM was carried out by the Grid Operator in 2010. It resulted in signing of DPM contracts for construction of 14 gigawatts of new power generating units with a total cost of 3 trillion RUR. These units had to be put into operation in the period of 2011-2016.

The chart below shows the amount of power generating units put into operation (in megawatts) for the period 2011-2015 (planned).



Among other power market players, there are Gazprom, E.ON Russia, as well as Enel and Fortum.

The obligation to fulfil the DPM investment programs is supplied by special control mechanisms and liabilities of the companies. There are also some stimulating measures aimed at the fulfillment of DPM.

One of these measures is that if the power supply delays the start of the generation unit for more than a year, all the power will be sold by tariff price. In case of late performance of DPM, the generating companies bear the responsibility at the rate of 37.5% of the DPM object power sale price.
All together over a period of 2011-2013 the Market Council (Sovet Rynka) placed the grounds for fining the companies 8.4 billion RUR for disregarding of provision.
The DPM mechanism in power generation was of single use and lead to an oversupply of available power since it was aimed at construction of new generation units and not at reconstruction of existing ones.

2. **Renewable energy**

Currently the DPM, with some modification, is used for the development of renewable energy. The privileges differ from localization ratio of the used equipment.

3. **The development of the East Energy System**

Alongside with the DPM in the United Energy System (UES) the independent East Energy System is developing without any stimulating measures. Most generation units are gas-fired. This development is the result of active government participation. In 2015-2016 five units are planned to be put into operation with a total 660 MW electrical capacity and 1.2 GW thermal.

4.5. Asia

Case of –Japan is reported in Chapter 2.

5. Technology status of gas fired power

Power Generation: World average efficiency of power plants (LHV) is 34% compared to BAT for coal-fired power plants (46%) and BAT for gas-fired power plants (61%).

Source : WEC

5.1 State of the art

Gas Turbine Size and efficiency

- Large choice of size from few MW up to
- The largest size : about 280 / 370 MW
- Heat rate : 9020/9050 BTU/KWh

Combined cycle gas fired Size and efficiency

- The size : about 800 / 1200 MW
- Heat rate : 5900 /6000 BTU/KWh
- Net plant efficiency: 55 / 58 %

Natural gas fired power plant reduce emissions

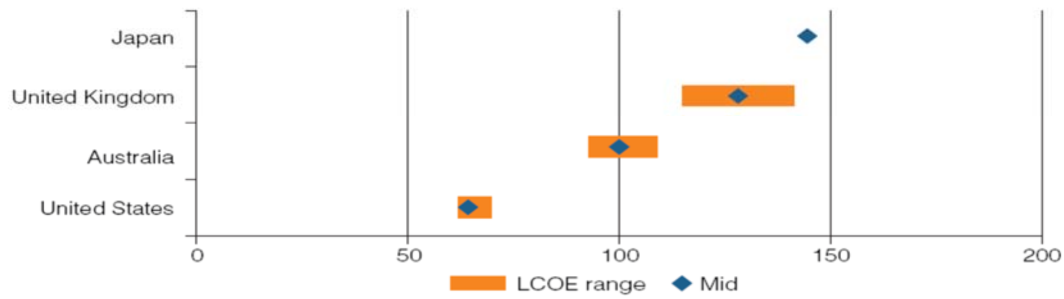
5.2 Costs and investment aspects

Combined-cycle gas turbines are much cheaper and easier to build than coal plants and are considerably cleaner. They are therefore more acceptable to local populations and if the economics are right, much more investable. The critical factor in the economics of CCGTs, and their viability, is the cost of gas. In the US – where the shale gas boom has pushed down natural

gas prices to currently around USD3–4/MMBtu – the economics of CCGT plants look particularly attractive. In Europe and Asia however the picture is somewhat different. Europe relies extensively on oil–linked contracts with Russian suppliers and imported LNG at USD10–12/MMBtu, ie up to three times as high as US domestic prices. Although the carbon pricing mechanism in Europe helps gas relative to coal, current carbon prices are nowhere close to the levels to achieve parity. At the current high price of gas and low price of coal, carbon prices need to be over €40/tCO2 to equalize the cost of running gas and coal plants. Carbon prices are currently around €5/tCO2. In Asia, gas prices are even higher. Japan for example no indigenous resources and imports its gas through expensive LNG cargos which are typically priced at USD16–18/MMBtu, some four times US prices.
These price differentials significantly affect the cost of generating power from gas plants. In Europe even the most recently built CCGT plants are being mothballed due to the effects of high gas prices and competition from renewable and existing coal plants. In Japan the LCOE of new build CCGT is around USD150/MWh, while in the US it is between USD60 and USD70/MWh.
Source : Cost of Energy Technologies - World Energy Council 2013

Levelised cost of CCGT electricity by region, USD/MWh

Source: Bloomberg New Energy Finance



Levelised cost of CCGT electricity by region

Source: Bloomberg New Energy Finance.
Note: *the given range is an average and does not reflect actual maximum and minimum values

Geography	CAPEX (USDm/MW)	OPEX (USD/MW/yr)	Capacity factor (%)	LCOE (USD/MWh)
United Kingdom*	0.76–0.90	23,182	80	114–141
United States*	0.97–1.00	14,620	60–80	61–69
Australia*	1.16	10,932	83	92–108
Global*	0.97	14,505	68	69
Japan*	1.51	58,000	78	148

6. Combined Heat and Power generation (CHP - Cogeneration)

General aspects
Power generation implies the use of primary energy (e.g. natural gas) to produce by means of a specific thermodynamic cycle electricity. Such a cycle is characterized by electric efficiency which represents the ratio between electricity produced and the input energy. The difference between input energy and electricity output is normally wasted in the atmosphere and is lost. But normally heat waste could be still used if it is available at certain level of enthalpy or temperature. So the use of both power and thermal energy drive to a maximum usage of the input energy enhancing the First principle Efficiency, which is the ratio between output energy (power + heat) and input energy (thermal energy of the fuel).

The combined and simultaneous generation in the same process of electric (or mechanical) energy and thermal energy is normally referred as "Cogeneration" or CHP (Combined Heat and Power).

The first rule for efficiency of a CHP System is to maximize the use of energy produced, both power and heat.

There are different ways to combine power and heat production, using various kind of elements.
CHP Plant consists of basic elements:

- a Prime Mover (Engine),
- an Electricity Generator,
- a Heat Recovery System,
- a Control System;
- fuel supply system, thermal and electric distribution nets.

To assure the best combination of production and use of Energy is of outmost importance to analyze some parameter.

- Technology
- Power size;
- Electric efficiency;
- Thermal efficiency;
- Heat to power ratio;
- The temperature of heat supplied;
- Type of fuel;
- Matching with type of thermal and power load.

In the following pages we will analyze these parameters.

Technology
With particular reference to natural gas CHP, basic and mature technologies for prime movers are:

- Internal combustion (or reciprocating) engines,
- Gas turbines,
- Micro turbines.
- Steam turbines (back pressure or extraction one),
- Combined cycle gas turbines,

Each of prime movers can provide different kind of heat available:

- Internal combustion Engine: from exhaust gas - high temperature (steam, hot air, direct use); from engine jacket, air turbo charger, lubricant cooling - low temperature (medium temperature water)
- Gas turbine: from exhaust gas - high temperature (steam, hot air, direct use but also low temperature hot water, medium temperature hot water);
- Steam turbines: steam
- CCGT (Combined cycle gas turbines): steam or hot water
- Micro gas turbines: medium temperatura exhaust gas (Hot water)

Size and heat to power ratio.
For each technology, an otpimal range of power size and power to heat ratio is expected..

With reference to industrial applications, power size range is generally the following:
- Gas turbine (~1 to 400 MW),
- Internal combustion Engines (~0.1-0.2 to 8-9 MW),
- Steam turbines (back pressure, ~1 to 100 MW, extraction one ~10 to 100 MW),
- Combined cycle gas turbines (~10 to 400 MW),
- Micro turbines (~30 to 250 kW).

For industrial CHP, size is normally below 20 MWe.
Other typical parameters are (following data are for reference purpose only):

Typical performance of CHP plants

	Electric efficiency	Heat-power ratio
Gas turbine	23 % — 36 %	2.3 — 1.8 (possibility of post combustion)
Internal combustion	28 % — 45 %	1.5 — 1.0
Micro turbines	25 % — 33 %	1.5 — 1.8

Internal combustion engines are developing very well up-to 6-8 MWe, owing to high electric efficiency.
Gas turbine, owing to their cost and lower electric efficiency, are normally used over 4-6 MWe.

The power range of the prime movers depends on technologies. CHP plants are also "modular", so it is possible to achieve high power generation.
It is also possible to distinguish two main "philosophies":
- big power plants for electricity production and heat distribution to industrial and/or civil customers;
- small-medium size industrial plants, sized to satisfy energy demand of the factory in which they are installed (mainly for self consumption).

Important developments in technology are:
- Packaging or modular systems, consisting of prime mover, electricity generator with tension elevator, heat recovery system (at low and/or high temperature)

● Better quality in connections between Electricity Generator and existing power distribution net, between heat recovery system and heat distribution net

● Low emission devices

● Better control systems (electric load following, heat load following) and remote control for remote diagnostic.

Level of temperature

As mentioned, the level of enthalpy and temperature available influences the use of cogeneration systems.
When heat request is mainly at more than 300 °C – 350 °C best technology is gas turbine. Exhaust gas temperature is about 400 °C – 600°C, which implies high thermodynamic energy content.
Concentrating all heat available in just one fluid simplify heat recovery systems, made by only one heat exchanger (for steam it is called HRSG Heat recovery Steam Generation)
From this source it is possible to produce hot water, steam, hot air or use directly exhaust gas (in some circumstances).

Reciprocating engines implies normally four kinds of heat sources:

- Exhaust gas: it is the source at highest thermodynamic level, since thery are at 350 ÷ 500 °C. It gives roughly 50 % of total heat available.
- Cooling system: at temperature lower than 100 °C, it is about 10÷ 20% of total heat.
- Olio lubrificante: available at low temperature (75 ÷ 90 °C), gives roughly 4 % - 7% of total heat
- Turbocharger cooling system: roughly 5% of total heat at low temperature.

To be noted that for reciprocating engines and gas turbine, heat recovery is achieved without modifying performance and power generation (while this happens for CCGT and Steam Turbines).

Fuel

Natural gas is one of the most suitable fuels for chp, for optimal combustion and low level of emissions.
The use of natural gas let the direct use of exhaust gas for some application (e.g. ceramic tiles)

Energy load

As mentioned before, the success of a chp plant with respect to separate generation of electricity and heat depends on various factors, but mainly on the balance between Energy generation and Energy request. Since a chp system produces simultaneously electricity and heat, but power and heat load couldn't be simultaneous, optimization should e taken into account to maximize the whole efficiency.
With reference to and industrial site, choosing separately power size or thermal size could drive to overcapacity of one of the two loads. So normally an integration and conventional system (grid connection for electricity and traditional boiler for heat) should be available.

Generally speaking, it is of outmost importance to maximize the amount of heat recovered and used in the site.
This "rule" is to be taken into account when choosing size of plant.
In some cases, to enhance heat recovery, when cooling is requested, an absorber can be coupled to the chp plant (tri-generation).

Industrial sectors.

Main industrial sectors for chp are:

- **Paper mill:** this is the one of the first sectors which used chp since paper production requires big amount of steam and electricity simultaneously. Steam turbines, Gas turbines and CCGT are the most used type of chp plant in this sectors.
- **Ceramics – Brics**: in such sectors direct use of exahust gas repalce the use of traditional burners
- **Chemical – pharmaceutical:** high and low temperature heat is used for process and packaging and also for air conditioning
- **Food:** heat is used for drying of foods (eg pasta)
- **Textile:** various level of temperatures for washing, dyeing.

New technologies are being developed in various countries: Micro turbine, Organic Rankin Cycle (ORC), Stirling engine, Tri-generation.
All these technologies have good points with specific reference to specific sector, but at this moment they are expensive and require investments in R&D to become cheaper and more reliable.

Feasibility study
As mentioned before, evaluating if chp is a good opportunity to enhance energy efficiency and reduce energy cost requires a good knowledge of energy loads of industrial plant and the evaluation of the right type and size of chp plant to be chosen.

To this extent, energy analysis and feasibility study is requested before start investment in chp plant.
A feasibility study is normally structured on the following path:

1. **Energy audit**: which lead to know detailed power and heat load (hourly) and various level of heat needed; actions for heat recovery has to be analyzed, which could reduce heat loads.
2. **CHP plant: type,** power size, temperature of recovered heat, electric energy efficiency (%), power to heat ratio, environmental constraints
3. **Management strategy of CHP plant:** running hours, part load etc.
4. **Calculation of estimated energy balance**
5. **Calculation of Economic comparison** between situation with and without CHP, taking inot account also o&m cost

Other parameters have to be taken into account: state of grid (elec and fluids), emissions constraint, availability of gas (and its pressure), etc.

Regulation has to be taken into account (costraints, incentives, etc.).

Regulation

In the European Union, 2004/8/EU directive defined precise rules for recognizing CHP as "High Efficiency CHP". This directive has been adopted in Italy in 2007 and in 2010 two new Ministerial Decrees established rules for giving CHP status of High Efficiency CHP and rules to give incentives to High Efficiency CHP.

In 2012, European directive 2012/27/EU has replaced both Energy Efficiency Directives of

2006 and the above mentioned 2008/4/EU directive on CHP.

The parameter used is PES (Primary Energy Saving), which expresses primary energy saving with reference to separate production of power and heat, adopting conventional efficiency for separate production.
The calculation is strictly connected to the amount of heat really used and recovered for useful applications.
If First principle efficiency is higher than 75%, all electricity and heat are taken into account for calculation of PES; otherwise, only a part of electricity has to be taken into account, that part linked with heat recovered.

Such regulation implies:

- chp plant can be divided into two “virtual” parts: high efficiency cogeneration part and non-cogeneration part;
- heat recovery, power gen, natural gas input have to be measured to derive energy balance of the systems.

In Italy, CHP is recognized as High Efficiency CHP if following rules are complied:

- if power size is below 1000 kWe, PES > 0
- if power size is over 1000 kWe, PES ≥ 10%

If CHP plants are recognized as High Efficiency CHP, it can be supported by White Certiifcates Scheme, which means an incentive given to plant basing on primary energy saved by the plant for 10 years.

7. Challenges of natural gas for power generating use

Technologies : Technology providers are stepping up to improve performance by developing larger sizes of turbines. Improving the performance of combustion is also an aspect that will play in the future to rely on natural gas as the cleanest fossil fuel of choice. Cost reduction technologies including the reduction of NOx and SOx systems are so many challenges to overcome.

The combining with Renewable: Concentrated Solar power (CSP) with combination (hybridization) of gas is today an issue, to perform efficiency and to guaranty the continuity of supply. We need better demonstrations with largest size to ensure that this solution can be a serious issue in the future.

Competitiveness with other sources : Gas and technology suppliers have important role to explain and to improve that gas fired power generation is one of the best solutions and make others believe on it, on developing efficient communication strategy as it's done for other sources and must be most aggressive for its promotion.

8. Case studies – CHP

Case study 1 – Feasibility study for CHP plant.

Industrial sector: Food
Annual consupmtion of gas: 2,3 Millions
Heat needs: steam, hot water
Annual consumption of electricity: 30 GWh

Design strategy: cover electricity needs and part steam and hot water needs
Type of engine: reciprocating engine
Chp electric size: 2.8 MWe (2 x 1.4 MWe)
Annual Electricity production:20 GWh
Annual Heat recovery: 18 GWh
Annual savings: 0,8 Million euros
Pay back time (simple): 3 years

Case study 2 – Feasibility study for CHP plant.

Industrial sector: agricultural products transformation
Annual consupmtion of gas: 1 Millions
Heat needs: hot air for drying of products

Annual consumption of electricity: 9 GWh
Design strategy: cover electricity needs and part steam and hot water needs
Type of engine: reciprocating engine
Chp electric size: 1x 840 kWe
Heat recovery: hot air
PES: 18%
Annual savings: 0,3 Million euros
Pay back time (simple): 3 years
White certificates: 400 certificates/y for 10 years

5. COMBINATION OF GAS AND RENEWABLE ENERGY

As mentioned before, energy from renewable sources are growing, also as the effect of country policies to reduce CO2 emissions. In the various scenarios, renewable share in energy supply is expected to increase.
The impact of renewables on energy sector and the way this matter could impact gas industry has been investigated in previous triennium report of WOC 5 SG 5.1 of IGU.
In the following pages, some refresh and case study on this item are represented.

All over the world you will see that we have two opportunities 1) Reduce energy consumption for example in Europe (France) significant progress have been made in energy efficiency of industrial processes. 2) Introduce renewable energy especially bio-fuelgas. Bio fuel-gas production is becoming more and more attractive, thanks to the introduction of regulatory restrictions. The production and valorisation is booming in Germany and has become Europe's fastest growing renewable energy sector.
Bio-fuel production for renewable gas is possible 1) through gasification. You get Syngas, and after upgrading the final product is called SNG gas. 2) Or through Anaerobic digestion and after upgrading you get bio methane.
On this moment you have different cases where Syngas (methane >95%) is used for examples for the production of glass the XYLOWATT gasifier is under development, or with REPOTEC technology to generate electricity and SNG gas see the GoBigas project in Goteborg Sweden.
Lot of applications you see for integration of renewable energies into industrial process and NG grid. You have the on site production and distribution GAYA project of GDF-Suez, the "groen gas" project in Holland, the Enexis green gas hubs, the absorption Chiller for solar cooking (Osaka gas and Tokyo gas).
All this new developments give hope that is possible to have on time new renewable sources when the current gas sources are used. The next decennium, all over the world, we must work together to work out the innovations ideas or the mentioned examples to good affordable equipments.

Towards green gases solutions for industry

Article proposed by Philippe Buchet

Author : Julien Duclos
Co-Author : B. Marchand, P. Buchet, M. Perrin, O. Guerrini

Abstract
Green gases represent a high potential to reduce carbon footprint for large industry emitters. GDF SUEZ is highly involved in several projects which are aimed at using syngas from biomass for industrial use or to produce 2nd generation Biomethane. Some of those new routes focused on renewable biosyngas, in addition with natural gas, will in a short term, be a helper for energy company to support their customers in lowering their dependencies on fossil fuels and GHG emissions. Direct firing of syngas into an industrial furnace for direct heating of a final product represents a very effective solution to reduce the use of fossil fuels. One of those projects ambitions is to produce a synthetic gaseous fuel coming from vineyards wood residues. The final goal is to manage to industrialize the use of biomass gasification for glass melting furnaces. A 1 MW gasifiers has been successfully installed and tested at GDF SUEZ Research Center. After combustion test on a semi industrial of the syngas produced by the gasifier, the whole installation has been transported and implemented on the industrial site. In the on-going test the gasifier will be coupled with the glass furnace. In addition to the developments on the synthetic gas, one of the key elements under investigation is the optimisation of the overall energy requirements of the integrated process.
Eventually, determination of the possible routes for the collection and preparation of the biomass resource with respect to the targeted application will allow the creation of a local and sustainable supply chain. For medium and long term perspectives, GDF SUEZ is also implicated in the development of the 2nd generation biomethane pathway with the GAYA project that aim to produce a renewable methane from lignocellulosic biomass through gasification and methanation. Those pathways are fully complementary and the aim is to propose to industry and others final users, a technology portfolio of green gases production for common uses of natural gas.

Main text
Reduce CO_2 emission in the industry

Major industrial actors recognized that solutions are needed to tackle CO_2 emissions. They have been highly proactive in improving energy use and reducing greenhouse gas emissions, and are now operating close to the limits of the set technologies. Further CO_2 reduction involves to find new routes to green the gases used in the industrial processes. Biomass is an opportunity to produce the green gases. However the use of those green gases in the industry is not yet highly developed.
Solid biomass (fresh wood, forestry bio-products, demolition wood and other woody wastes) is one of the biggest source of renewable energy around the world. Among the 13% of renewable in the primary energy consumption in 2010 in the world, biomass represents the major contributor. When it is valorized in a sustainable way, solid biomass has a high development potential. Unfortunately, a significant share of this usage is not made with high standard of both energy efficiency and low environmental impact. The main difficulty for an efficient use of solid biomass is its transportation to the place of use. In that framework, biomass gasification has a high potential for upgrading and widening biomass energy applications.

Aims

Once transformed into a gas (syngas) the gasified biomass can be valorised through two paths[1]:

- Direct firing of the syngas into an industrial furnace for direct heating of the final product (glass, brick, ceramics,…),
- Transformation into a bio Synthetic Natural Gas (SNG or biomethane) that is injected into the gas grid in middle scale plants (10-50 MW) to keep as low as possible the impact of biomass transportation from crop zone to transformation zone.

The last two applications has the advantage to respectively,

- allow an industrial gas customer to keep fossil Natural Gas as its fuel for heat production while having a significant part of his energy mix being renewable,
- decoupled the biomass transformation location to the place of use by using existing natural grid to transport the "wood" natural gas, while keeping the wide range of natural gas applications (heat, cooling, electricity, vehicles)

For gas companies also active in business of Services to Energy, such business activities are giving a wide perspectives through local production of green gases and sales of renewable heat, power or fuel gas.

GDF Suez with other partners (industrial gas consumers, gasification technology developers, professional and academic organizations) has launched several project to develop such applications.

- BioVive with St Gobain (Verralia) for direct firing application in the glass melting industry, supported by the French Research Agency

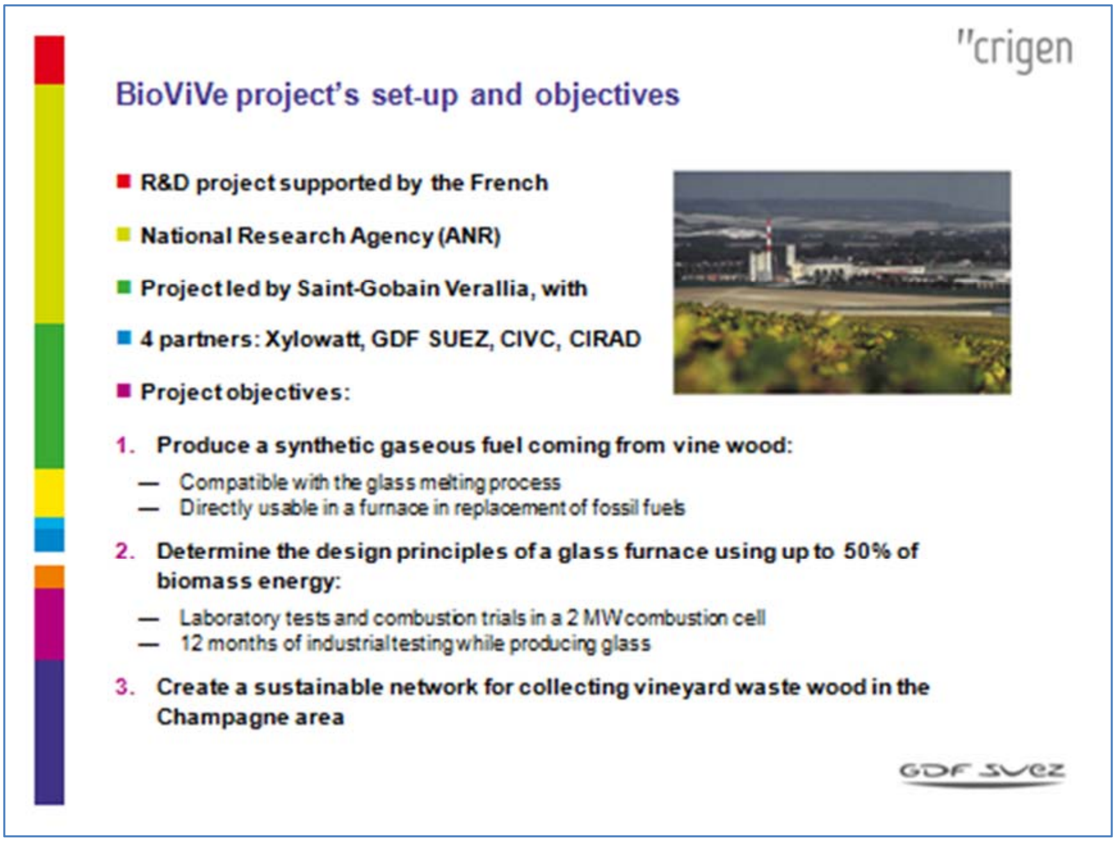


Fig. 1

Replacing fossil fuels with syngas form biomass in furnaces

Replacing a part of the fossil fuel by syngas requires coupling the furnace to a gasification unit. Depending on the application, treatment unit will be require to clean the syngas before firing in the process. A general overview of the integration is depicted in the Figure 2. .

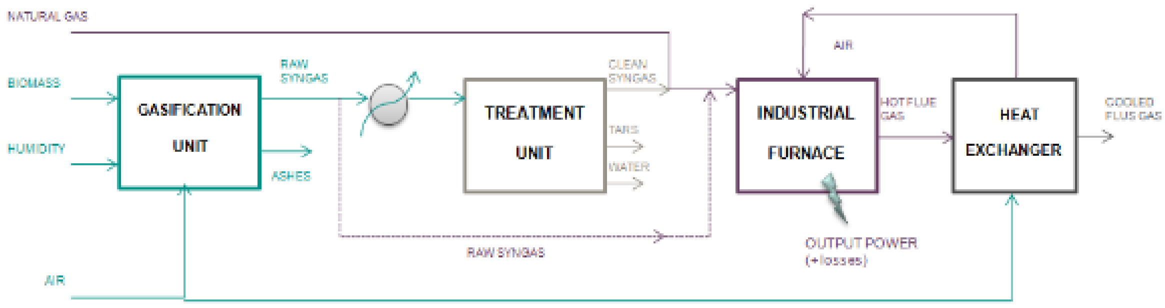


Figure 2 – Process flow of gasifier unit coupled with an industrial furnace

Integration of the gasifier in the process can be enhanced. Recovering the fumes heat losses to dry the biomass before introduction in the gasifier can improve the overall energy efficiency.

Various choices gasifiers technology for direct firing

Syngas is generated by low-temperature (<1000°C) gasification. For biomass applications the direct processes (i.e. autothermal processes) are typically operated with air as gasification medium. The main direct and indirect processes are:

- Fixed-bed updraft;
- Fixed-bed downdraft;
- Fluidized bed (bubbling and circulating, i.e. BFB and CFB); and
- Indirect fluidized bed (steam-blown).

The choice of the gasifier technology for the industrial application is important. Several technologies of gasification are compatible with syngas production for direct use in a furnace. The choice of the gasifier technology mainly depends on the size and type of industrial process downstream.

Syngas contains CO, H_2, CH_4, C_xH_y aliphatic hydrocarbons, benzene, toluene, and tars (besides CO_2 and H2O). The composition of the syngas strongly depends on the technology and the oxidant used for gasification (cf. Table 1).

% mol	H_2	CO	CH_4	C2+	CO_2	N_2	NCV kWh/Nm3
Fixed-bed downdraft composition	17	22	2	0	11	45	1,4
Fluidized bed composition (steam-blown)	38	25	11	2,6	21	2,5	3,5

Table 1 - Composition of syngas

Combustion and properties depend on the gases composition and also on the tar concentration. Tar concentration in the downdraft gasifier is low, usually around 0.015 to 0.5 g/Nm^3[2]. For special application with engines, tars concentration can be strongly reduced up to less than 100 mg/Nm^3 with the use of low tar technologies in the treatment unit (filtration stages, cyclones, scrubbers and cooling exchangers).

The power range of most industrial furnace is between several hundreds of kW and several tens of MW. If all of the syngas produced fire the industrial furnace, the thermal output power of the gasification unit has to match with the input thermal power of the furnace.
While steam-blown fluidized bed technologies produce syngas with higher NCV (Net calorific values) compared top fixed bed technologies, the size, power and CAPEX of those units is larger (cf. Table 2).

	NCV kWh/Nm3	Air volume (Nm3 air / Nm3 fuel)	Fumes volume (Nm3 fumes / Nm3 fuel)
Natural Gas	10.25	9.8	10.8
Syngas (downdraft)	1.51	1.15	1.94

Table 2 - Syngas combustion properties

Major drawbacks of downdraft technologies are that it Is very sensitive to the biomass particle size and requires very low humidity (< 10%). Another difficulty is that large gasifiers (> 4 MW) are not developed. However technical works are currently under way to increase the gasifier diameters and output power.
However, the simplest and the cheapest gasification technologies are the most appropriate for direct firing, especially fixed bed gasifiers. However the NCV is low. When replacing the natural gas or fuel oil on a combustion unit, the flue gas volume is largely increased and the flame temperature is decreased. Hence energy efficiency of the whole installation is reduced.
Research activities are currently under way [3] to increase the NCV with the use of oxygen instead of gasification air and therefore reduce the nitrogen concentration in the gases.

Simulation tool to assess technical feasibility
An energetic study of natural gas substitution to synthesis gas, clean or raw, was conducted via a model of mass and energy balances. GDF SUEZ has developed a simulation tool that enables the coupling of a simplified gasifier model and an industrial process (mainly furnace).

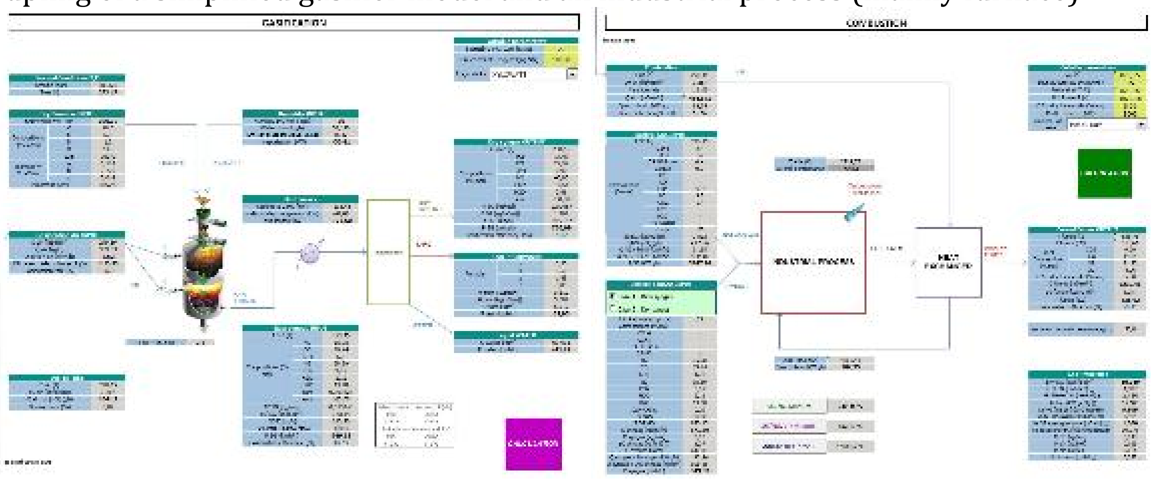


Figure 3 – Screenshots of the gasification and combustion sub-models

The model allows to achieve results on the combustion from natural gas and/or synthesis gas from a gasification unit, calculate the flow of gas and oxidizer to introduce into the industrial furnace, depending on the rate of substitution chosen and the output power of the furnace, determine the composition of syngas and the amount of biomass introduced into the gasifier from data on the clean syngas, calculate energy efficiencies in various industrial settings.
The model is able to consider two alternatives: with or without the use of a treatment unit. Without a treatment unit raw syngas is produced. If the industrial process supports it, raw

syngas can be used instead of cleaned syngas. The main advantage is that raw syngas flows out of the gasifier at high temperature (around 600°C) and contains tars that can be used to increase NCV and radiation emission of the syngas. However, raw syngas contains a large concentration of water which does not participate to the combustion reaction but improve the flame radiation.
It was calculated on a reheating furnace case that compared to a fully fossil fueled combustion, energy efficiency fell by 13 and 17% at a total substitution into synthesis gas (respectively raw and clean), while overall performance fell by 14 and 35%. The volume of fumes increased from 23 and 47%. The results are affected by the configuration of the industrial furnace and the fumes temperature (which is directly linked with the temperature set point of the product to be heated).

Within sectors of metals, materials, pulp and paper, food industries, many industrial processes can run on cleaned syngas (with partial or total substitution of natural gas). Due to less constraints on the atmosphere, reheating furnace (steel), kiln (brick & tile), limestone rotary kiln are the processes that can handle raw syngas.

Other points need to be carefully considered to study technical feasibility of fossil fuel replacement by syngas. Specific safety measures are required due to the presence of large amount of carbon monoxide and hydrogen in the syngas. The gasifier has to be fed with local biomass to ensure the sustainability of the whole installation and to reduce costs: study of different logistics scenarios is therefore mandatory.

Experimental tial test of connection between gasifier and industrial glass melting furnace.

BioViVe project is a research project partly funded by the ANR French program aimed at using biomass from vine woods to replace fossil fuel in a glass furnace**. The project led by Saint-Gobain Verallia with four partners: GDF SUEZ, Xylowatt, CIVC and CIRAD has several objectives**:

- To produce a synthetic gaseous fuel coming from vine wood, compatible with the glass melting process and directly usable in a furnace in replacement of fossil fuels
- Determine the design principles of a glass furnace using up to 50% of biomass energy: through semi industrial combustion trials in a and industrial testing while producing glass
- Create a sustainable network for collecting vineyard waste wood inthe Champagne area

A 1 MW wood gasifier has been built to produce the best suited specific syngas combustion into a glass melting furnace. It has been tested successfully at GDF Suez CRIGEN Research Center. It produces a clean syngas that could be injected into a laboratory combustion test cell representative of a slice of a glass melting furnace (cf. Figure 4 and Figure 5).

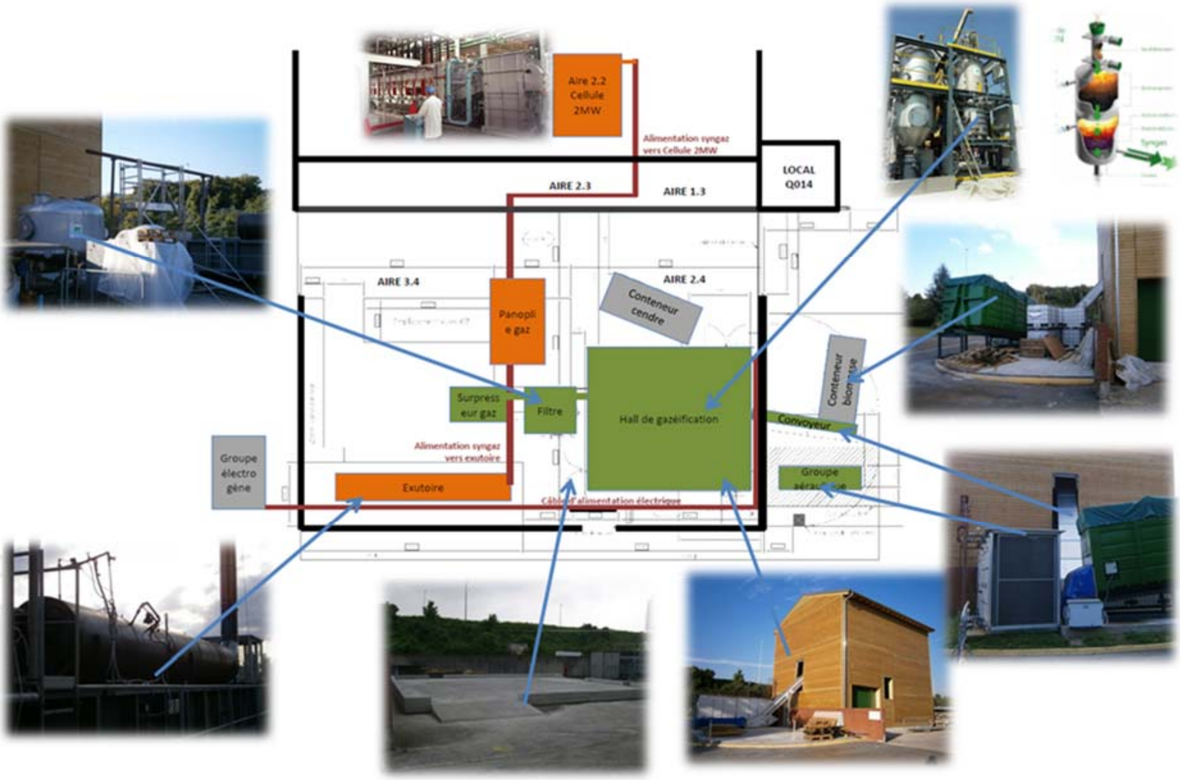


Figure 4 - Gasifier implementation on CRIGEN site

Different blends of NG and syngas are under intense testing with different injections modes into the combustion test furnace. Enhancing the power output and combustion qualities of the syngas, are also addressed. Detailed measurements are being made to find the best combustion adjustments.

Figure 5 - Biomass gasifier and combustion test cell for BioVive Project

GDF SUEZ has carried out 4 weeks of trial for a comprehensive characterization of air combustion of biomass syngas in CRIGEN's 2 MW combustion facility, representative of a glass furnace. Preheated air combustion, natural gas / air-gasified syngas, up to 100% of syngaz. To increase syngaz NCV, oxy-gasified syngas has also been tested. The trials result in a comprehensive characterization of syngas combustion, up to 100% of syngas, in a combustion facility representative of a glass furnace and an assessment of energy efficiency.

Figure 6 - Combustion visualization through CRIGEN furnace hub [3]

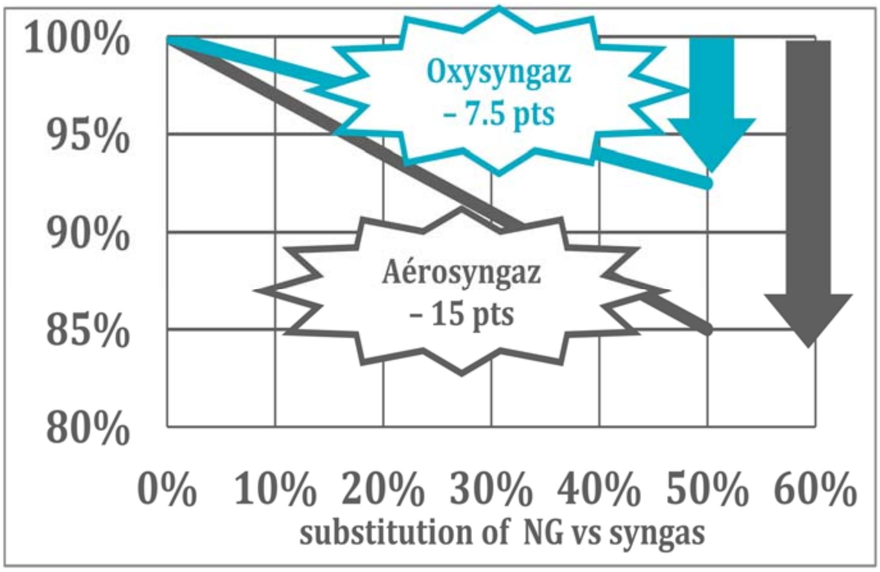


Figure 7: Effect of syngas substitution to heat tranfer

One of the conclusion of the project is partial substitution of NG by syngas is possible, but there is an effect, especially for high temperature process, on energy transfer or energy efficiency. Different Syngas has been test produce by aero-gasification or Oxi-gasification biomass process. This will affect the global efficiency of the process and of course the profitability of the energy conversion.

Today, in vineyard Champagne region (France), GDF SUEZ and its partners are currently testing to validate the industrial phase and ensure that the coupling between the gasifier and the glass furnace works properly into Saint GOBAIN-VERALLIA glass plant. A demonstration of the technology is expected to be done within the end of 2014.

Figure 8: Industrial implementation at Oiry VERALLIA plant (France)

Conclusions

CRIGEN with Saint GOBAIN-VERALLIA and BioViVe partners have successfully tested the firing of green gases from biomass on a process similar to industrial ones. A large range of industrial processes can run with syngas from biomass as a partial substitution of fossil fuel to reduce their CO_2 emissions. Keep an input of natural gas in the process gas is required especially for high temperature furnaces or high heat transfer processes, du to the reduction of heat transfer. Use of local biomass is mandatory for a good sustainable process and final costs of syngas produced. Specific safety measures are needed to handle the CO and H2 in the syngas, in order to guaranty the quality of combustion and energy efficiency.
Nevertheless, Partial conversion of industrial furnaces to biomass syngas is possible , for low temperature process or Steam production or high temperature processes, partial conversion of energy input to Biomass syngas with NG could be a good solution to reduce drastically the CO_2 emissions and reinforce the implementation of the factories ,by using local Biomass, in the territories.

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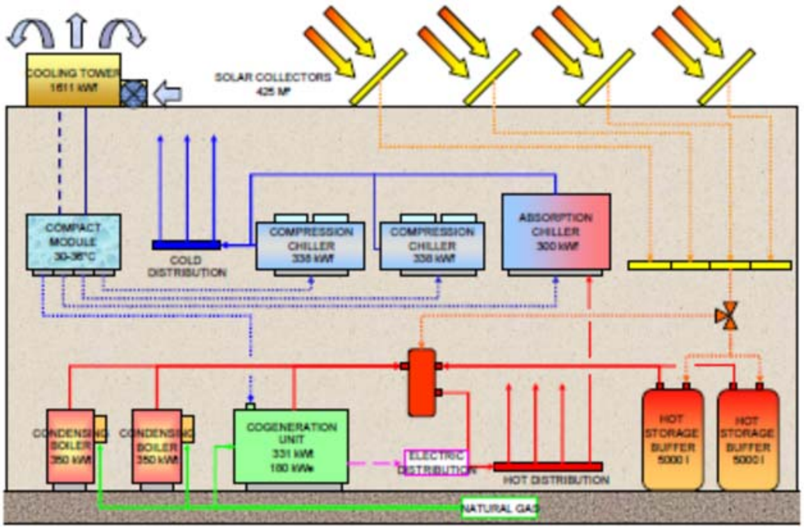
Trigeneration

Authors: Koen Wiersma and Alì Zatout

In many industrial processes and utility buildings besides electricity, steam and hot water also cooling is necessary. Trigeneration is an option with provides a few advantages. Trigeneration or combined heat, power and cooling (CHPC), is the process by which some of the heat produced by a cogeneration plant is used to generate chilled water for air conditioning or refrigeration. The basis of a trigenerator is a cogeneration plant (CHP) or the waste heat of a industrial process. The heat could also be produced by solar thermal collectors (STC). An absorption chiller is the device that uses the heat for cooling. A absorption chiller is an alternative for the regular applied compressor chiller.

The benefits of trigeneration are;
•Onsite, high efficiency production of electricity and heat
•Reduced fuel and energy costs
•Lower electrical usage during peak summer demand
•Engine heat can be used to produce steam of hot water for onsite use
•Significant reductions in greenhouse gas emissions

Case; EURAC
In the regional institute for applied research EURAC in Bolzano (Italy) a trigeneration-unit is providing the electricity-, heat- and cooling needs. In the figure below a schematic overview of this installation.



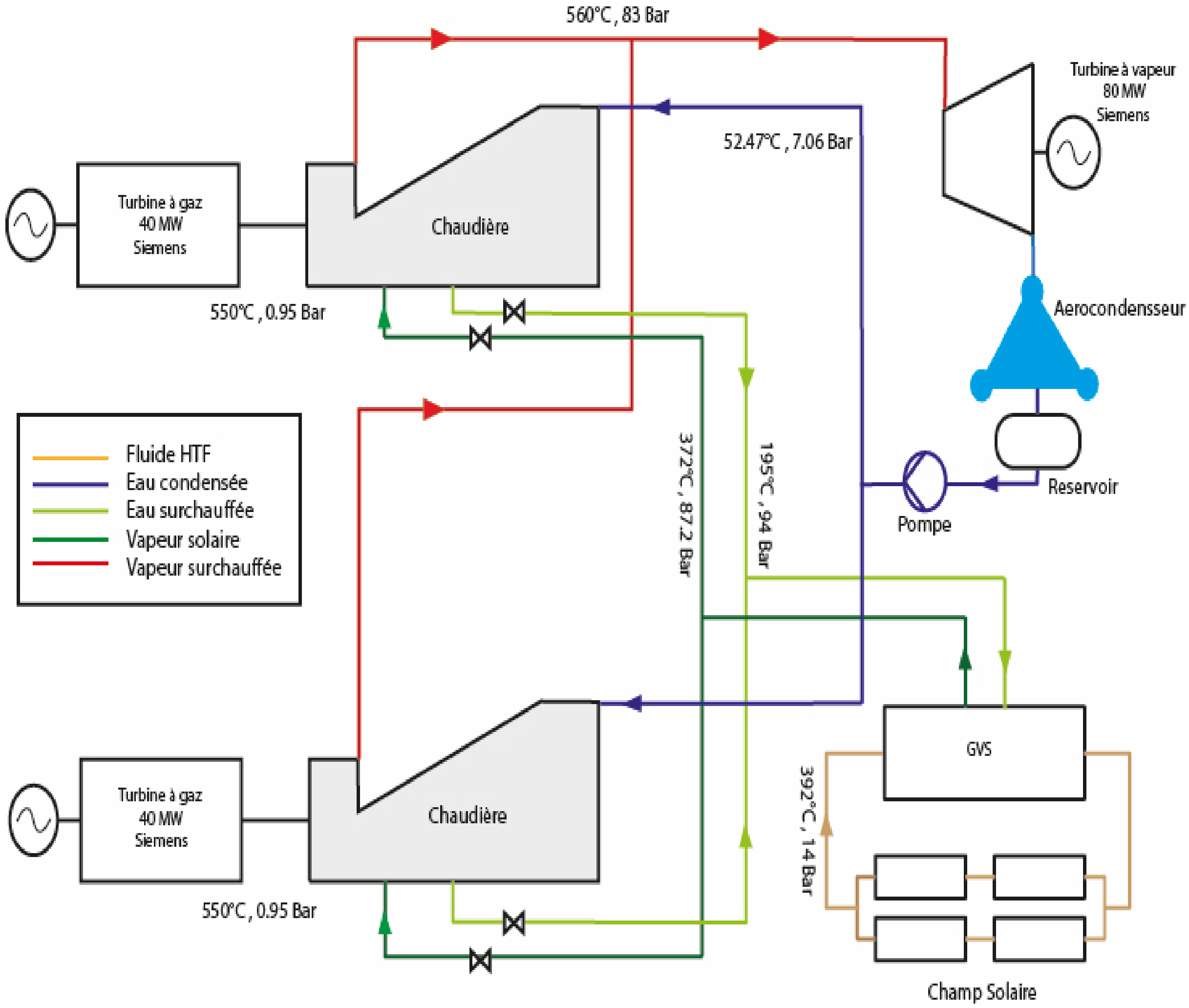
The hot water is produced by a gas engine (180kWel, 331 kWth), two condensing boilers (each 350 kWth) and solar collectors with an suface area of 425m2. The cooling is supplied by two compression chillers (each 338 kwth) and an absorption chiller (300 kWth)[2].

[2] Trigeneration Systems Assisted by Solar Energy Design Criteria and Off Design Simulations; Assunta Napolitano; University of Bergamo;

Hybrid solar and gas of Hassi R'Mel 150 MW – SPP1 Algeria

Authors : Koen Wiersma and Alì Zatout

The first hybrid solar-gas plant in Algeria and also in the world was opened July 14, 2011. Located Hassi R'Mel this Central was named SPP I, the name of the company who performed, Solar Power Plant One.



General Description

SPP1 plant of Hassi R'Mel is a hybrid one. By this we mean that it runs on natural gas and solar energy. It produces 150 MW (net ISO) with a solar contribution of 20% giving a rated power of 30 MW.

The plant is composed of two parts, the solar field and the combined cycle:

a. The solar field consists of parabolic trough over two surfaces. Each area contains 28 loops of four modules, divided into two rows. The module consists of 12 segments each with several mirrors. The direct component of the solar radiation is concentrated by the mirror on a receiver located at the focal point of the parabola. A coolant HTF (Heat Transfer Fluid) circulates inside the receiver. The heated fluid, the temperature can reach 393 ° C, passes through a series of heat exchangers to transfer its heat to the water and thereby producing steam (solar steam generator).

b. The combined cycle consists of two gas turbines (natural gas) with nominal power per unit of 45 MW. The combustion heat of these turbines is recovered in two horizontal natural circulation boilers, and steam turbine with a rated output of 80 MW.

It should be noted that the strength of this hybrid plant is the addition of the steam produced by the solar field to the steam recovered by heat recuperation of gas turbine outlet heat to provide the steam turbine . The electrical power produced by the plant increases accordingly.
This technology opens the opportunity to realize CSP (Concentrated Solar Plant) without storage target (expensive actually and not efficient, natural gas will ensure the continuity of power production at night and in cloudy weather.

Changing use of biogas for heat and power to biomethane fuel production. First Danish case. (this case also in May 2014, was reported to IEA, task 37 "Energy from Biogas")

Article proposed by Aksel Hauge Pedersen

Introduction

The first full scale biogas up-grading plant in Denmark, was built by Dong Energy, one of the leading energy groups in Northern Europe, in the autumn of 2011. The plant upgrades the biogas produced by Fredericia municipality's wastewater treatment plant, and delivers the upgraded biogas to the national gas grid.

Mission and vision

Policy makers in Denmark agree that biogas should have its breakthrough as energy source in Denmark, and both the energy and the agricultural sectors are aware of the great potential and benefits of biogas. Upgrading and grid injection is considered a must in a situation where the Danish CHP-plants cannot use all biogas produced.

The idea of establishing a biogas up-grading plant in Fredericia arose in 2008, as a stepping stone in the "climate partnership" signed between Fredericia Municipality and Dong Energy. The agreement is based *inter alia* on the objective of the municipality to have the municipal buses running on environmentally friendly gas, on one hand, and on the other hand on the overall strategy of Dong Energy of gradually switching to green energy production. In the same "green" context, Fredericia Municipality has launched the project, "Fredericia Forms Future - From North Sea Gas to Fredericia Gas", where biogas has a central role. The project is a public-private innovation partnership between Fredericia and Dong Energy's technology company, REnescience, aming to make Fredericia a municipality that uses waste and wastewater as resources, able to create value and jobs, through production of renewable energy.

A new approach

The wastewater treatment plant in Fredericia is Denmark's second largest, treating yearly around 10 million m^3 of wastewater from very large companies including a Shell Refinery, Dong's plant at the port, Carlsberg and Arla. The wastewater treatment plant is also one of the biggest energy consumers in Fredericia Municipality, with a great potential to be a net source of energy.

Figure 1: General view of Fredericia WWT- plant, including the upgrading plant at the bottom left corner. Source: Fredericia Rensningsanlæg.

Biogas is a by-product of the wastewater treatment process. The sludge generated by the wastewater treatment is fed to the biogas reactors, to be co-digested with bio-pulp, which is added to boost the digestion process. The biogas produced at the wastewater plant was earlier used to produce a small amount of power, for process heat and for heating various warehouse buildings in the area while the surplus was simply flared, and therefore wasted.

The very fact that the municipality's approach to biogas changed from being considered a by-product to being seen upon as a valuable resource paved the way for many opportunities and for new challenges. One of them was to double the amount of biogas produced by feeding more methane-rich feedstock material to the biogas reactors. The source of more methane proved to be the digestible household waste from the municipality. Before being fed to the biogas reactors, the household waste is pre-treated using the REnescience technology for separation and enzymatic treatment of solid waste, at ambient temperatures.

Biogas upgrading

To upgrade the biogas to natural gas quality biomethane, a water scrubbing technology was chosen with a well-established and energy efficient upgrading unit. The modular unit installed is designed for raw gas capacities of 300 Nm3/h, which represents roughly the equivalent of powering 1250 cars per year with petrol or heat demand of 500 households.

Using a well-established upgrading system was important for ensuring efficient use and minimum maintenance. The modular unit enabled rapid installation. The technology adopted is environmentally friendly, as the main process uses water as the cleaning fluid.

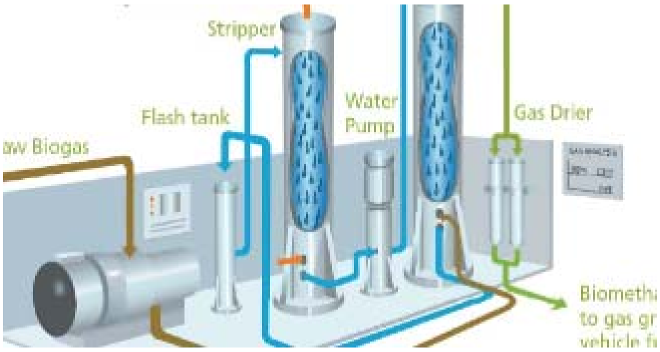


Figure 2: Schematic representation of the water scrubber. Source: Greenlane Biogas and DONG Energy.


Figure 3: The upgrading plant. Source: DONG Energy.

Process description

The raw biogas, which is moist but without content of condense water, is fed into the upgrading facility, where it is compressed to a pressure around 6 bar. The compressed gas is then scrubbed with process water. As the ability of water to absorb CO_2 under pressure is

significantly better than its ability to absorb methane in the same conditions, CO_2, H_2S and siloxanes bind to water in this part of the process.
This process is sufficient to purify biogas to a quality which complies with the requirements of the Danish Gas Regulations, and is then ready to be injected into the natural gas grid. The process water is fed to the stripper where the pressure is removed and the CO_2, H_2S and siloxanes are released from the process water, which is subsequently recycled and reused.

In order to avoid unwanted deposits in the downstream equipment, the removed siloxanes are retained by an activated carbon filter. The exhaust air is cleaned by a thermal process, where the small amount of methane, which has been transferred to the water and the H_2S are converted to CO_2 and water.

All operational steps and sub-processes at the plant are monitored and controlled by a PLC system, which ensures optimal technical operational safety. The PLC system can be remotely monitored via the Internet by the supplier and the operating staff of the plant.

Results

The project in Fredericia has demonstrated an effective strategy for changing from low grade heat and power generation to high efficiency biogas upgrading to biomethane using a well-established technology and grid injection. This has led to accelerated the development of biogas up-grading and eased the way for future biogas upgrading projects in Denmark. It has highlighted the specific needs related to gas grid connection in the country, the challenges related to gas quality and certification standards, specific needs for procurement of equipment, construction and commissioning as well as operation and maintenance routines. Overall, the plant is now considered a "hands on" experience of establishing and operating a biogas upgrading plant, complete with
lessons learned ranging from the choice of materials to keeping the process water clean.

Nominal Capacity	100-300 Nm3/hr (raw gas)
Raw Gas Requirements (Typical)	CH4 = 50 - 65% volume CO2 = 35 - 50% volume H2S = <2500ppm (extra cost may apply if exceeded) O2 + N2 + Other = < 0.5% (higher inerts may degrade outlet gas quality) H2O = Saturated Inlet Pressure ≥ 50 mbar(g), ≤ 200 mbar(g) Inlet temperature, nominal 30°C
Product Gas Delivery (Typical)	CH4 = 98% }1% volume CO2 = 1 - 2% volume Total Inerts (O2, N2) = <1 - 2% volume H2S < 5 ppm (0.1 - 1ppm very typical) Dew point @ 1 bar(a) = -80°C or less Pressure = 8 – 9 bar(g) at maximum raw gas flow
Product Gas Flow-rate	Dependent on raw gas flow and composition, refer Mass Balance Diagram
Utility Consumption	Refer to Kanuka, Performance & Utility Datasheet

Table 1. Process design Data

Gas Compressor	Single Stage Screw Compressor, SRM K419
Compressor Motor	45 kW, 2 Pole, IP55, ATEX, High Speed Electric Motor (For EU)
Process Water Pump	Lowara Vertical Multistage Pump, Model SV3307/1N185T
Water Pump Motor	18.5 kW, 2 Pole, IP55, ATEX, Electric Motor (For EU)
Variable Speed Drives	Main Drive Compressor VSD: 45kW 88 Amps IP21 CFW110105T4OSZ (For EU) Water Pump Motor VSD: 18.5kW 38 Amps IP21 CFW110038T4OFAZ (For EU)
Process Vessels	Scrubbing Vessel, GRP with polypropylene packing media and distribution trays Stripping/Flashing Vessel, GRP with polypropylene packing media and distribution trays
Biomethane Drying and Polishing	Patented PSA/TSA adsorber is included. Dual column type with auto changeover valving. Installed Regeneration Heater, 3 kW, EX rated.
PLC & HMI	PLC = Siemens 6ES7-200 Safety PLC; HMI = 5.7" Colour Touchscreen Model KTP600
Communication Protocols	Ethernet and/or Profibus
Switch Gear/ MCC & Isolation	Included, typically Schneider NS/NSX switchgear, GV2 motor protection, C60 MCB, DPN Vigi RCD, LC1 contactors

Table 2. Key components

The future

The future plans of the Fredericia plant are to continue the process optimisation. The lessons learned will be used not only for operational optimisation and troubleshooting, but also to guide future equipment procurement and installation and to optimise the framework for future biogas upgrading plants in terms of overall financial performance throughout the operating life. Operating and maintenance procedures will be continuously improved.

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6. SMALL SCALE LNG FOR INDUSTRY

Authors: Nuno Moreira, Fairos Roslan, Vladislav Karasevich

1. Introduction

The availability of LNG is spreading all over the word. New terminals are being built and new station to deliver LNG locally are being installed, both on new and existing terminals.

Global LNG demand keeps on increasing with Qatar and Australia leading the new addition in supply.

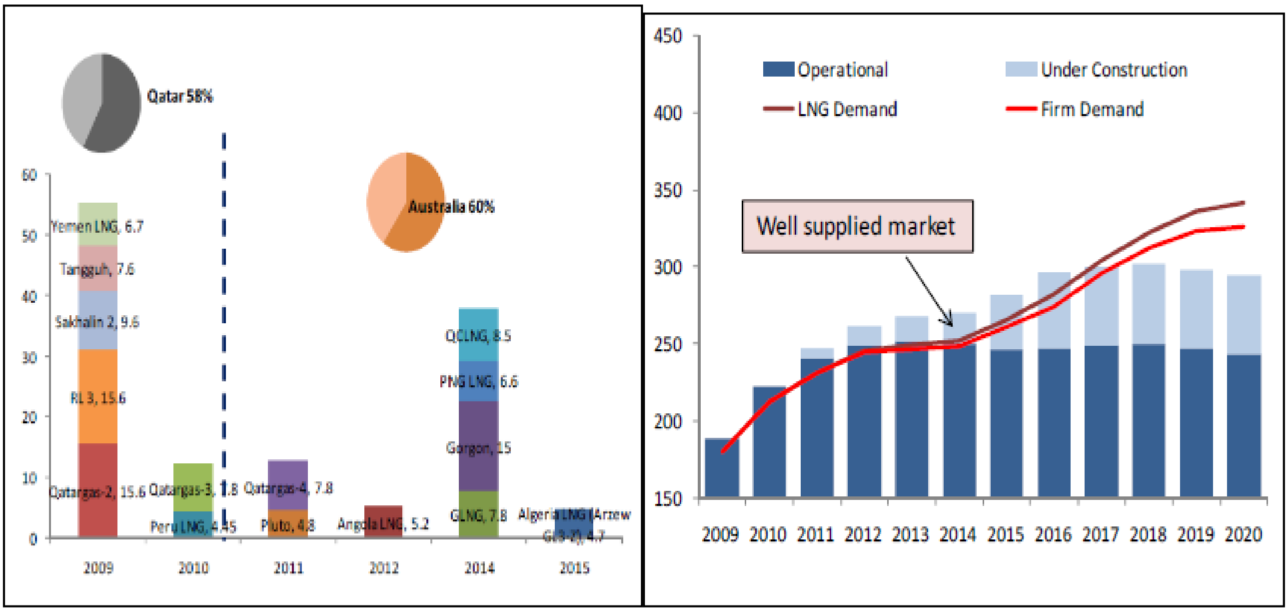


Figure 1: LNG demand.

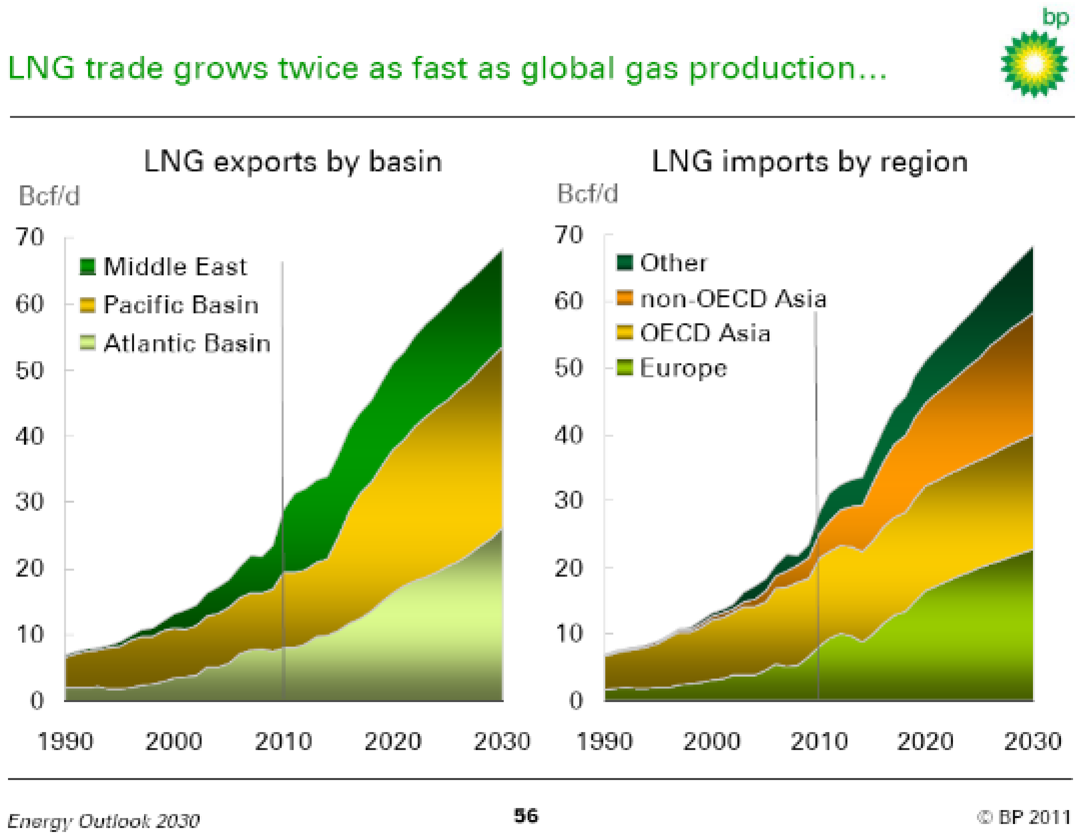


Figure 2: LNG trade.

Gas producers eager to bring their products into Asia to reap the opportunities in gas price differences

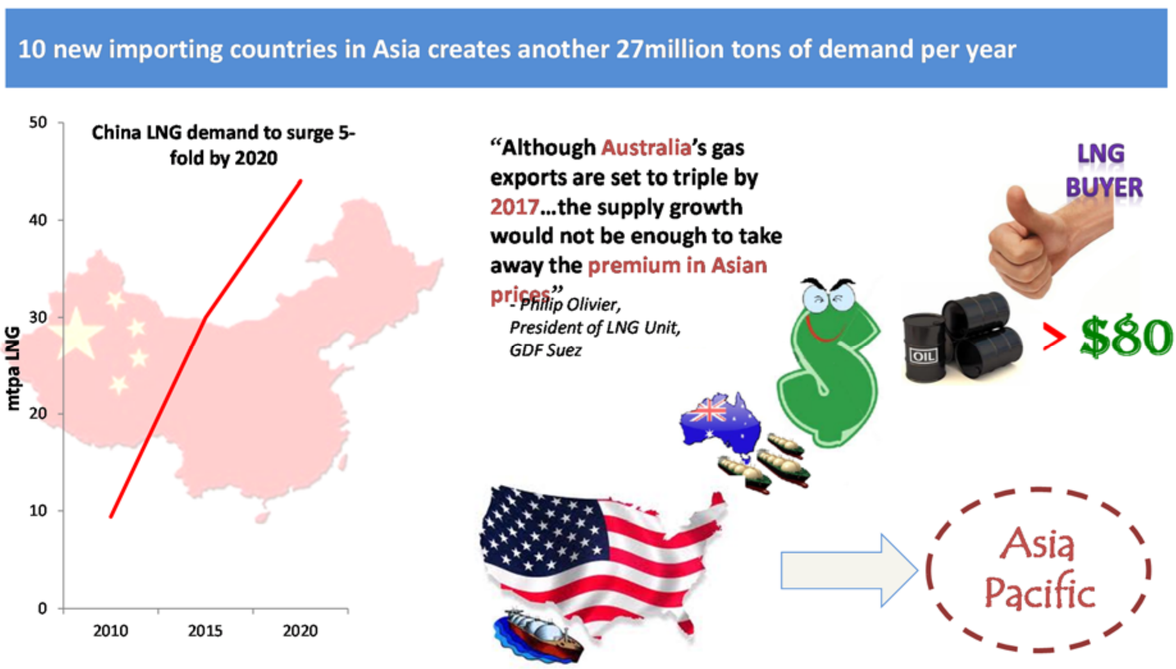


Figure 3: LNG new import countries.

South East Asia Regasification Terminals development

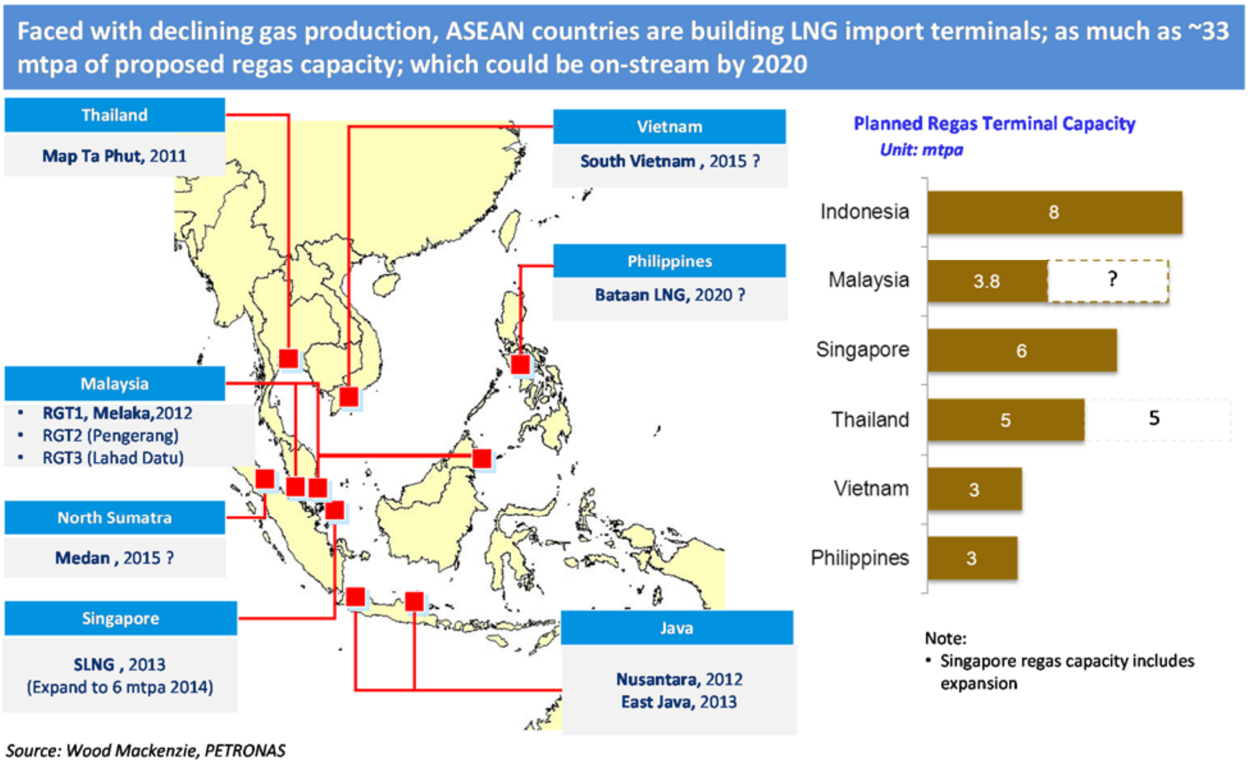


Figure 4: LNG import terminals.

2. LNG retail

The retail of LNG is much dependent on the availability of the LNG terminal to fill truck tankers.
In Spain, LNG is being transported by road since the early 1980's. In Japan the first steps where made in the 1970's. In China, the transport of LNG by road is very well developed, and some important amount of LNG is transported.
LNG is transported by road mainly to industrial customers that are not served with gas grid. Some other case exits for small gas networks and peak shaving facilities.
In most of the cases road tanker is unfilled on satellite plants where LNG is gasified for local industrial.

LNG import terminal truck loading plant is normally part of the terminal, and regulations of the import LNG terminal often are applied.
Road LNG tankers regulations are commonly established on combustible gases road transport regulations.
Satellite plants have special regulations attending its security characteristics:
- EN 1473:2007 Installations and equipment for liquefied natural gas - Design of onshore installations.
- EN 13645 – Installations and equipment for liquefied natural gas. Design of onshore installations with a storage capacity between 5 t and 200 t.

The technology in LNG Distribution is already matured and available in all region of the world

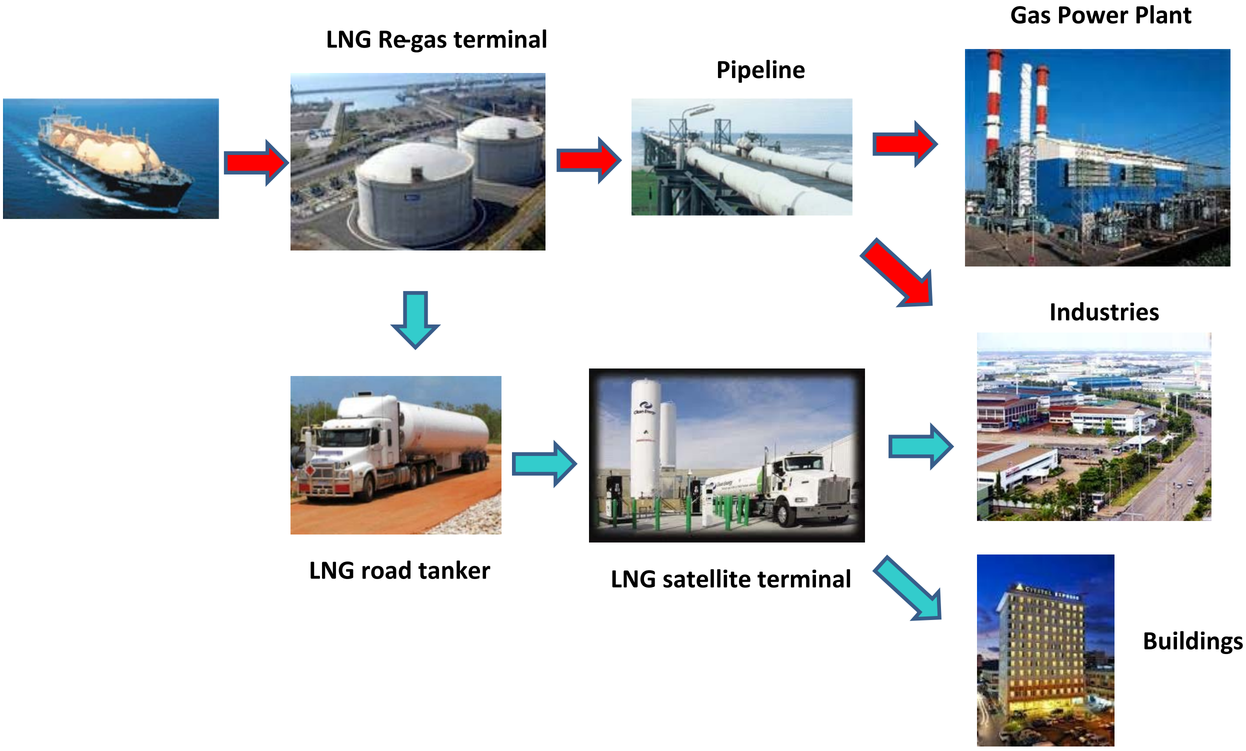


Figure 5: Logistic scheme of LNG utilization.

Traditional LNG logistic

New retail LNG logistic

3. Technical

The availability of truck loading facilities on the terminal is a crucial constrain on LNG road transport. Gas LNG Europe (GLE) presented a map of facilities in Europe. Truck loading facilities are present in some, but many other are planning the construction.
Road tankers, as any other LNG tank, produce boil-of-gas (BOG), and these characteristic must have to be considered when dimensioning the tank for the truck.
The tank must be engineered taking in order to meet this need. The maximum pressure should be adjusted to the distance covered.
Tankers where built on isolation material (polyurethane), but new rules determine that only double wall vacuum isolated type are approved (Chart?).
Satellite plants technology is derived from air gases industry. Considering the necessary adaptions, satellite plants are very similar to the plants on liquid air gases used for several decades on industry, hospitals and others.
There are mainly two types of satellite stations: for industry and local grids, and for stand-up peak shaving. The two different engineering projects attend the different need for regular gasification or peak gasification processes.

The distribution chain is very simple:

- Truck tanker is filled with LNG on the terminal truck loading facility. Cryogenic pump is normally used.
- Truck drives from the terminal to the satellite plant. Pressures from 1 to 4 bar are most used.
- LNG in the truck is unfilled to the satellite plant cryogenic tank. Differences on pressure or unloading pump are both used. Pressures on the satellite plant from 4 to 20 bar are common.

- Besides one or several LNG tanks satellite plant have several other equipment to produce and regulate the gas delivered.

Satellite cryogenic tank size is very variable; there are tanks from 2 to 2000 LNGm3. One or more tanks can be used. Attached to the tank a small vaporizer is used to build the pressure inside the tank, if it is necessary. Pneumatic and electric valves are normally used .
ISO containers can also be moved by road. This option must be validated where a special need is present. Due to its own weigh ISO containers have limitations on road transport.

4. Costs
The cost of LNG truck transport is mostly dependent on the tanker used and distance covered. For a standard 56 LNG m3, the cost per km is presented in the graphic.

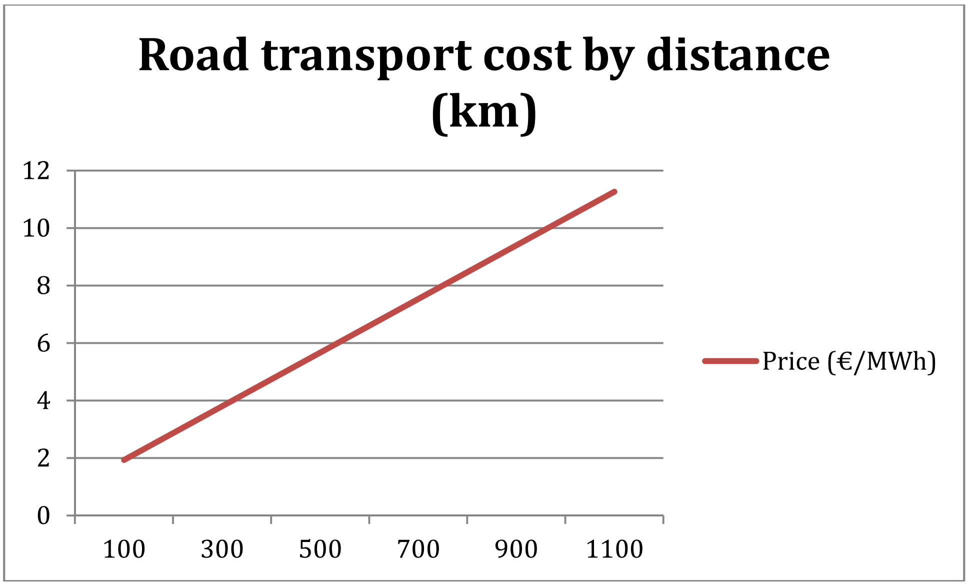


Figure 6: Road transport cost by distance.

5. Examples of road distribution
In Portugal dourogás is using the “LNG retail” for LPG substitution in clients where grid is not present.
The project consists on a intermediate satellite plant that receives the LNG from Sines terminal, filling small truck tanker. The small tanker retail LNG to several micro satellite plants, ranging from 2 LNGm3 to 30 LNGm3.
Investment (capex) and operational (opex) cost are estimated on the basis of the annual client consumption:

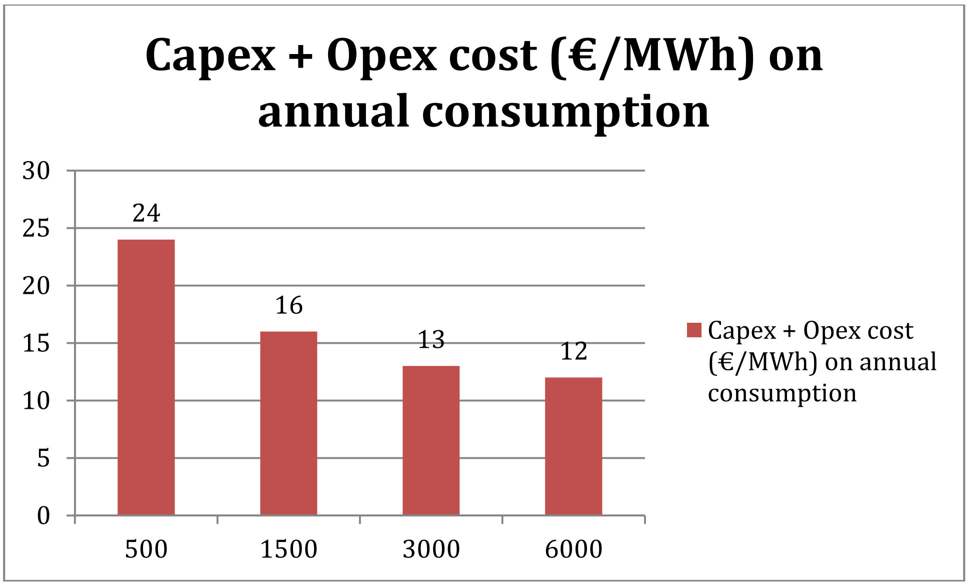


Figure 7: Operational and investment costs.

This table shows the minimum size retail profile client. Considering the opportunity value of the energy, there are good chances to have economic feasibility.
In Spain during the year 2012 has been record-breaking load of tanks in the Spanish gas system with a value of 45,293 tanks, 80% were loaded on ENAGAS terminals.

Case studies

Case Study i) Development of LNG sector in Russia

Presently the LNG sector in Russia is developing in two ways. The first is the construction of large-scale plants that export the LNG. The second way is building small and medium-scale plants for the internal market. Below is an overview of both large and small-scale projects.

The LNG-for-export plants

According to a number of experts, the amount of produced LNG in Russia is inadequate to the resource potential and the status of the country on the world energy market. In the recent years, Russia produced only 10 mln ton p.a. of LNG, that is just 4-5% of the world production. At the same time, the demand on LNG on the external market is growing, and by 2030, it will reach 400 mln tons p.a. If Russia can manage to accomplish all the planned export-oriented projects (such as Yamal LNG, LNG production of the Shtokman field and Sakhalin-2), it can capture up to 20-25% of the world LNG market share.
The main companies on this market are JSC Gazprom, JSC Rosneft and JSC Novatek.

JSC Gazprom projects

Sakhalin-2
The LNG plant was constructed in 2009 in the framework of the Sakhalin-2 project as a part of the Prigorodnoye asset, which also includes a cot crude oil terminal.

The complex is located in the southern part of the island, on the coast of creek Aniva, 15 km west from the city of Korsakov. The Aniva creek does not freeze in the winter, making it the perfect place for oil and LNG dispatching.
The operator of the project is Sakhalin Energy ltd, which is owned by JSC Gazprom (50%+1 stock), Shell (27,5%+1 stock), Mitsui (12,5% share) and Mitsubishi (10%).
The plant consists of two processing trains and common facilities. The gas is prepared and liquefied on the processing trains. The technology (developed by Shell) of a mixed refrigerant is used to produce LNG.
This technology, being the leading up to present day, was specially designed for the Sakhalin LNG plant to achieve the maximum efficiency of LNG production in conditions of cold Sakhalin's winters. The capacity of the plant is 9,6 mln tons of LNG p.a.
After liquefaction, LNG is stored in two reservoirs 100 thousand cm each. The LNG is stored there until the liquefied gas tanker arrives. The dispatch of LNG is made through a special terminal, which can accept tankers with a capacity range from 18 to 145 thousand cm.
In 2013 the plant produced 10,8 mln tons (14,9 billion cm of natural gas) of LNG, which then was transported to Japan, Korea and China with client's own fleet and tankers, provided by the company itself. In total, as of 2013, the amount of sold LNG is ca. 47,7 mln tons (65,8 billion cm).

Baltiyskiy LNG
JSC Gazprom is planning construction of LNG plant in the St. Petersburg region.
The capacity of the plant is up to 10 mln tons p.a. It is planned, that the plant will be put in commission in 2019.
With the project implementation, JSC Gazprom is interested in participation of one or more partners with a total share of 49% (industrial partnerships, potential large-scale consumers and investors). Project finance is expected.
Presently a feasibility study is carried out (planned to end in 2014) and a site for construction is selected.
Source – www.gazprom.ru

Vladivostok LNG
The project Vladivostok-LNG assumes a construction of and LNG-plant in Hasan district of Primorski krai (on the Lomonosov peninsula, Perevoznaya bay), comprising of three processing trains 5 mln ton LNG p.a. each. The first train is expected to start in 2018.
The resource base for the first two trains is the natural gas from Sakhalin-3 production field, where JSC Gazprom owns four licenses: Kirinskiy, Ayashskiy, Vostochno-Odoptinskiy and Kirinskoe production field. The gas sources for the Sakhalin-3 project are estimated at 1.1 trillion cm. The most of the resources are concentrated on the Kirinskiy part.
The third production train is planning to use the resources of Yakutskiy and Irkutskiy production centres. The target markets are the countries of Asian-Pacific Region.
In February 2013, the project moved on to the investment stage. JSC Gazprom defined the range of possible external partners for this project, with a possible total share up to 49% providing the purchasing of not less than 6 mln ton LNG from this project. The negotiations with prospect LNG consumers are currently in progress.
The investment amount for this project (according to the Government of Primorski krai) is 10.5 bln euro.
Source – http://vladivostok-lng.gazprom.ru/

Regasification terminal in Kaliningrad region
JSC Gazprom is planning construction of a regasification terminal in Kaliningrad region with capacity of no less than 9 mln cm per day in order to improve reliability of the regions energy supply.

The terminal is planned to start its operation in 2017. The source is the external LNG market, which will be replaced by LNG from the Baltiyskiy project, expected to start in 2018.
Currently a number of possible sites are studied. In 2014 the feasibility study is expected to be completed.
Source – www.gazprom.ru

JSC Rosneft projects

The largest is the Dalnevostochniy LNG project on the isle Sakhalin. The projects capacity is 5 mln ton p.a. and is expected to expand in future. The resource base for the plant, which is expected to start in 2018, are the stocks of JSC Rosneft on Dalniy Vostok and the stocks from Sakhalin.
During 2013-2014 JSC Ronseft and ExxonMobil plan to complete the design works, including the liquefaction technology and the main specifications of the facilities, the engineering surveys, the FEED documentation, the design works for the waterworks and the supplying gas pipeline, as well as the environmental effect assessment. The investment amount for this project is estimated at 7 – 10 bln euro.
JSC Rosneft is also looking at the possibility of purchasing a 51% share in the project Pechora LNG from the company Alltech. The project assumes the LNG plant construction with a resource base of Kuzhminskoe and Korovinskoe production fields in the Nenetskiy autonomous district with a total stock of 160 bln cm.

JSC NOVATEK projects

The shareholders of JSC Yamal LNG, which will be the operating company of the LNG plant, are JSC NOVATEK (60% share), Total (20%) and CNODC (a subsidiary of CNPC, 20%).
The LNG plant will consist of three process trains with a capacity of 5.5 mln ton p.a. each, and will also include storage tanks. Infrastructure for the LNG offloading will consist of the jetty with two quays in the port of Sabetta, furnished with ice protection structures. LNG will be transported with specially designed tankers of enhanced ice class Arc7.
The total investment amount in the complex is estimated at 15 bln euro. This will be the first plant of such class built in condition of high north.
JSC Yamal LNG owns the development license of Yuzhno-Tambeyskiy production field on the Yamal peninsula valid until 2045. As of 31 December 2013 the field had 492 bln cm of proven reserves of natural gas and 14 mln tons of liquid hydrocarbons by SEC standards. The potential production level is over 27 bln cm of natural gas p.a. The gas produced on the field is planned to be sold as LNG on the external market.
In order to make the project more profitable the Russian Federation Council in July of 2011 approved establishment (as of 1 January 2012) of zero-level tax on the extraction of commercial minerals for the natural gas, produced in the Yamal LNG project. In 2013, the procurement phase of the project was completed.
In particular, the EPC contract for the LNG plant was signed with a joint venture of Technip and JGC, the contractor for the arctic tankers will be Daewoo Shipbuilding & Marine Engineering, with which a contract for 16 tankers was signed. As of end of 2013, the supply orders were made for the long-lead equipment, such as cryogenic heat exchangers, gas turbines and compressors. Commercial use of the project is planned to start in 2017.
As of the end of 2013, the long-term contracts for more than 75% of produced LNG were signed, the range of expert credit agencies and commercial banks was defined, which are involved in project finance.
Source – www.novatek.ru

Internal LNG supply plants

Presently the popularity of small-scale LNG plants is rapidly growing. Their main markets are local Russian regions. There are two main technological solutions: small-scale LNG with cryogenic scheme and LNG plants on gas distribution stations, which use cold from natural gas pressure reduction.

LNG plant in Karagayskiy district of Perm region
The project is implemented by JSC Gazprom Gazenergoset, a subsidiary of JSC Gazprom, as a part of gas supply of Perm region. The expected output is 13 thsnd ton LNG p.a. The gas will be sent to consumers in of local districts.
The company is also looking at possibilities of LNG plants construction in Khabarovsk region, Altay Republic, Hakassia, Tyva, Tyumen and Tomsk regions.

LNG plant in Ekaterinburg
The project is implemented by LLC Gazprom transgaz Ekaterinburg, a subsidiary of JSC Gazprom, as part of a pilot project on the gas distribution plan GRS-4 of the city of Ekaterinburg.
The singularity of this project is LNG production by means of pressure drop between the gas transport and gas distribution networks. A part of cold for the LNG production is generated on the turbo gas expansion engine, which provides a part of auxiliary needs of the station. This means that preliminary heating of natural gas before its expansion is not required anymore.
The capacity of the plant is 3 tons of LNG per hour. The consumer of the gas is a locomotive, converted to operate on LNG.

LNG Plant in Irkutsk region
LLC Irkutsk Oil Company is planning to build an LNG plant with a capacity of 84 thsd ton p.a. The project is expected to start in 2017.
The production is aimed to supply of LNG in Eastern Siberia, Zabaykalye in particular, which has a signed agreement with Irkutsk region on developing this sector. 26 thsd ton are expected to be sold for marine transport of Lenksoy and Angara-Baykal regions. Since the plant is located near Lena-Vostochnaya railroad station, LNG will be transported by rail.
The lead-time is from 12 to 19 months. The resource base are the Yaraktinskoe and Markovskoe oil, gas and condensate fields located on the north of the Irkutsk region.
There is no official info on the cost of the project, but by our assumptions, it is around 40 mln euro. The approximate cost of LNG without transport is around 200 euro per thsd cm (143 euro per ton LNG).

Case study ii) LNG retail in Portugal – Dourogás group

1. State of the art

Portugal has a good infrastructure on LNG. Receiving terminal of Sins is well organized and access to the infrastructure is provided from the independent operator REN.

2. Origin

Portuguese NG imports are around 6 bcm, divided in some 3,5 bcm on LNG coming from Nigeria and Trinidad e Tobago and 2,5 bcm on gas coming inside pipeline from Algeria.

3 . Market

The market is divided: 2 bcm for power generation, 1,5 bcm for industries and 2,5 bcm for distribution.

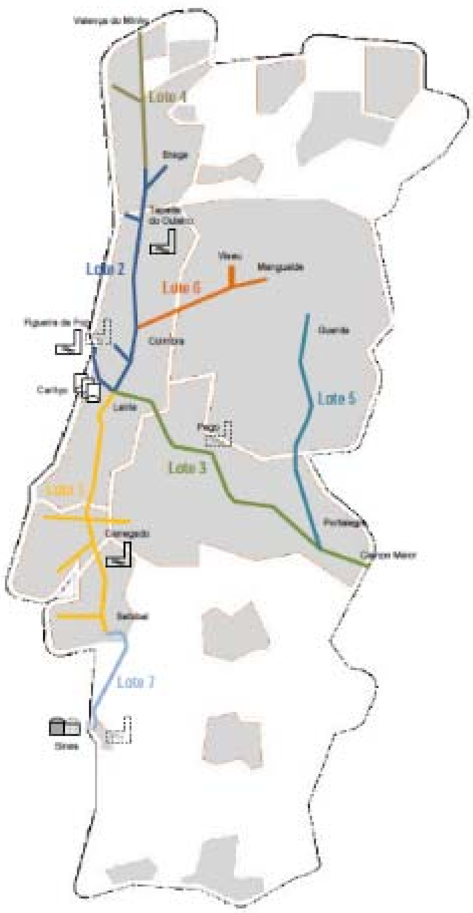


Figure 8: Portuguese NG network.

4. Opportunities for LNG

i) Sines terminal is used above the capacity. The capacity used can be increased.

ii) There are about 30 Satellite plants that use around 0,1 bcm/y, supplied by LNG trucks

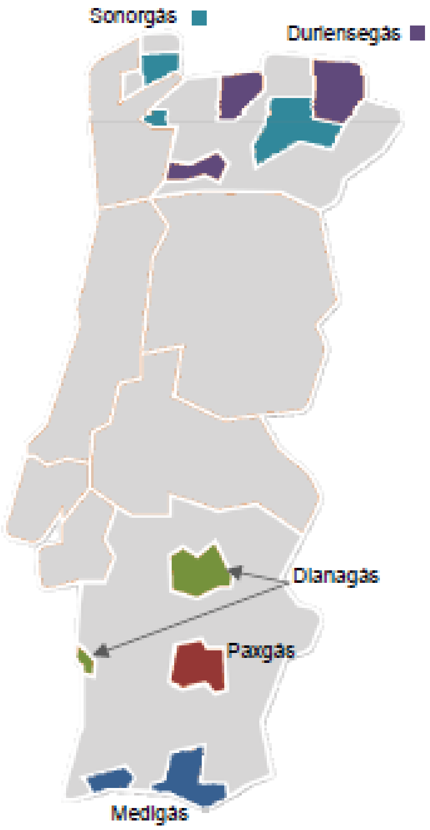


Figure 9: Portuguese LNG regional satellite plants

iii) New projects on small and micro scale are being implemented:

- Small satellite plants for industries;
- Small satellite for NGV and LNGV
- Micro satellite for household

Figure 10: Micro satellite LNG plant (2m3) .

5. Case study on Mirandela LNG Satellite plant

The logistic system is an application of transport and supply of natural gas through LNG to industrial complexes, residential customers and NGV facilities. The platform provides the transportation of LNG via trucks (from Spain) and its distribution to satellite centers. From the latter the LNG can be produce gaseous NG to be entered in local networks or reloaded on trucks of less capacity for subsequent widespread distribution. The heart is represented by regasification systems of small scale based on small storage tank (2-5-10 m3). The multipurpose station of Mirandela, owned by Dourogas/GoldEnergy. It is feed by LNG tankers and has a storage capacity of 20 m3 from which you can: enter the net GEN to 2.5 bar; supplying vehicles/trucks with CNG at 250 bar; load the LNG on small trucks, which in turn can provide smaller sites.


Figure 11: Multipurpose station.

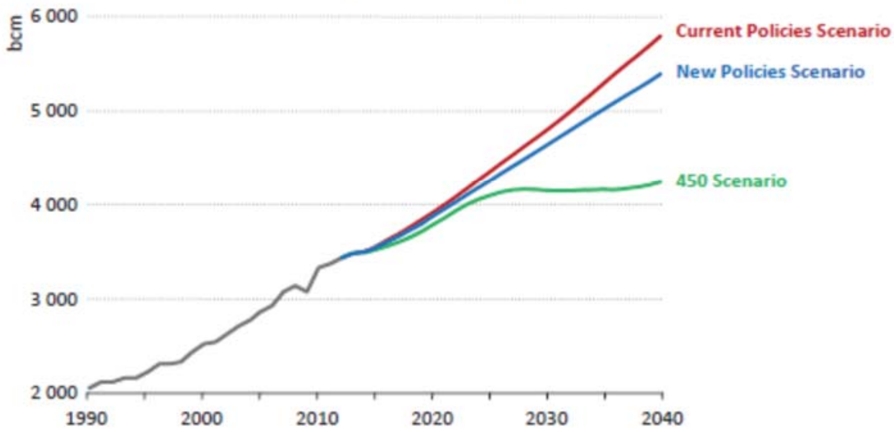
Figure 12: LNG dispenser.

CONCLUSIONS

In the IEA World Energy Outlook 2014 various scenarios have to be taken into account to describe trends in energy consumption. Different scenarios are influenced by growth of population, change in GDP, energy prices and technological evolutions. This last parameter has strong influence, through energy efficiency.

According to the "New Policies Scenario" (which considers existing and planned government policies), the world primary energy demand increases by 37% between 2012 and 2040, less than in the previous period, mainly due to energy efficiency gains and less energy-intensive activities development. With respect to global gas use, it continues to grow in all scenarios compared with today's levels. Different scenarios reflects also government policies evolutions.

Figure 4.1 ▷ World natural gas demand by scenario



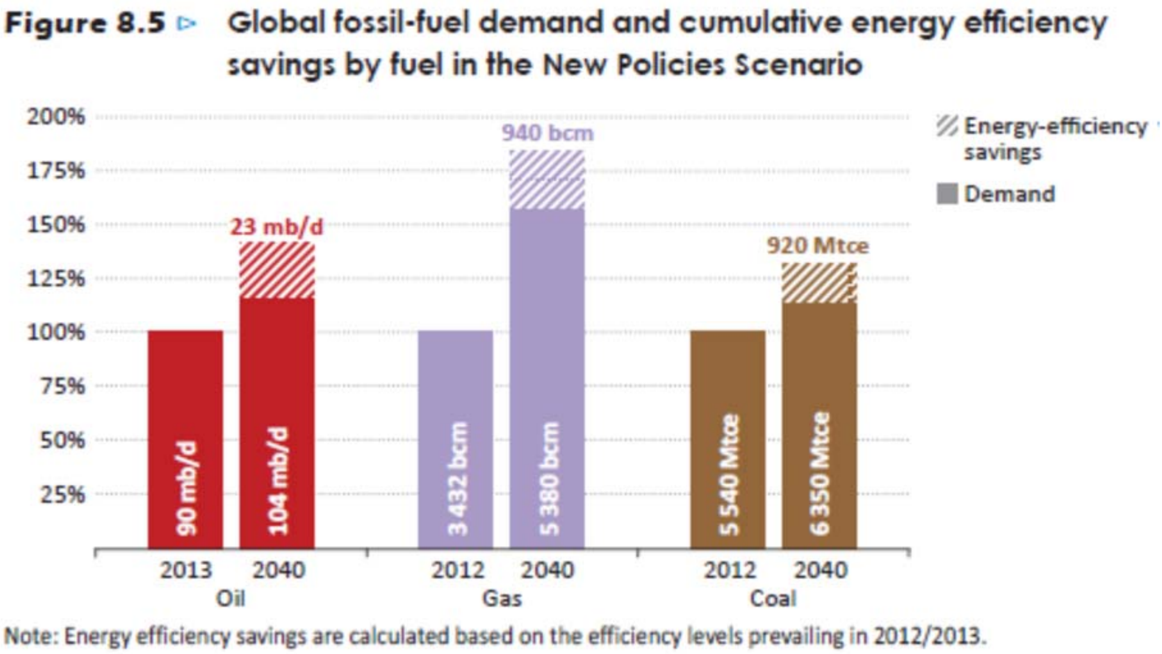
Source IEA – WEO 2014

In the New Policies Scenario, the share of natural gas in the global energy mix increases from 21% in 2012 to 24% in 2040, drawing level with coal in the process.
Natural gas demand in the 450 Scenario is held back as a consequence of reduced electricity demand and the introduction of additional policies to reach the goal of limiting the long-term global temperature increase to two degrees Celsius.

The power sector is the single largest source of incremental gas demand over 2012-2040. The second-largest sector for gas demand today is industry.

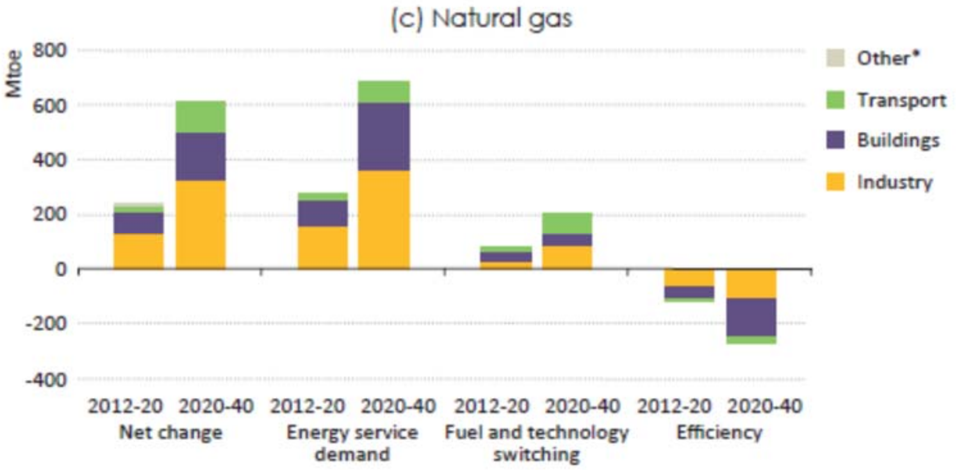
One chapter of WEO 2014 is dedicated to energy efficiency.
Energy efficiency can lead to lower energy bills, better trade balances and reduced CO_2 emissions. WEO 2014 estimate that "adopting energy efficient technologies in energy-intensive industries, such as steel, aluminium or plastics, can partly alleviate concerns about declining competitiveness because of disparities in energy prices between high- and low-cost regions. By exploiting the full energy efficiency potential of these sectors, the European Union could close the energy cost gap with the United States by 10-35%."

In the New Policies Scenario, energy efficiency measures play an important role in mitigating the growth in demand for fossil fuels. Cumulative efforts to increase energy efficiency from 2012 reduce demand for coal, oil and gas by almost one-fifth. While most oil savings arise from efficiency improvements in transport, industry and power generation are responsible for the bulk of efficiency savings related to coal and gas.



Source IEA – WEO 2014

Beside general reductions in consumptions, fuel switch can play an important role in final total use of fuels.



Source IEA – WEO 2014

In order to explore the drivers that could lead to the enhancement of the role of gas, in this report two main drivers, fuel switching and energy efficiency, and three more items (gas to power, combination with renewables and small scale LNG) have been considered.

There is no doubt that natural gas has the lowest impact on the global environment among the fossil fuels, however, it is not the perfect reason for natural gas to take the major share of the energy used in the industrial sector. There are some obstacles for natural gas to enhance its share, such as necessity of huge infrastructure, high equipment costs, or restriction for gas emissions. However, looking at this from a different angle, it is also true that there is room for natural gas to increase its share and potential to contribute to prevent the global warming.

In order to do so, natural gas needs to replace oil, electricity or coal in the industrial sector: the "Fuel Switching".

In this paper, it has been shown that the reason why the fuel switching is necessary, how the fuel switching can be realized and technologies for the fuel switching with case studies. Even there are obstacles, there are ways to overcome them and it is our duty to continue to enhance the usage of natural gas in the industrial sector for our industry, our society and our planet.

Moreover, through this report we have seen that reduction of energy consumption and implementation of energy efficiency is major subject for industrial companies but also for countries. This interest for energy efficiency is due to:

- World economical context with a high volatility of energies in the different part of the world and general context of reduction of reserve of fossil energies
- Commitments of Countries in regards of reduction of GHG emissions and more balanced economical situation
- Implementation of regulation and associated tools (ISO 50001, EN 16247) for energy efficiency increases, rational use of energy and energy transition to a better energy mix in the next 25 years

In this context of drastic modification of the energy mix with a mix between low carbon fossil fuels and renewable energies, there is a high level of opportunities for gas companies to develop use of natural gas and development a large range of high efficiency technologies coupled or not with renewable energies.
Some of examples presented in this report show clearly the potential for natural gas solutions to give suitable answer to energy efficiency demand of industrial customers.
In the frame of energy transition, the energy efficiency programs launch by countries or industrial companies will have to be more ambitious and not only think about how to improve the energy efficiency of production line or an industrial plant but think and have a look on what is happening around the industrial plant or in a territory.

The future challenge of gas companies will be to develop new natural gas solutions integrating:

- renewable energies in the energy mix of the factories (Biogas, Hydrogen, solar, wind, ...);
- local production of energy through valorisation of waste, gas process, by-products or heat recovery;
- drastic reduction of energy demand due to implementation of low carbon footprint factories concept;
- flexible energy demand of industrial plants and request of energy hybrid solutions;

and to develop technical and economical Services in order to support industrialist to go from energy efficiency of processes to industrial Ecology concept or the territorial Ecology concept.

All this new developments give hope that is possible to have on time new solutions when the current fossil fuel sources are used. In the next decennium, all over the world, we must work together to work out the innovations ideas or the mentioned examples to good affordable equipment in order to be able to provide solution to Global warming climate change.

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Appendix

Detailed market situation in various countries of the world.

Europe

Area: about 10,18 million sq. km; Population: 739,16 million people.

Key figures

GDP/cap	2013	26.1 kUS$05
GDP (ppp)/cap	2011	30.5 kus$ppp
Energy production	2013	1,055 Mtoe
Net Imports	2013	856.6 Mtoe
Total energy consumption	2013	1,843 Mtoe
Electricity consumption	2013	3,300 TWh
CO2 Emissions	2013	3,850 MtCO2

Key indicators

Consumption per capita	2013	3.0 toe/hab
Global intensity	2013	0.11 koe/$05
Global intensity (PPP)	2013	0.12 koe/$05p
Electricity Consumption per capita		n.a.
CO2/Energy consumption	2013	2.1 tCO2/toe

Table 5. Natural gas consumption within industrial sector in Europe

Activities	Unit	Year				
		2009	2010	2011	2012	2013
Natural gas consumption within industrial sector	bcm	117,71	130,3	131,6	131,47	132,48
Rate of increase	%		+10,7	+1,0	-0,1	+0,8

The diagram below (Figure 5) shows industrial natural gas consumption by the countries of European region.

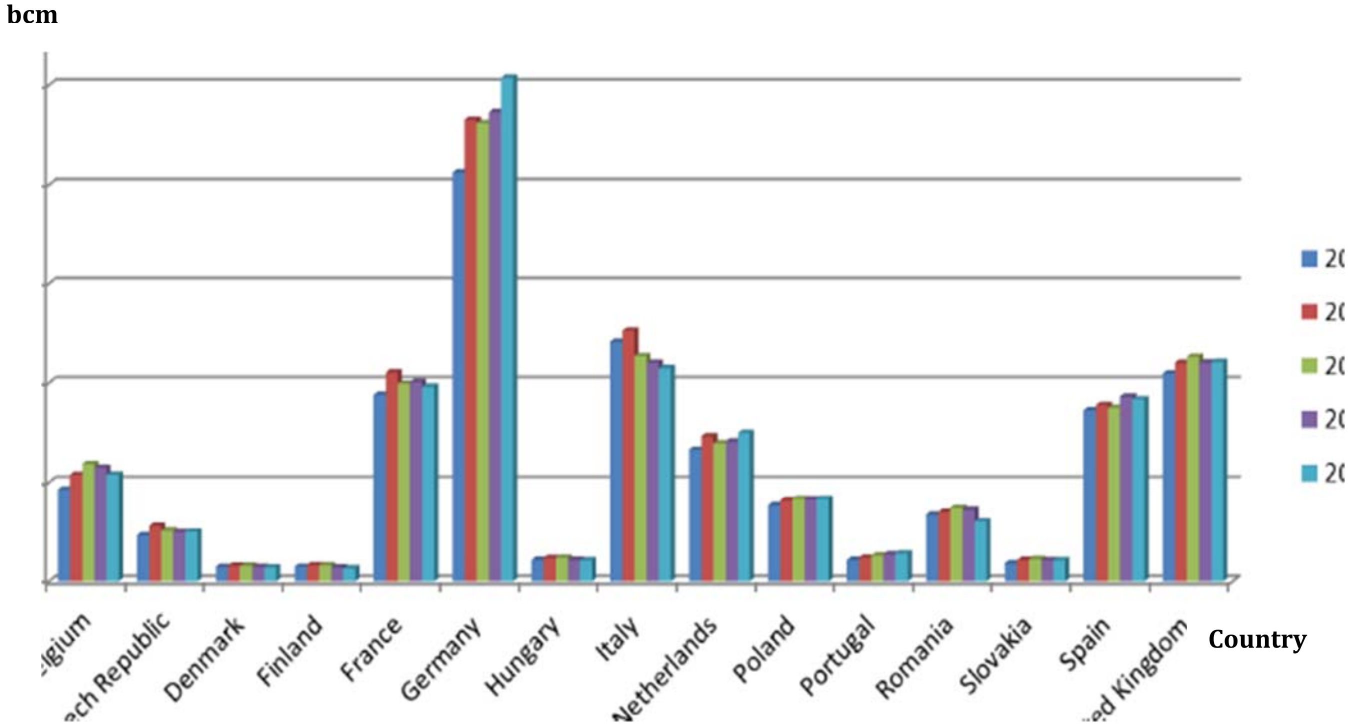


Fig. 5. Natural gas consumption within industrial sector in 2009-2013

The analysis of the diagram shows that as of at the end of 2013 the leader in natural gas consumption within industrial sector in Europe is Germany (25,4 bcm). Its share in natural gas consumption within industrial sector accounts for about 20%. Besides, the most great industrial sector natural gas consumers in Europe are:

Great Britain – 11,06 bcm;
Italy – 10,7 bcm;
France – 9,81 bcm;
Spain – 9,21 bcm;
the Netherlands – 7,51 bcm.

Germany

Source: OCHA/ReliefWeb

Area: 357 thous. sq. km
Population: 80,78 million people
Per capita GDP: $ 37,81 thous.

Economic Indicators

		1990	2010	2011	2012
Population	million	79.4	81.8	81.8	81.7
GDP growth rate	%/year	5.3	4.2	3.0	0.9
GDP/capita	US $	21584	40 430	44 641	42 045
Inflation Rate	%/year	2.7	1.1	2.1	2.1
Exchange rate	lc/$	0.83	0.76	0.71	0.78

Sources : World Bank , IMF

ENERGY SECURITY		1990	2010	2011	2012
Energy independence rate	%	54	40	40	40
Share of oil imported(+) exported(-)	%	96	97	97	97

ENERGY EFFICIENCY		1990	2010	2011	2012
Total consumption/GDP *	koe/$05	0.172	0.120	0.110	0.110
Total consumption/GDP *	2005=100	132	92.3	84.6	84.6
Rate of T&D power losses	%	4.7	4.9	4.6	4.6
Efficiency of thermal power plants	%	32.3	36.5	38.1	37.8

CO_2 EMISSIONS		1990	2010	2011	2012
CO_2 emissions/GDP *	$kCO_2/\$05p$	0.455	0.271	0.254	0.258
CO_2 emissions/capita	tCO_2/cap.	11.8	9.1	8.8	9.0

* at purchasing power parity

Since the liberalization of the sector, 2.6 million domestic customers have switched supplier, corresponding to a market share of 26% (September 2013). In 2012, 73% of the total volume of gas supplied to households was supplied by alternative suppliers.
Five companies produce about one sixth of German gas supplies from indigenous gas fields. ExxonMobil produces about 45% of the domestic natural gas (12.2 bcm in 2012) while Shell (20%), RWE (15%), Wintershall (10%) and GDF (5%) manage the remaining production. Gas production reached 13 bcm in

2012, down from 15 bcm in 2009. That production level represented 15% of the demand. In 2013 the main natural gas suppliers were Russia (39%), Norway (30%) and the Netherlands (26%).
Germany has 38 underground natural gas storage facilities, with a total capacity of 22.5 bcm of gas, representing more than 26% of the yearly consumption. Natural gas is imported through a large pipeline network which ensures access to:
- Dutch gas via the MTEG (E.ON Ruhrgas/Shell), NETG (E.ON Ruhrgas/ Thyssengas) and SETG (E.ON Ruhrgas/Shell) pipelines;
- Norwegian gas via the Dornum/Emden (Statoil), Emden/Etzel (E.ON Ruhrgas/Statoil), NETR (E.ON Ruhrgas/BEB/Statoil) and the MIDAL (Wintershall/Gazprom) pipelines;
- Russian gas via the MEGAL (E.ON Ruhrgas/GDF-SUEZ/OMV), STEGAL (Wintershall/Gazprom), Sayda/Berlin (VNG) and, since 2011, the Nord Stream pipelines.

Natural Gas Consumption (bcm)

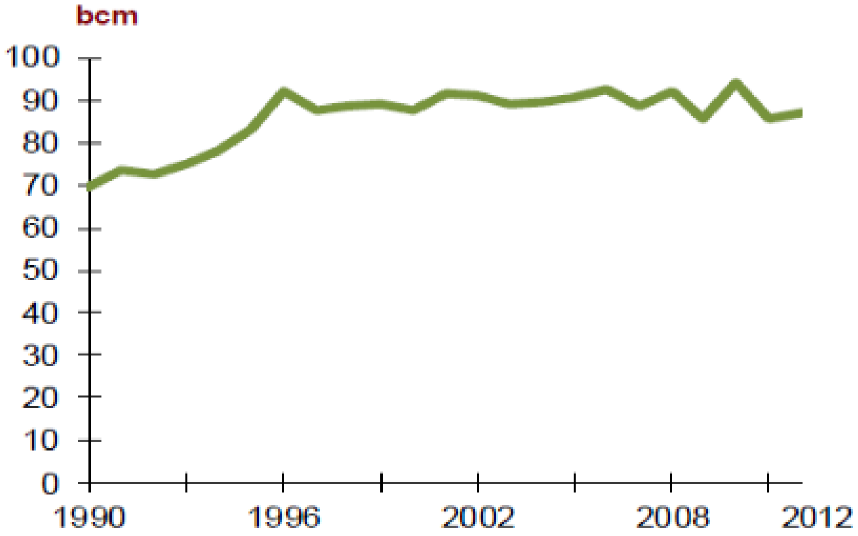
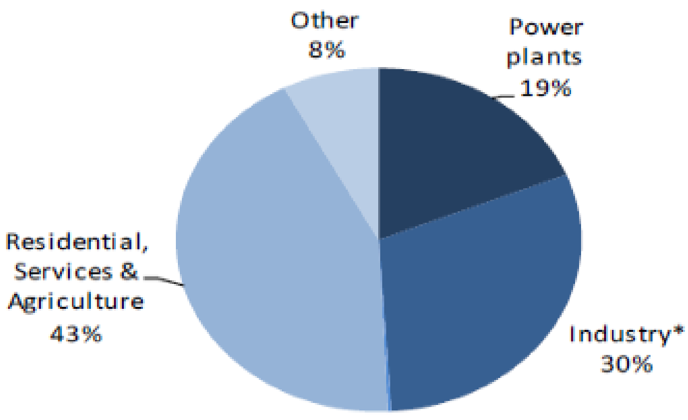


Fig.6. Natural gas consumption in Germany

Gas consumption has been decreasing since 2009 (-5% in 2009, -4% in 2010 and - 11% in 2011), falling to 87 bcm (2012). The drop is mainly due to the residential tertiary sector, which cut its consumption by 15% in 2011 as a consequence of a milder-than-usual winter. In 2012, the residential-services and agriculture sector was still the largest gas consumer (43%), followed by the industrial (30%) and electricity sectors (19%), while the latter represented 24% of the gas consumption in 2010. About half of the residences are heated with gas. The gas market share for the new residences is approximately 75%.

Gas Consumption Breakdown by Sector (2012, %)



* Including non energy uses

Fig.7. Natural gas consumption by sector

Gas prices continued to decrease in 2010 for households (by 9%) but rose by 2% for industry. In 2011 they increased more sharply in industry (+11%) than in the residential sector (+5%), while the opposite occurred in 2012: prices continued to rise for households (+5%) and almost stabilised for industry (+1%). Since 2003, the Eco-tax on gas is €5.5/MWh.

Gas Prices for Industry and Households (€c/kWh GCV)

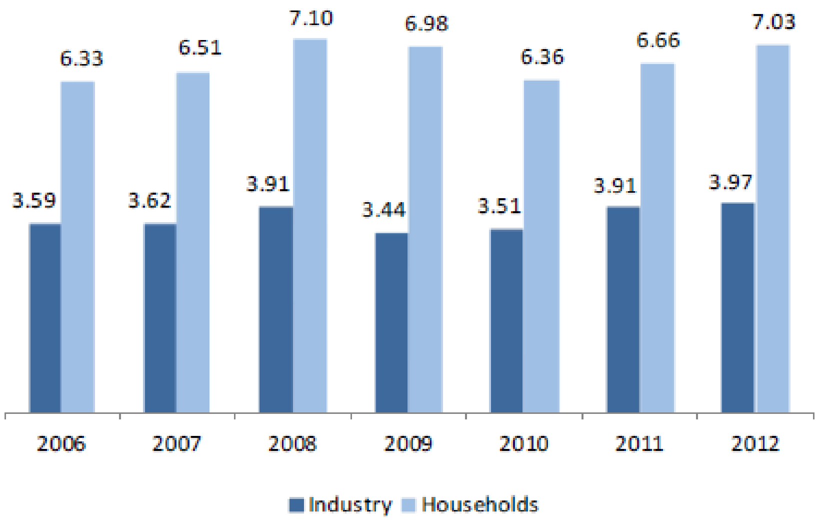


Fig.8. Gas prices in Germany

Consumption of natural gas in Germany for 2013 is given in Table 6.

Table 6. Consumption of natural gas in Germany in 2013, **mcm**

Sector	**2013**
Energy sector	23 107,45
Industry	25 384,36
Residential, Services & Agriculture	41 249,71
Other	2 885,40
Total	92 626,91

Further, natural gas consumption by industry sectors is reviewed (Fig.9).

The most gas consuming branches of industry in Germany are:
Chemical industry (26,24%)
Food and tobacco industry (13,60%)
Non metallic mineral industry (13,19%)
Steel industry (12,34%)
Paper and pulp industry (10,93%)
Machinery (9,18%)

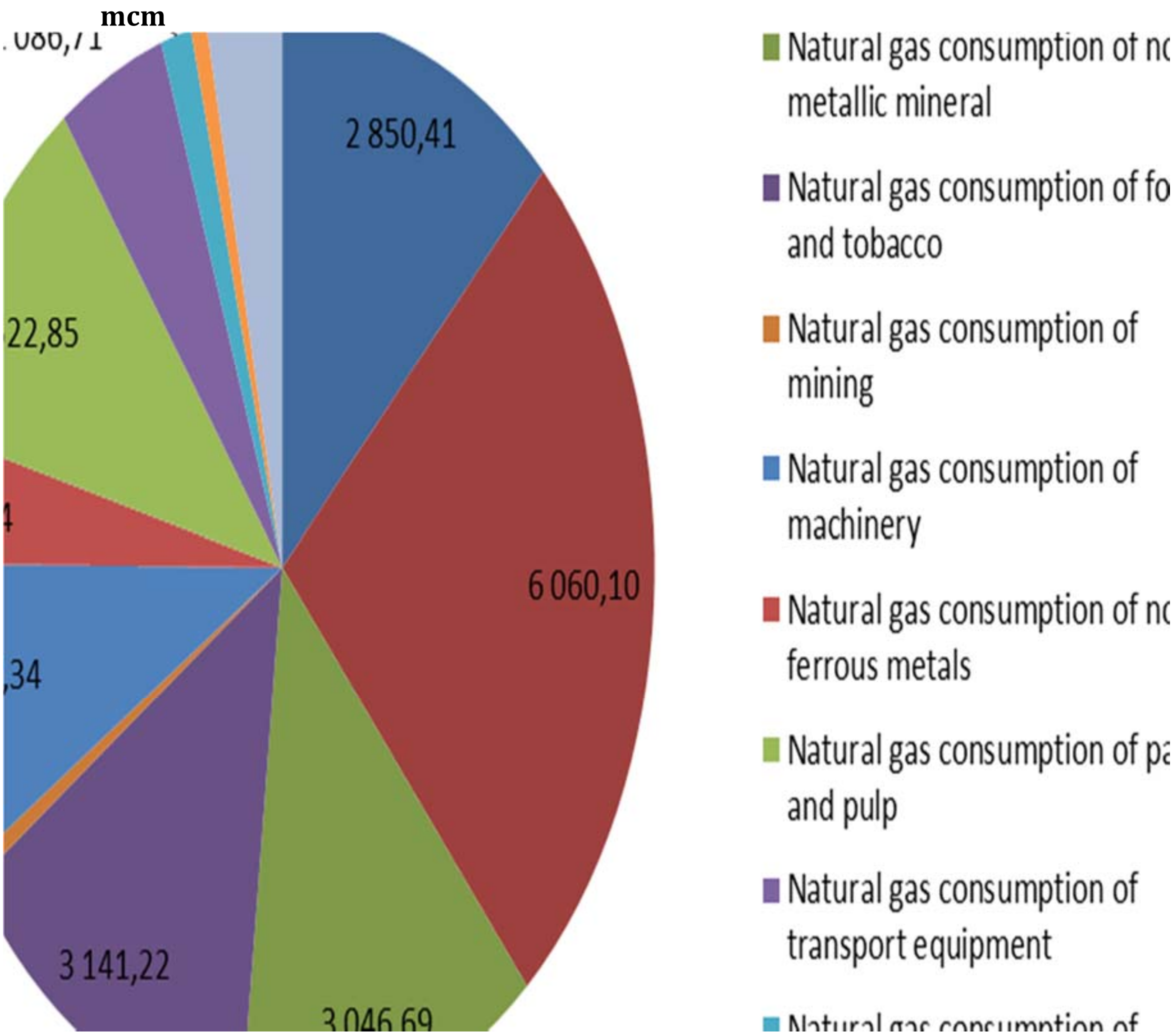


Fig. 9. Sectoral structure of industrial natural gas consumption in Germany

Great Britain

Source: OCHA/ReliefWeb

Area: 243,809 thous. sq.km
Population: 63,39 million people
Per capita GDP: $ 34,92 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	57.2	62.7	63.2	63.7
GDP growth rate	%/year	0.78	0.8	0.2	1.4
GDP/capita	US $	17688	38 716	39 039	40 180
Inflation Rate	%/year	7.0	4.5	2.8	2.7
Exchange rate	lc/$	0.56	0.62	0.63	0.64

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	69	61	57
Share of oil imported(+) exported(-)	%	-13	27	36	40

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.154	0.091	0.093	0.091
Total consumption/GDP *	2005=100	137	81.5	82.7	81.0
Rate of T&D power losses	%	8.1	7.9	9.7	9.2
Efficiency of thermal power plants	%	36.9	43.6	41.6	41.6

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	0.408	0.216	0.222	0.214
CO_2 emissions/capita	tCO_2/cap.	9.5	7.1	7.2	7.0

* at purchasing power parity

The deregulation of the gas industry was completed in 2004. Launched in 1986 with the privatisation of former monopoly British Gas, the liberalisation of the gas market has allowed many companies to develop and promote the use of gas. During 2013, 2.2 million domestic customers changed supplier, i.e. a switching rate of 10% (10% in 2012, 15% in 2011, 16% in 2010).
The liberalisation of the natural gas market initially led to a considerable fall in the price of gas for industry. However, prices increased between 1997 and 2005. In 2010 the price for industry was back at its 2005 level of around €2.1c/kWh. It increased by 18% in both 2011 and 2012, and by 6% in 2013, bringing it to €3.17/kWh. In the residential sector, the price grew by 8%/year, on average, between 2003 and 2013, with sharp increases in 2006 (+30%), 2011 (12%) and in 2012 (17%). The residential price increased by 4% in 2013 to reach €5.8c/kWh. The total cost of the gas price for residential

consumers is split between wholesale costs (56%), network costs (21%), environmental costs (5%), suppliers operating costs (13%) and VAT (5%) (April 2014).

Gas Prices for Industry and Households (€c/kWh GCV)

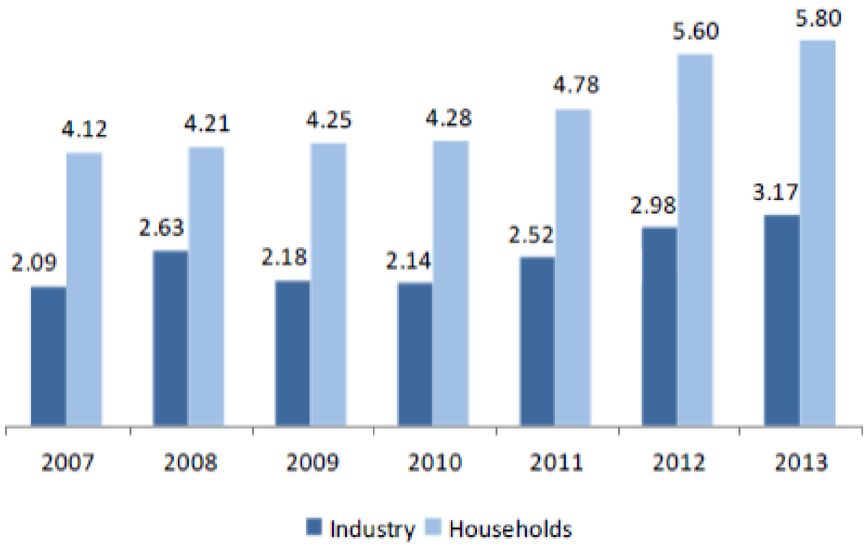


Fig.10. Gas prices in Great Britain

Natural gas consumption strongly increased until 2000, and then remained stable at around 100 bcm until 2004 before decreasing as a result of a lower use by power plants and the slowdown in the energy needs of the tertiary-residential sector. In 2013 consumption stood around 77 bcm, i.e. 22% below its 2008 level. The residential-tertiary sector is the main consumer, with 51% of the total in 2013 (41% in 2011). The electricity sector ranks second (24%; 34% in 2011), followed by industry (15% including non-energy uses, 18% in 2000) (Fig.11).

Natural Gas Consumption (bcm)

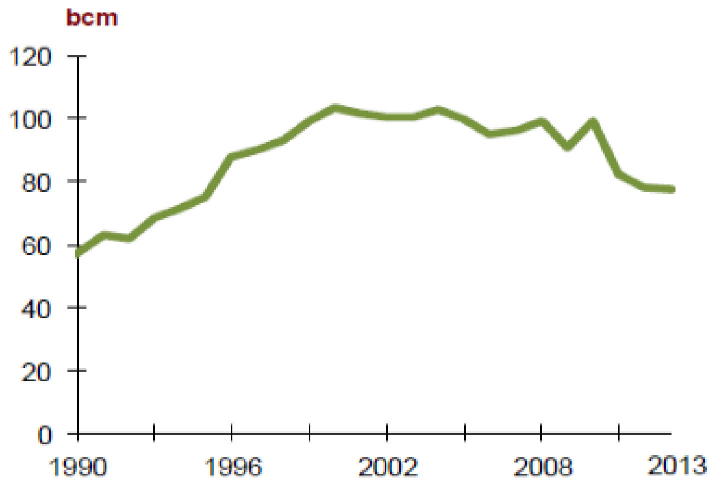


Fig.11. Natural gas consumption in Great Britain

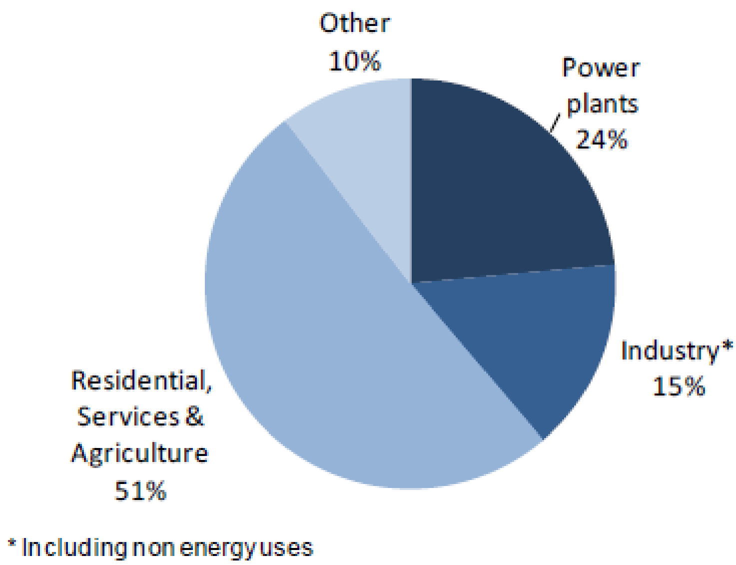


Fig.12. Natural gas consumption by sector

Demand Indicators

		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	3.6	3.8	3.2	3.2	3.0	3.0	3.0
Electricity	kWh	4968	5778	5339	5420	5194	5136	5066
CONSUMPTION TRENDS								
Total	%/year	-0.53	0.47	-5.6	2.7	-6.0	1.6	-0.66
Total with climatic corrections	%/year	-0.33	-0.05	-5.4	0.19	-3.6	-0.14	n.a.
Gas	%/year	3.2	3.0	-7.5	0.6	-17.2	-5.9	-0.74
Gas with climatic corrections	%/year	3.6	2.9	-7.1	4.6	-12.9	-8.4	n.a.
Electricity	%/year	1.8	2.5	-5.7	2.3	-3.4	-0.4	-0.6
TOTAL CONSUMPTION								
Total	Mtoe	206	223	196	202	188	191	190
of which								
Oil	%	37	33	33	31	32	31	30
Gas	%	23	39	40	42	37	35	35
Coal, lignite	%	31	16	15	15	16	20	19
Primary electricity*	%	9	11	10	9	11	11	12
Biomass	%	0	1	3	3	3	3	4

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

		1990	2000	2009	2010	2011	2012	2013
FINAL CONSUMPTION								
Total	Mtoe	140	153	133	139	128	130	131
By energy								
Oil	%	44	41	42	40	42	41	40
Gas	%	30	34	31	34	30	33	33
Coal, lignite	%	9	4	3	3	3	3	3
Electricity	%	17	19	21	20	21	21	21
Heat	%	0	2	1	1	1	1	1
Biomass	%	0	0	1	2	2	2	1
By sector								
Industry	%	24	24	20	20	21	21	21
Transport	%	28	27	31	29	32	31	30
Households & services	%	40	41	43	45	41	43	43
Non energy uses	%	8	7	6	6	6	5	6

Italy

Source: OCHA/ReliefWeb

Area: 309,547 thous. Sq. km
Population: 61,48 million people
Per capita GDP: $ 32,52 thous.

Economic Indicators

		1990	2010	2011	2012
Population	million	56.7	60.5	60.7	61.0
GDP growth rate	%/year	2.0	1.8	0.4	-2.4
GDP/capita	US $	20066	34 010	36 639	33 564
Inflation Rate	%/year	6.5	1.5	2.7	3.3
Exchange rate	lc/$	0.62	0.76	0.71	0.78

Sources : World Bank , IMF

ENERGY SECURITY		1990	2010	2011	2012
Energy independence rate	%	17	18	19	21
Share of oil imported(+) exported(-)	%	95	92	92	91

ENERGY EFFICIENCY		1990	2010	2011	2012
Total consumption/GDP *	koe/$05	0.113	0.104	0.102	0.101
Total consumption/GDP *	2005=100	101	93.6	91.7	90.5
Rate of T&D power losses	%	6.9	6.2	6.2	6.2
Efficiency of thermal power plants	%	40.7	40.6	40.1	39.3

CO_2 EMISSIONS		1990	2010	2011	2012
CO_2 emissions/GDP *	kCO_2/$05p	0.289	0.238	0.231	0.226
CO_2 emissions/capita	tCO_2/cap.	6.9	6.4	6.3	5.9

* at purchasing power parity

Italy's National Energy Strategy, adopted in April 2013, aims to cut primary energy consumption by 20 Mtoe/year by 2020 and final energy consumption by 15 Mtoe/year. The transport sector should contribute 35% towards the achievement of the final energy savings objective (5.5 Mtoe/year), industry 27% (4.2 Mtoe/year), households 25% (3.8 Mtoe/year) and services 13% (2 Mtoe/year).

Gas Prices for Industry and Households (€c/kWh GCV)

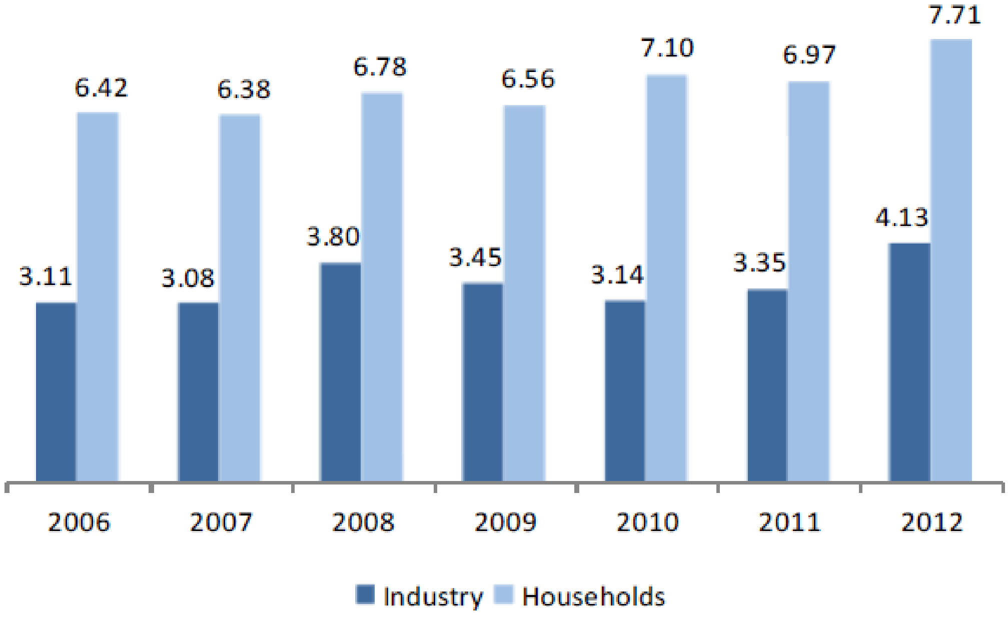


Fig.13. Gas prices in Italy

In 2012 the average cost on the liberalised market was €40.69c/m3 (€34.78c/m^3 in 2011), compared to €57.68c/m3 on the regulated market (€50.43c/m^3 in 2011). Regulated tariffs are revised quarterly on the basis of oil prices over the previous 9 months. Between January 2011 and January 2013 gas tariffs increased every quarter, but that trend reversed as of April 2013. Tariffs remained stable on 1 January 2014.

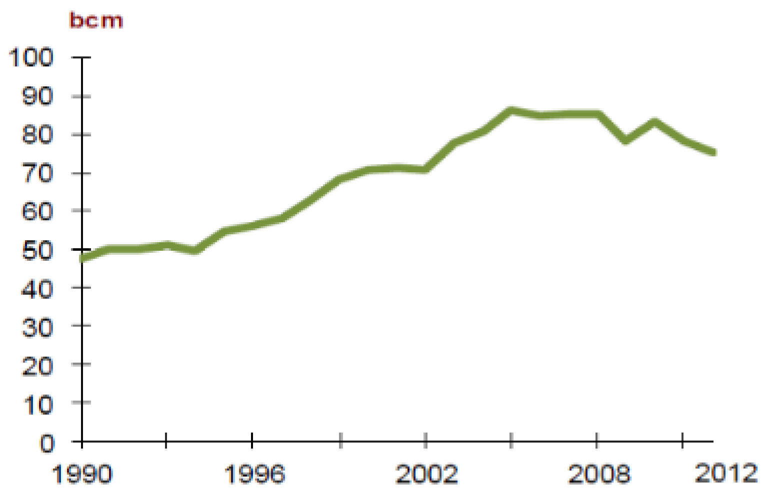


Fig.14. Natural gas consumption in Italy

The strong development of gas-fired electric capacities and the gas diffusion in the tertiary and household sectors led to a sharp increase in natural gas consumption until 2005 (4%/year, on average, between 1990 and 2005). Consumption then stabilised until 2008, and has been declining ever since (-3.9% in 2012 and -6.5% in 2013, to 70 bcm). This decrease is due to the economic crisis, the drop in the demand of the tertiary and household sectors induced by milder-than-usual winters and a lower gasfired electricity production (11% fall in gas demand from the power sector in 2012).

Power plants accounted for 38% of the gas demand in 2012 (compared to 30% in 2000 but 45% in 2008), households and services for 42% and industry for 16% (Fig.15).

Gas Consumption Breakdown by Sector (2012, %)

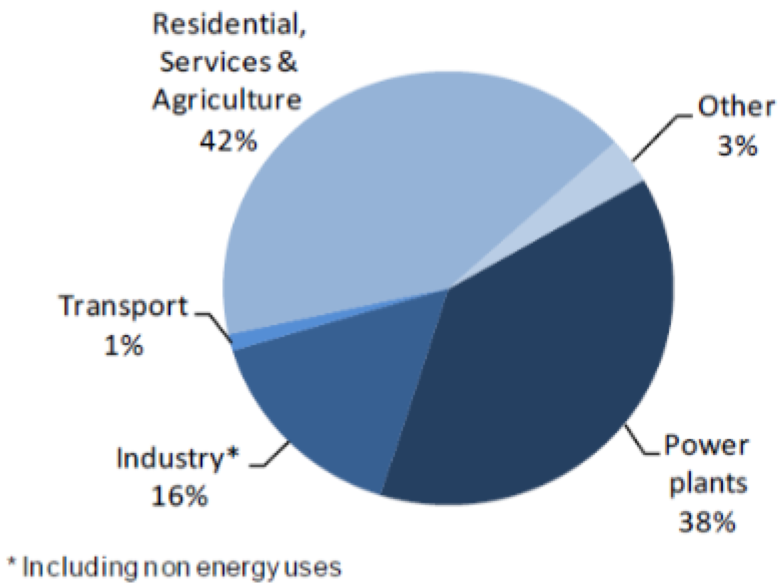


Fig.15. Natural gas consumption in Italy

Natural gas consumption by industry sectors in Italy for 2013 is given in Table 7.

Table 7. Consumption of natural gas in Italy, 2013

Sector	mcm
Energy sector	27 423,94
Industry	10 744,30
Residential, Services & Agriculture	30 388,80
Transport	955,79
Other	555,75
Total	70 068,58

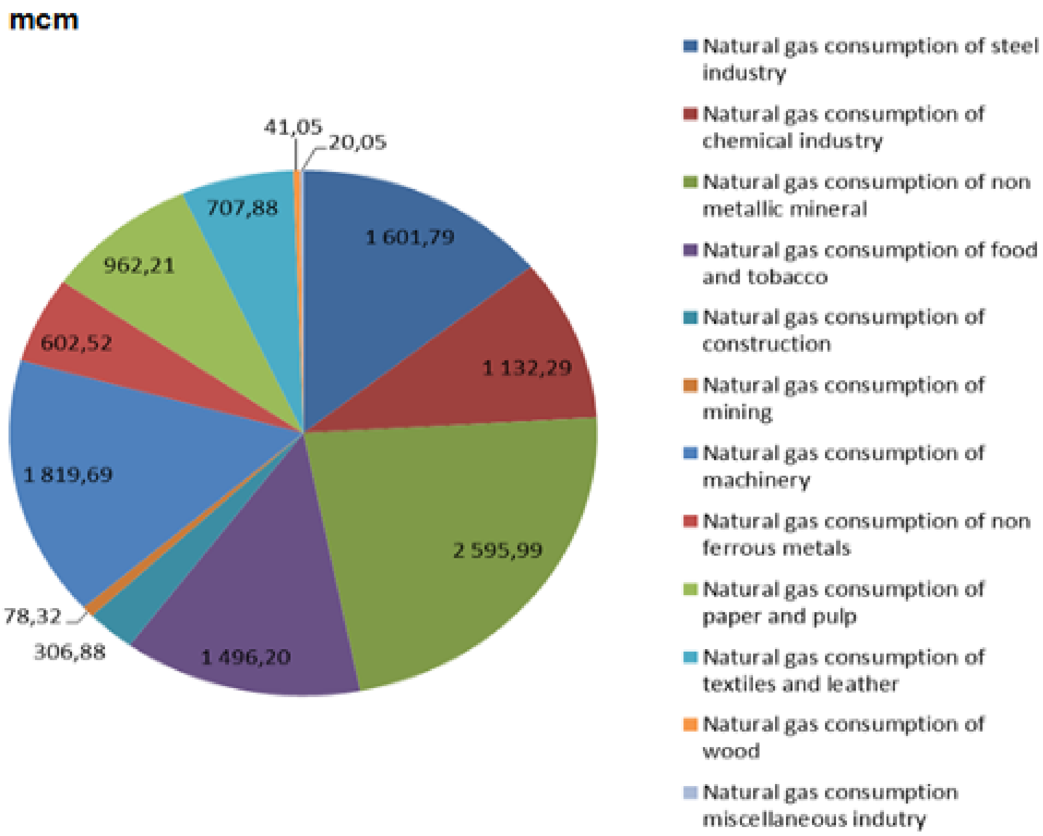


Fig. 16. Sectoral structure of industrial natural gas consumption in Italy, mcm

The most power-consuming branches of industry sector in Italy are:
- Non metallic mineral industry (22,8%)
- Machinery (16,0%)
- Steel industry (14,1%)
- Food and tobacco (13,1%)
- Chemical industry (9,96%)

America

Area: 42,549 million sq. km;
Population: 953,7 million people.

In 2009, natural gas consumption within industrial sector in America (see Table 8) accounted for 236,68 bcm, in 2013, natural gas consumption increased by 17,5% and amounted to 278,20 bcm. For many years now North America has been the leader in natural gas consumption in the world. Its share accounts for about 30% of the world's natural gas consumption within industrial sector.

Table 8. Natural gas consumption within industrial sector in America

Activities	**Unit**	**Year**				
		2009	2010	2011	2012	2013
natural gas consumption within industrial sector	bcm	236,68	262,88	263,54	272,48	278,20
Rate of increase	%		11,1	0,2	3,6	2,1

The diagram below (Figure 17) shows industrial natural gas consumption by the countries of America.

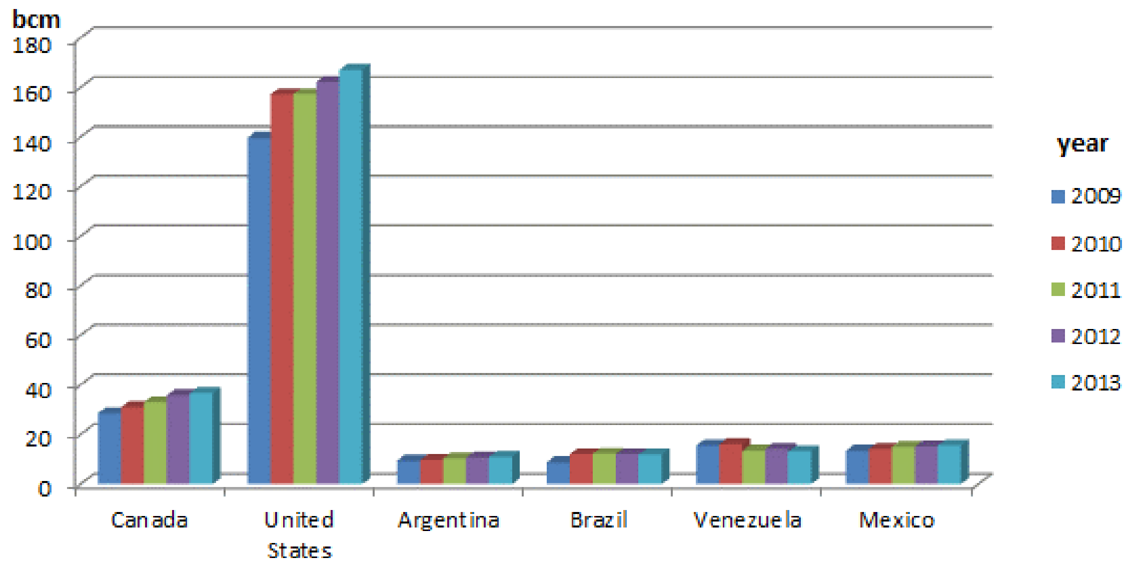


Fig. 17. Industrial natural gas consumption in America, bcm

The diagram analysis shows that the USA the leader in natural gas consumption within industrial sector in America (167,03 bcm at the end of 2013). Its share accounts for about 60% of natural gas consumption within industrial sector in America.

USA

Area: 9.5 million sq. km
Population: 309.2 million people
Per capita GDP: $ 46.4 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	250	311.6	314.1	316.6
GDP growth rate	%/year	1.9	1.7	2.8	1.6
GDP/capita	US $	23038	48 112	50 067	51 150
Inflation Rate	%/year	5.4	3.2	2.1	1.4
Exchange rate	lc/$	1.0	1.0	1.0	1.0

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	86	81	85	86
Share of oil imported(+) exported(-)	%	46	56	50	43

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.240	0.166	0.157	0.158
Total consumption/GDP *	2005=100	130	89.7	85.0	85.7
Rate of T&D power losses	%	9.9	6.3	7.1	7.5
Efficiency of thermal power plants	%	35.8	39.7	40.3	39.9

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	$kCO_2/\$05p$	0.600	0.394	0.367	0.370
CO_2 emissions/capita	tCO_2/cap.	19.1	16.7	15.9	16.2

* at purchasing power parity

The main natural gas production companies are ExxonMobil, Chevron, ConocoPhillips, Valero and Marathon. Interstate natural gas transportation (90 pipelines) functions according to the principle of third party access to the network. Transport is dominated by 14 companies that account for 85% of the gas transported in the United States, the most important ones being Kinder Morgan (bought El Paso Energy in 2012), Duke Energy and PG&E. Gas distribution companies operate on a local level and their status differs greatly from one state to another.

Natural gas production is increasing rapidly (+35% between 2005 and 2013) and reached 690 bcm in 2013. This significant growth is mainly linked to the large increase in shale gas production, which accounted for 43% of total gas production in 2012 (294 bcm). Net imports fell by 65% between 2007 and 2013 (from 107 bcm to 37 bcm). Gas is mainly imported (via gas pipeline) from Canada (around 90%), a country which seems to have reached its maximum gas production potential.

The average price of gas for industry has remained relatively stable for the past few years, while the price for residential consumers declined until last year ($1.54c/kWh GCV and $4.13c/kWh GCV, respectively).

Gas Prices for Industry and Households (USc/kWh GCV)

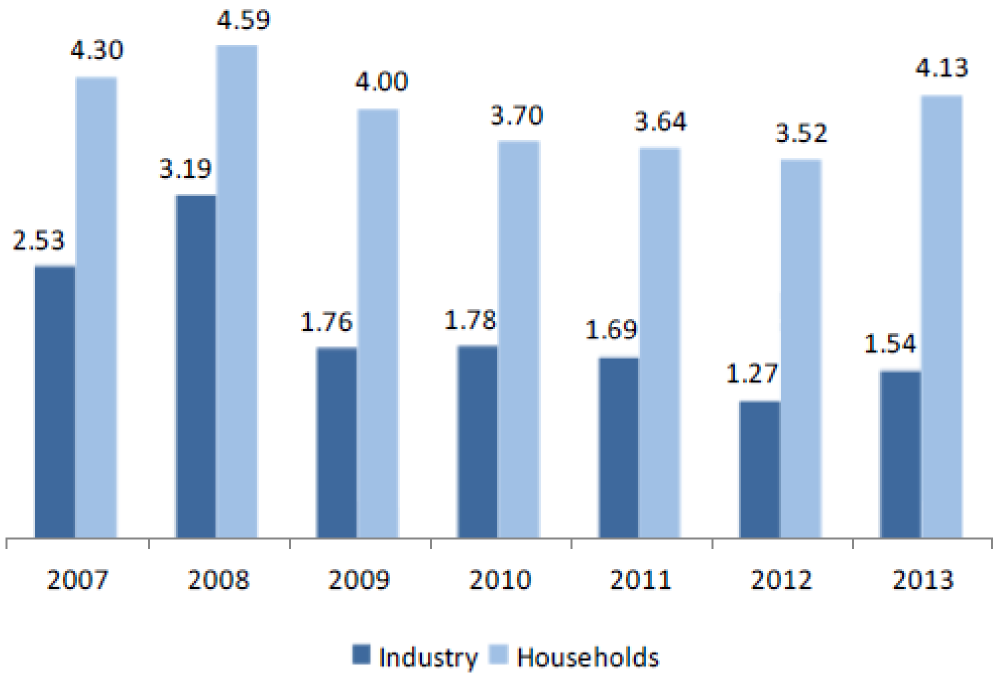


Fig. 18. Gas prices in America

Gas consumption has been rising since 2006, reaching 735 bcm in 2013 (Fig.19).

Natural Gas Consumption (bcm)

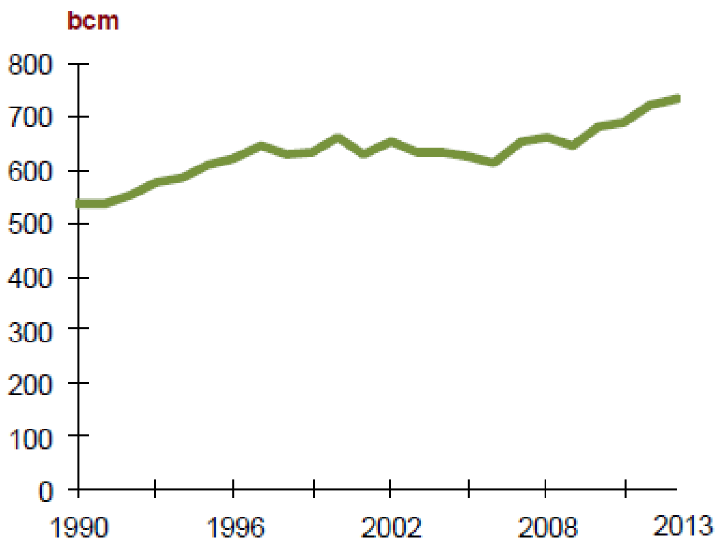


Fig. 19. Industrial natural gas consumption in USA, bcm

The electricity sector (34%) and residential-service sector (32%) are the main consuming sectors, followed by industry (23%, including non-energy uses).

Sectoral distribution of natural gas consumption in the USA is shown in Figure 20.

Gas Consumption Breakdown by Sector (2013 %)

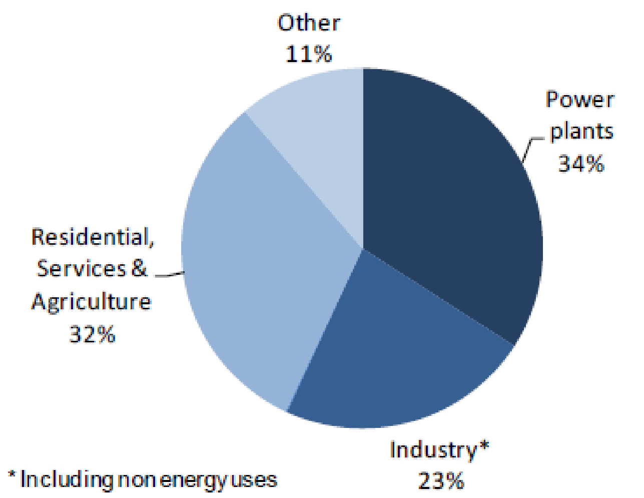


Fig. 20. Natural gas consumption in the USA

Natural gas consumption by industry sectors in the USA for 2013 is given in Table 9.

Table 9. Consumption of natural gas in the USA, 2013

Sector	mcm
Power plants	333 538,11
Industry	167 028,05
Residential, Services & Agriculture	233 410,96
Other	961,96
Total	734 939,08

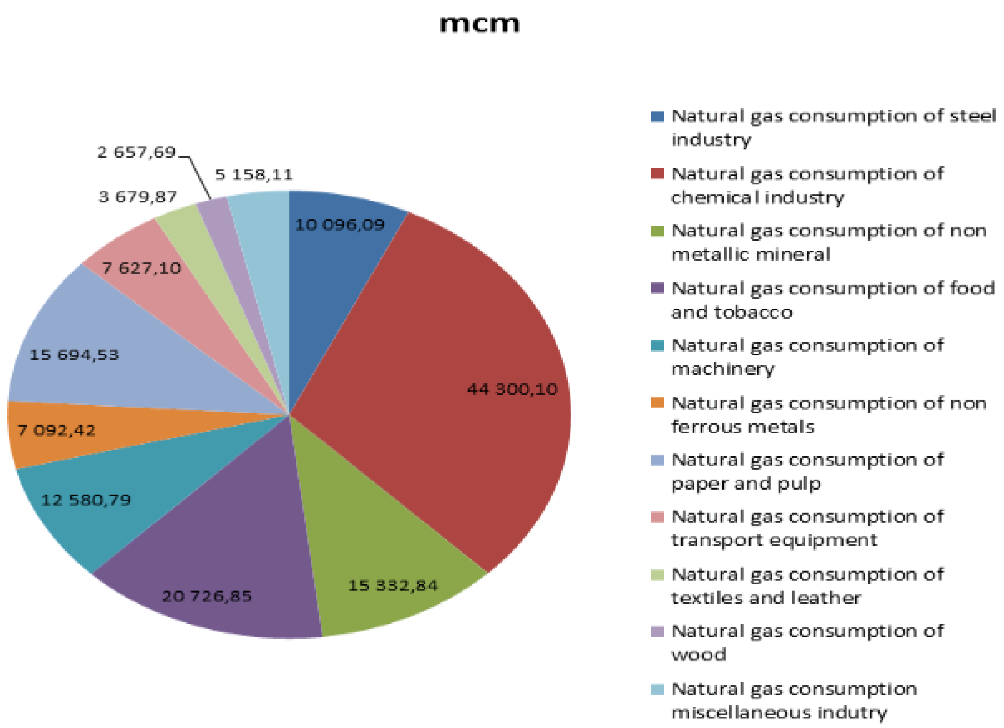


Fig. 21. Sectoral structure of industrial natural gas consumption in the USA, mcm

The leading industry sector in consumption of natural gas in the USA is chemical industry, despite the fact that during 2009 - 2013 period its share in total consumption had reduced by 20%, at the end of 2013 the weight of chemical industry accounted for about 27%. The second greatest gas consumer in the USA is food and tobacco industry, its share accounts for about 13% of total industrial gas consumption. Also, from 2009 to 2013 shares of natural gas consumption of the following branches of industry were increasing: machinery, paper and pulp, non metallic mineral industry.

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	7.7	8.0	7.1	7.2	7.0	6.8	6.9
Electricity	kWh	10867	12722	12141	12583	12461	12159	12060
CONSUMPTION TRENDS								
Total	%/year	-1.7	2.9	-4.9	2.3	-1.1	-2.6	2.5
Total with climatic corrections	%/year	n.a.	2.3	-4.8	2.2	-0.88	-1.6	n.a.
Gaz	%/year	-1.3	4.5	-1.0	3.8	2.3	4.6	2.0
Gaz with climatic corrections	%/year	n.a.	3.4	-1.0	3.9	2.7	5.9	n.a.
Electricity	%/year	2.9	3.8	-4.7	4.5	-0.3	-1.6	0.0
TOTAL CONSUMPTION								
Total	Mtoe	1910	2269	2166	2217	2193	2135	2107
of which								
Oil	%	40	38	37	36	36	36	35
Gas	%	23	24	25	25	26	28	28
Coal, lignite	%	24	24	22	23	22	20	20
Primary electricity*	%	10	11	12	12	12	12	12
Biomass	%	3	3	4	4	4	4	4

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

FINAL CONSUMPTION		1990	2000	2009	2010	2011	2012	2013
Total	Mtoe	1300	1538	1447	1507	1492	1459	1509
By energy								
Oil	%	53	52	51	50	50	50	50
Gas	%	22	22	21	21	21	20	22
Coal, lignite	%	4	3	2	2	2	2	2
Electricity	%	17	20	22	22	22	22	21
Heat	%	0	0	1	1	1	1	1
Biomass	%	3	3	4	5	5	5	5
By sector								
Industry	%	24	22	18	19	19	20	19
Transport	%	37	37	39	39	39	39	39
Households & services	%	30	31	34	33	33	32	33
Non energy uses	%	9	10	9	9	9	9	9

Canada

Source: OCHA/ReliefWeb

Area: 9,985 million sq. km
Population: 34,57 million people
Per capita GDP: $ 47,2 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	27.8	34.5	34.9	35.3
GDP growth rate	%/year	0.19	2.5	1.7	1.6
GDP/capita	US $	20968	50 368	50 915	49 906
Inflation Rate	%/year	4.8	2.9	1.5	1.1
Exchange rate	lc/$	1.2	0.99	1.00	1.04

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-19	-108	-121	-138

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.278	0.205	0.202	0.199
Total consumption/GDP *	2005=100	116	85.2	83.9	82.9
Rate of T&D power losses	%	7.3	6.0	5.9	5.9
Efficiency of thermal power plants	%	36.3	37.4	37.5	35.9

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	0.569	0.429	0.411	0.406
CO_2 emissions/capita	tCO_2/cap.	15.3	15.3	14.8	14.6

* at purchasing power parity

The price of gas in industry has been trending downward since 2005, reaching its current 2013 level of US$1.35c/kWh. In the residential sector the price has been following a similar, but more varied, trend with a residential price of US$3.53c/kWh in 2013 (compared to US$4.35c/kWh in 2008).

Gas Prices for Industry and Households (USc/kWh GCV)

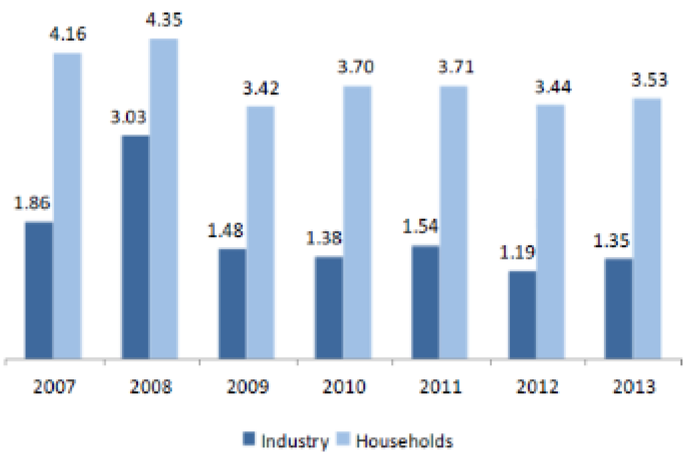


Fig. 22. Gas prices in Canada

Natural Gas Consumption (bcm)

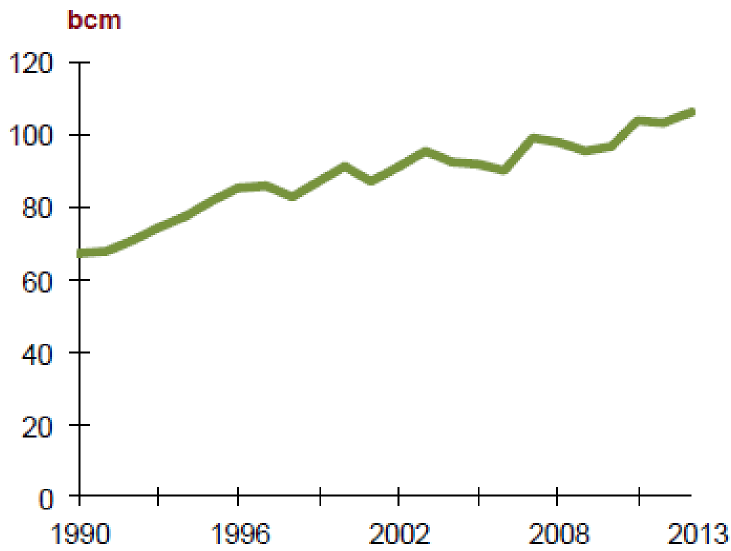


Fig. 23. Natural gas consumption in Canada, bcm

The consumption of natural gas increased, with slight fluctuations, from the mid-90s until 2013 (+1.4% per year on average), when it reached 106 bcm. The residential– tertiary sector represents 29% of the total consumption of natural gas, industry 35% and power plants 18%. Of the total, 18% is consumed by the "other" sectors which, in particular, include the exploitation of oil sands in Alberta (Fig.24).

Gas Consumption Breakdown by Sector (2013, %)

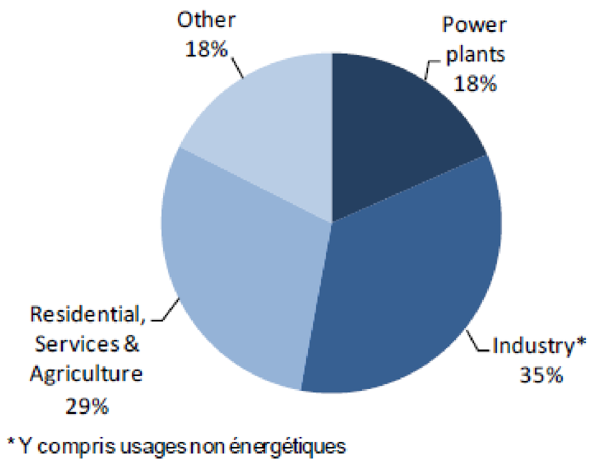


Fig. 24. Natural gas consumption in Canada

Natural gas consumption in Canada should increase in the future (+53% by 2020), in particular in the power sector. That evolution will be heavily dependent on the needs of the unconventional oil industry (which may use up to 65 mcm/d, versus 15 mcm/d today). The demand from unconventional oil production is likely to strongly impact future gas exports. In the short term, according to the National Energy Board (NEB) gas production should stop decreasing in the coming years and begin increasing after 2018 following increased tight and shale gas development.

CONSUMPTION PER CAPITA

Total	toe	7.5	8.2	7.5	7.4	7.3	7.2	7.2
Electricity	kWh	15584	16365	14564	15626	15865	15684	15840

CONSUMPTION TRENDS

Total	%/year	-3.9	2.9	-5.0	-0.21	0.28	0.12	0.38
Total with climatic corrections	%/year	n.a.	2.0	-5.1	0.86	-0.14	0.70	-0.41
Gas	%/year	-2.5	4.4	0.14	0.39	6.2	-0.14	2.5
Gas with climatic corrections	%/year	n.a.	3.0	0.0	1.9	5.6	0.6	1.5
Electricity	%/year	0.0	3.3	-7.0	8.6	2.6	0.0	2.1

TOTAL CONSUMPTION

Total	Mtoe	208	251	252	252	252	253	254
of which								
Oil	%	37	35	34	34	32	33	32
Gas	%	26	30	31	31	33	33	34
Coal, lignite	%	12	12	9	9	8	8	7
Primary electricity*	%	21	19	21	21	22	22	22
Biomass	%	4	5	5	5	5	5	5

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

FINAL CONSUMPTION

Total	Mtoe	157	186	190	198	202	199	201
By energy								
Oil	%	44	43	45	45	44	44	42
Gas	%	26	26	26	25	26	27	28
Coal, lignite	%	3	3	2	2	2	2	2
Electricity	%	23	22	21	22	22	22	23
Heat	%	0	0	0	0	0	0	0
Biomass	%	5	5	5	5	5	5	5
By sector								
Industry	%	31	30	27	29	28	30	30
Transport	%	25	25	29	28	28	27	28
Households & services	%	34	34	32	30	32	31	32
Non energy uses	%	10	11	11	12	12	13	11

Natural gas consumption by industry sectors in Canada for 2013 is given in Table 10.

Table 10. Consumption of natural gas in Canada for 2013

Sector	mcm
Energy sector	38 197,55
Industry	36 693,84
Residential, Services & Agriculture	31 300,60
Transport	44,07
Total	106 236,06

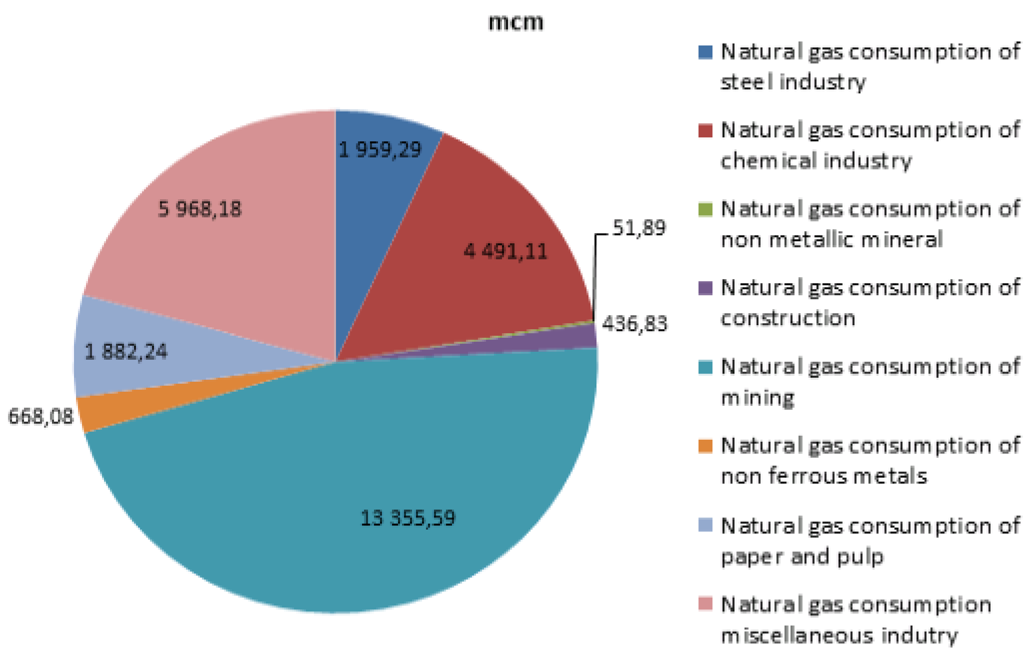


Fig. 25. Sectoral structure of industrial natural gas consumption in Canada, bcm

Sectoral distribution of natural gas consumption in Canada is shown in Figure 25. The industrial sector in Canada accounts for about 30% of the total consumption of natural gas in the sectors of the country's economy.

The most gas consuming branch of industry in Canada is mining industry (13,355 bcm). The second best consumer of natural gas in Canada is production of vehicles and equipment (about 25% of the total natural gas consumption within industrial sector).

The most power-consuming branchies of industry in Canada are:

mining (36,4%)
miscellaneous industry (16,3%)
chemical industry (12,2%)

Natural gas consumption in Canada in 2008 and 2009 dropped by 7%. Residential-tertiary sector represents 33% of the total consumption of natural gas, industry 30% and power plans 10%. Of the total, 27% is consumed by the «other» sectors which, in particular, include the exploitation of tar sands in Alberta.

Mexico

Source: OCHA/ReliefWeb

Area: 1.97 million sq. km
Population: 120.29 million people

Economic Indicators

		1990	2010	2011	2012
Population	million	84.3	113.4	114.8	116.2
GDP growth rate	%/year	5.1	5.5	3.9	3.9
GDP/capita	US $	3116	9 123	10 057	10 141
Inflation Rate	%/year	26.7	4.2	3.4	4.1
Exchange rate	lc/$	2.8	12.6	12.4	13.2

Sources : World Bank , IMF

ENERGY SECURITY		1990	2010	2011	2012
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-84	-58	-51	-44

ENERGY EFFICIENCY		1990	2010	2011	2012
Total consumption/GDP *	koe/$05	0.147	0.126	0.125	0.122
Total consumption/GDP *	2005=100	113	96.5	96.2	93.5
Rate of T&D power losses	%	13.8	17.1	17.1	17.1
Efficiency of thermal power plants	%	35.8	43.6	42.5	42.5

CO_2 EMISSIONS		1990	2010	2011	2012
CO_2 emissions/GDP *	kCO_2/$05p	0.308	0.289	0.285	0.282
CO_2 emissions/capita	tCO_2/cap.	3.1	3.6	3.6	3.7

* at purchasing power parity

The gas sector was opened to private investors in October 1995. In 1999, the 4% tax on natural gas imports was abolished in order to support the development of exchanges with the United States.
The gas sector was partly reorganised after Pemex's monopoly on the transport, storage, and distribution of gas came to an end in 1995. In the field of gas transportation, the access to the network has been open from a legal point of view since 1997 and in practice since 1999, following the definition by CRE of transparent access tariffs. The distribution of gas is largely dominated by private operators Gas Natural (distribution in the areas of Bajio Norte, Bajio On) and GDF Suez (distribution in the area of Puebla Tlaxcala and distribution network of Guadalajara). Vopak (60%) and Enagas (40%) owns the

LNG import terminal of Altamira (7.4 bcm/year), that was commissioned in 2006. Vopak and Enagas purchased the terminal in 2011 for $408m from a consortium made up of Shell (50%), Total (25%) and Mitsui (25%). In 2008, Sempra LNG (subsidiary of Sempra Energy) commissioned a second LNG import terminal of Energia Costa Azul (10.3 bcm/year). Mitsui, Kogas and Samsung commissioned the Manzanillo LNG import terminal in September 2011 (5.1 bcm/year). Average gas prices were approximately US$2.0c/kWh for industry (2009) and US$3.3c/kWh for households (2013). Residential gas prices are lower than in the United States.

Gas Prices for Industry and Households (USc/kWh GCV)

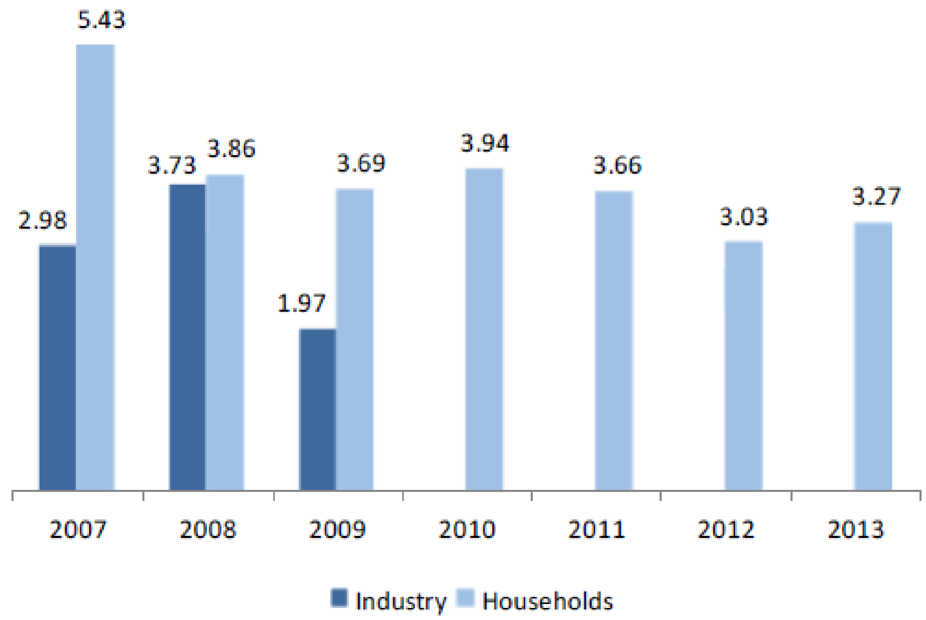


Fig. 26. Gas prices in Mexico

Gas demand has been increasing rapidly since 2000 (over 6%/year, on average). This increase is mainly due to the commissioning of numerous CCGT power plants between 2000 and 2013 (+16 GW of capacity).

Natural Gas Consumption (bcm)

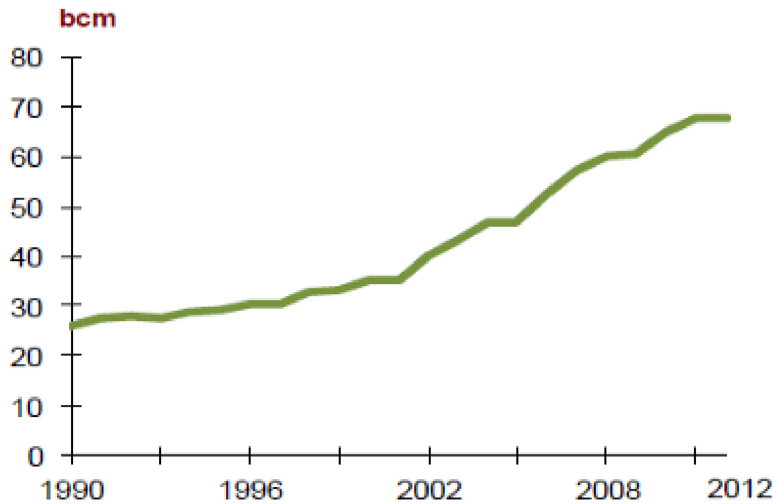


Fig. 27. Natural gas consumption in Mexico

Over 50% of the demand is used for the production of electricity, 23% by industry and approximately a quarter by the energy sector (2012).

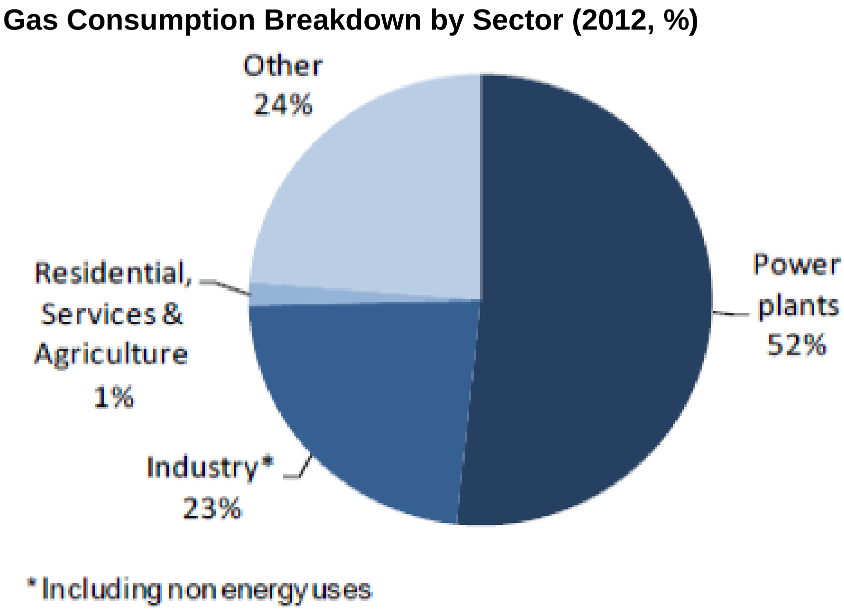


Fig. 28. Natural gas consumption in Mexico

The increase in the domestic consumption of gas (between 9-11% per year over the next ten years) should lead to an increased effort in the field of explorationproduction activities (objective to raise the replacement rate of the reserves to 50% in 2012 compared to 41% in 2006) and to develop imports, mainly through pipelines from the United States (according to plans, 20% of consumption will be supplied by imports). According to the Energy Ministry, the LNG demand will reach 20 bcm by 2017 (nearly 4 times the amount of LNG imported in 2012).

Demand Indicators		1990	2000	2008	2009	2010	2011	2012
CONSUMPTION PER CAPITA								
Total	toe	1.5	1.5	1.6	1.6	1.6	1.6	1.6
Electricity	kWh	1188	1668	1897	1861	1898	2019	2040
CONSUMPTION TRENDS								
Total	%/year	4.2	-0.96	2.9	-3.6	2.0	3.6	1.0
Electricity	%/year	4.7	7.5	2.3	-0.68	3.3	7.7	2.3
TOTAL CONSUMPTION								
Total	Mtoe	124	145	181	175	178	185	186
of which								
Oil	%	66	62	57	57	55	54	56
Gas	%	19	20	27	28	30	30	30
Coal, lignite	%	3	5	4	4	5	5	5
Primary electricity*	%	6	7	7	6	6	6	5
Biomass	%	7	6	5	5	5	5	4
FINAL CONSUMPTION								
Total	Mtoe	84.2	98.8	115	110	114	116	118
By energy								
Oil	%	61	62	66	66	65	64	64
Gas	%	17	13	11	11	11	12	12
Coal, lignite	%	2	2	1	1	2	1	1
Electricity	%	10	14	15	16	16	17	17
Heat	%	0	0	0	0	0	0	0
Biomass	%	10	8	7	7	6	6	6
By sector								
Industry	%	31	29	24	24	24	24	24
Transport	%	34	37	45	46	46	45	45
Households & services	%	24	25	22	23	23	23	23
Non energy uses	%	11	10	8	7	7	8	8

* Nuclear (1TWh = 0.26 Mtoe), hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geotherma (1 TWh = 0.86 Mtoe)

Natural gas consumption by industry sectors in Mexico for 2013 is given in Table 11.

Table 11. Consumption of natural gas in Mexico, 2013

Sector	**Mcm**
Energy sector	54 061,56
Industry	15 499,44
Residential, Services & Agriculture	1 139,56
Total	70 700,56

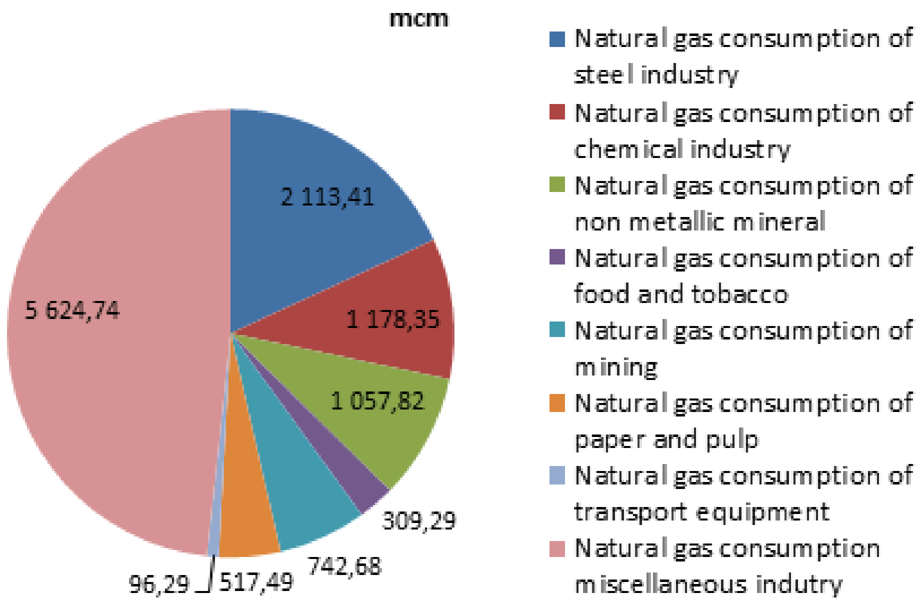


Fig. 29. Sectoral structure of industrial natural gas consumption in Mexico, mcm

The leading industry sector in consumption of natural gas in Mexico is miscellaneous industry (5,6 bcm). The second greatest gas consumer in Mexico is steel industry, its share accounts for about 14% of total industrial natural gas consumption.

Venezuela

Source: OCHA/ReliefWeb

Area: 0,92 million sq. km
Population: 28,45 million people
Per capita GDP: $ 11.9 thous.

Economic Indicators		1990	2000	2009	2010	2011	2012	2013
Population	million	19.8	24.3	28.4	28.8	29.3	29.7	30.2
GDP growth rate	%/year	6.5	3.7	-3.2	-1.5	4.2	5.6	1.0
GDP/capita	US $	2382	4819	11606	13658	10810	13609	13307
Inflation Rate	%/year	40.7	16.2	27.1	28.2	26.1	21.1	37.9
Exchange rate	lc/$	0.05	0.68	2.1	2.6	4.3	4.3	6.0

Sources : World Bank , IMF

Supply Indicators		1990	2000	2009	2010	2011	2012	2013
RESERVES*								
Oil	Mt	8171	10456	28731	40340	40486	40486	40509
Gas	bcm	3429	4179	5062	5521	5525	5558	5595
CAPACITY*								
Refining capacity	mb/d	1.3	1.2	1.3	1.3	1.3	1.3	1.3
Electricity capacity	GW	18.8	21.0	23.7	24.9	25.7	27.5	30.9
of which Thermal	GW	8.8	7.8	9.1	10.2	11.1	12.9	15.4
Hydroelectricity	GW	10.0	13.2	14.6	14.6	14.6	14.6	15.4
Nuclear	GW	0	0	0	0	0	0	0
Geothermal	GW	0	0	0	0	0	0	0
Wind	GW	0	0	0	0	0	0.03	0.07
PRODUCTION								
Oil	Mt	115.2	173.9	157.1	155.4	157.2	162.1	159.4
Gas	bcm	21.8	28.4	23.1	24.9	25.1	26.7	26.5
Coal	Mt	2.2	7.9	3.3	2.7	2.1	3.1	2.3
Electricity	TWh	59.3	85.3	120	118	122	127	131
of which Thermal	%	37.7	26.3	28.1	35.1	31.5	34.9	31.2
of which Coal	%	0	0	0	0	0	0	0
Gas	%	26	17	15	20	17	19	17
Hydroelectricity	%	62	74	72	65	69	65	69
Nuclear	%	0	0	0	0	0	0	0
Geothermal	%	0	0	0	0	0	0	0
Wind	%	0	0	0	0	0	0	0
EXTERNAL TRADE*								
Crude oil	Mt	-64.3	-113	-92.2	-93.8	-93.3	-100	-93.0
Oil products	Mt	-30.0	-37.1	-31.1	-24.6	-30.8	-28.4	-29.8
Gas	bcm	0	0	1.8	2.2	2.1	1.8	0.19
Coal	Mt	-1.5	-7.9	-3.0	-2.5	-1.8	-2.8	-2.0
Electricity	TWh	0	-0.05	-0.37	0	-0.25	-0.28	-0.29

* On December 31 st (Reserves, Capacity)

* Imports(+) exports(-) balance (External trade)

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	2.3	2.4	2.5	2.6	2.4	2.5	2.5
Electricity	kWh	2387	2600	2927	2906	2970	2991	2987
CONSUMPTION TRENDS								
Total	%/year	6.8	2.5	-0.02	7.5	-6.0	3.7	3.7
Gas	%/year	16.8	4.3	-2.9	8.9	0.52	4.7	-6.3
Electricity	%/year	1.4	4.7	3.6	0.9	3.8	2.3	1.5
TOTAL CONSUMPTION								
Total	Mtoe	45.7	59.0	70.8	76.1	71.5	74.2	76.9
of which								
Oil	%	45	44	55	56	52	53	56
Gas	%	45	46	34	34	36	37	33
Coal, lignite	%	1	0	0	0	0	0	0
Primary electricity*	%	7	9	10	9	10	10	10
Biomass	%	1	1	1	1	1	1	1
FINAL CONSUMPTION								
Total	Mtoe	26.7	33.8	45.1	50.9	46.0	47.7	49.3
By energy								
Oil	%	51	50	46	51	52	52	55
Gas	%	31	32	36	33	31	31	28
Coal, lignite	%	2	0	1	0	0	0	0
Electricity	%	15	15	15	14	16	16	15
Heat	%	0	0	0	0	0	0	0
Biomass	%	2	2	2	1	1	1	1
By sector								
Industry	%	48	45	49	54	53	53	51
Transport	%	34	33	33	31	30	30	32
Households & services	%	15	17	15	14	15	15	15
Non energy uses	%	3	5	2	2	2	2	2

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

The final energy consumption has been increasing at a rate of 3% per year since 1990 (reaching 44 Mtoe in 2009). Oil products cover approximately 57% of the final consumption, natural gas 26%, and electricity 16% (2009).
The industrial sector absorbs 48% of the final consumption (including 8% for non-energy uses), transport approximately 37% and the residential-tertiary sector 15%. Electricity consumption is shared between industry and the residential-tertiary sector (respectively 45% and 55%).
Sectoral distribution of natural gas consumption in Venezuela is shown in Figure 21. The industrial sector in Venezuela accounts for about 51% of the total consumption of natural gas in the sectors of the country's economy.

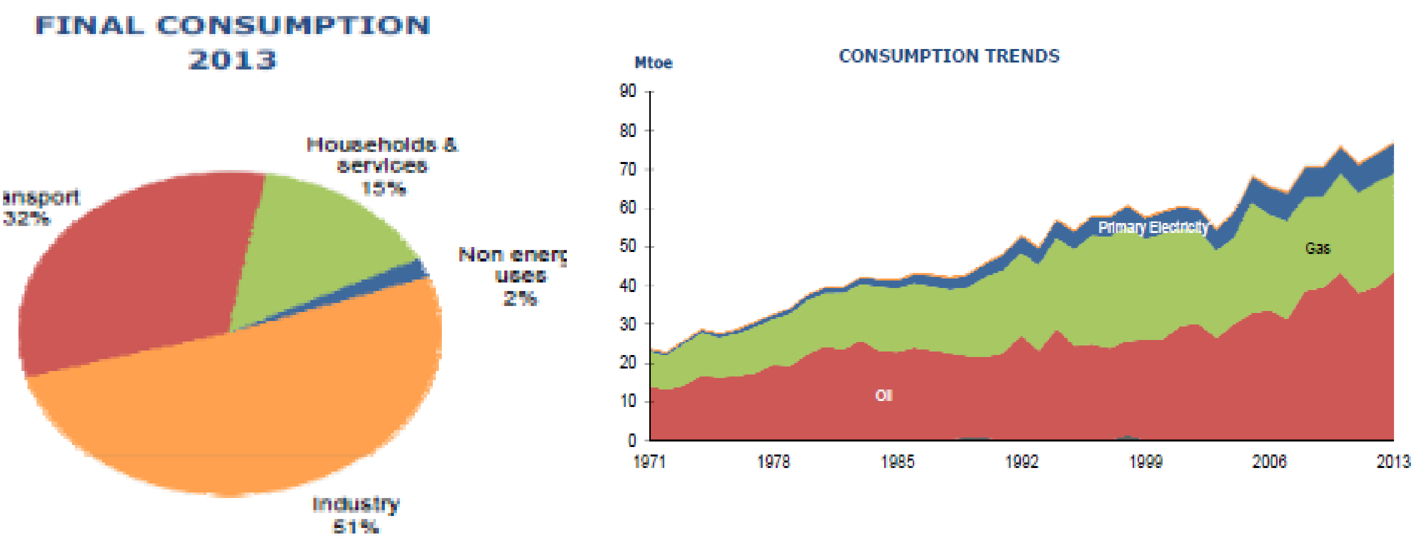


Fig. 30. Final consumption of natural gas in Venezuela

Brazil

Source: OCHA/ReliefWeb

Area: 8.5 million sq. km
Population: 192.5 million people
Per capita GDP: $ 10.5 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	150	196.7	198.4	200.1
GDP growth rate	%/year	-4.3	2.7	0.9	2.5
GDP/capita	US $	2607	12 594	11 369	11 040
Inflation Rate	%/year	2950	6.6	5.4	6.3
Exchange rate	lc/$	0	1.67	1.95	2.17

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	74	92	89	86
Share of oil imported(+) exported(-)	%	46	3	7	12

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.131	0.134	0.138	0.140
Total consumption/GDP *	2005=100	96.3	98.4	102	103
Rate of T&D power losses	%	12.8	15.6	16.2	16.2
Efficiency of thermal power plants	%	33.8	43.0	42.7	42.8

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	0.178	0.195	0.208	0.218
CO_2 emissions/capita	tCO_2/cap.	1.3	2.0	2.1	2.3

* at purchasing power parity

Gas prices decreased between 2000 and 2007; the Government then announced that prices would be increased in order to redress the imbalance between gas demand and supply. In 2013 the gas price was US$2.61c/kWh for industry. The gas price is revised every quarter.

Gas Prices for Industry (USc/kWh GCV)

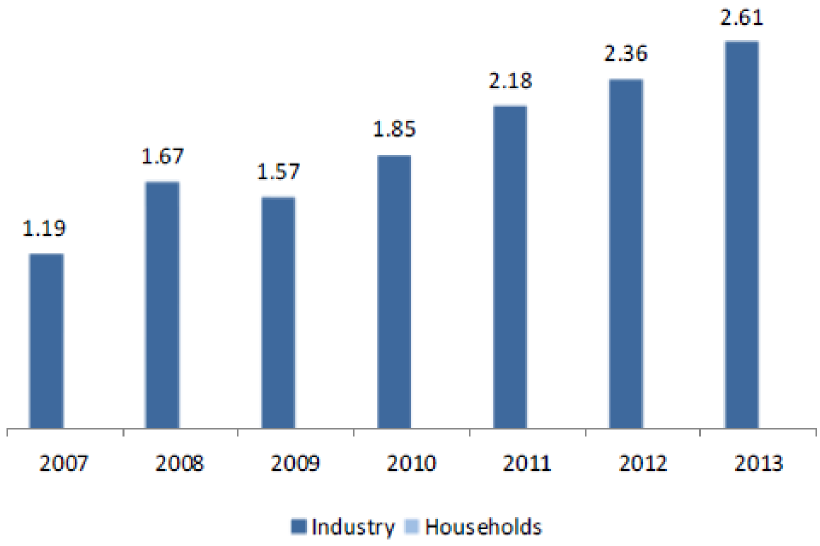


Fig. 31. Gas prices in Brasil

Gas represents a low share of total energy demand (10%). Demand has been rising strongly since 1999, which is when the first imports from Bolivia took place. It reached 38 bcm in 2013 (+18% compared to 2012).

Natural Gas Consumption (bcm)

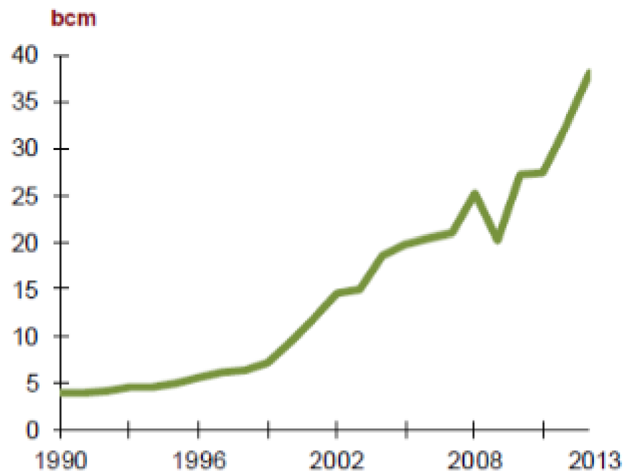


Fig. 32. Natural gas consumption in Brasil

Industry accounts for 31% of the demand and power plants for 40%.

Gas Consumption Breakdown by Sector (2013, %)

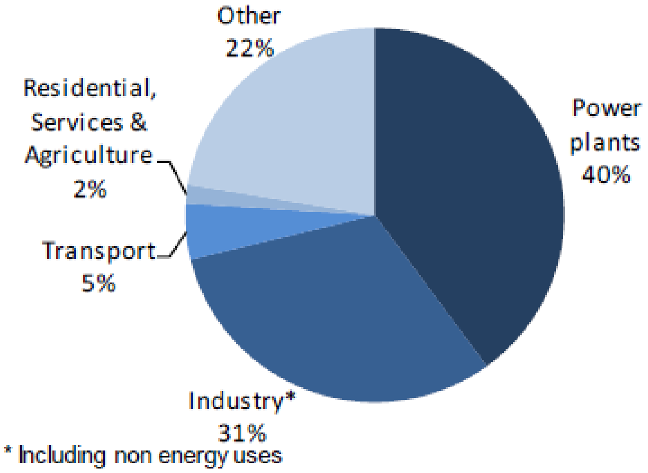


Fig. 33. Natural gas consumption in Brazil

Sectoral distribution of natural gas consumption in Brazil is shown in Figure 34. The industrial sector in Brazil accounts for about 31% of the total consumption of natural gas in the sectors of the country's economy.

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	0.94	1.1	1.2	1.4	1.4	1.4	1.5
Electricity	kWh	1442	1886	2176	2356	2416	2477	2541
CONSUMPTION TRENDS								
Total	%/year	-3.6	0.37	-3.2	10.5	1.6	4.1	4.1
Gas	%/year	1.6	30.0	-19.9	35.4	-0.57	17.6	17.7
Electricity	%/year	2.5	5.1	-0.5	9.2	3.4	3.4	3.5
TOTAL CONSUMPTION								
Total	Mtoe	141	188	241	266	271	282	293
of which								
Oil	%	42	47	40	39	40	41	40
Gas	%	2	4	7	9	8	10	11
Coal, lignite	%	7	7	5	5	6	6	6
Primary electricity*	%	15	17	17	16	16	16	14
Biomass	%	34	25	32	31	29	28	28
FINAL CONSUMPTION								
Total	Mtoe	114	157	195	215	223	230	235
By energy								
Oil	%	46	51	44	43	45	46	47
Gas	%	2	3	5	6	6	5	5
Coal, lignite	%	5	6	4	5	6	5	4
Electricity	%	16	18	18	17	18	18	18
Heat	%	0	0	0	0	0	0	0
Biomass	%	31	23	29	28	26	25	26
By sector								
Industry	%	38	38	38	39	39	38	36
Transport	%	29	30	33	33	34	35	37
Households & services	%	25	23	22	21	20	20	20
Non energy uses	%	8	9	7	8	7	7	7

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

Natural gas consumption by industry sectors in Brazil for 2013 is given in Table 12.

Table 12. Consumption of natural gas in Brazil, 2013

Sector	**mcm**
Energy sector	23 719,23
Industry	11 891,1
Residential, Services & Agriculture	617,9
Transport	1 827,87
Total	38 056,1

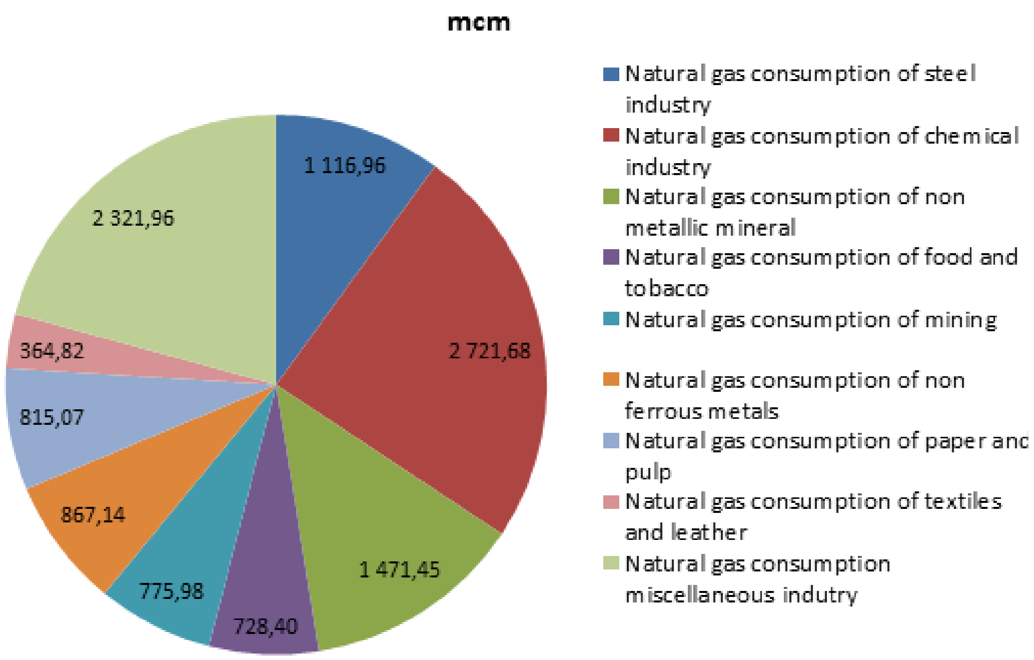


Fig. 34. Sectoral structure of industrial natural gas consumption in Brazil, bcm

The leader in natural gas consumption in Brazil is chemical industry. Its share accounts for about 23% of the total natural gas consumption within industrial sector. By the significant gas consumption in Brazil are also marked out such industry sectors as miscellaneous and non metallic mineral mining industry.

Argentina

Source: OCHA/ReliefWeb

Area: 2,76 million sq. km
Population: 42,61 million people
Per capita GDP: $ 17.38 thous.

Economic Indicators

		1990	2010	2011	2012
Population	million	32.6	40.4	40.8	41.1
GDP growth rate	%/year	-2.4	9.2	8.9	1.9
GDP/capita	US $	4330	9 162	10 994	11 071
Inflation Rate	%/year	2314	10.5	9.8	10.0
Exchange rate	lc/$	0.49	3.90	4.11	4.54

Sources : World Bank , IMF

ENERGY SECURITY		1990	2010	2011	2012
Energy independence rate	%	100	100	96	92
Share of oil imported(+) exported(-)	%	-19	-7	-3	-10

ENERGY EFFICIENCY		1990	2010	2011	2012
Total consumption/GDP *	koe/$05	0.189	0.134	0.127	0.128
Total consumption/GDP *	2005=100	118	84.1	79.2	79.8
Rate of T&D power losses	%	18.7	13.0	13.9	14.1
Efficiency of thermal power plants	%	29.9	39.8	39.5	39.7

CO_2 EMISSIONS		1990	2010	2011	2012
CO_2 emissions/GDP *	kCO_2/$05p	0.412	0.304	0.288	0.291
CO_2 emissions/capita	tCO_2/cap.	3.1	4.4	4.5	4.6

* at purchasing power parity

The price of natural gas is set for each one of the privatised companies. The concession contract allows prices to be modified if there are exogenous factors that affect the producers or consumers. Twice a year, on average, ENARGAS makes a decision regarding the modifications that need to take place. In Argentina, the average price of gas is US$1.07/kWh for households and US$0.88/kWh for industry (2011).

Natural gas consumption has been increasing at the very rapid rate of about 4%/year since 2002, reaching 50 bcm in 2012. Argentina is the largest gas consumer in South America. Electricity production absorbs almost 40% of that consumption.

Natural Gas Consumption (bcm)

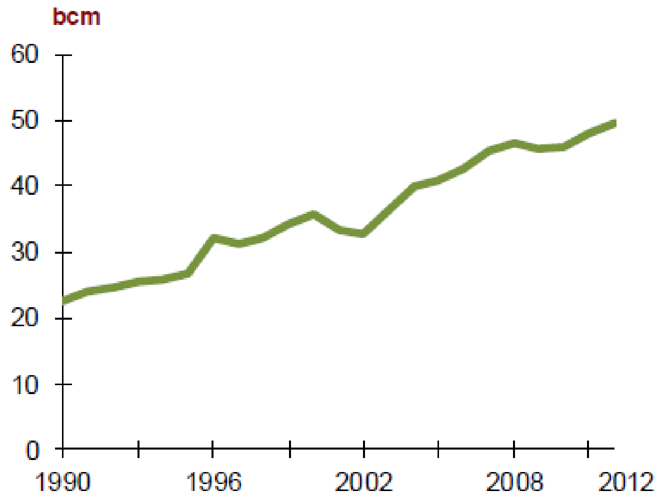


Fig. 35. Natural gas consumption in Argentina, bcm

Gas Consumption Breakdown by Sector (2012, %)

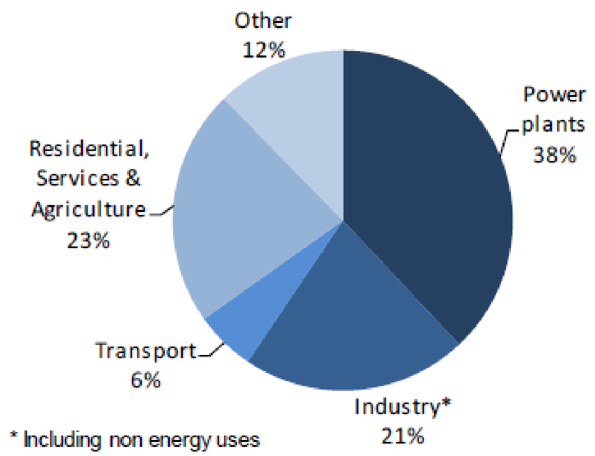


Fig. 36. Natural gas consumption in Argentina

Demand Indicators		1990	2000	2008	2009	2010	2011	2012
CONSUMPTION PER CAPITA								
Total	toe	1.4	1.7	2.0	1.9	1.9	2.0	2.0
Electricity	kWh	1236	2043	2695	2655	2790	2845	2934
CONSUMPTION TRENDS								
Total	%/year	-0.92	0.89	5.6	-2.2	2.5	2.5	2.7
Electricity	%/year	0.99	6.5	9.7	-0.62	6.0	2.9	4.0
TOTAL CONSUMPTION								
Total	Mtoe	46.1	60.9	77.8	76.1	78.0	80.0	82.2
of which								
Oil	%	46	38	39	37	39	38	38
Gas	%	41	49	51	51	49	51	51
Coal, lignite	%	2	1	1	1	1	2	1
Primary electricity*	%	8	7	6	7	7	7	6
Biomass	%	4	5	3	3	4	4	4

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

FINAL CONSUMPTION		1990	2000	2008	2009	2010	2011	2012
Total	Mtoe	30.4	46.8	56.3	54.2	56.7	58.1	59.6
By energy								
Oil	%	51	48	46	45	45	43	43
Gas	%	31	31	34	34	34	34	35
Coal, lignite	%	1	1	1	1	1	1	1
Electricity	%	11	14	16	17	17	17	17
Heat	%	0	0	0	0	0	0	0
Biomass	%	5	6	3	3	3	4	4
By sector								
Industry	%	28	32	31	31	29	30	30
Transport	%	32	28	26	25	28	29	29
Households & services	%	34	31	35	36	35	33	33
Non energy uses	%	6	9	8	9	8	8	8

Natural gas consumption by industry sectors in Argentina for 2009 is given in Table 13.

Table 13. Consumption of natural gas in Argentina, 2009.

Sector (2009)	**mcm**
Power plants	11.791,02
Industry	7.860,68
Residential, Services & Agriculture	7.860,68
Transport	2.143,82
Other	6.074,16
Total	35.730,37

Further, natural gas consumption by industry sectors in 2010 is reviewed (Table 14).

Table 14. Distribution of natural gas uses by branches of industry in Argentina for 2010.

Sector	**mcm**
Natural gas consumption by the steel industry	1,891.43
Natural gas consumption by the non metallic mineral industry	1,536.73
Natural gas consumption by the food and tobacco industry	1,054.58
Natural gas consumption by the paper and pulp industry	340.54
Natural gas consumption by the transport equipment	65.85
Natural gas consumption by the wood industry	29.04
Other*	3,054.33
TOTAL	**7,972.50**
*Including Natural gas consumption of non ferrous metals, Natural gas consumption of textiles and leather	

The share of industrial gas consumption accounts for around 22%, which is approximately equal to 8 bcm in absolute value.

The most power-consuming branches of industry in Argentina are:
- Steel industry (23.7%)
- Non metallic mineral (19.3%)
- Food and tobacco (13.2%)

Africa

Area: 30,2 million sq. km (without islands);
Population: around 1 bln people.

In 2009 natural gas consumption within industrial sector in Africa (see Table 15) accounted for 23,64 bcm, and in 2013 natural gas consumption increased to 28,52 bcm. Through 2009 to 2013 period there was a growth in branchies of industry's consumption of natural, which is evidenced by the rate of increase in the table given further. From 2009 to 2013 natural gas consumption increased by 20,6%, despite the fact that recently there is a slight decrease in natural gas consumption. Consumption of natural gas in Africa is given in Table 15.

Table 15. Natural gas consumption within industrial sector in Africa

Activities	**Unit**	**Year**				
		2009	2010	2011	2012	2013
natural gas consumption within industrial sector	bcm	23,64	26, 60	26, 73	29, 86	28,52
Rate of increase	%		+12,5	+0,49	+11,7	- 4,5

The diagram in Figure 37 shows industrial natural gas consumption by some countries of Africa.

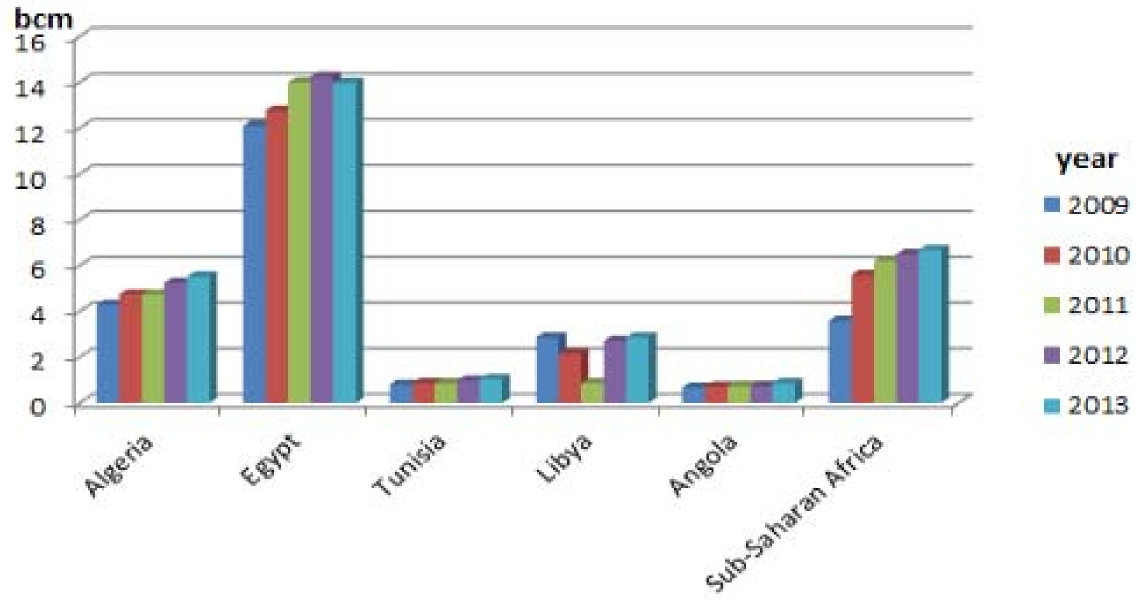


Fig. 37 Natural gas consumption within industrial sector in Africa, bcm

The diagram analysis shows that in Africa the leader in natural gas consumption within industrial sector is Egypt (13,96 bcm at the end of 2013). Also, some significant share in natural gas consumption within industrial sector is taken by Sub-Saharan (6,69 bcm) and Algeria (5,52 bcm).

Egypt

Area: 1.0 million sq. km
Population: 85,29 million people
Per capita GDP: $ 6,2 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	56.8	82.5	84.0	85.5
GDP growth rate	%/year	5.7	1.8	2.2	1.8
GDP/capita	US $	1091	2 789	2 981	2 811
Inflation Rate	%/year	16.8	10.1	8.6	6.9
Exchange rate	lc/$	1.6	5.9	6.1	6.9

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-87	-9	-3	-6

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.176	0.169	0.174	0.170
Total consumption/GDP *	2005=100	93.3	89.9	92.2	90.2
Rate of T&D power losses	%	10.4	11.0	12.1	13.0
Efficiency of thermal power plants	%	35.0	42.0	42.0	42.0

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	0.411	0.402	0.413	0.405
CO_2 emissions/capita	tCO_2/cap.	1.3	2.2	2.3	2.3

* at purchasing power parity

IEOC (International Egyptian Oil Company), a subsidiary of ENI, is the main gas producer in Egypt, along with BP and BG (formerly British Gas). In 2001 Egyptian Natural Gas Holding Company (EGAS) became the national gas company; EGAS is independent from EGPC.
The marketed production has been slightly decreasing since 2008 (58 bcm in 2013). It increased very rapidly between 2000 and 2008 (3.5-fold increase from 18 bcm to 62 bcm) thanks to the commissioning of many gas fields, especially offshore. In 2010 ENI started the production from the offshore Tuna field, with gas production estimated at 1.6 bcm/year.

Gas consumption has increased strongly since 2000 (almost 10%/year, on average). That rapid trend is mainly driven by industry and electricity production. More than 60% of the gas is used for the generation of electricity, and about one-fourth is used in industry.

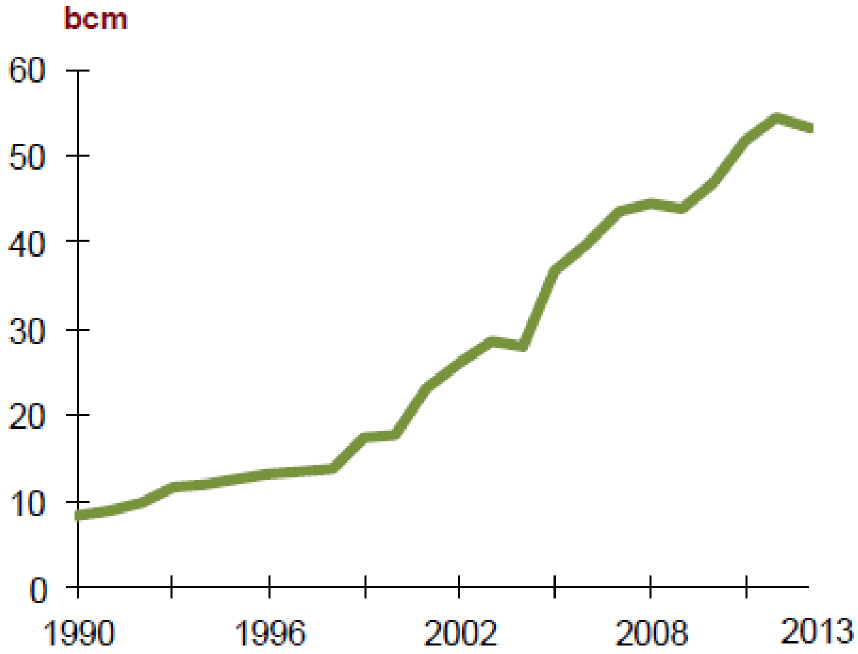


Fig.38 Natural Gas Consumption (bcm)

Sectoral distribution of natural gas consumption in Egypt is shown in Figure 39.

Gas consumption breakdown by sector (2013,%)

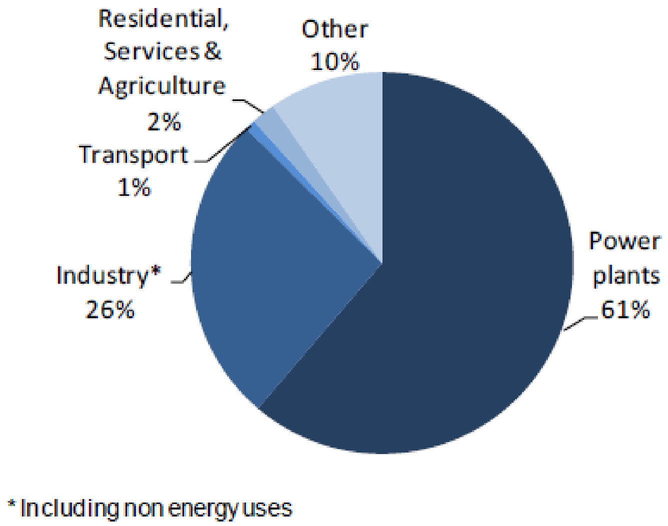


Fig. 39. Natural gas consumption in Egypt

Natural gas consumption by industry sectors in Egypt for 2013 is given in Table 16.

Table 16. Consumption of natural gas in Egypt, 2013

Sector	mcm
Energy sector	37 778,24
Industry	13 958,29
Residential, Services & Agriculture	1 079,44
Transport	471,88
Total	53 287,85

The share of industrial gas consumption in Egypt accounts for about 37%.
It includes the following industry sectors:
miscellaneous industry,
steel industry,
non metallic mineral,
textiles and leather.

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	0.57	0.60	0.90	0.91	0.94	0.97	0.95
Electricity	kWh	637	951	1492	1547	1623	1670	1649
CONSUMPTION TRENDS								
Total	%/year	5.2	-4.6	-0.90	2.9	5.5	4.8	-0.37
Gas	%/year	3.8	1.5	-1.8	6.9	10.8	4.9	-2.0
Electricity	%/year	5.8	5.8	6.4	5.5	6.8	4.7	0.5
TOTAL CONSUMPTION								
Total	Mtoe	32.4	40.7	71.4	73.5	77.6	81.3	81.0
of which								
Oil	%	71	56	45	43	41	41	41
Gas	%	21	35	50	52	55	55	54
Coal, lignite	%	3	2	1	1	1	1	1
Primary electricity*	%	3	3	2	2	1	2	1
Biomass	%	3	3	2	2	2	2	2
FINAL CONSUMPTION								
Total	Mtoe	23.0	31.2	48.2	49.6	52.1	54.2	54.3
By energy								
Oil	%	68	63	51	50	49	49	50
Gas	%	11	13	23	24	24	24	23
Coal, lignite	%	3	2	2	2	2	2	2
Electricity	%	14	18	21	22	22	22	22
Heat	%	0	0	0	0	0	0	0
Biomass	%	5	4	3	3	3	3	3
By sector								
Industry	%	45	34	26	26	30	29	29
Transport	%	22	30	28	26	25	26	26
Households & services	%	23	26	32	34	32	32	32
Non energy uses	%	9	10	14	14	12	12	12
ELECTRICITY CONSUMPTION								
Total	TWh	36.2	64.3	119	125	134	140	141
of which								
Industry	%	47	38	33	32	31	28	28
Households	%	37	37	40	41	42	43	43
Services	%	13	21	23	23	22	25	24

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

Algeria

Area: 2,38 million sq. km
Population: 38,08 million people
Per capita GDP: $ 7,24 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	25.3	36.0	36.5	37.0
GDP growth rate	%/year	0.80	2.5	3.3	3.1
GDP/capita	US $	2453	5 244	5 468	5 659
Inflation Rate	%/year	16.7	4.5	8.9	5.0
Exchange rate	lc/$	9.0	72.9	77.5	79.9

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-491	-321	-276	-217

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.144	0.155	0.166	0.167
Total consumption/GDP *	2005=100	103	110	118	119
Rate of T&D power losses	%	14.5	19.4	19.3	19.2
Efficiency of thermal power plants	%	34.6	39.9	39.9	39.8

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	0.327	0.372	0.396	0.400
CO_2 emissions/capita	tCO_2/cap.	2.0	2.8	3.1	3.2

* at purchasing power parity

Sonatrach is the largest African gas company, the world's third largest LNG exporter, and the world's fifth largest natural gas exporter. Sonatrach is continuing its efforts to reinforce its position in Europe (it is already the largest supplier in Spain) through Med LNG & Gas, a company jointly created in 2001 with GDF SUEZ for the sale of LNG on the European and American markets.
Between 2000 and 2012 production of natural gas has fluctuated around 80 bcm. It fell by 6% in 2013 (75 bcm in 2013) because of the terrorist attack at the Tigantourine plant. The gas extracted from the Hassi R' mel area represents approximately 60% of the national production. Production

strongly increased between 1990 and 2000 (+80%). The share of exports is decreasing due to the rising domestic consumption (61% in 2013 compared to 70% in 2008). In 2013 exports reached 45 bcm (over 60% of which were exports by gas pipeline).

Italy's status as the country's main gas customer was reinforced in 2008 through additional deliveries (6.5 bcm/year) to be carried out under two new agreements with Enel, and under existing contracts with Edison, Mogest, Begas and WorldEnergy, signed within the framework of the first phase of the extension of the capacity of the TTPC (Trans Tunisian Pipeline Company) gas pipeline. Since 2008, Sonatrach exports 6.2 bcm/year to Italy (contracts ending in 2019). In 2011, it signed a 10-year contract to export 0.64 bcm/year to Morocco. Finally, 20 year contracts were signed in 2011 to export 5.1 bcm/year to Spain, with 0.8 bcm/year added in 2013. Sonatrach's network length increased from 11 500 km in 1995 to 15 900 km in 2013. Sonelgaz's gas network is made up of 78 550 km of high and medium pressure pipes, supplying 3.67 million customers (2012). Local public gas distribution is also developing quickly. The penetration rate of gas increased from 31% in 2000 to 48% in 2012.

The reference price for the gas exported by Algeria is calculated monthly by ALNAFT according to a method fixed by decree. The standard gas price is indexed on Algerian oil (the Sahara blend) and readjusted every 3 months by ministerial decree. Gas prices on the domestic market are US$0.39c/kWh for households and US$0.20c/kWh for industry (2013).

Gas Prices for Industry and Households (US$c/kWh GCV)

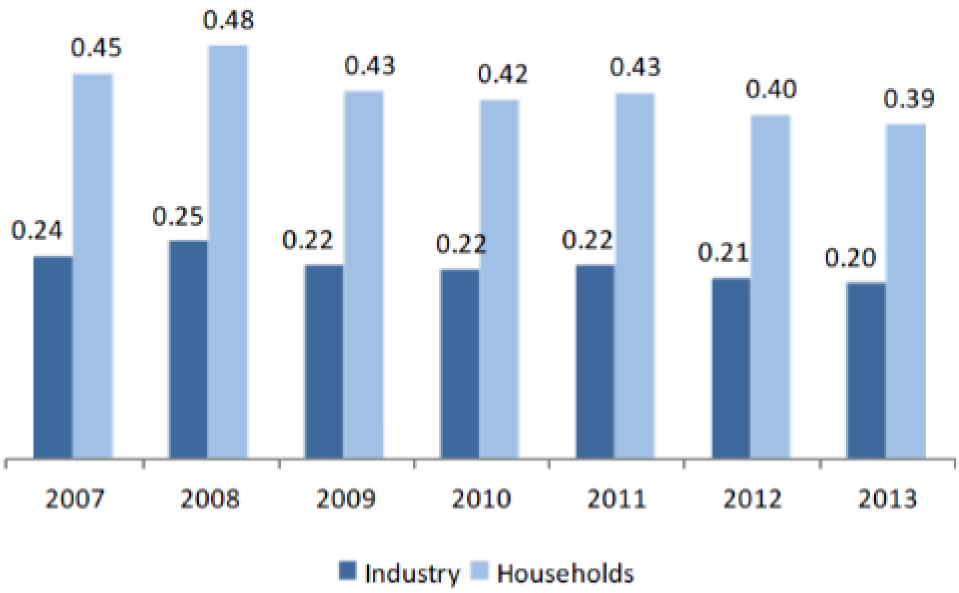


Fig. 40. Gas prices in Algeria

Gas consumption has been increasing by an average of 4.4%/year since 2000. Power plants consume 43% of the gas, followed by the residential and services sector (21%) and industry (17%) (2013). The remaining percentage is used by the actual energy sector.

Natural Gas Consumption (bcm)

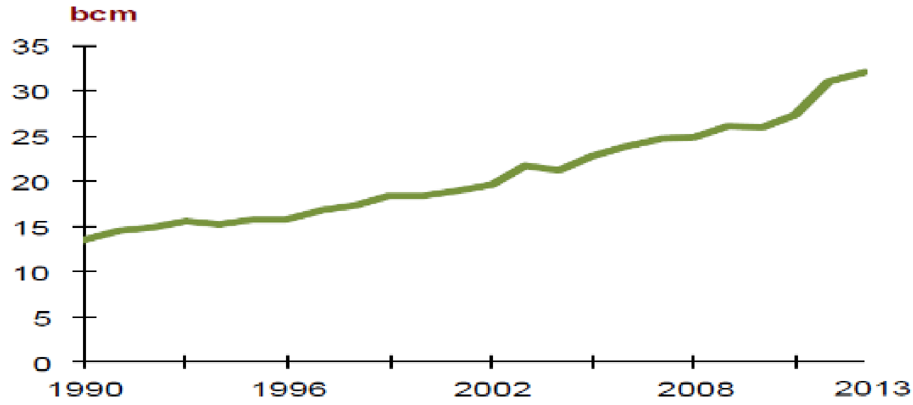


Fig. 41. Natural gas consumption in Algeria

Sectoral distribution of natural gas consumption in Algeria is shown in Figure 42.

Gas Consumption Breakdown by Sector (2013, %)

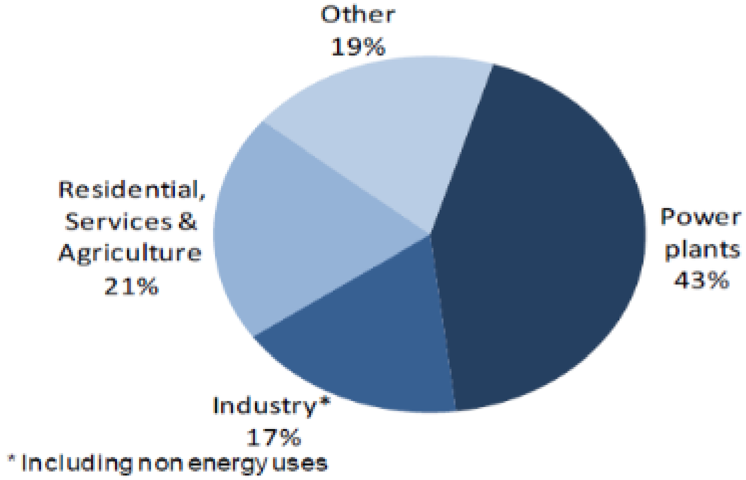


Fig. 42. Natural gas consumption in Algeria

Natural gas consumption by industry sectors in Algeria for 2013 is given in Table 17.

Table 17. Consumption of natural gas in Algeria, 2013.

Sector	**mcm**
Energy sector	19 936,34
Industry	5 520,68
Residential, Services & Agriculture	6 636,46
Total	32 093,48

The most power-consuming branches of industry in Algeria are:
Construction (73%)
Steel industry (9,1%)
Food and tobacco (11%)

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	0.90	0.91	1.2	1.2	1.2	1.3	1.3
Electricity	kWh	541	695	876	1031	1145	1267	1279
CONSUMPTION TRENDS								
Total	%/year	7.1	1.9	8.8	-1.7	4.2	10.6	3.9
Gas	%/year	0.07	0.81	6.5	-2.8	6.3	12.9	3.7
Electricity	%/year	4.5	6.1	-7.0	19.5	12.6	12.4	2.4
TOTAL CONSUMPTION								
Total	Mtoe	22.7	27.8	41.5	40.8	42.5	47.0	48.9
of which								
Oil	%	43	37	41	42	41	40	40
Gas	%	54	60	58	57	58	60	59
Coal, lignite	%	3	2	1	1	1	1	1
Primary electricity*	%	0	0	0	0	0	0	0
Biomass	%	0	0	0	0	0	0	0

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
FINAL CONSUMPTION								
Total	Mtoe	12.4	14.7	24.8	25.7	26.8	29.9	31.2
By energy								
Oil	%	63	55	56	54	53	53	52
Gas	%	25	32	33	33	34	35	35
Coal, lignite	%	3	2	1	1	1	1	1
Electricity	%	9	11	10	11	11	12	12
Heat	%	0	0	0	0	0	0	0
Biomass	%	0	0	0	0	0	0	0
By sector								
Industry	%	21	20	19	21	21	18	18
Transport	%	38	32	38	39	38	39	39
Households & services	%	26	33	33	32	34	34	34
Non energy uses	%	14	14	10	8	7	9	9
ELECTRICITY CONSUMPTION								
Total	TWh	13.7	21.2	30.6	36.6	41.2	46.3	47.4
of which								
Industry	%	44	33	33	35	32	32	33
Households	%	25	30	32	31	30	31	31
Services	%	18	22	23	23	22	22	22

CIS (including Russia)

Table 18. Natural gas within industrial sector in CIS, 2009-2013

Regions of the world	Unit	Year				
		2009	2010	2011	2012	2013
CIS	bcm	94,10	109,62	110,21	108,69	105,05
Rate of increase	%		+16,5	+0,5	-1,4	-3,3

The diagram below (Figure 43) shows industrial natural gas consumption by the countries of CIS.

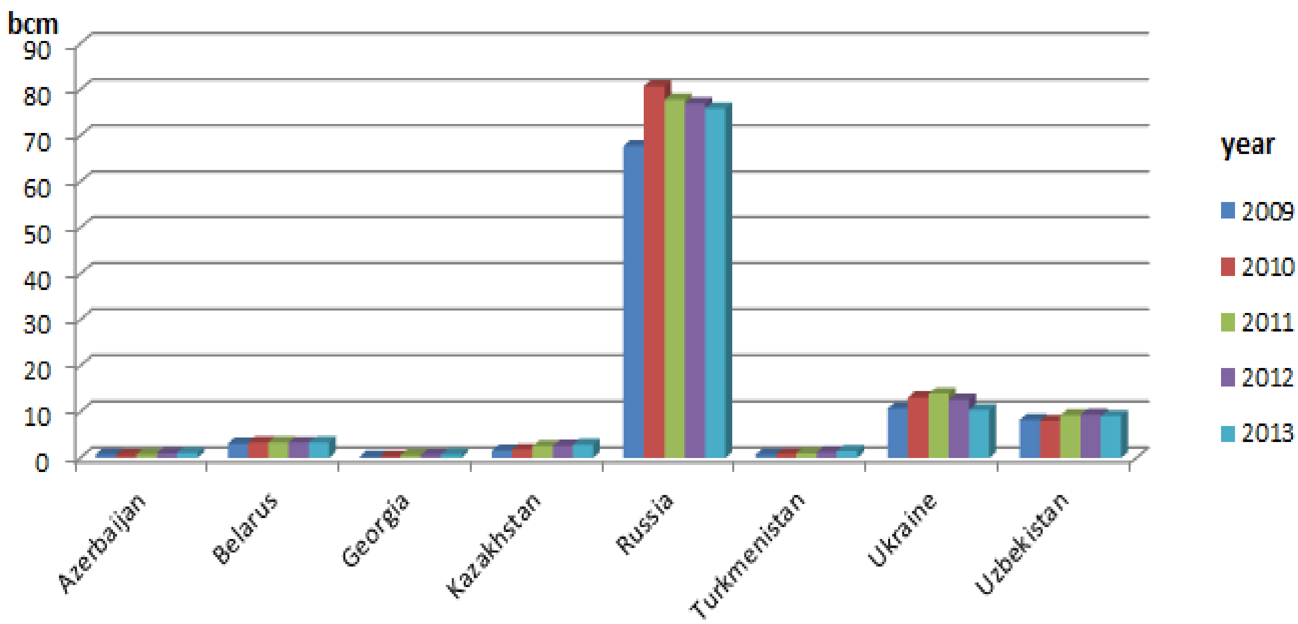


Fig.43 Natural gas consumption by the countries of CIS

The analysis of the diagram shows that as of at the end of 2013 the leader in natural gas consumption within industrial sector in CIS is Russia (75,8 bcm). Besides, the most great industrial sector natural gas consumers in CIS are:

Ukraine – 10,4 bcm;
Uzbekistan – 9,1 bcm.

Russia

Area: 17,12 million sq. km
Population: 143,67 million people
Per capita GDP: $ 14,04 thous

Economic Indicators

		1990	2011	2012	2013
Population	million	148	143.0	143.3	143.8
GDP growth rate	%/year	-3.0	4.3	3.4	1.5
GDP/capita	US $	n.a.	12 995	13 419	14 014
Inflation Rate	%/year	n.a.	8.4	5.1	6.7
Exchange rate	lc/$	n.a.	29.4	30.8	31.9

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-99	-207	-204	-196

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.471	0.347	0.338	0.331
Total consumption/GDP *	2005=100	123	90.5	88.0	86.2
Rate of T&D power losses	%	8.4	10.9	10.9	10.9
Efficiency of thermal power plants	%	24.6	25.3	25.3	25.3

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	kCO_2/$05p	1.160	0.783	0.758	0.737
CO_2 emissions/capita	tCO_2/cap.	14.6	11.5	11.5	11.3

Gazprom is the main national gas company. It is a vertically integrated financial company in which the State has a 50% stake plus one share. According to a new law, foreign groups cannot hold a stake of over 20% in Gazprom, with the State keeping a minimum stake of 50% plus one share in its capital.
Gazprom controls 70% of the country's reserves and accounts for 78% of the national production and 14% of the worldwide production (2012). Gazprom has the export monopoly and exports to 27

countries (although the company authorized Itera to export to Ukraine and Belarus). The company provides gas for the production of 50% of Russia's electricity.
Novatek is the leading independent gas producer and the second largest gas company (Volga Resources 20.77%, Gazprom 10%, Total E&P Artic Russia 19.4%). In 2011, it accounted for approximately 9% of the natural gas produced in Russia.
Gas production has been increasing by 1.2%/year, on average, since 2000 (and by 3.6%/year since 2009), reaching 669 bcm in 2013. In 2009 it decreased strongly, by 12%, down to 583 bcm, due to a decline in both domestic and export demand triggered by the economic crisis. Net exports also increased since 2009, reaching 203 bcm, compared to 163 bcm in 2009. Outside the CIS, Germany is Russia's largest gas consumer (16% of total exports in 2012), followed by Turkey and Italy (13% and 7%, respectively).
The price of gas is controlled by the State and determined according to the cost-plus pricing method. Certain cross-subsidies occur, in particular between industry and the residential sector. With the aim of bringing domestic wholesale gas prices for industrial consumers closer to the level of profitability of export supplies, Russia had planned an average annual increase in gas prices on the national market of 15% between 2005 and 2013. However, in order to support the domestic economy, the Government decided to lower the next gas price increases for industry to just 4.8% and 4.9% in July 2015 and 2016, respectively. The price of natural gas remains low, at US$1.15c/kWh GCV for industry in 2013 and US$0.92c/kWh GCV for households in 2013. The price of gas increases regularly. The final decision regarding the timeframe for the adjustment of domestic prices to export prices (initially planned for 2011 but postponed to at least 2015) has not yet been taken because of widespread public opposition to price increases.

Gas Prices for Industry and Households (USc/kWh GCV)

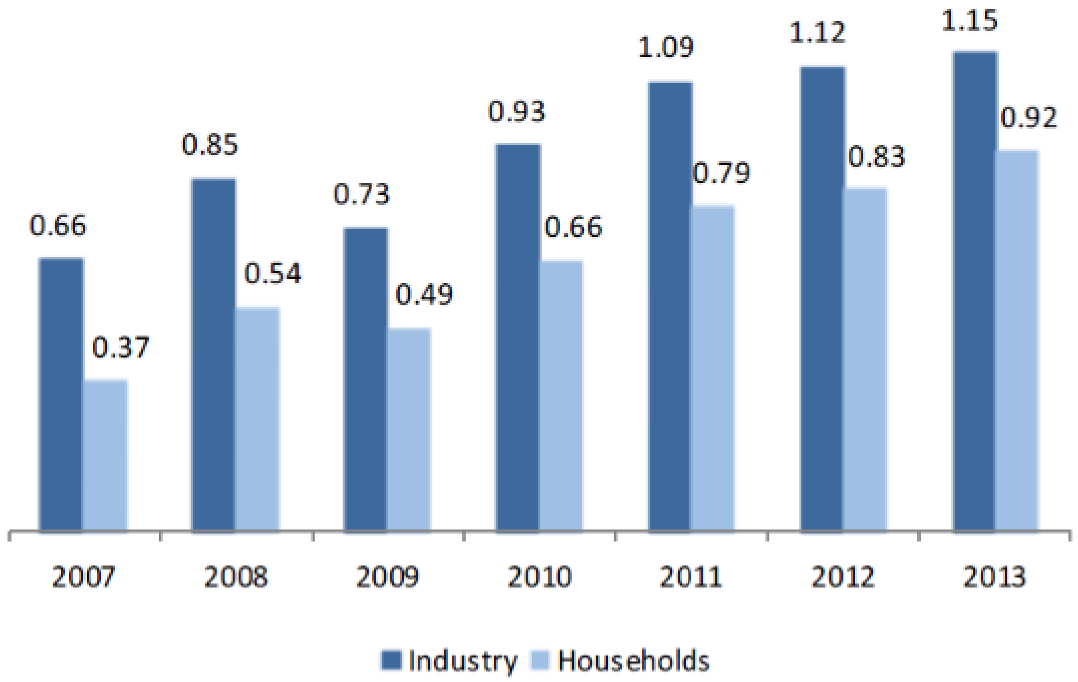


Fig.43. Gas prices in Russia

Gas consumption increased by 1.8%/year, on average, between 2000 and 2011, when it reached 477 bcm, before decreasing in 2012 and 2013. Gas is mainly consumed in the electricity sector (43%, substantially above its 2000 level of 39%). Industry represents 16% and the residential-tertiary sector 11% (down from 15% in 2000). The energy sector represents around 30% of gas consumption.

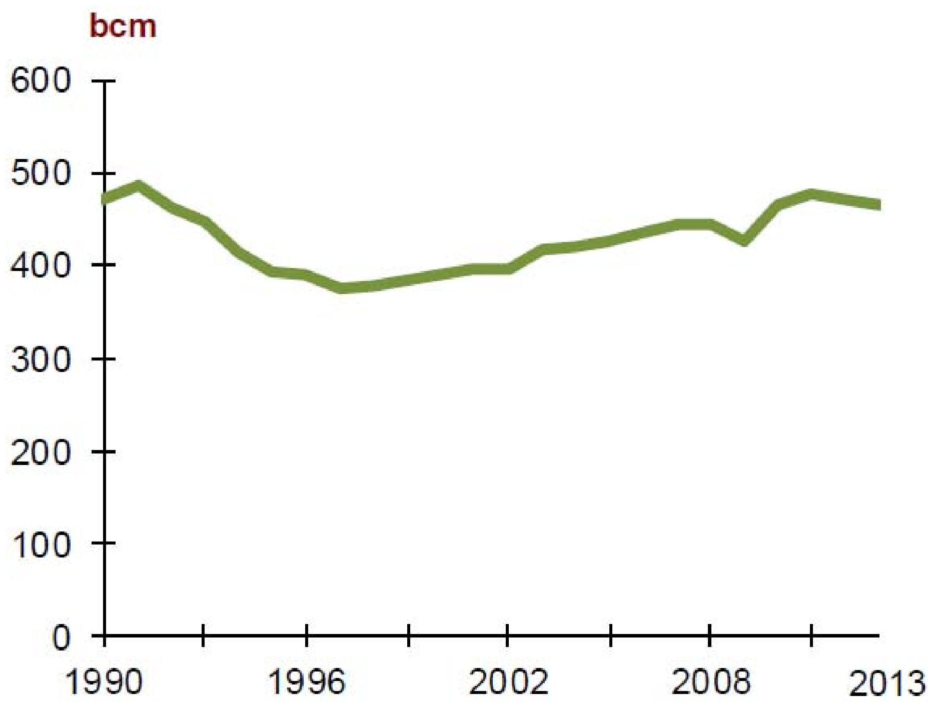


Fig.44. Natural gas consumption in Russia

Sectoral distribution of natural gas consumption in Russia is shown in Figure 45.

Gas Consumption Breakdown by Sector (2013, %)

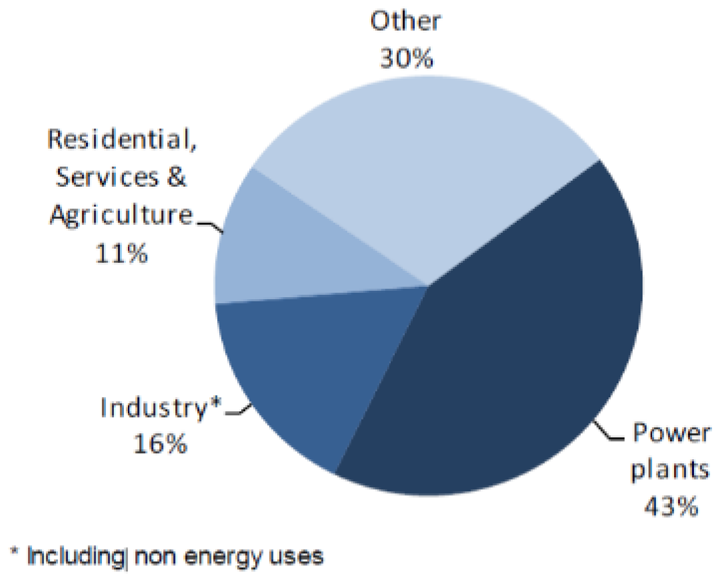


Fig. 45. Natural gas consumption in Russia

The most power-consuming branches of industry in Russia are:
- Steel industry (41,5%)
- Non metallic mineral (32,6%)

According to the Energy Strategy for Russia, the production of natural gas should increase strongly, reaching approximately 700 bcm in 2015, 800 bcm in 2020 and more than 900 bcm in 2030. Gazprom recently revised its production estimates downwards to 518 bcm in 2014 and 2015. Total exports would be increased to around 300 bcm in 2015 and to 350 bcm in 2030, and the share of exports for Europe should decrease to 55% while exports to Asia should reach 20%.

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	5.9	4.2	4.6	4.9	5.1	5.1	5.1
Electricity	kWh	6187	4736	5693	5974	5989	6073	5953
CONSUMPTION TRENDS								
Total	%/year	n.a.	1.7	-6.0	8.5	4.1	0.55	-0.61
Gaz	%/year	n.a.	1.4	-4.3	9.5	2.0	-1.1	-1.4
Electricity	%/year	n.a.	3.5	-4.2	5.3	0.7	1.6	-1.7
TOTAL CONSUMPTION								
Total	Mtoe	882	619	647	702	730	735	730
of which								
Oil	%	30	20	21	20	22	22	23
Gas	%	42	52	54	55	54	53	52
Coal, lignite	%	22	19	15	16	16	16	15
Primary electricity*	%	5	8	9	8	8	8	8
Biomass	%	1	1	1	1	1	1	1

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

		1990	2000	2009	2010	2011	2012	2013
FINAL CONSUMPTION								
Total	Mtoe	603	400	397	419	440	445	445
By energy								
Oil	%	24	23	25	25	26	27	28
Gas	%	18	23	25	26	24	24	23
Coal, lignite	%	11	7	7	7	7	7	7
Electricity	%	11	13	14	14	14	14	14
Heat	%	34	34	27	27	28	28	28
Biomass	%	1	1	1	1	1	1	1
By sector								
Industry	%	38	36	33	34	34	34	33
Transport	%	13	11	15	15	15	14	15
Households & services	%	42	44	39	37	36	36	36
Non energy uses	%	7	9	13	14	15	16	16
ELECTRICITY CONSUMPTION								
Total	TWh	917	693	808	851	856	870	856
of which								
Industry	%	53	45	39	38	39	39	39
Households	%	12	20	15	15	15	15	15
Services	%	7	9	19	20	19	19	19

Asia

Area: 44,58 m. sq. km (including islands)
Population: 4,16 billion people.

In 2009 natural gas consumption within industrial sector in Asia (see Table 19) accounted for 121,34 bcm, and in 2013 natural gas consumption increased to 156,89 bcm.
Generally, in Asia from 2009 to 2013 natural gas consumption within industrial sector increased by 29,3% to 156,89 bcm.
Consumption of natural gas in Asia is given in Table 19.

Table 19. natural gas consumption within industrial sector in Asia

Activities	**Unit**	**Year**				
		2009	2010	2011	2012	2013
natural gas consumption within industrial sector	bcm	121,34	119,58	138,17	147,20	156,89
Rate of increase	%		-1,45	+15,5	+6,5	+6,6

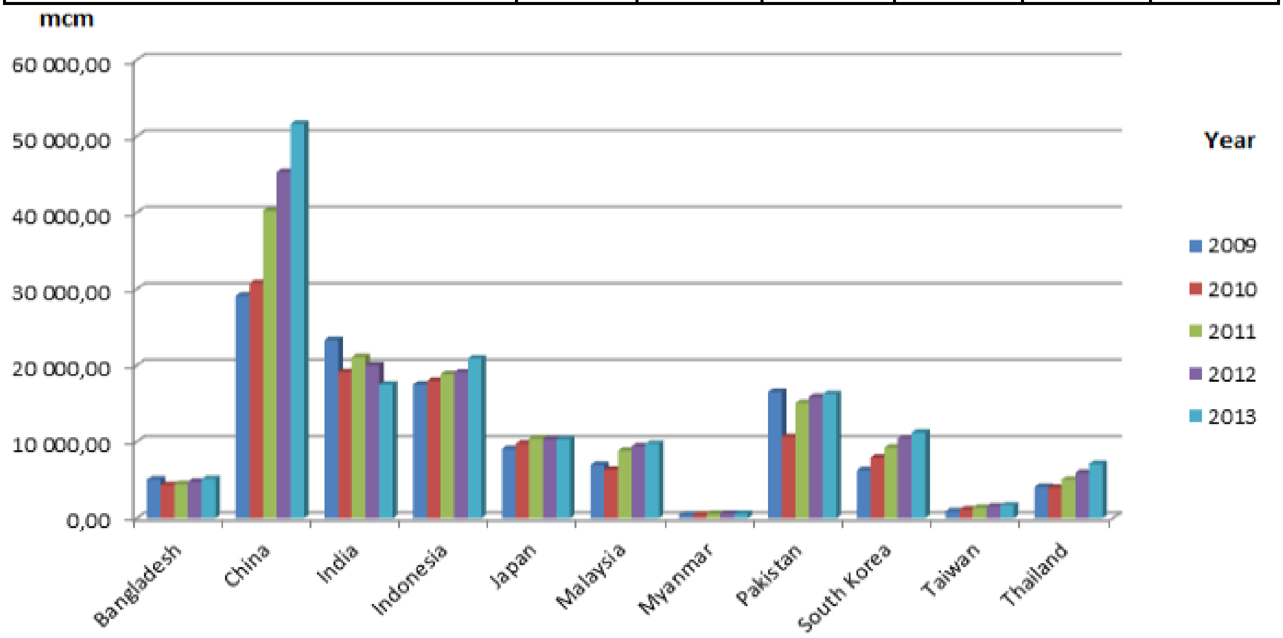


Fig. 46. Natural gas consumption within industrial sector in Asia, 2009-2013, bcm

The diagram analysis shows that in Asia the leader in natural gas consumption within industrial sector is China (51,6 bcm at the end of 2013). Significant ratios of natural gas consumption within industrial sector are also shared by Indonesia,India Pakistan and Japan.

China

Area: 9,6 million sq. km
Population: 1,37 bln people
Per capita GDP: $ 6,57 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	1135	1344	1351	1357
GDP growth rate	%/year	3.8	9.3	7.7	7.6
GDP/capita	US $	344	5 445	6 132	6 864
Inflation Rate	%/year	3.1	5.4	2.7	2.7
Exchange rate	lc/$	4.8	6.46	6.31	6.20

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	89	88	86
Share of oil imported(+) exported(-)	%	-21	57	58	58

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.716	0.274	0.268	0.261
Total consumption/GDP *	2005=100	216	82.7	81.1	78.9
Rate of T&D power losses	%	7.5	6.2	6.2	6.2
Efficiency of thermal power plants	%	27.1	33.7	33.7	33.7

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	$kCO_2/\$05p$	1.859	0.782	0.747	0.727
CO_2 emissions/capita	tCO_2/cap.	2.0	5.8	5.9	6.2

* at purchasing power parity

The gas sector is dominated by CNPC and CNOOC. CNPC is the largest gas pipeline contractor and operator. It owns and operates pipeline networks and storage systems covering 28 provinces,

municipalities and autonomous regions. By the end of 2012, CNPC's gas pipelines in China totalled around 41 000 km, accounting for around 80% of the gas pipeline network, including import links (Central Asia, Myanmar). CNOOC is the largest offshore gas producer in China.
Production has been growing at the fast pace of around 12%/year, on average, since 2000, which has made China the world's 7th largest producer (116 bcm in 2013). Since 2009 China has imported significant quantities of natural gas, and in 2013 domestic production covered just 73% of the consumption. Four areas are particularly rich in gas: Tarim, Shaanxi-Gansu-Ningxia, Sichuan and Qinghai.

Prices are set at rates below international prices. In order to boost LNG imports, China announced that VAT rebates will be granted for natural gas from Central Asia and LNG imported between 2011 and 2020, calculated according to the difference between import and domestic prices (applicable when average import costs over a quarter are higher than domestic wholesale prices).
Natural gas consumption has increased strongly since 2000 (15%/year over 2000-2013, on average). Industry is the main consumer (32% including non-energy uses). The share of the power sector is still weak (16%), but is increasing rapidly (7% in 2000).

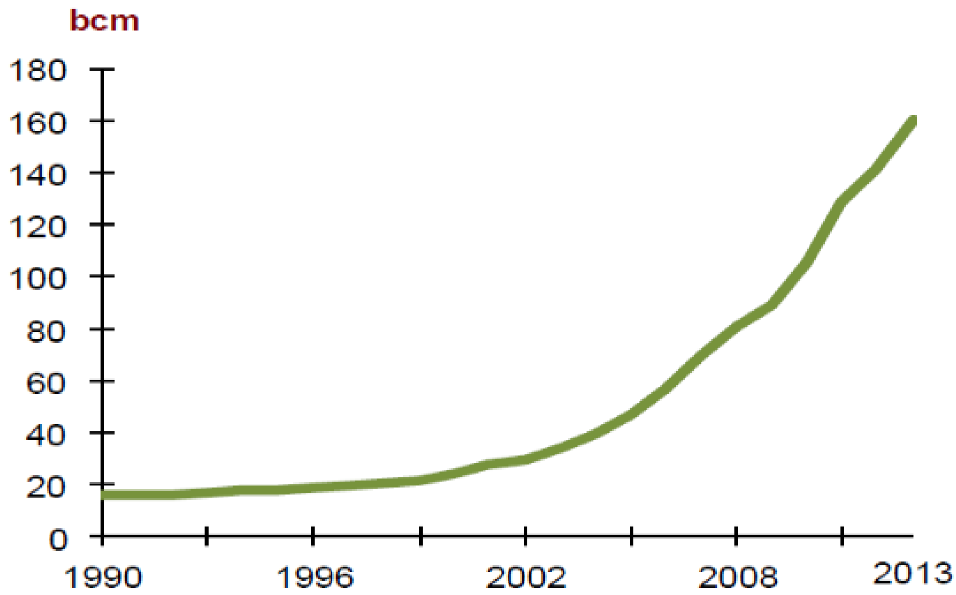


Fig. 47 Natural Gas Consumption (bcm)

Sectoral distribution of natural gas consumption in China is shown in Figure 48.

Gas Consumption Breakdown by Sector (2013, %)

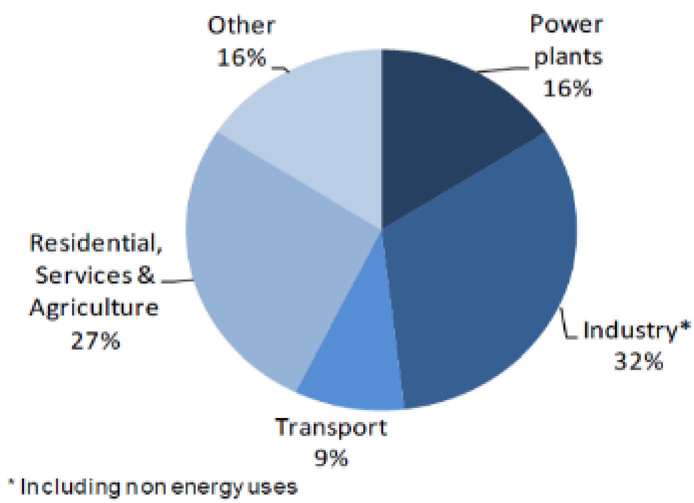


Fig. 48. Natural gas consumption in China

The most power-consuming branches of industry in China are:
- Chemical industry (40%)
- Non ferrous metals (20%)
- Machinery (10%)

Demand Indicators		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	0.79	0.92	1.7	1.9	2.0	2.1	2.2
Electricity	kWh	471	902	2421	2710	3014	3166	3350
CONSUMPTION TRENDS								
Total	%/year	6.2	5.5	7.8	10.1	8.4	5.5	4.7
Electricity	%/year	5.8	9.1	7.8	12.5	11.7	5.5	7.6
TOTAL CONSUMPTION								
Total	Mtoe	894	1161	2284	2516	2728	2879	3013
of which								
Oil	%	13	19	16	17	16	16	16
Gas	%	1	2	3	4	4	4	4
Coal, lignite	%	62	60	68	67	68	68	67
Primary electricity*	%	1	2	3	3	3	4	4
Biomass	%	22	18	9	8	8	8	8

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

		1990	2000	2009	2010	2011	2012	2013
FINAL CONSUMPTION								
Total	Mtoe	703	849	1525	1636	1755	1892	2042
By energy								
Oil	%	12	21	22	23	23	22	21
Gas	%	1	2	4	4	4	4	5
Coal, lignite	%	50	39	40	38	38	39	40
Electricity	%	6	11	17	18	19	19	18
Heat	%	2	3	4	4	5	5	5
Biomass	%	29	24	13	12	11	11	11
By sector								
Industry	%	38	42	51	51	51	52	52
Transport	%	5	10	11	12	12	12	11
Households & services	%	50	40	31	30	29	29	29
Non energy uses	%	6	7	7	8	7	8	7
ELECTRICITY CONSUMPTION								
Total	TWh	534	1138	3223	3626	4052	4276	4600
of which								
Industry	%	64	61	63	65	66	64	64
Households	%	9	13	15	14	14	15	15
Services	%	8	12	13	12	12	13	13

.

Indonesia

Area: 1,92 million sq. km
Population: 253,6 million people
Per capita GDP: $ 4,3 thous.

Economic Indicators

		1990	2011	2012	2013
Population	million	184	242.3	244.8	247.4
GDP growth rate	%/year	9.0	6.5	6.2	5.3
GDP/capita	US $	621	3 495	3 579	3 576
Inflation Rate	%/year	7.8	5.4	4.3	7.3
Exchange rate	lc/$	1843	8 770	9 387	10 501

Sources : World Bank , IMF

ENERGY SECURITY		1990	2011	2012	2013
Energy independence rate	%	100	100	100	100
Share of oil imported(+) exported(-)	%	-118	37	40	44

ENERGY EFFICIENCY		1990	2011	2012	2013
Total consumption/GDP *	koe/$05	0.267	0.210	0.197	0.190
Total consumption/GDP *	2005=100	105	82.8	77.4	74.6
Rate of T&D power losses	%	10.1	9.5	9.9	9.9
Efficiency of thermal power plants	%	34.3	34.2	34.4	34.4

CO_2 EMISSIONS		1990	2011	2012	2013
CO_2 emissions/GDP *	$kCO_2/\$05p$	0.373	0.419	0.404	0.401
CO_2 emissions/capita	tCO_2/cap.	0.75	1.7	1.7	1.8

* at purchasing power parity

Natural gas consumption increased very quickly until 1998 (10%/year). It then stagnated until 2008 (due to supply constraints) and has recently increased very rapidly. The hydrocarbons sector, in particular the oil and gas extraction and the liquefaction plants, absorbs a large fraction of the consumption (26%); the weight of industry is 47%, while power plants account for 26%.

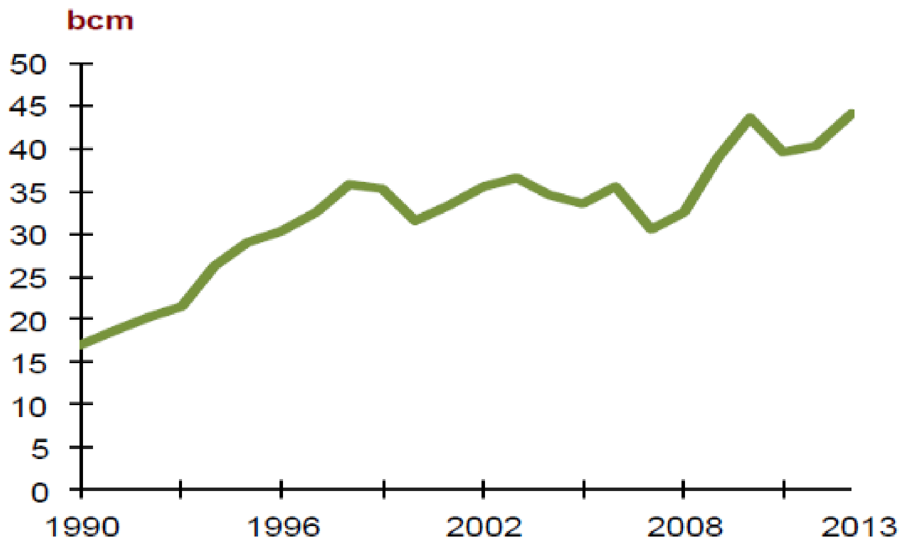


Fig. 49. Natural Gas Consumption (bcm)

Sectoral distribution of natural gas consumption in Indonesia is shown in Figure 50.

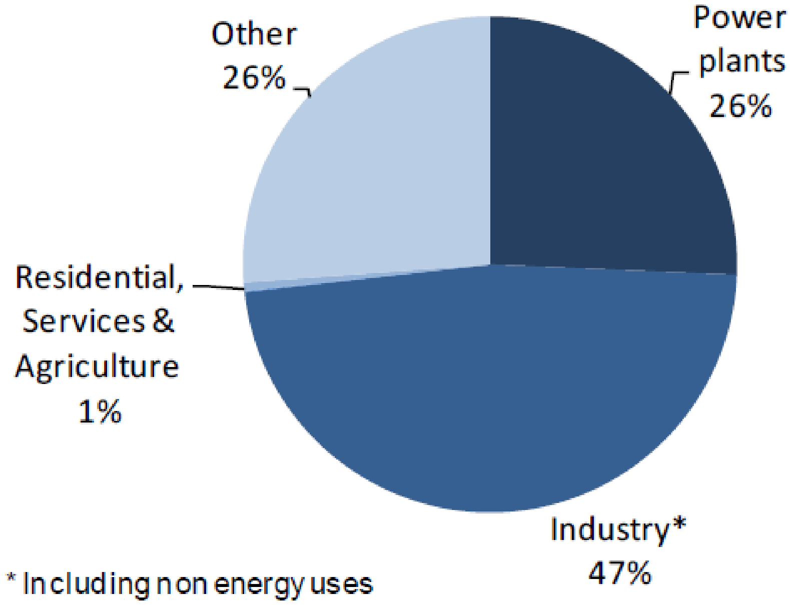


Fig. 50. Natural gas consumption in Indonesia

Demand Indicators

		1990	2000	2009	2010	2011	2012	2013
CONSUMPTION PER CAPITA								
Total	toe	0.54	0.73	0.84	0.88	0.86	0.85	0.85
Electricity	kWh	153	371	573	617	660	719	763
CONSUMPTION TRENDS								
Total	%/year	21.2	7.7	7.1	5.7	-1.1	-0.60	1.3
Gas	%/year	24.8	-6.2	15.4	12.9	-10.4	1.5	9.5
Electricity	%/year	20.4	11.0	5.6	8.8	8.0	10.1	7.2
TOTAL CONSUMPTION								
Total	Mtoe	98.7	155	200	211	209	207	211
of which								
Oil	%	34	37	33	33	35	36	36
Gas	%	16	17	17	18	17	17	18
Coal, lignite	%	4	8	15	14	15	16	16
Primary electricity*	%	2	6	8	8	8	7	6
Biomass	%	44	32	26	26	25	25	23

* Nuclear (1TWh = 0.26 Mtoe), Hydroelectricity and wind (1 TWh = 0.086 Mtoe), Geothermal (1 TWh = 0.86 Mtoe)

		1990	2000	2009	2010	2011	2012	2013
FINAL CONSUMPTION								
Total	Mtoe	79.4	120	145	155	157	156	157
By energy								
Oil	%	34	40	38	39	40	42	43
Gas	%	8	10	11	10	11	11	12
Coal, lignite	%	3	4	7	8	7	6	5
Electricity	%	3	6	8	8	9	10	10
Heat	%	0	0	0	0	0	0	0
Biomass	%	53	40	36	34	33	32	31
By sector								
Industry	%	23	26	28	29	29	28	28
Transport	%	13	18	21	23	24	25	26
Households & services	%	55	48	44	42	41	41	40
Non energy uses	%	9	8	6	5	6	6	7
ELECTRICITY CONSUMPTION								
Total	TWh	28.3	79.2	136	148	160	176	189
of which								
Industry	%	51	43	34	35	35	35	35
Households	%	32	39	41	41	41	41	41
Services	%	16	18	25	25	24	24	24

Middle East

Area: 14,4 million sq. km

Population: 411,2 million people

In 2009, natural gas consumption within industrial sector in the Middle East (see Table 20) accounted for 112,19 bcm, and in 2013 natural gas consumption increased to 147,87 bcm. Through 2009 to 2013 period there was a growth in natural gas consumption by branches of industry, which is evidenced by the rate of increase in the table given further.

Table 20. natural gas consumption within industrial sector in the Middle East

Activities	Unit	Year				
		2009	2010	2011	2012	2013
natural gas consumption within industrial sector	bcm	112,19	117,65	137,91	143,62	147,87
Rate of increase	%		+4,9	+17,2	+4,4	+3

The diagram in Figure 51 shows industrial natural gas consumption by some countries of the Middle East.

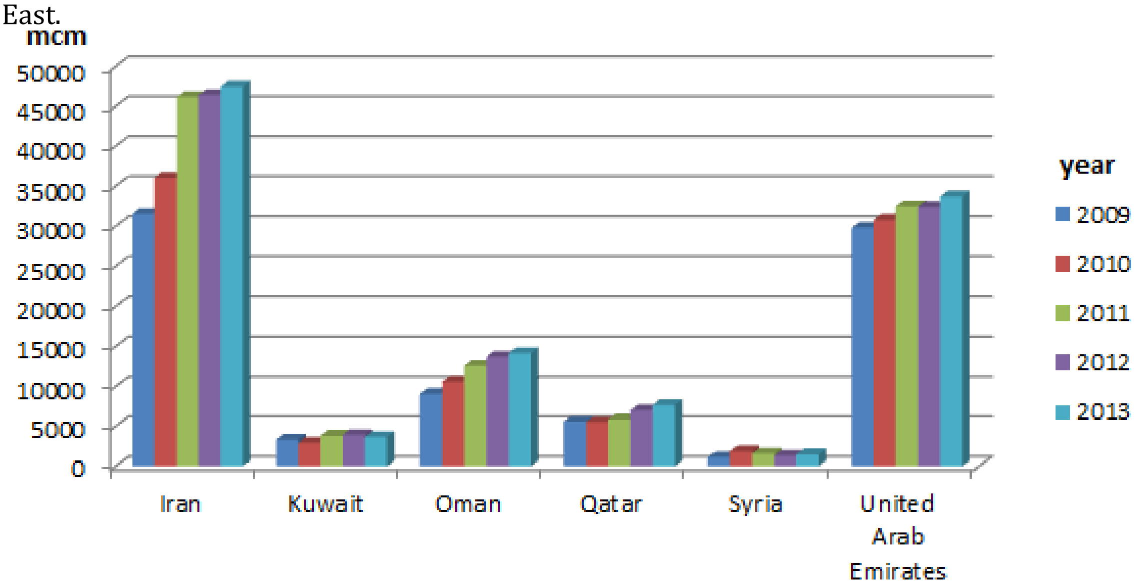
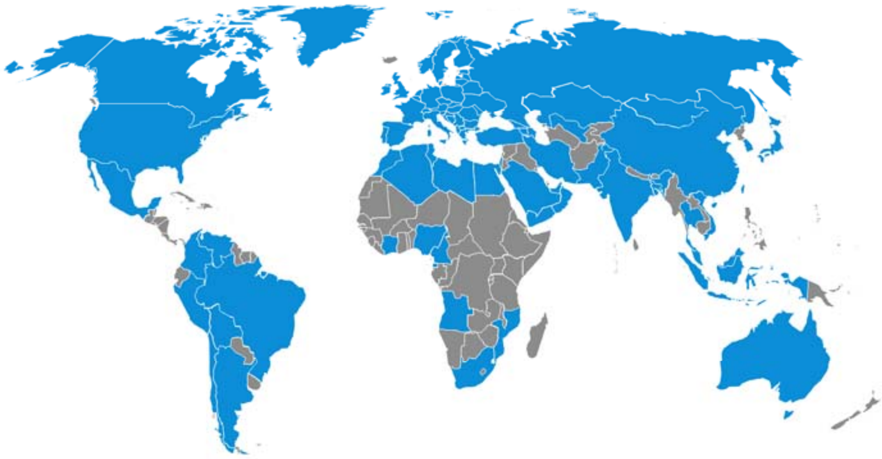


Fig. 51. Natural gas consumption within industrial sector in the Middle East, 2009-2013

The diagram analysis shows that in the Middle East the leader in natural gas consumption within industrial sector is Iran (47,46 bcm at the end of 2013). Significant ratio in natural gas consumption within industrial sector is also shared by the United Arab Emirates (33,7 bcm).

NOTES



The International Gas Union (IGU) was founded in 1931 and is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. The IGU has more than 142 members worldwide and represents more than 97% of the world's gas market. The members are national associations and corporations of the gas industry. The working organisation of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit **www.igu.org**

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