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"How to use in complementary ways, renewable and natural gas solutions in order to improve efficiency and sustainability of energy master plan of industrial plants"

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Industrial gas utilizations

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Abstract:

In a context of reduction of carbon emission and economical crisis the most important challenge for this century for industrial market will be to develop innovative concept of industrial factory in order to guardant competitiveness and sustainability of industrial business, especially in occidental countries. One of the solutions will be the development of advanced new concepts of low carbon footprint industrial plants.
In this frame what could be the place of Natural gas and what new technologies available for Gas Companies to reach this industrial demand and what type of innovative solutions and business gas Companies have to develop in order to help their customers to implement low-carbon Foot print energy master plan of their industrials plants and/or processes.

Executive Summary....

In a context of high prices and volatility of energy, strengthening of environmental regulations, implementation of national strategic energy plan, drastic reduction of energy consumption (CO2 reduction) of processes in order to fight against climate change; energy efficiency is becoming one of the most important issues for the competitiveness of industrial plants.
In another way development of ISO 50001 Norms on energy management, will reinforce the necessity for industrial plant to do energy balance of their plans and defined progress plan on energy 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
- Implementation of high level of heat/energy recovery
- Energy conversion of processes
- Re-engineering of energy master plan of the industrial plants
- And **implementation of renewable energy in the energy mix of the plants.**

If the development of renewable energy is a major topic all over the world, in response to various environmental (reducing greenhouse gases emissions), geopolitical (reducing dependency on fossil fuels) and economic (developing new activities) issues. Especially for industrial companies to be able to have access to green sources of energy will be one of the key point to reach their goal of reduction plan and for development of low-carbon foot print industrial plant.

In this article we will try, through examples of innovative projects or case studies, to show that in this context, technological solutions combining renewable energy with natural gas can be a good compromise to achieve the objectives of industrial companies while keeping up a key place to natural gas in the energy mix of the plants. Examples analyzed will be:

- On site production of Syngas through biomass gasification and direct use of it in furnaces;
- Bio-methane production, through biomass gasification and use in furnaces or boiler and CHP (Mass production or delocalized production) ;

- On site production of biogas through anaerobic digestion ;
- Cooling system coupling thermal solar panels with cooling appliances ;
- Production of hot water with technical solution coupling thermo solar panels with boiler or immerged NG combustion tube
- Synthetic methane produce by methanation process with CO2 recycling and H2

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 efficient industrial plants to Eco-Design plant (very Low carbon foot-print plants) and an economical analysis will be carried out to support the development of this innovative pathway in the natural gas economy.

1. Context:

a. Introduction on new energy and regulations context

The fight against climate change has become a major concern of all industrial countries or pre-industrial world including the European Union. Many scenarios have been studied in an attempt to limit or stabilize the amount of greenhouse gases in the 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 effective energy in buildings, industry and transport, the introduction of renewable in the energy mix and use of bio-fuels (see fig. 1)

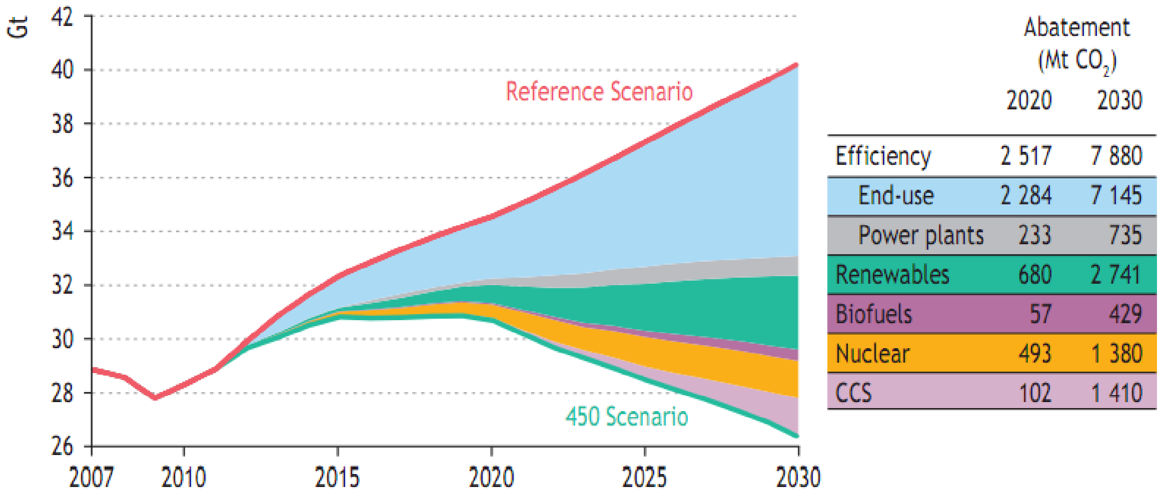


Figure 1: Scenarios of CO_2 emissions in the hearth atmosphere regarding solutions
(Source: International Energy *Agency, World Energy Outlook 2009)*

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

The action plan focuses on three objectives for 2020:

- 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: Standards for energy 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, 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 the integration of renewable energy in industrial processes and the gas industry, including 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.

2. Markets needs

In the present economical context the main issue of industrial markets is the profitability of their activities. Due to the energy scarcity, but also the liberalization of the markets and speculation, the energy prices have steadily increased over the past decade. This upward trend has no reason to slow down, or reverse at long term, unless in case of localized fluctuation. The share of energy prices in the cost of production will therefore continue to increase steadily. Add to that the other energy-related costs (energy taxes and various environmental taxes ie CO2; NOx…), the main focus of industrial markets in the coming years will be to reduce this share, especially in developed countries where energy cost is already high.

To achieve these objectives two main types of actions need to be conducted:

- The implementation of drastic energy efficiency policies ;
- The development of hybrid solutions integrating renewable energy (solar, biomass ...)

a. Reduction of energy cost in production ratio: Implementation of Energy efficiency plans

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.

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, in the last three years, the annual energy consumption in the industrial market (except power production) is roughly 300 TWh per year (Fig 2). 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 high temperature 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 2). 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.

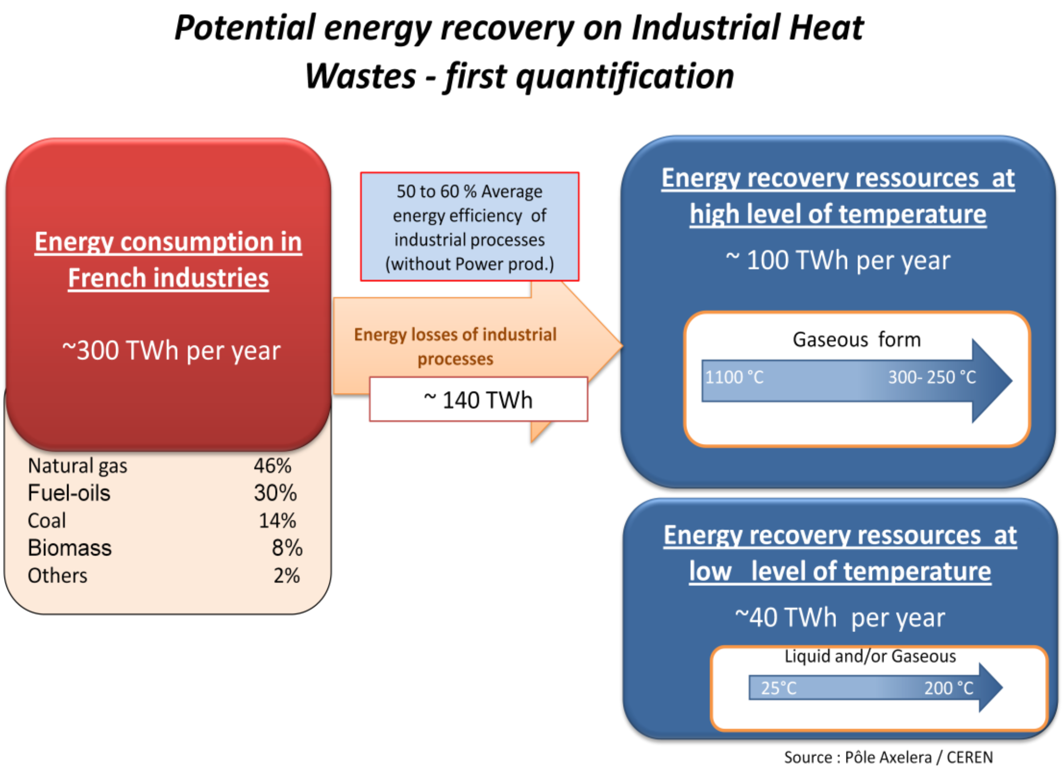


Fig 2: Estimation of industrial heat waste in France

Energy efficiency is therefore the first steps to implement to reduce energy consumption (ie : CO_2 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 is not enough and must be complemented by the development of hybrid solutions integrating / combining renewable to fossil fuels in processes and energy master plans of the industrial plants.

b. Renewable energies: Production and sales of Green gas interest for Natural gas companies?

The fuel-gas called "renewable or green gases" are they competitors of natural gas?
In a certain way yes, because it is true that in most cases they will be implemented in substitution of natural gas. However, they are a good opportunity to place natural gas as a future energy and "non-fossil" energy. In fact because of its specificity and those of the distribution infrastructure, natural gas is the best energy source for a rapid implementation of renewable energy in future energy mix.

- The transport and distribution grids can be used to distribute fuel “green gas” or bio fuel-gas ;
- Natural gas can be perfectly blended with poor fuel-gas or refined bio-methane. The only constraint is related to the specifications of the gas network or traces components for some processes ;
- The characteristics of natural gas and their easy to be used, can help the operation of biomass to energy conversion units. For example : Use of low grad biomass in biomass boiler - Compensation of biomass quality fluctuations by a natural gas boosting burner ;
- The storage capacity of NG networks, can be use as a regulatory factor and increasing of the value of renewable energy which are mostly intermittent and somewhat non controllable

c. Reduction of Carbon footprint

In a context of high prices and volatility of energy, strengthening of environmental regulations, which means, drastic reduction of energy consumption (CO_2 reduction); energy efficiency is becoming one of the most important issues for the competitiveness of industrial plants. Many industrial companies like steel, chemical, paper mill, glass and paper industries are committing long term (15 to 20 years) energy efficiency plans with ambitious targets of consumption reduction (CO2 reduction).

These action plans start from simple energy efficiency action plans to complex action plan including Re-engineering of energy master plan in order to reduce drastically Carbon footprint or development of free CO2 industrial plants.
To reach this objective industrial market need competitive solutions on the both topics energy efficiency and introduction of renewable energy in their energy master plan. This means development of tools and industrial solutions for:

- Methodologies and expertise to do energy audits
- High efficiency process regarding energy consumption and environmental
- Solutions for Implementation of high level of heat/energy recovery on site or with the near territory
- Solutions to provide free carbon energy resources and free carbon raw materials.
- And **implementation of renewable energy, especially bio-fuel gas, in the energy mix of the plants.**

In this way, there are already existing innovative initiatives such as:

- The research conducted by the CANMET-Energy in Canada around the energy integration of industrial processes, the implementation of innovative assessment methodologies (ex: LCA or Pinch analyzes) and that in many industries sectors (Pulp and paper, oil refining, iron and steel);
- Specific references:
  - Tembec mill in SKOOKUMCHUCK, British Columbia (Canada)-Significant reductions in freshwater demands, effluent levels and energy consumption for a pulp mill
  - The treatment plant Saputo whey in St-Hyacinthe, Quebec (Canada) - A study on the integration of processes to identify opportunities to reduce energy consumption by 20% in a whey processing plant
- Initiatives in the area of Chemistry (Methods: 12 principles of green chemistry - United States) and innovation campus (IDEEL - Institute for the Development of Eco-Technologies and low-carbon Energy of Lyon - France)

In this context, there are opportunities but also obligations for natural gas companies to help their customers to reach those targets. These opportunities for new business will take a form into development of high energy and environmental performance technologies; Expertise services for high level of energy efficiency and energy services to implement and operate these innovative technical solutions. All of this new offer could be built with new business approaches.

3. Available Resources of Bio fuel-gas (bio-methane and biogas)

Biomass sources:

- Sewage or manures: Sewage treatment plants produce methane rich gases from controlled anaerobic digestion.
- Landfill wastes: All landfills produce methane rich gases. Collection, treatment and utilization of the waste gases is quite well possible.
- Cleaning of organic industrial waste streams: Anaerobic digestion processes are often successfully applied to clean the waste streams of agricultural processing industry. The methane rich gases are mainly utilized to produce electricity.
- Agricultural organic waste: Mesofil and Thermophil digestion of municipal organic waste in compact installations convert at higher temperatures to methane rich gases.
- Non-food cellulosic material, and ligno-cellulosic material or Wood: Generally conversion to energy is made by thermo-chemical (like gasification) process to bio-methane/bio fuel-gas

Bio fuel-gas/bio-methane or biogas:

Bio fuel-gas production is becoming more and more attractive, thanks to the gradual introduction of regulatory restrictions on the treatment of organic waste and several renewable energy commitments made by a lot of countries all over the world. Legislation and policies covering agricultural, environmental and energy aspects have an impact on the development and implementation of plants for biomasses to energy conversion. Among European countries there is a general strong political tendency towards supporting renewable energy, especially after the Kyoto agreement.
Bio-fuel gas production is a promising/efficient way to satisfy all the European Union policies expectations. First, it’s a good answer to the main objective of the Renewable Energy Directive (2009/28/EC) which aims for a 20% share of energy from renewable sources in overall Community energy consumption by 2020. Biogas upgraded to bio-methane could be use as natural gas in any industrial process.
Besides, this text plans that the contribution made by biofuels and bio-methane produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that of other biofuels, which makes the “fuel-grade biogas” use far more attractive.
Biogas from anaerobic treatment also meets the European organic waste management objectives enshrined in European regulations (Directive 1999/31/CE on the landfill of waste) that requires Member state to reduce the amount of biodegradable waste disposed of in landfills and to implement laws encouraging waste recycling and recovery (Directive 2008/98/EC on waste.)

Biogas production and valorisation is booming in Germany and has become Europe’s fastest growing renewable energy sector. Across the European Union, the rapid progress of the sector is obvious, as in 2009, primary energy growth increased by 4,3%[1]. No doubt that the “gas” Directive (2009/73/EC) has contributed to this boost. In fact, this directive invites all Member State to adopt concrete measures in order to encourage a stepped-up use of biogas, by extending the regulations made for natural gas to the gas produced from biomass provided that all the safety standards and technical rules remain fulfilled.

Most countries are interested in using bio fuel-gas for combined heat and power (CHP) production in order to increase the supply of ”green” electricity. In countries such as Denmark, Germany and Austria, the investors in biomass conversion to energy plants get

[1] Biogas barometer – EUROBSERV’ER – NOVEMBER 2010

investment subsidies, a higher sale price on electricity or reduced interest on bank loans. This has clearly created incentives in these countries for building new plants. This context many initiative or programs to develop energetic valorization of biomass are in development especially in Europe:

- In Germany, the "Integrated Energy and Climate Program" (IEKP), shall act as part and parcel for reaching the goal of reducing the green house gas emissions by 40 % in 2020 compared to 1990. The package consists of 29 concrete measures, which help to define the subvention programs and regulation concerning renewable energies.
- In the Netherlands, the program Clean and Efficient (Schoon en Zuinig) describes the climate goals for the Netherlands. The targets of this climate policy are; a reduction of greenhouse gas emissions by 30% compared to 1990, a rate of energy efficiency improvement of 2% per year and a share of renewable energy of 20% in 2020. the commercialization of biogas, a green certificate system has been created, called Vertogas.
- In Sweden a lot of incentives for developing biogas are existing. This energy is exempt from CO2 tax and for each biogas plant the government allocates a grant up to 30% of the amount of the total investment (Climate Investment Program Klimp).
- In Switzerland, the national gas industry organization has established a clearing fund to support biogas and since 2001 the “Naturmade certification” has been created to value electricity coming 100% from renewable sources.
- In the United Kingdom, market mechanisms have been established to support the biogas sector - Renewable Obligation Certificates (ROCs) has been implemented, as well as feed-in-Tariffs for electricity.
- In France, the Grenelle II law sets the principle of a new feed-in tariff, more attractive, which should encourage investors and boost the biogas market. In fact, a series of incentives are currently under discussion to define the framework for bio-methane injection opportunitie.

Outside of Europe the United States are also concerned, a lot of Federal programs and state programs in primarily California, Pennsylvania, Wisconsin and New York state have been major drivers for the development of Biomass energy plants in the U.S.

Although Russia shows a high potential for biogas production, it will have to change the internal policy in the field of renewable sources of energies and waste management in order to direct the country to a more sustainable path of development.

Driven by strong growth in countries like China, India, Japan and Australia, the renewable energy sector in Asia Pacific is expected to grow rapidly in coming years. China will lead the growth of renewable energy in the Asia-Pacific. The Chinese Government has established a target of generating 15% of country’s electricity through renewable by 2020 and has also initiated support measures for small hydro and biomass facilities. China, Australia and Japan use both Renewable Portfolio Standards (RPS) and feed in tariffs to promote renewable. In Thailand offers additional fixed tariffs for small renewable energy projects.

Bio-methane resources in Europe [[2]]:

The total EU27 bio-methane potentials currently range from 1 075 TWh/yr to about 1 350 TWh/yr.

[2] DBFZ- “Evaluation of the European resources for gaseous biofuels in the agricultural, forest, industrial and waste sectors with the main focus on France and Germany” - Ruth Offermann ; Marcel Buchhorn; Daniela Thrän ; October 2009

As biomass potentials in general have to face various uncertainties, it is appropriate to generate result ranges rather than averages. The French contribution to the potential is the largest of all European countries and varies between 200 and almost 250 TWh/yr. The German potentials are slightly smaller ranging from 150 to 225 TWh/yr. Most of these potentials currently remain unused.

The Figure 3 show the current potentials of bio-methane in the European Union member states separated into biogas and Bio-SNG based potentials.

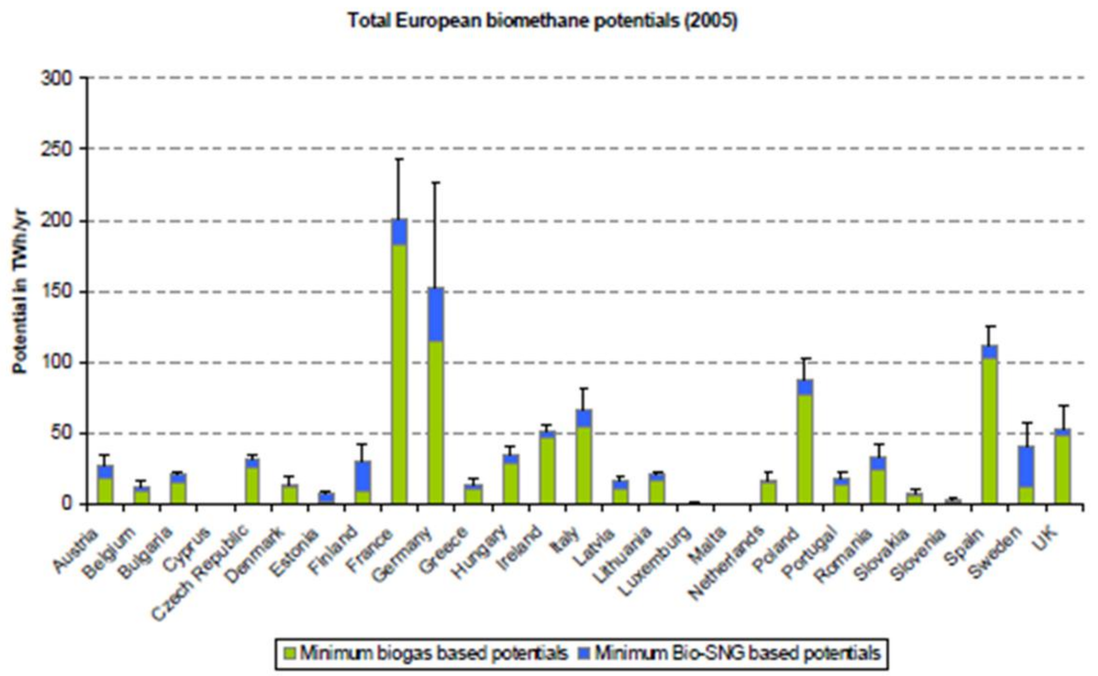


Fig 3: Total European biomethane potentials (2005)

Overall, it can be expected that the potential of bio-methane will increase in the future. This assumption is supported by the fact of increasing agricultural production trends, likely improvements of waste collection systems and presumably significant rises of energy crop yields. Thus, all scenarios show an increasing overall bio-methane potential until 2020, whereby the smallest growth occurs in the Sustainability scenario. The BiomassMax scenario shows that the total European bio-methane potential in 2020 is between 1 500 and about 3 200 TWh/yr, depending on the scenario chosen and the corresponding ranges of the potentials.

Taking a closer look on the composition of the French potential, it becomes obvious that the current potential here is mostly dependent on energy crops cultivated for the purpose of producing biogas. The second important resource presently is represented by agriculture residues. Depending on the different scenarios, the relative shares of these resources will change, partly significantly, until 2020. In the Sustainability scenario the meaning of biogas energy crops diminishes substantially as forest resources and particularly short rotation coppice become more important. Also in the BiomassMax scenario short rotation coppice has a much higher potential than today but also biogas energy crops are at a relatively high level so that after all the BiomassMax potentials are clearly exceeding those obtained in the other scenarios.

4. **Different study cases and emerging solutions focus on How to reduce carbon foot-print of fossil fuel energy uses by integration of renewable energies**

a. Energy conversion of Biomass: Biogas or Bio-methane or Syngas production from Biomass?

Bio-fuel production processes: Renewable gases or gases from biological origin include methane- or hydrogen-based gases that can be produced by using different biomass fractions as raw materials and different technologies for fuel conversion. There are two main conversion technologies to produce methane-based gases: anaerobic digestion and gasification.

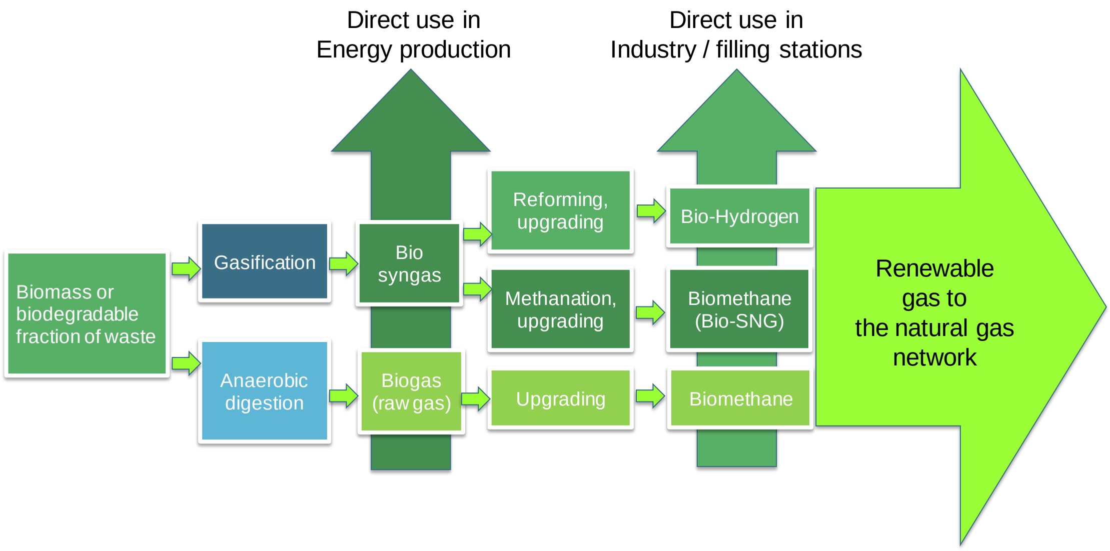


Fig 4: Chain process for Biomass conversion to energy

Potential raw materials in anaerobic digestion include sewage sludge, landfill gases, animal manure, co-products of food industry, planted energy crops, algae-based biomass and other decomposed biomass. In gasification process, wood or other lignin rich biomass is used. So, also co-products of forest industry are an interesting option.

Definition:

Biogas: Anaerobic digestion of biomass produces biogas, sometimes called also raw biogas. Typically biogas consists of 35-65 per cent methane. The other components of biogas include carbon dioxide, water vapour and nitrogen compounds. Biogas can be combusted as such in energy production plants or it can be upgraded via treatment to meet the quality requirements of gas fed into the natural gas transmission system.

Syngas: Thermo-chemical process (gasification) of biomass produces Syngas or synthesis gas. Syngas contains among others carbon monoxide, carbon dioxide, hydrogen and methane; typically Syngas consists of 20-25 per cent carbon monoxide and environ 30 per cent Hydrogen. Depending of thermo-chemical processes, Syngas include also water vapour and nitrogen compounds. The product gas is cleaned and via different synthesis processes different final products can be produced. Syngas can be combusted as such in energy production plants and processes or it can be upgraded via methanation process to meet the quality requirements of gas fed into the natural gas transmission system. In the case the synthesis process is methanation, the final product is called SNG (synthetic natural gas or substitute natural gas) or bio-SNG

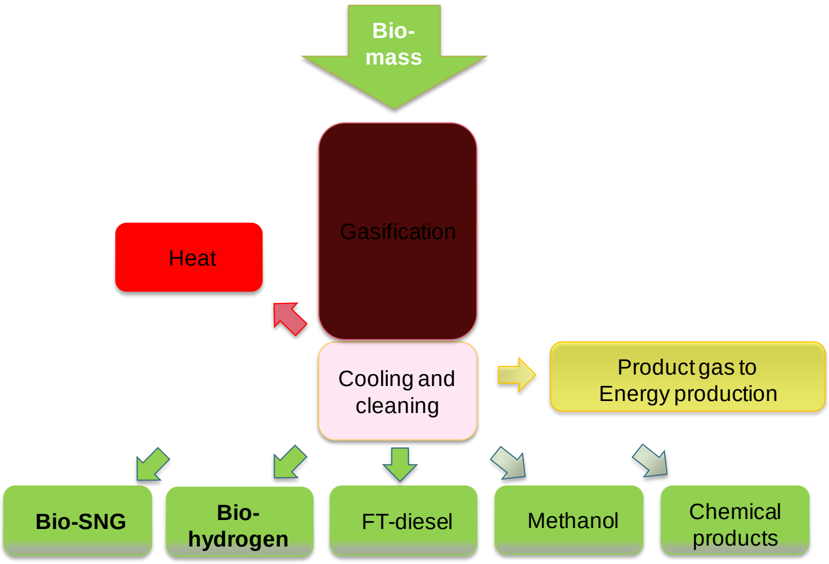


Fig 5: Thermo-chemical biomass to energy conversion

Bio-methane or bio-SNG: Upgraded biogas or Syngas typically consists 95-97% of methane. Often it is called bio-methane. The Gas Technology Institute (GTI) defines biomethane as follows: "Bio-methane is the the portion of biogas which consists primarily of methane. Biomethane is generally extracted from raw biogas through cleanup or "conditioning" to remove "other" gases which impact gas quality or produce from Syngas méthanation process treatment. biomethane can be up to 99% methane, with concentrations of "other" gases. However, "raw" biogas or Syngas may contain only 35 – 65% methane. Bio-methane is considered suitable for many end-use applications and may be considered suitable for inclusion in general pipeline systems, depending upon other characteristics of the gas and specific tariff requirements.

Biomethane is also called as 'green gas' in the Netherlands or 'renewable natural gas' in the United States.

Similar way by Fischer–Tropsch synthesis liquid FT-diesel can be produced. Therefore, bio-SNG and bio-hydrogen are potential final products of bio-refinery.

Similar way to natural gas, also bio-methane can be compressed to high pressure up to 200 bar and it can be used as transportation fuel in cars and buses. For example, in Sweden and the Netherlands compressed bio-methane is called as compressed biogas (CBG).

These processes are generally developed with three different strategies:

- Decentralized production units of biogas or Syngas using local resources of biomass or wastes coming directly from factory or collect locally and distributed directly to local processes or boiler workshop.
- Decentralized production units of bio-methane using local resources of biomass or wastes coming directly from factory or collect locally and provide via injection in the natural gas distribution grid ;
- Mass production units of bio-methane using meanly import biomass and provide in a large territory via injection in the transport natural gas grid.

In the next paragraph we will show through some example of innovative projects what could be opportunities for natural gas companies to develop new activities and guaranty place of natural gas in the next energy mix.

b. Direct use of bio-fuel gas through : Biomass gasification (Direct use of syngas in furnaces – BioVive project) – (GDF Suez + others)

Production of glass (hollow glass or flat glass) requires very high temperature (~1 600 °C) of process. Melting sand and chemical components, in order to obtain appropriated melting glass to be processing in different pieces, like bottles, needs a high level energy consumption (30 to 40 % production cost). Even if recycling process for the glass waste is well organized the final CO2 contains of glass bottles is high. In the new energetic context glass manufacturers and producers of fine wines, try to find solutions in order to reduce drastically the consumption of energy (CO2 emissions) in their bottles factories and in order to move forward to Eco-design products.

In this context Saint-Gobain Packaging (VERALLIA), GDF SUEZ, XYLOWATT, CIRAD and the CIVC have been mobilized to accelerate the substitution of fossil energy in new and renewable energy as fuel-gas for glass melting furnaces. The partners have joined around one goal: replace some fossil fuels by a syngas coming from the gasification of biomass, including wood wine yard residues.

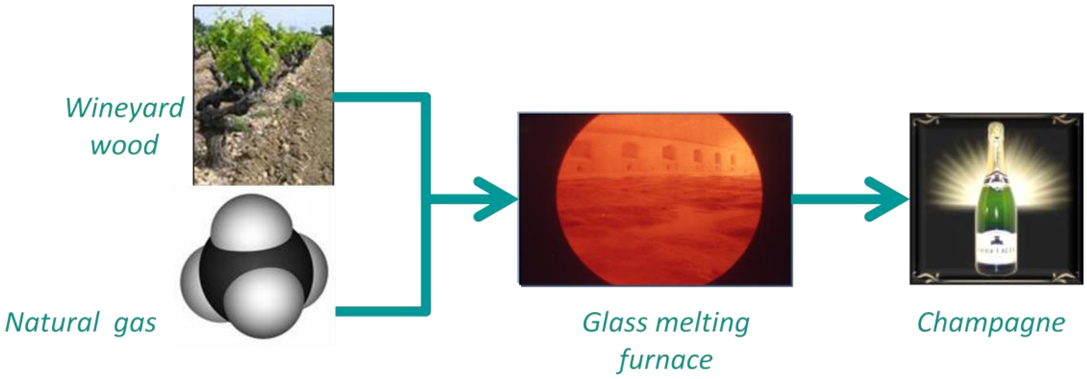
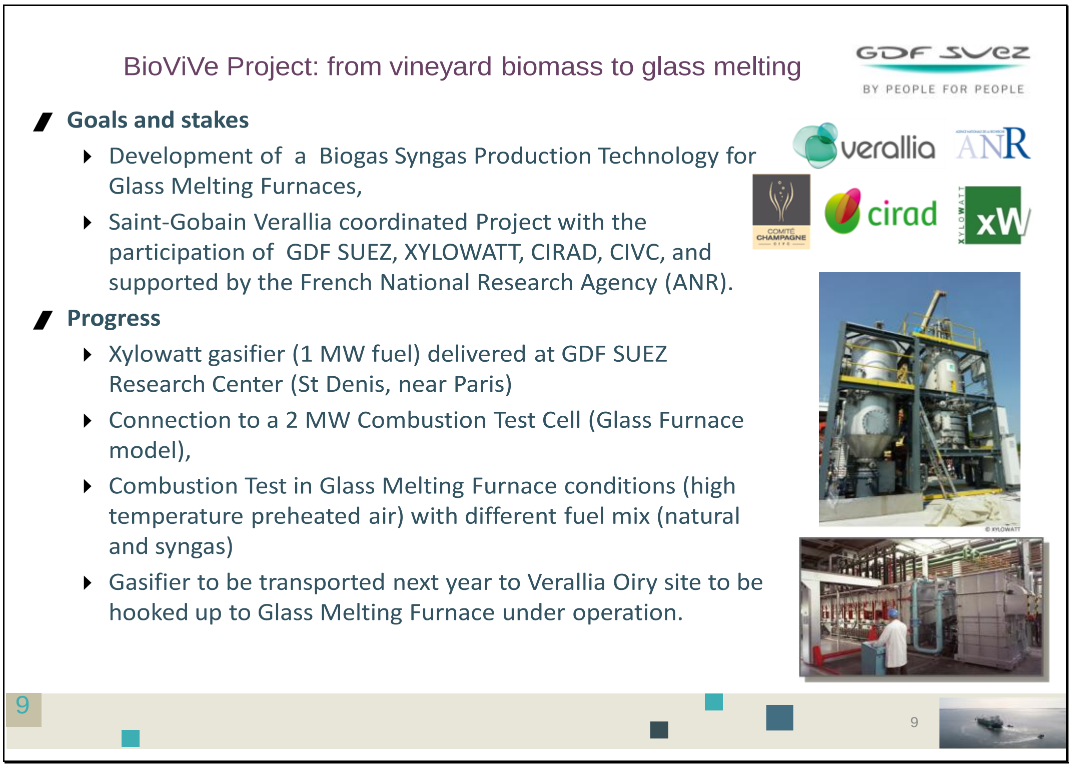


Fig 6: BioVive Project - Value chain to reduce CO2 contain of champagne bottles

For this, a pilot project entitled BioVive (Biomass Wine in the glass furnace via a gasification process) and based on drastic CO2 reduction of glass bottle contains for wine region of Champagne, a complete study and characterization of energy conversion of a furnace has been build. The project includes:

- The development of a gasification technology with a nominal output power of 1 MW Syngas,
- The development of specifics Syngas burners and test for optimum combustion
- Test on pilot furnace in order to characterize combustion system and heat transfer to the glass bath (2011)
- And finally a demonstration operation on a production site located in the Champagne region (2012-2013).

This project will assess and characterize also the resource "waste wood of wines" in Champagne and optimize the gasification process to obtain a synthesis gas that best suits the needs of the glass industry.



The technology of gasification use XYLOWATT is the NOTAR® technology. This gasification reactor is a multi-stage flow reactor with a nominal capacity to produce 1 MW of Syngas. The temperature of biomass gasification is between 700°C to 1200°C. The global efficiency expected is around 98%.

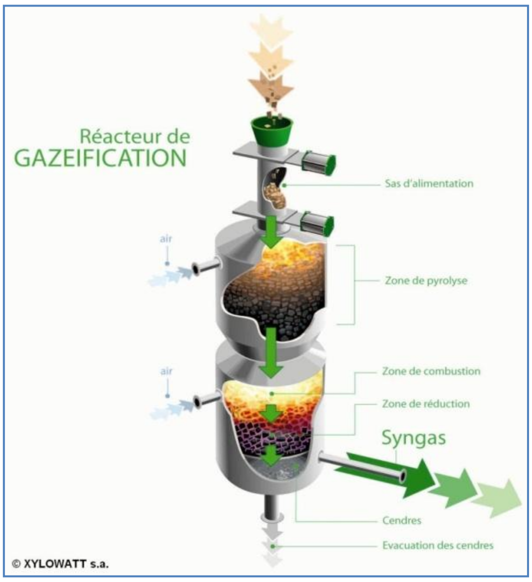


Fig 7: Xylowatt NOTAR® technology [3]

At the end of this program of research and development, the partners hope to test a BioVive substitution rate to about 7% of the fuel feeding the glass furnace and have acquired the knowledge necessary to deploy the technology to other furnaces and markets. The project

[3] XyloWatt web site – description of Notar technology

with a global budget of 5 M€, is funded by the ANR (French National Research Agency) and has been labelized by the Food industries clusters (Champagne Ardennes - Picardie).

c. Mass production of Bio-methane from thermo-chemical treatment of Biomass (Götheborg ENERGI - EON – GOBIGas project [4])

In the eighties national natural gas grid was built in southern and western parts of Sweden, with natural gas from Denmark. This network is an important part of the conversion to renewable energy. Gothenburg Energy invests heavily in biogas and sees biogas as one of tomorrow's most important energy sources. A major benefit of biogas is that you can use the existing natural gas grid for distribution. Natural gas is becoming a bridge over to the renewable biogas.

Gothenburg Biomass Gasification Project, GoBiGas, is the name of Göteborg Energi's large investments in biogas production by gasification of biofuels and waste from forestry. The project is run in partnership with E.ON. GoBiGas was granted financial aid at 222 million in September from the Swedish Energy Agency, as one of three selected projects, provided acceptance from the European Commission. Göteborg Energi expects to deliver in 2020 biogas equivalent of 1 TWh. It represents about 30 percent of current deliveries in Gothenburg or fuel to 75 000 cars.

Biogas replaces natural gas – biomass becomes biogas

The GoBiGas biogas project is about producing bio-methane (Bio-SNG) by thermal gasification of forest residues as branches, roots and tops. The biomass is converted to a flammable gas in the gasification plant. This so-called synthesis gas is purified and then upgraded in a methanation plant to biogas with a quality comparable to natural gas to enable the two types of gases to be mixed in the gas network, until the natural gas is phased out. Since biogas is produced from renewable sources this does not contribute to increasing emissions of carbon dioxide as fossil fuels do.

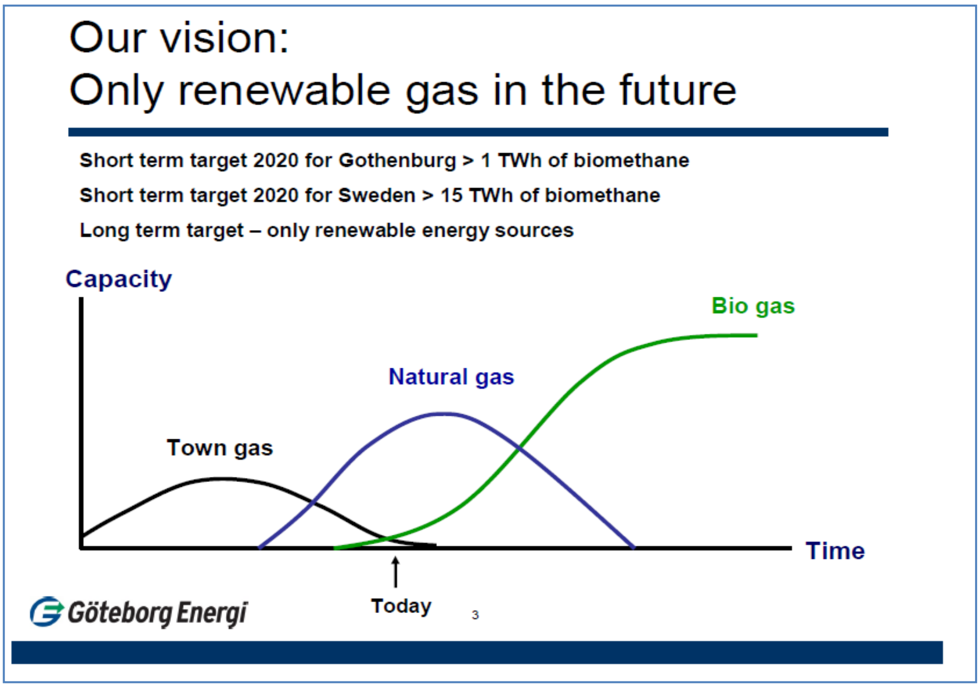


Fig 8: Use of Bio-methane – future integration in energy system

[4] Göteborg Energi web site – GoBiGAs project.

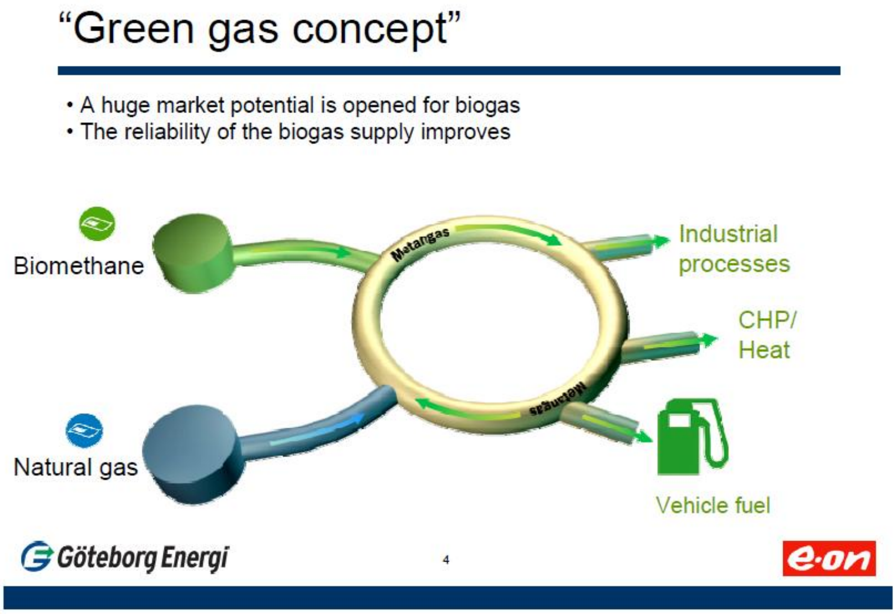


Fig 9 : Green gas concept – future integration in energy system

GoBiGas based on new technology

In spring 2006, Göteborg Energi conducted a feasibility study with Swedish and Dutch expertise in order to compare the technology and economics of the two gasification technologies, indirect gasification and pressurized oxygen blown gasification. In 2007 in-depth studies of various gasification technologies with multiple suppliers were carried out. The choice fell on indirect gasification with technology from the Austrian company Repotec, based on technical and economical performance and operational experience. Göteborg Energi cooperates in particular with Chalmers University of Technology and has invested in a research facility for the indirect gasification constructed together with an existing biofuel boiler, built with CFB technology.

In 2008/2009 a Basic Design was conducted of the proposed technique for stage 1. Repotec has built a small gas plant in Güssing, Austria, which has been in commercial operation since 2002. Adjacent, on the same site, there is also a pilot methanation plant, based on technology from the Swiss company CTU. The project GoBiGas involved in the operation with operational staff on site from October 2009 to January 2010 in order to evaluate the technology.

Objective to achieve good performance

In the choice of technology and plant design the project aims to get as high efficiency as possible. The goal is to reach 65 % of the biomass into biogas, and that the overall energy efficiency will be over 90 %.

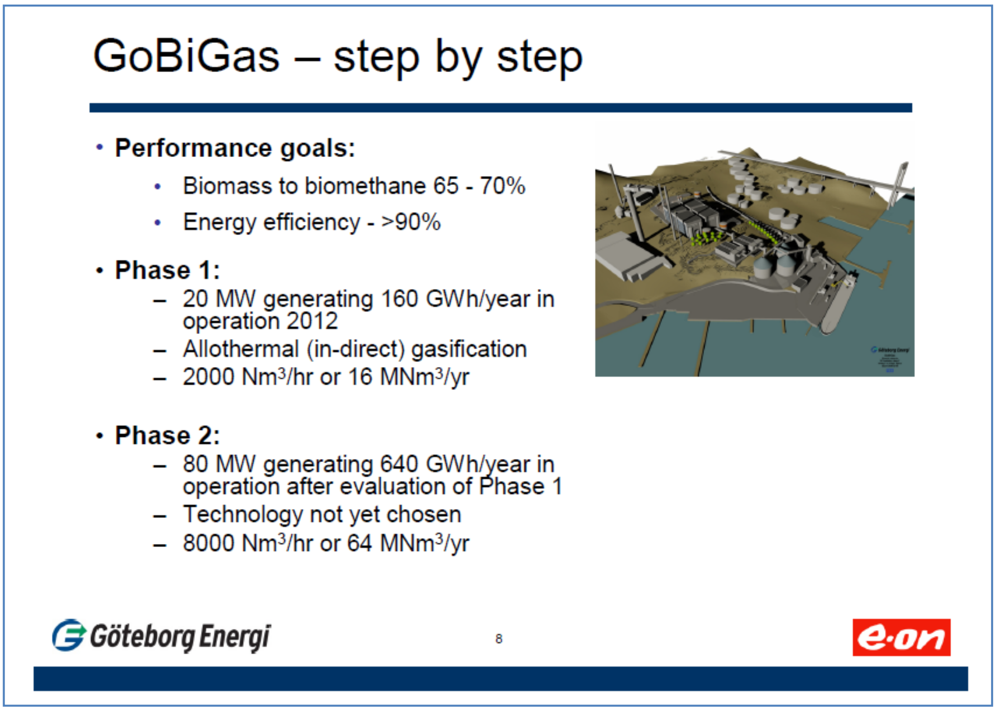


Fig 10: A deployment step by step

The plant is split into two stages

The gasification plant is scheduled to be built in two stages, the first stage (about 20 MWgas) to be built during 2010-2012 and to be operational in late 2012. The second stage (about 80 MWgas) is scheduled to be built in the years 2013-2015 and put into service 2016. Next step will be to build 2 or 3 installations, with for each a nominal capacity of 100 MWgas, in order to reach 10 TWh per year of bio-methane production in 2020.

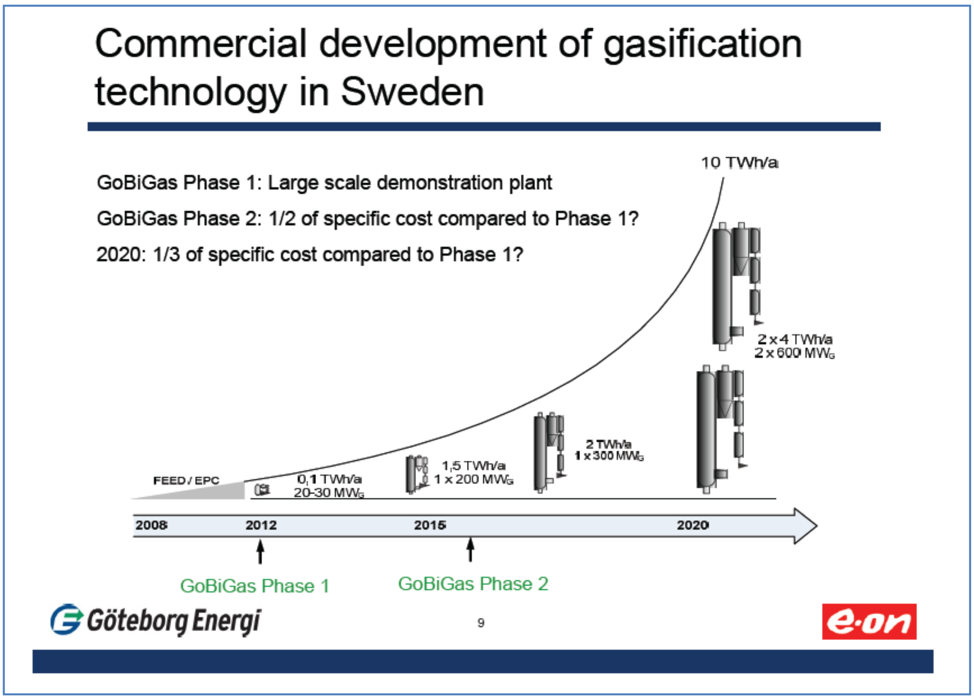


Fig 11: perspectives of technology deployment in Sweden

Localization in the Rya area on Hisingen

The plants will be built in the Rya harbour. The location has been chosen so that the plant will be close to a hub for Gothenburg in electricity, gas and district heating, and also allowing a long-term and flexible fuel reception because it has the potential for both ship and rail transport. Cooling water to the process can be taken from adjacent Göta River.

5.4 Decentralized or on site production and distribution of bio-methane –- GDF SUEZ -GAYA project)

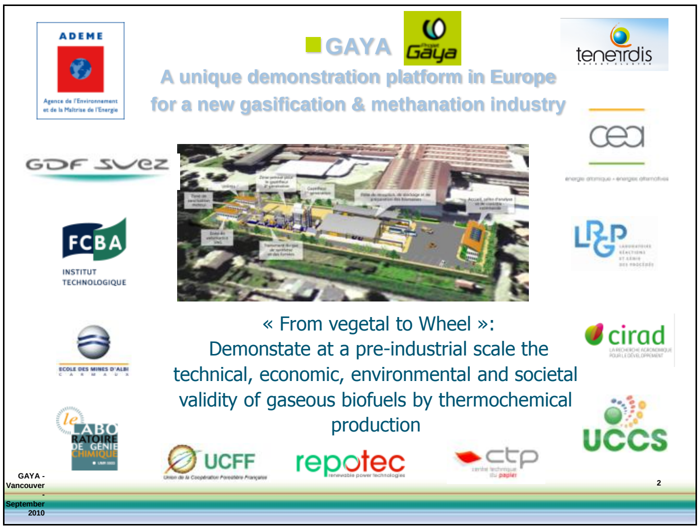
Context

To reach its European commitments in terms of energy production from renewable source, FRANCE need a strong development of the biomass, beside Wind mill and Solar energy. Biomass is part of renewable energy where the potential for growth is the highest in France and where implementation through thermal and electrical applications covers more areas in industrial market. In addition to the environmental aspects, the development of biomass responds to strong geopolitical issues (diversification of energy sources) and economic (job creation and new business development) regional development. ADEME (French Energy and environment Agency) estimated that 150,000 jobs could be created in 2040-2050 by the development of the conversion of Biomass to energy activities sector.

GDF SUEZ which is leader in Europe and third rank Utilities in USA in biomass to energy conversion, with 700 MW installed capacity of electricity production and 600 MW thermal capacities, had decided to be involve in the development of new process chain for the Fuel-gas energy valorisation of Biomass.

Le project GAYA:

In order to promote rapid development of this new sector, GDF SUEZ has developed an ambitious project titled "GAYA" (~50 M€) including a R & D platform on biomass conversion process to Bio-methane. This industrial demonstrator platform included a pilot plant for gasification at a pre-industrial size and innovative process to do conversion of syngas to bio-methane. This project builds in partnerships with 11 industrial companies; technical centres and universities and has a duration of 7 years. It is supported and funds since 2010, by French government through ADEME (French Energy and environment Agency) R&D program on "Innovative Renewable bio-fuels".



Gaya project: A vision of the production of bio-methane decentralized and integrated into the territory

The objective of the project is to develop a sustainable process chain for decentralized production of Bio-methane; well integrated in the territory and using local Biomass resources. Le technology propose is based on medium capacity units (20 to 60 MW bio-methane) which means 100 000 to 300 000 T per year of Biomass. The bio-methane will be provide directly to associate industrial plants or distributed locally through Distribution natural gas Grid. As methanation process generates heat hot water or steam), local distribution of the heat generated will be implemented in order to improve the global energy efficiency and profitability of the production plant.

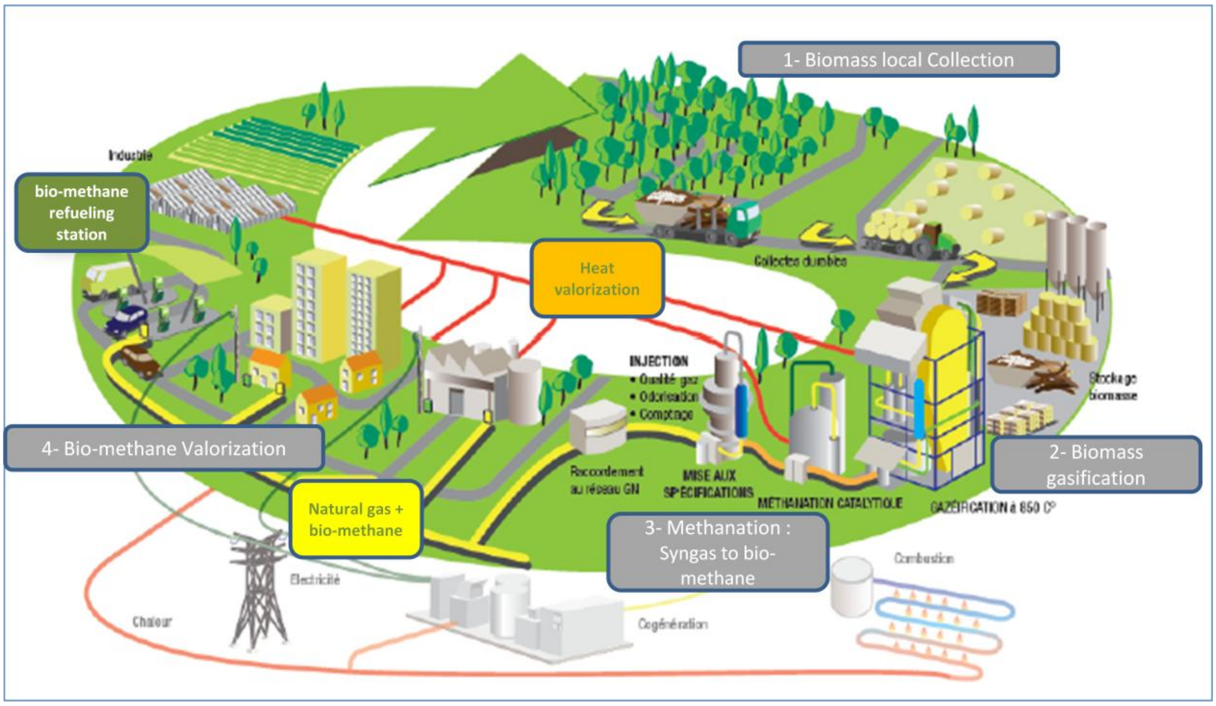


Fig 12: Project Gaya – territory integration of bio-methane production

Gasification is expected to optimize the energetic valorization of biomass

The Gasification technology has been chosen because it’s expanding the scope of ways to do energetic valorisation of Biomass. Indeed; through direct use or treatment; the Syngas can be used to produce:

- Electricity and heat (cogeneration) with a yield of electricity higher than that of conventional technology in cogeneration (steam and combustion in boiler steam turbine): ~ 29% instead of 15%
- Bio-Methane green Bio-fuel of second generation
- Hydrogen.

These facilities are very good overall efficiencies up to 85%.Gasification is therefore in a context of diversification and optimization of biomass conversion.

Project GAYA – a proven technology

For gasification the technology defines is the Fluidized Bed (FICFB technology from REPOTEC Austrian Company). This technology is already running since 2002 in Güssing with biomass fuel.

- FICFB (Fast Internal Circulating Fluidised Bed) ➔ innovative process to produce a high grade synthesis gas
- It could produce Combined heat and power (CHP) plant or Bio-methane with associated méthanation process
- Each module capacity of production is (CHP 2 MW of power and 4 MW of heat for the local district heating network; with 1 T/h wood biomass) or 560 to 700 kw bio-methane

The gasification zone is separated from the combustion zone using two fluidized bed reactors. The technology as demonstrated is reliability through a running more than 7000h /year during 5 years. Syngas quality produce after gasification is well adapted to methanation (~10% CH_4) due to the high level of methane contains.

Fig 13: Repotec FICFB gasification process – Güssing cogeneration units and méthanation pilot plant

Project GAYA – the first demonstration platform for biomass conversion to bio-methane in Europe

The project was build around the development of a new R&D platform for industrialisation of a complete chain of bio-methane production. The R&D program (duration 5 ans) has been developed on:

- Optimization of biomass conversion in Syngas
- Energy efficiency optimization of gasification process
- Optimization of conversion efficiency and reliability of methanation process
- Development of engineering tools and numerical modelling to improve process design and reliability of operating mode of the complete chain

The platform will be an open R&D platform for the development of innovative process like Pre treatment of biomass, cleaning of Syngas and bio-methane and development of advanced catalyst for méthanation process.

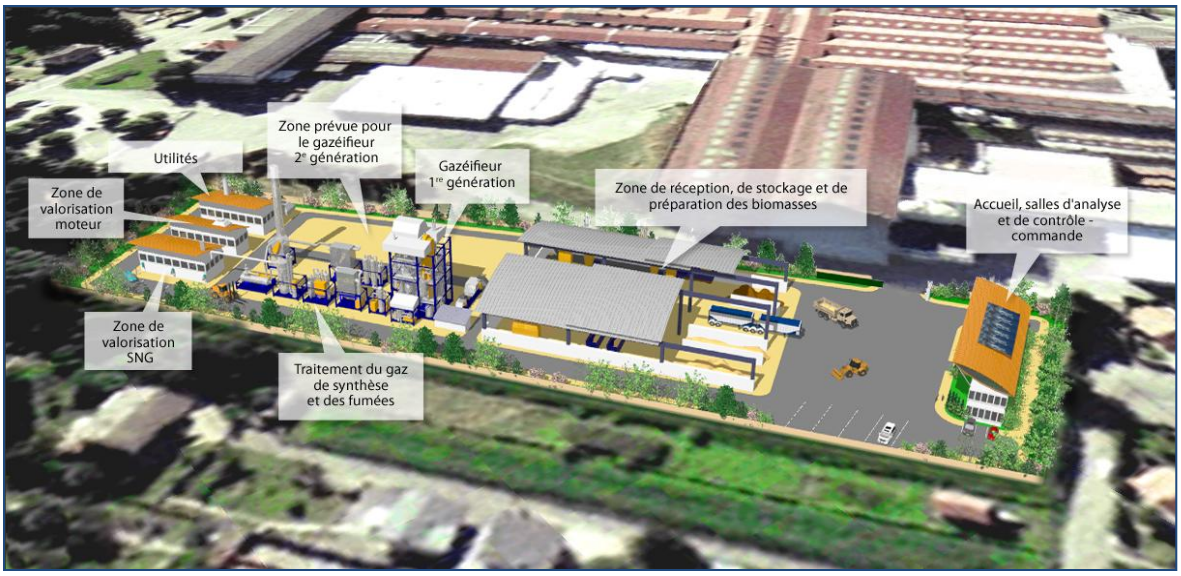


Fig 14: GAYA project - Virtual view of the demonstration and R&D platform which will be installed near Lyon town France

Project GAYA – Commercial deployment in France and Europe

In preparation of the project and during the step 1 of the project different studies has been done on assessment of Biomass resources in Europe and others countries (ex: like Brazil) and also on potential demands of Bio-methane. These studies show that there is a big amount of potential for this kind of supply chain. Results shows that, only for France, there is a potential of 25 TWh in of bio-methane to injection into the natural gas Grid, which means 100 to 200 medium production units using local resources of biomass. For all of Europe the potential can be estimate at roughly 6 times French potential, with of course differences between countries.

5. On site production of biogas through anaerobic digestion integration in energy master plan of industrial plan

The natural process of anaerobic digestion (methanisation) is produced in closed tank (the digester), in which the organic material (biomass or sludge) has a residence time of up to 10 to 20 days. The biogas produced by methane bacteria, is collected and part of it is used to maintain the digester to a temperature between 35 and 55 ° C, for optimal activity of micro-organisms. The rest of Biogas can be burned in boilers to provide heat. It can also be used as fuel in a CHP to provide electricity and heat and /or cleaned to be injected in Natural gas grids. Dehydration and cleaning of biogas to remove pollutants such as sulphur is often necessary prior to recovery or final use.

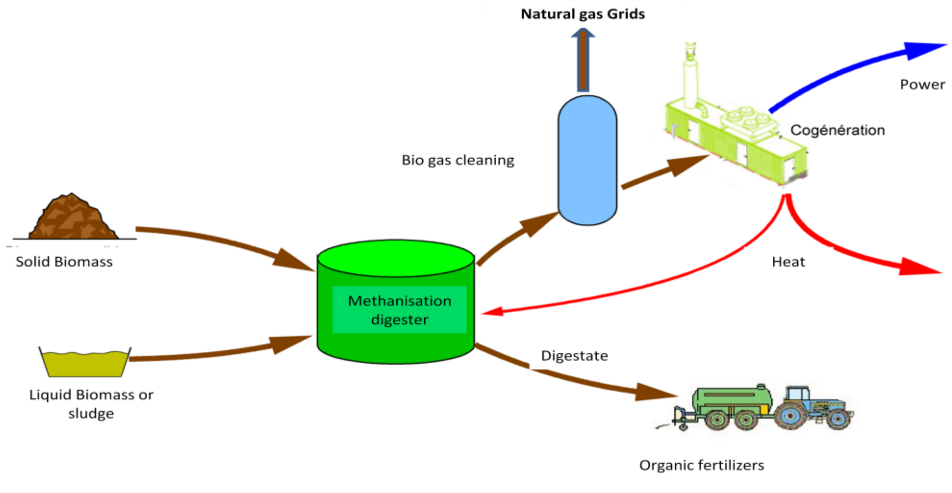


Fig 15: Classical of methanisation process

In addition to biogas, anaerobic digestion produces a by-product - the digestate - consists of minerals and easily degradable organic material (such as wood waste) initially present in the biomass. Stabilized, largely rid of pathogens (bacteria, but viruses and parasites) it has retained some of the fertilizer capacities. However, it's quality is not sufficient to be use directly and valued as an amendment agriculture. The valorization of the digestate is a major issue of industrial implementation and profitability of this kind of plants. Indeed, post-treatment of biogas but also of digestate, such as dehydration, drying or composting, are Key financial factors for this plants.
Nevertheless, due to the large amount of material resources (wet biomass, sludge, manure...) there is a great interest for this technology for local or regional production of green energy, especially in countries where agricultural activities are important.

In Europe the most important industrial projects on the use of methanisation for local production of green energy are:

- In nineties implementation of anaerobic digestion treatment of pork manures coming from pork farm in Denmark. In this project more than ten industrial plants were built and operated and connected to regional districts heat plants or dedicated biogas grids.
- More recently the **GROEN GAS** project developed by KEMA company [5] and supported by Dutch government. The ambition of this project is to test at the scale of a region in Netherlands a full injection of biogas in 40 bar natural gas distribution networks (See fig 16 here under). The objective are to test the uses of biogas everywhere the natural gas is used (transport sector; Commercial and residential markets...) and develop a complete certification system, call VERTOGAS, in order to facilitate deployment of biogas supplying into natural gas infrastructure. The next steps of the project will be develop Green gas Hubs, to couple this project to the rest of the natural grid and renewable resources of energy in order to develop a sustainable energy distribution smart grids .

[5] "Transport of renewable gases in the gas infrastructure"– Pierre M.G. Bartholomeus - KEMA.

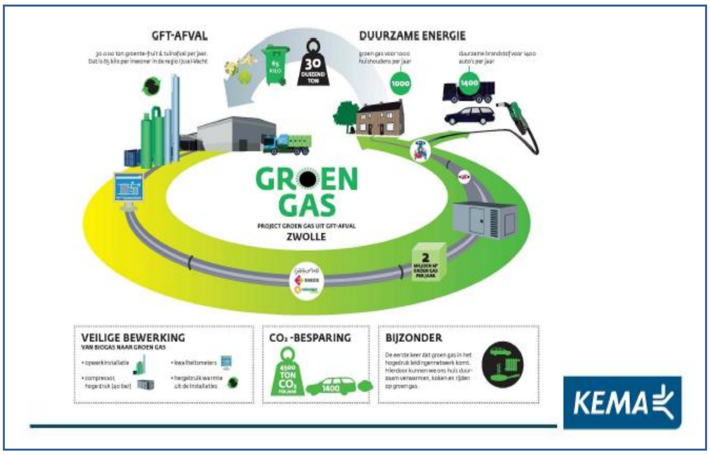


Fig 16: Groen Gas project - Netherlands

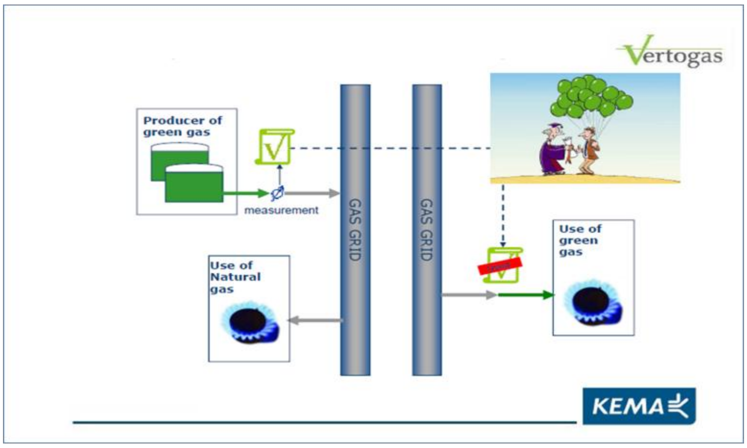
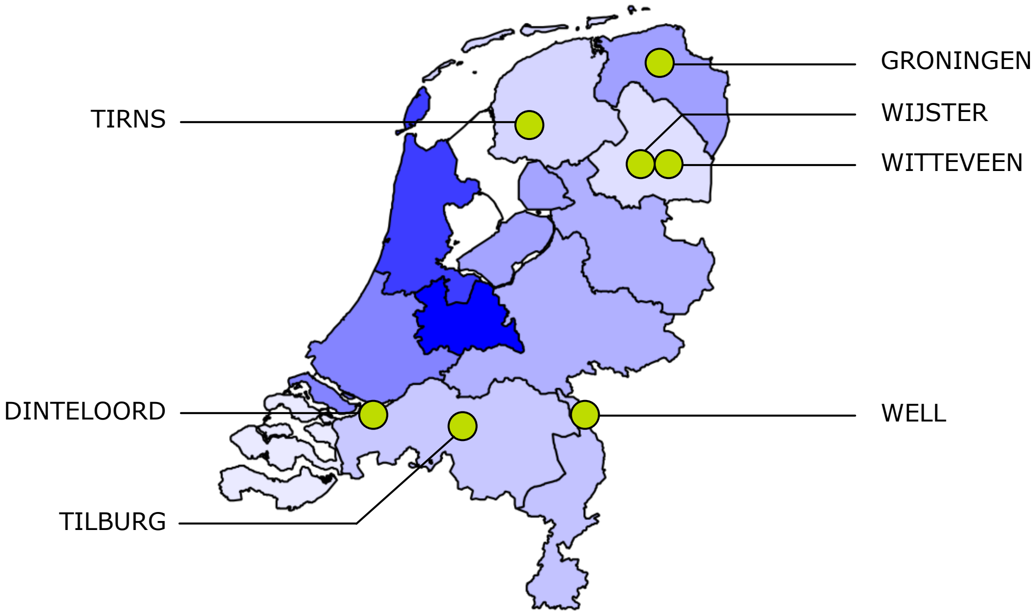


Fig 17: Injection into 40 bar natural gas Grid

New example: ENEXIS green gas tests injection /Hubs

In the Netherlands you have more than 10 locations where Green gas is produced en feeding the national or regional grids. Early 2009 the feeding production was 1200 Nm^3 Green gas/hour at the end of 2011 the production was raised to 24.000 Nm^3 Green gas/hour. This is lesser then 0.1 % of the use of gas inside the Netherlands. The purpose for 2014 is 300 million m3 /year and for 2030, 3 billion m3/year.
Upgraded biogas is injected in the Enexis gas grid at seven locations. Every year injection is approximativally about 28 million m^3 and representing 17.500 households. This biogas is produced from both organic materials in landfills and organic waste, which has been collected separately.



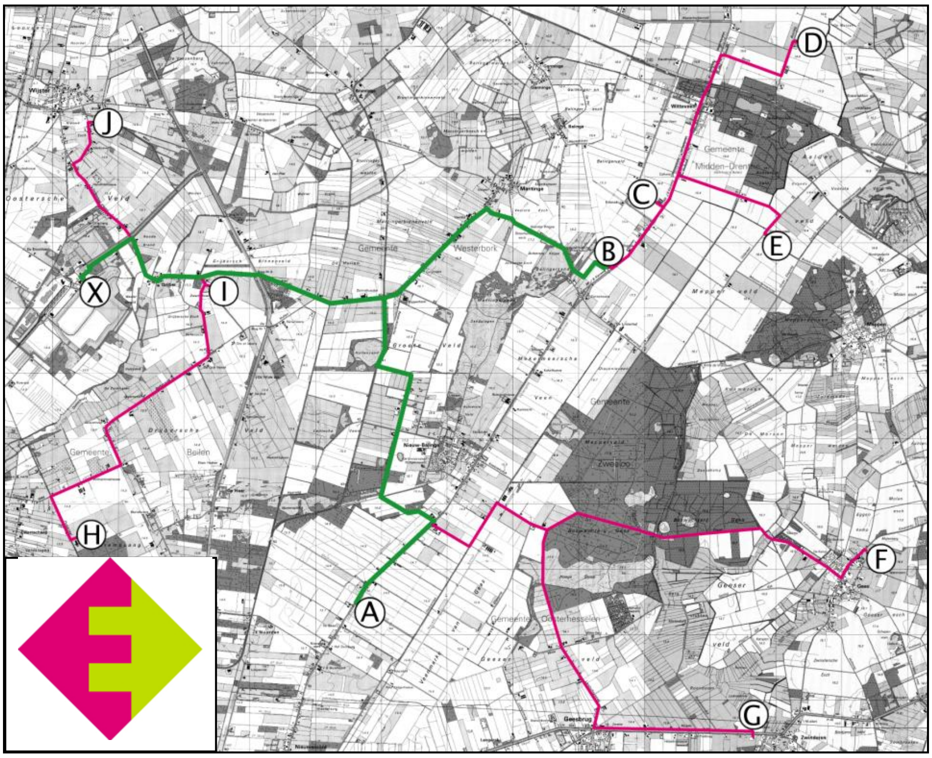
Tirns	200 m3/h	Witteveen	200 m3/h
Groningen	700 m3/h	Well	300 m3/h
Wijster	500 m3/h	Tilburg	300 m3/h
Dinteloord	900 m3/h		

Fig 18: Netherlands. Repartition of green gas hour production per land

In the northeastern part of Friesland, in Wijster and in Overijssel, biogas hubs are being developed with a total production capacity of approximation 92 million m^3 crude biogas.

In rural areas, crude biogas is transporting to a central location – a biogas hub – seems to be an obvious solution. Several producers inject crude biogas into a central pipeline which transports the gas to either an industrial consumer or an upgrading facility that upgrades the biogas to green gas quality for injection into the natural gas grid.

For example: Biogas Hub in Wijster: crude biogas from several local producers is transported to a central upgrading facility by Attero and then injected in the national gas grid (4 bar)

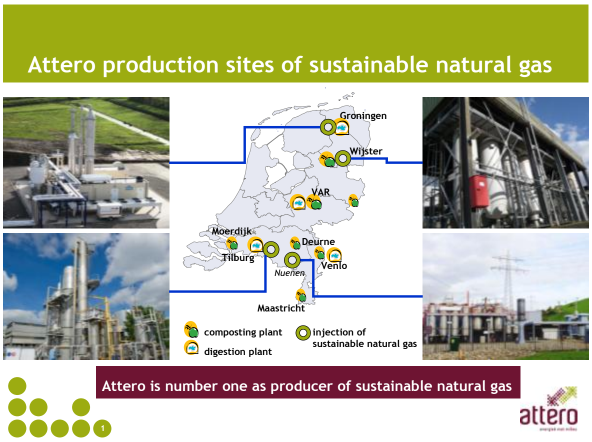


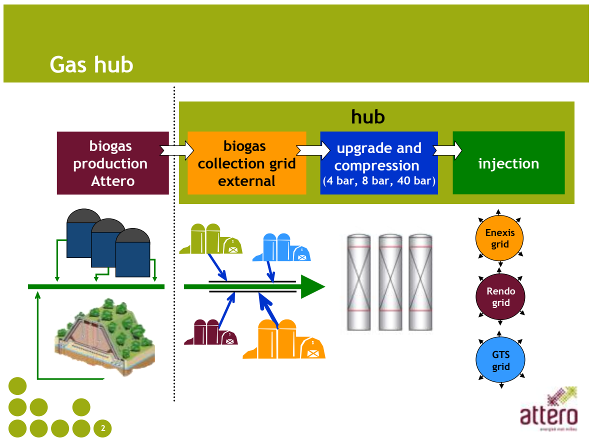
FACTS:

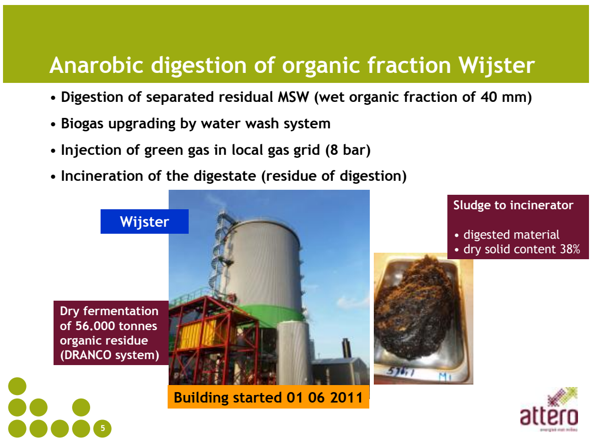
- max. production: 5000 m3/h biogas
- upgraded green gas enough for 15.000 households
- 10 potential biogas producers (A-J)
- 1 central biogas upgrading facility (X)
- 16 km of central pipelines (*green*)
- 33 km of connection pipelines (*purple)*
- Operating pressure: 4 bar

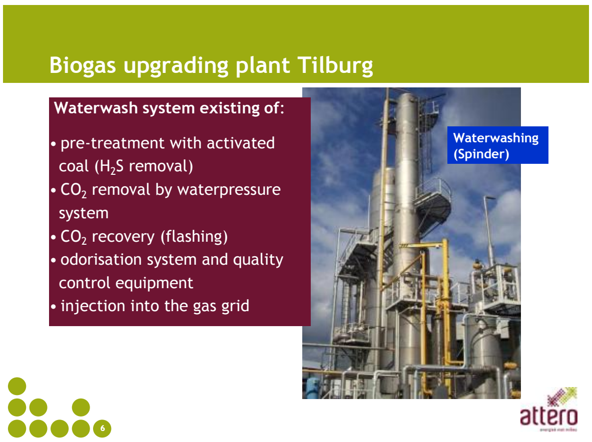
Producers are willing to commit themselves to the project, but without subsidy from the Dutch government (SDE+), this project would not yet be financially feasible. Several producers have received the required subsidies, others are waiting. It is expected that at the end of 2012, the first part of this biogas network is operational.

Further you have as example Attero, where the above mentioned hub is a part of the installation. Attero is a Dutch leading waste company active in the large scale processing of waste into sustainable energy. Attero started to upgrade landfill gas in 1989 at its location the Wijster.









6. Coupling of Thermal solar panel with Hot water or Cooling appliances

6.a.1. Development of Absorption Chiller for Solar Cooling (OSAKA gas and Tokyo gas) [6]

Summery

An advanced absorption chiller for solar cooling (solar absorption chiller) was developed to maximize absorption chillers' efficiency with solar power by Tokyo Gas Co., LTD., Osaka Gas Co., LTD., Toho Gas Co., LTD., Kawasaki Thermal Engineering Co., Ltd., Sanyo Electric Co., Ltd., Hitachi Appliances, Inc.. To enhance system efficiency, a single/double effect combined absorption chiller is adopted for solar absorption chiller, a generator driven by solar power and a condenser are added to a conventional absorption chiller.

System flow

Option (1) Single/double effect

Solar absorption chiller has a back-up gas burner and can be driven by both solar hot water and natural gas. Because natural gas is a heat source for the high temperature generator to drive in double effect (COP: 1.5) and solar hot water is the other heat source for the low temperature generator to drive in single effect (COP: 0.8), the system with it has higher system efficiency than system with a conventional absorption chiller. It utilizes solar hot water by priority and natural gas complements lack of solar hot water by measuring chilled water temperature and controlling the gas burner.

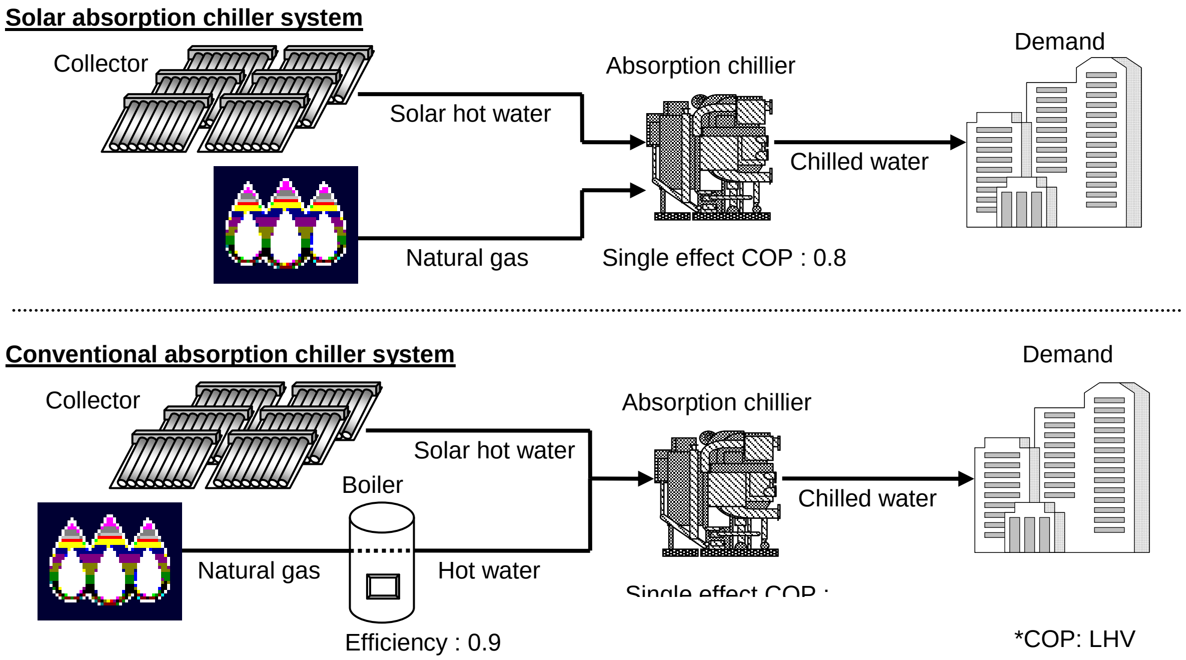


Fig. 19 : Difference of Heat Source Supply between Developmental and Conventional System

Option (2) Solar generator and condenser

Because solar collector has higher efficiency at lower temperature, necessary temperature of solar hot water to drive solar absorption chiller is lowered by combining a low temperature generator (solar generator) and condenser (solar condenser) to enhance collector efficiency.

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6 Keisuke Kajiyama, Solution Technology Department, Tokyo Gas Co., LTD - Tametoshi Matsubara, Commercial and Industrial Market Department, Osaka Gas Co., LT.

To lower saturated temperature in the solar generator and necessary temperature of solar hot water, cooling water is fed to the solar condenser at first.

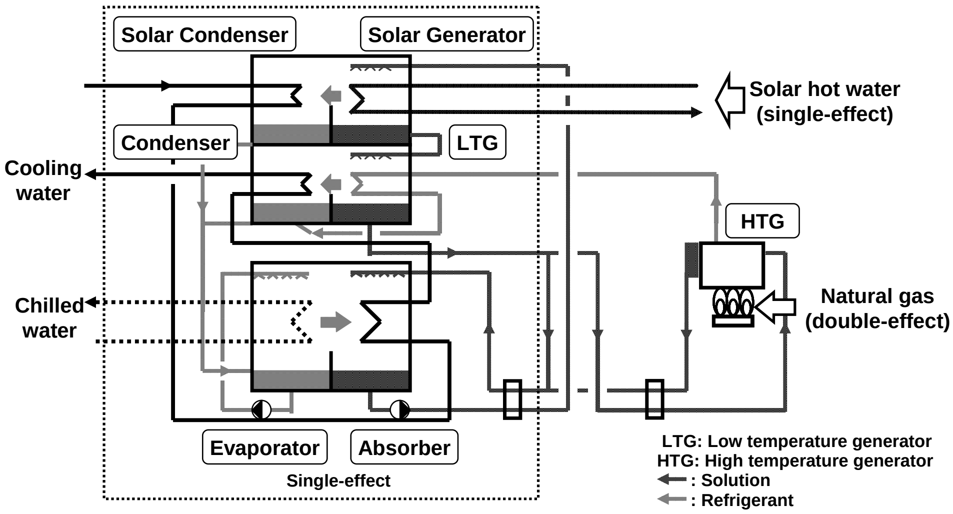


Fig. 20: Diagram Example of Solar Absorption Chiller

Solution water temperature output

To minimize electric consumption of solar hot water pump and lower collector temperature, a temperature sensor is set inside the solar generator to control the pump. Because conventional absorption chiller cannot output its temperature of solution water, the pump can be operated even when irradiance is not enough to heat solar hot water to the temperature that is necessary to drive the chiller. Solar absorption chiller output solution water temperature inside the solar generator and the pump can be operated only when solar hot water temperature reaches high enough but as low as possible to drive the chiller. This function minimizes electric consumption of the pump and enhances collector efficiency.

Demonstration examples

The demonstration plant was constructed in one of Tokyo Gas's branch offices, and has been operated to verify the features since Feb. 2011.

Tab. 1 : Specification of Demonstration Plant

Building	Place	Kanagawa Pref. Japan
	Floor Area	4558m^2
	Application	Office and Showroom
Collector	Total Area	205m^2
	Rated Output*	108kW
Solar Absorption Chiller	Chilling Capacity	352kW
	Rated COP without solar hot water [output of chilled water] / [input of natural gas(LHV)]	1.43
	Rated COP with rated output solar hot water [output of chilled water] / [input of natural gas(LHV)]	1.90

	Chilled Water Temperature	12 -> 7deg.C
	Cooling Water Temperature	31 -> 36.7deg.C

* Irradiance: 1.0kW/m2, Collector temperature: 75 deg.C, Ambient temperature: 30 deg.C

(1) Single/double effect

As shown in Fig. 3, COP with solar hot water was about 2.4 from 14:00 to 16:00, and from 15:20 to 15:45 the solar absorption chiller was driven only by solar hot water without consuming natural gas. The inputs were fluctuating to follow the fluctuant air conditioning demand and kept chilled water temperature stable. If the system was conventional one shown in Fig. 1, average COP from 14:00 to 16:00 would be only about 1.5.

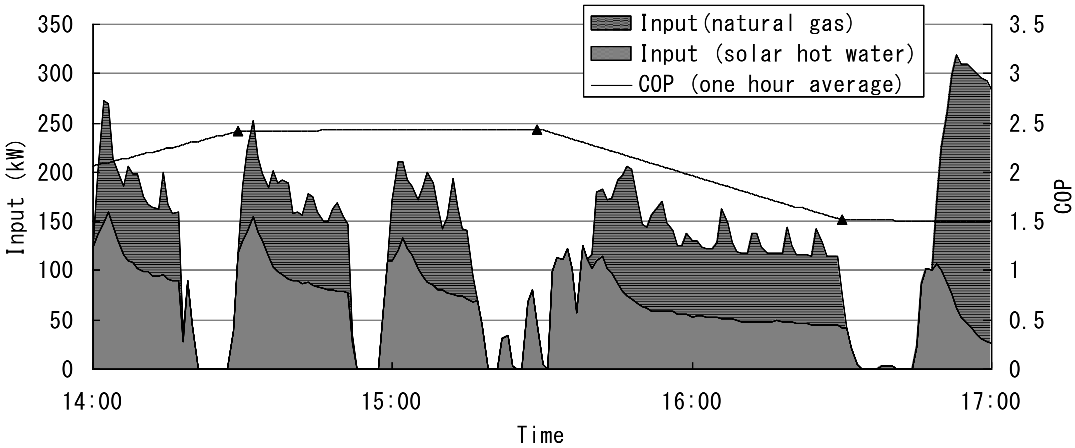


Fig. 21 : Input and COP of Solar Absorption Chiller (16th/Jul./2011)

(2) Solar generator and condenser

As shown in Fig.4, solar absorption chiller inlet temperature is about 75 deg.C, although rated temperature of conventional absorption chiller is 85~90 deg.C.

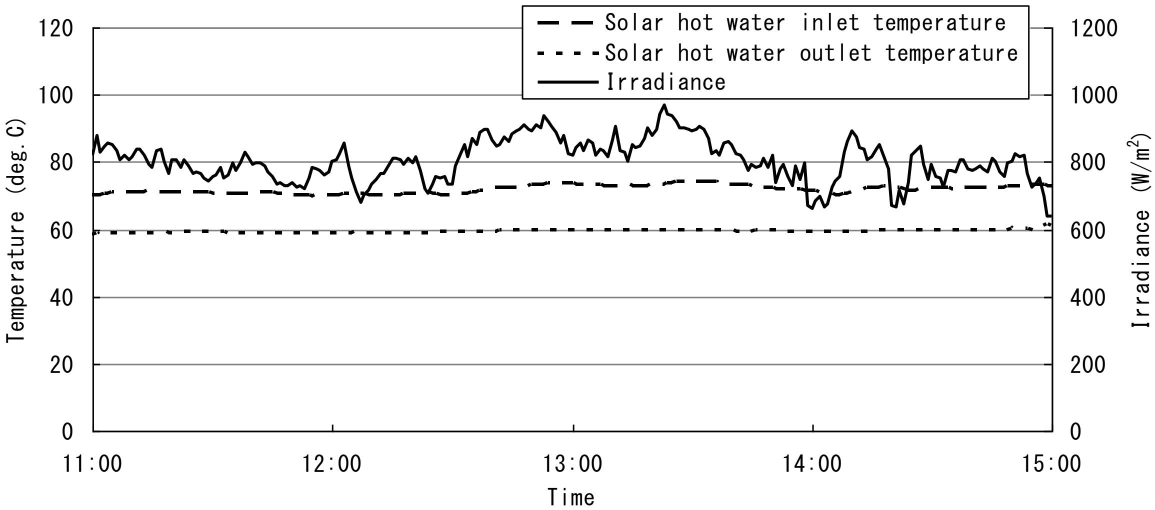


Fig. 22: Temperature of Solar Absorption Chiller and Irradiance (24th/Jun./2011)

(3) Solution water temperature output

As shown in Fig.5, the pump was operated only when collector outlet temperature reached minimum temperature that is enough to drive the solar absorption chiller. At 14:25, the pump was stopped because outlet temperature was not enough, although the temperature was about 65 °C.

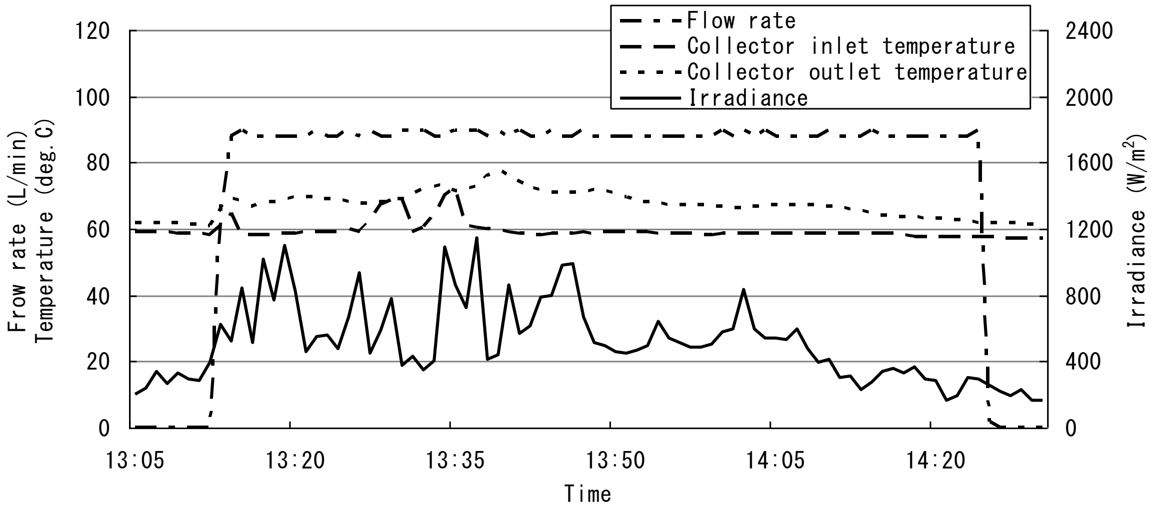


Fig. 23: Operation Status of Pump and Collector Temperature (7th/Jul./2011)

Results :
An advanced absorption chiller for solar cooling (solar absorption chiller) was developed. To maximize the system efficiency, followings were verified.

- The solar absorption chiller could be driven by both solar hot water and natural gas and natural gas complement unstable solar hot water.
- Although solar hot water temperature was unstable, the chilled water temperature could be stable with natural gas fired burner.
- Collector efficiency is higher at lower solar hot water temperature. So by adding a generator driven by solar power and condenser, solar hot water temperature was lower and the system efficiency was enhanced.
- The solar hot water pump was operated only when solar hot water temperature reaches high enough but as low as possible to drive the solar absorption chiller, to minimize the pump electric consumption and enhance the collector efficiency.

b. Coupling solar panel and Boiler or immerged natural gas radiant Tube- Hybrid solutions for production of hot water: (THERMIGAS company – FRANCE)

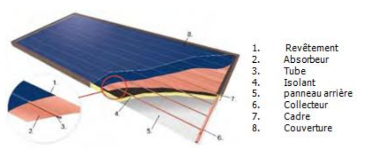
In many industries (Food industries, Chemical, pharmaceutical industries, Surface treatment industries, laundry industries...) production of hot water represents a large part of the energy consumption. Hot water is produce generally in two ways:

- In a centralized Boiler workshop and distributes in the factory;
- In decentralized system like for example immerged compact radiant tubes.

In most of installations, the energy use is Natural gas or Fuel-oil for boiler. As Solar energy is a free energy and in regard of needs to reduce energy consumption and CO2 emissions some manufacturers have developed new hybrid solutions using, in base line Solar panel for production of hot water, and natural gas burners or boilers to produce complementary heat or pics heat demands. The combination of both technologies increases the global energy efficiency of the system, reduce CO2 emissions and reduce energy bill for industrial customers. The necessary investments costs (CAPEX) could be reduce in certain case through national or regional funds policies.

We will see, in this paragraph, an example of one hybrid solution appliance developed by THERMIGAS Company – France for Food industries.

The technology use Solar panel in a complementary way with natural gas equipment in order to produce directly or indirectly a part of energy to pre-heat or heat the water for process. Solar panels used are classical devices developed for Buildings appliances.

TECHNOLOGIES		
Technologies	**Strengths**	**Witness**
Flat panels  	Low prices (~250-800€/m²) Good efficiency (kW/m²) Good reliability	Temperature limited (>90°C) Weight: Highest charge on roof
Panels with under vacuum tubes 	High efficiency for high temp. (>70°C) Easy maintenance Weight: Less charge on roof.	Highest costs (~400-1000€/m²) Limited surface of panels Efficiency losses with duration Less industrial feed backs

Two types of hybrid solutions have been developed: one for pre-heating crude water for boiler and second for direct heating of process water.

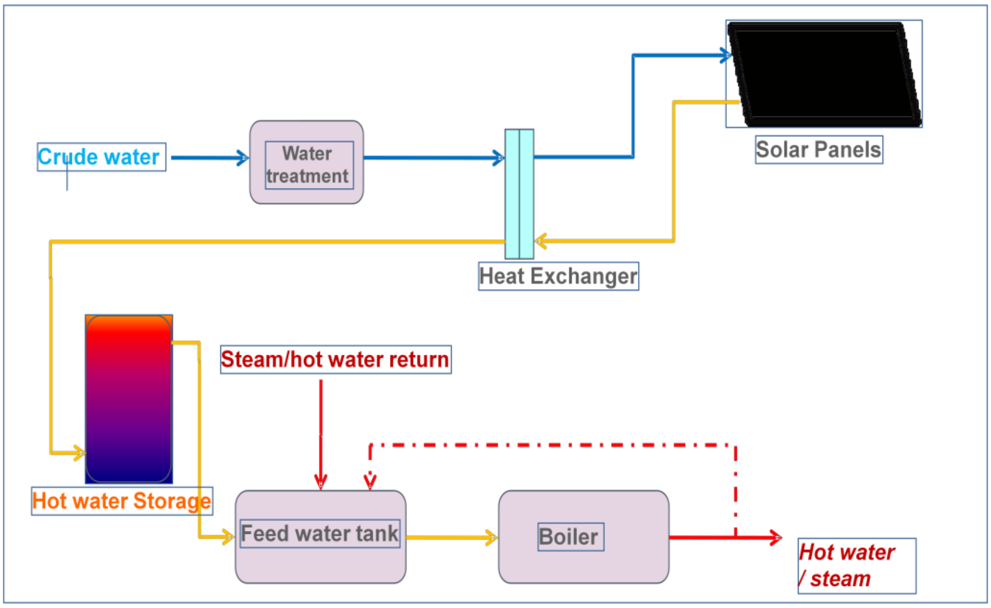


Fig 24: Option 1 - Pre-heating of crude water before boiler

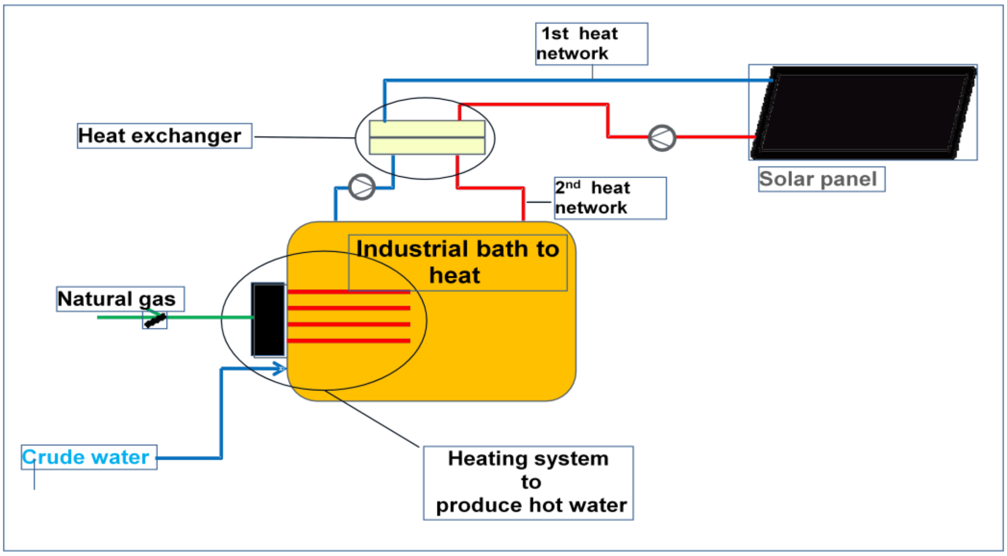


Fig 25: Option 2 - Direct heating of process water

As the financial and uses constraints are, in industrial markets, quite different than the commercial or residential markets. So to have a profitable implementation, this kind of technologies requires some Key factors. The Key factors are:

- To have good energy efficiency or ROI return on investments the temperature needs for hot water or thermal heating, have to be less than **120°C** ;
- The needs of heat or operating time have to exist during at least ¾ of year and have to include summer time. **Duration of operation must be at least 5 days each weeks ;**
- The implementation of the technologies in sunny region is more profitable than in the North. Panel's orientation has to be well studied in regards of the sun illumination (Orientation to the south is preferable, but east or west is possible with specific conditions. No sun screen or shadows…) and load on roof (20-30kg/1m²).
- The solution have to be design in order to have a supply of solar energy less than 60 or 70 % of the nominal thermal needs. The classical technical ratios that can be expected are:
    - 0.7 kW produce for 1 m² of solar panel
    - Range of power output for existing product line – 100 kW to 700 kW
    - Full Cost (installed) is approximately 296 €/m^2

As example, this technology (option 2) was implemented in a Food industry (Production of canned for bio-vegetables – PICODINE Comp. in Penzé Brittany in France) for production of 20 to 60 % of thermal needs (hot water at 80 °C) of the factory. The goal was to reduce the energy bill of the factory, but also in regards of the bio-commitment reduce the environmental impact of the industrial activity. The energy saving is 30% higher than expected and with a drastic reduction of CO_2 emissions. The ROI is less than 5 years.

7. On site production of synthetic methane with CO_2 captured and Bio-hydrogen[7]

Synthetic methane or SNG can be produced in many ways. Today the “green methane” is in focus instead of the production SNG through gasification of coal as basis for the CH_4 production.

For the “green methane” production several pathways are open, but the production of SNG combined with the integration of renewable power from wind and sun seems in focus today. This means a power based electrolyzing process combined with steam and CO_2. Biogas that contain 30 – 40% CO_2 might be used in the last mentioned process – with the final result upgraded biogas.
Another production possibility is to use biomass and gasification, but that possibility will not be further mentioned here.

First step in the process for power to green gas is to produce hydrogen through the electrolyzing process.

Electrolysis:

Passing energy generated by wind turbines or solar panels through water decomposes the water into oxygen and hydrogen.

$2H_2O \rightarrow 2H_2 + O_2$

Storage, transportation, and combustion of hydrogen raise several technical challenges and remain a costly option, but new technology using a simple chemical reaction to produce methane out of hydrogen will solve most of these problems.
The oxygen generated from the electrolysis might be used for a combustion process, which will generate a very high CO_2 content in the exhaust gas (from 10 – 15% for normal air feeded combustion to 80 – 85% when using pure O_2) or used in different industrial purposes.

Methanisation

The hydrogen resultant from the electrolysis process might be added to the Sabatier process, which is a reaction of hydrogen with carbon dioxide using a nickel catalyst at high temperature and pressure to methane and water.

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

[7] Aksel Hauge Pedersen (Dong energy- Danmark)

The water resultant from the Sabatier process is recycled for further electrolysis, making the sourcing of pure water for this process a one-time affair.
Several prototypes for this system is already operational and systems in the MW class is supposed to become operational by 2013/14.

The CO2 for this process might come from the combustion of methane, but another possibility is to use the process in combination with the upgrading of biogas to methane. Biogas contain 60 – 70% CH4 and 30 – 40% CO2. Using the Sabatier process feed with biogas and H2 from a electrolyzing process will produce methane (see figure below)

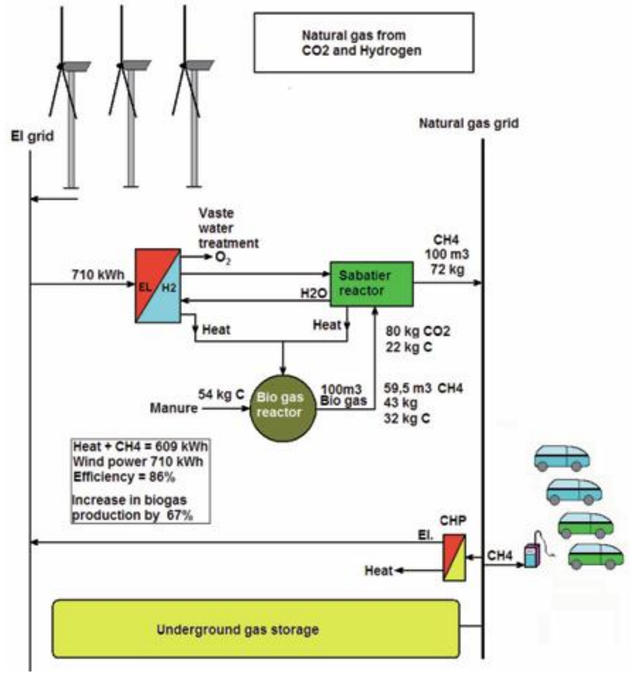


Fig 26: Producing CH_4 from windpower and biogas

The efficiency of the process – power to methane - is app. 60% with present technology level. Still it's possible to gain an efficiency of + 80% through the use of the SOEC electrolyzing process in combination with methanization (see below).

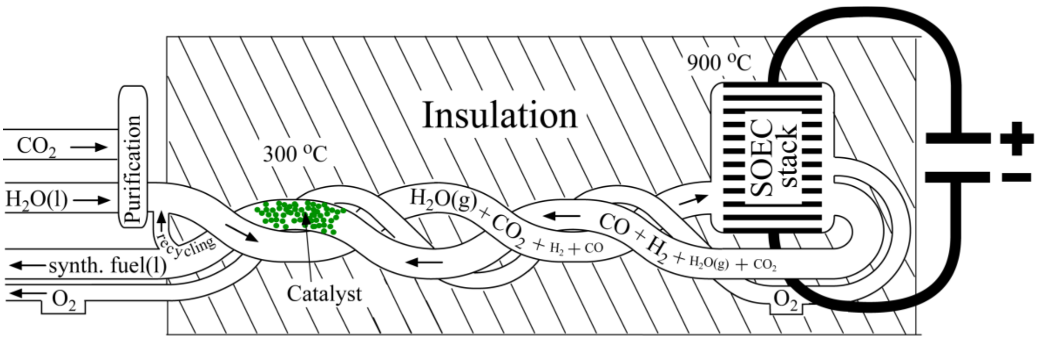


Fig 27: The SOEEC electrolyzer

The primary advantages of described methods are that power can be stored as green gas for future use. The storage of renewable energy as synthetic natural gas contributes to balancing the power system, and have several advantages related to other storage possibilities. The green gas solution can store energy from seconds to seasonal storage of energy and the storage system (Natural gas network) already exist in most countries. Power from the system might be deliverable in seconds. One major outstanding challenge is the development of the technology – another to secure the economy for the system. Future will show if we succeed.

8. Opportunities and types of new Business models for gas companies

As we try to explain in this article, in the present economical context the main Challenge of industrial during next 30 years, will be to do a complete re-engineering of their energy master plans in order to find solutions to keep the profitability of their activities and to be in conformity with new environmental and energy regulations. To reach this objective, industrial will need competitive solutions on the both topics energy efficiency and introduction of renewable energy in their energy master plan. This means development of tools and industrial solutions for:

- Methodologies and expertise to do energy audits
- High efficiency process regarding energy consumption and environmental
- Solutions for Implementation of high level of heat/energy recovery on site or with the near territory
- Solutions to provide “free carbon” energy resources and free carbon raw materials.
- And **implementation of renewable energy, especially bio-fuel gas, in the energy mix of the plants.**

Even if the natural gas, due to his low carbon contain, will find naturally a place in this new energy scheme , the development and new uses of renewable energies, like (biomass, thermal solar panel, green electricity, biogas…), will take a part of the existing market of natural gas or a part of opportunities of energy conversion. In this context, there are great opportunities, but also obligations, by providing innovative offers ranging from sale of green gas; consulting services to outsourcing services for integration in industrial processes of such renewable energy or renewable technologies. In this paragraph we will quickly review some examples of what could be the opportunities of new business or new offers for the next future.

a. Sales and Trading of bio-methane.

From the date of availability of significant quantities of “free carbon fuel-gas” (Biogas , bio-methane…) on the market, there will be a great interest for gas companies to organize and develop new offers on sale and trading of this type of gas. We can imagine new innovative offers and business, like in a first step for green electricity, specifics sale offers with special price to reduce carbon foot-print and in a second time more complex offers including trading of CO_2 ; share of CO_2 taxes reduction ; share of with permitting , etc. Some of this kind of new business or offers, have already started, but the present level of activities on carbon trading market is not still significant for profitable business. For example: we have seen that available potential of bio-fuel-gas in France is around 150 TWh per year. If we take a gas price equivalent to NG price for industrial market between 20 to 30 €/MWh, the potential turn over for green gas selling is roughly between 3 to 4 Billion of Euros per year, with a potential turn over in Europe 6 to 10 times greater.

b. Mass or Local production of bio-methane

In this context of depletion of fossil energies, drastic increase of environmental pressure (regulation, country commitment…) the market will need more and more new sources of energy providing or free carbon fuels. Natural gas grid is a tremendous asset for distribution, storage of this green gas energy. Once set the standards on quality and safety conditions to allow the injection of green gas into the natural gas grid; the main problem will be on how to produce locally or massively significant quantity of green gas in regards of markets demand. The background of utilities or Gas companies on electricity production; CHP plants or storage; transportation and distribution of natural gas is a great advantages to develop new offers for that new markets. We can think about development of new business like:

- Development and operation of production units, selling of green gas into the grid or end user, and selling of associated heat to industrial plants or industrial plat-form.
- Collect of local biomass or importation of biomass to provide raw materials to the unit.

The business model will include the return on capital investment, collect services; services for O&M; sales of green gas (directly or through special local regulated fix price); sales of heat produce by units to local customers.

c. Global services for onsite production of green gas

In the same context and way, than in next paragraph, in order to reduce carbon foot-print of their industrial plants or territory, many customers will study possible scenarios to introduce green energy easily distributable onto their plants or territory. To bring response to that, Gas companies will have the opportunity to develop new innovative offers on :

- Development and operation for a third part, of production units, and selling of green gas, and associated heat produce, to end users (industrial plants or industrial plat-form and/or municipality).

This global service will include Collect of local biomass; pre-treatment of biomass; construction of production units (with capital investment or not) and O&M services. This kind of services is very similar to global services provide for Cogeneration plants. Added value could be done to this global services with introduction of advanced control-command of local energy grid "local smart grid appliances" function of reduction of energy consumption, production rate; emissions of GHG regulation….).

d. Services around implementation of renewable/NG hydrid solutions

In the context of high prices and volatility of energy, strengthening of environmental regulations, which means, drastic needs for reduction of energy consumption (CO_2 reduction); energy efficiency is becoming one of the most important issues for the competitiveness of industrial plants. Many industrial companies like steel, chemical, paper mill, glass and paper industries are committing long term (15 to 20 years) energy efficiency plans with ambitious targets of consumption reduction (CO_2 reduction). These action plans include simple energy efficiency action plans but also complex action plan including Re-engineering of energy master plan of industrial plants.
To reach this objective industrial market need a strong support from energy utilities on the both topics of energy efficiency and introduction of renewable energy in their energy master plan. This is good opportunities for energy companies to provide to their customers innovative new offers around:

1. Consultancy on energy efficiency;
2. Global services for Implementation of high level of heat/energy recovery on site or with the near territory ;
3. Global services to study "free carbon" energy master plan or very carbon foot print factory;
4. Global services for Implementation hybrid (renewable and natural gas) technologies.

These technical services could include engineering services on consultancy services; project management; technical studies, technical support to implementations and why not, sale of global engineering services including process integration of the solutions with performance guarantee.

9. Conclusions

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.

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