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”Direct production of bio-methane through biomass gasification and grid injection”

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Expert Forum WOC 5 - 5 A

"How to integrate renewable power – in the natural gas grid"?

WGC 2012

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Abstract:

In a context of fighting against Climate changes and economical crisis the most important challenge for this century for countries, especially in occidental countries, will be to develop innovative concept of energy master plans in order to guardant competitiveness and sustainability (reduction of carbon foot print) of commercial and industrial markets. In a similar way, local authorities and cities also want to set up territorial master plan including sustainability and reducing carbon footprint of quarter and district.

One of the solutions is a massive the introduction of renewable energies in energy master plans of Industrial plants and cities. In this sense, the development of production units (centralized or decentralized) of bio-fuel gas energies (Biogas, bio-methane…) and injection of bio-fuel-gas into natural gas networks is a perfect solution and almost a duty for natural gas companies to support the implementation of new advanced concepts of energy master plans. It's also a great opportunity for this Natural gas companies to reinvent their businesses. In this article we will try through some examples of industrial and R&D projects in development in Europe, on bio-methane production through biomass gasification processes, to demonstrate the value of these technologies and new businesses.

Executive Summary.

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 and occidental cities, to be able to have access to green sources of energy will be one of the key points to reach their goal of reduction plan for CO2 emissions.

Biomass gasification for production of syngas or bio-methane is a promising way to make renewable energy directly use in preindustrial processes. This technology produces syngas which can be turned into different kinds of energy:

- CHP (Combined Heat Power),
- Combined Bio-gasoline (Fischer–Tropsch process) and heat;
- Combined **Bio-methane fuel** (**BioSNG: a green substitute natural gas**) and heat.

Combined Bio-methane/heat is environment-friendly (high energetic and chemical yields, local heat valorization, reasonable biomass supply and valorization) and is complementary to the other renewable energies. The green fuel-gas is easily transport from production plants to end-users through dedicated gas grid or through natural gas grid blended with natural gas. This presentation has the ambition, after a short recall of the context (energy strategies, regulations,…) to do :

- A review of different strategies study and apply for the production and distribution of this bio-methane,
- A technology watch trough presentation of different associated industrial projects or R&D projects in course to demonstrate the feasibility of the process (ex: GOBI gas project -Sweden; GAYA project- France; Güssing – Austria)
- Give some figures of these models/case study expected
- Propose and analyze opportunities and type of business models available for Gas companies

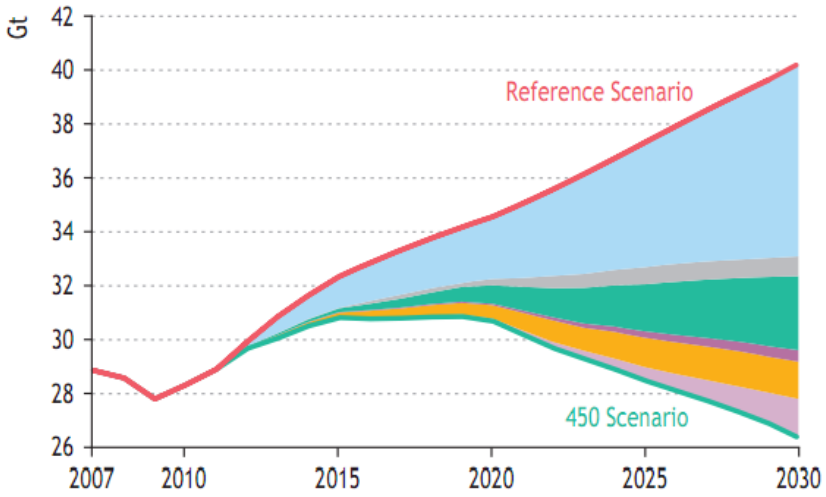
Somme figures are provided of a comparative life cycle study of a virtual facility has been undertaken to assess the energetic balance and the potential environmental impacts of the whole process chain from the biomass production to the bio-methane combustion.

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)



	Abatement ($Mt CO_2$) 2020	2030
Efficiency	2 517	7 880
End-use	2 284	7 145
Power plants	233	735
Renewables	680	2 741
Biofuels	57	429
Nuclear	493	1 380
CCS	102	1 410

Fig 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, one of the challenge of the gas companies, will be, in order to respond to these requests, to introduce renewable energy, especially green Fuel gas, in their distributed energies portfolio. This major challenge for the gas companies will be in particular to develop innovative solutions for the integration of these renewable energies, including gas renewable fuels such as biogas, bio-methane, SynGas and at least hydrogen, into their natural gas Grids.

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 ...) in energy mix of industrial plants and cities
- Develop profitable Green Fuel-gases production plants in order to inject them into natural gas Grids

a. Introduction of Renewable fuel gas in energy mix:

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 vector of "non-fossil" energies. In fact because of its specificity and those of the distribution infrastructure, natural gas is the best energy vector 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 the easy way to use it, can help the development and operation of biomass to energy conversion units. For example : Use of low grad biomass in biomass boiler, can be easily improved by 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.

b. Renewables energies and reduction of Carbon footprint

Introduction of renewable energies in the energy mix of an industrial plants or cities, produce a direct and proportional reduction of the Carbon foot-print. Many industrial companies like steel, chemical, paper mill, glass and paper industries are, presently, committing long term (15 to 20 years) energy efficiency and partial conversion to renewable energies resources plans with ambitious targets of consumption reduction (CO2 reduction).

For introduction of renewable energies, these action plans start from simple implementation of Solar panels or Wind mill systems 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 to have access to renewable energy resources for their factories. In the same way, many cities or territories are studying implementation of renewable energies resources programs. This means necessity to develop tools and industrial solutions for:

- High efficiency process regarding energy consumption and environmental
- New processes including a part of renewable energy systems
- Industrial solutions for massive production of "green gas or bio fuel-gas" which could be distributed through dedicated gas grid or natural gas grids to the Country/territory or cities
- Industrial solutions for local production of "green gas or bio fuel-gas" which could be distributed through dedicated gas grid or natural gas grids to industrial plants or platform.
- And **implementation of a complete range of renewable resources, especially bio-fuel gas, in the energy mix of the plants to reach free Carbon foot print.**

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 to reinvent gas sales business will take a form into development of high energy and environmental performance technologies; Expertise services with high level of added value on energy efficiency and implementation of centralized and decentralized green gas production and distribution units.
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c. Energy conversion of Biomass: Biogas or Bio-methane or Syngas production from Biomass?

Bio-fuels 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.

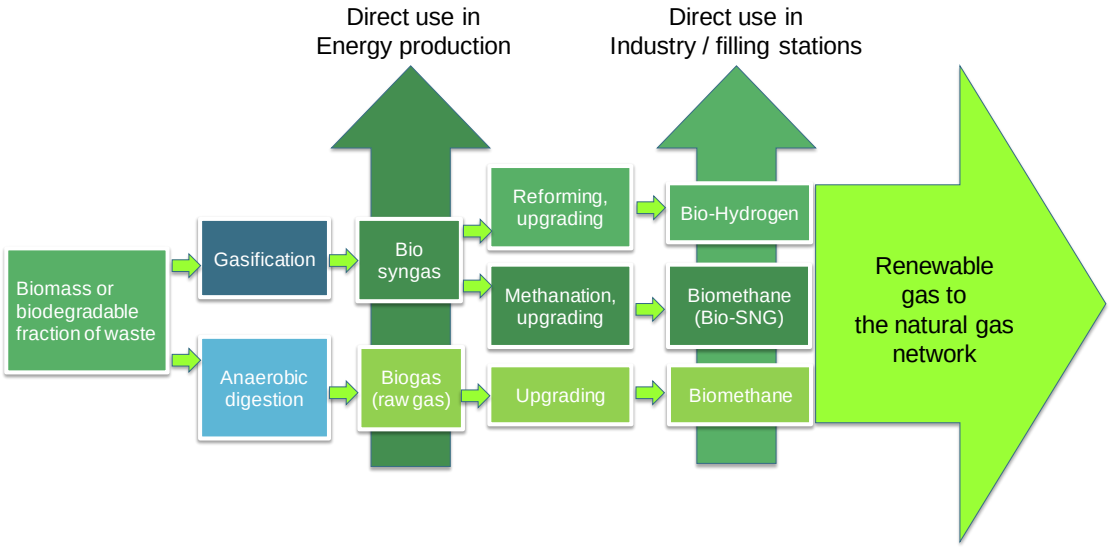


Fig 2: Chain process for Biomass conversion to energy

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.

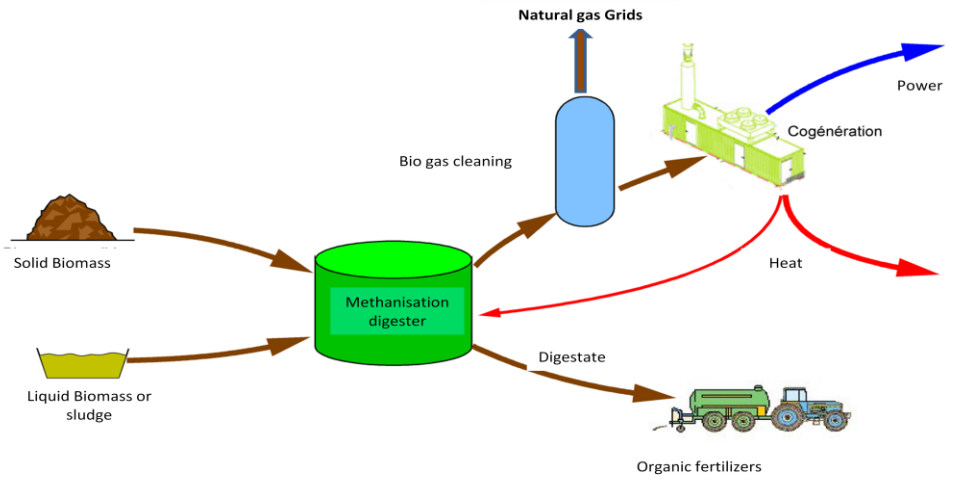


Fig 3: Classical of anaerobic digestion process

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

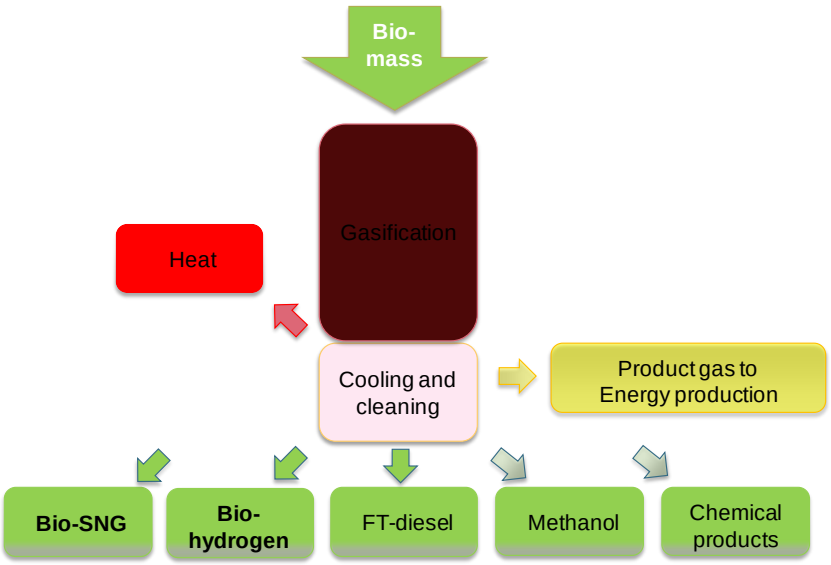


Fig 4: Thermo-chemical biomass to energy conversion

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).

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.

3. Available biomass resources to produce 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. 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.
For example, 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 and industrial 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 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

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

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 opportunity.

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. 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

[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

German potentials are slightly smaller ranging from 150 to 225 TWh/yr. Most of these potentials currently remain unused.

The Figure 5 show the current potentials of bio-methane in the European Union member states separated into biogas and Bio-SNG based potentials.

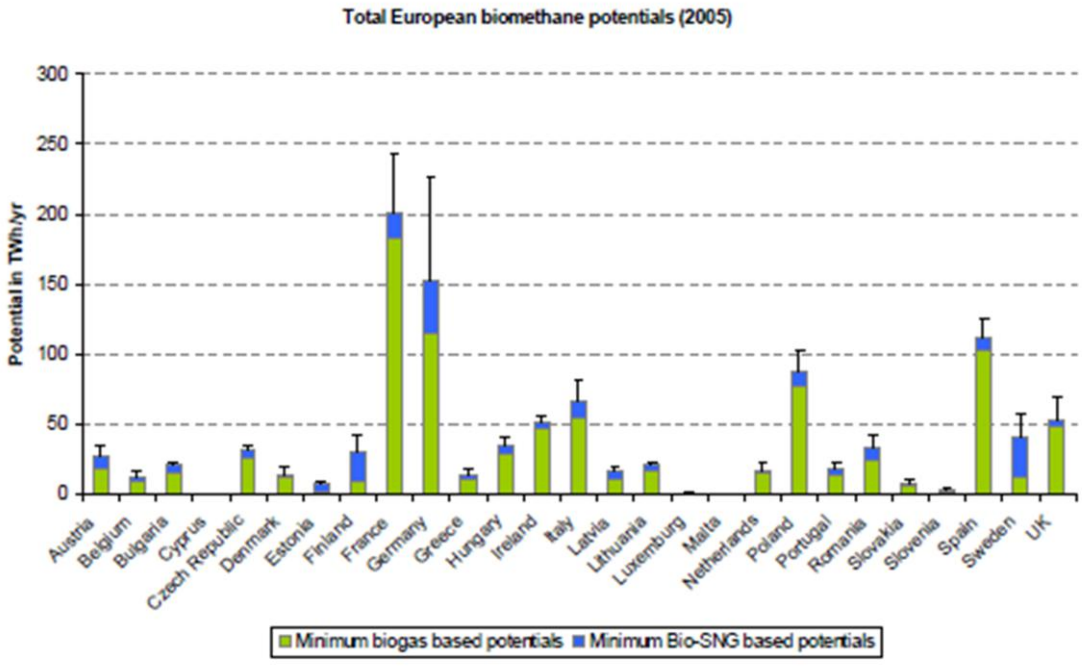


Fig 5: Total European biomethane potentials (2005)

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 direct production of bio-methane through biomass gasification and grid injection

As we explain, Bio fuel-gas production is becoming more and more attractive way for countries and industrial companies to reach rapidly their commitments on reduction of CO_2 emissions. Many R&D or Pre-industrial initiatives, especially in Europe and USA, are in development to demonstrate the feasibility of this processes and new businesses. These new approaches of production of green gas energies are generally developed with three different strategies:

- Decentralized production units of biogas or Syngas using local resources of biomass (ex: wood) 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 or collected in a large territory and distributed via injection in the transport and/or distribution natural gas grid.

In this paragraph we will try to demonstrate, through some examples of industrial and R&D projects in development in Europe, on bio-methane production through biomass gasification processes, the value/interest for gas companies of these technologies and new businesses.

a. Mass production of Bio-methane from thermo-chemical treatment of Biomass (Götheborg ENERGI - EON – GOBIGas project [3])

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.

[3] Göteborg Energi web site – GoBiGAs project.

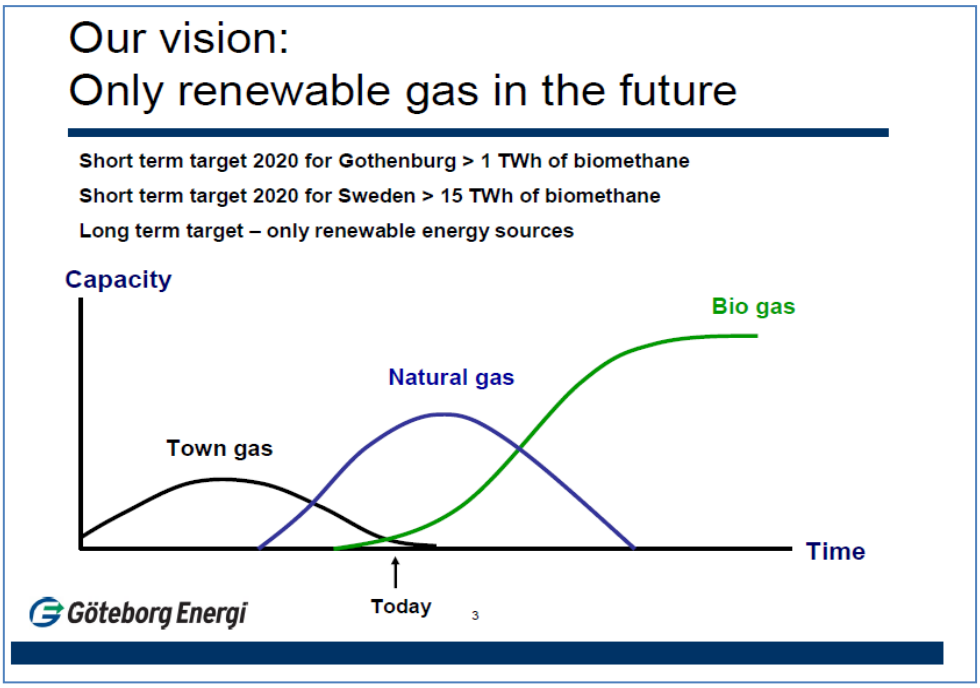


Fig 6: Use of Bio-methane – future integration in energy system

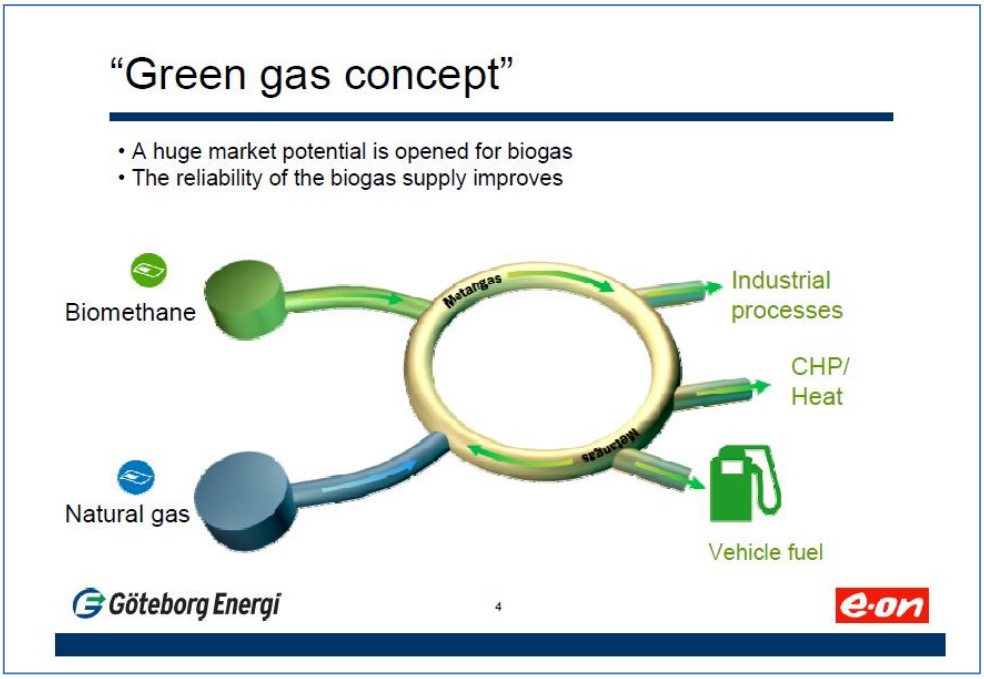


Fig 7 : Green gas concept – future integration in energy system

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.

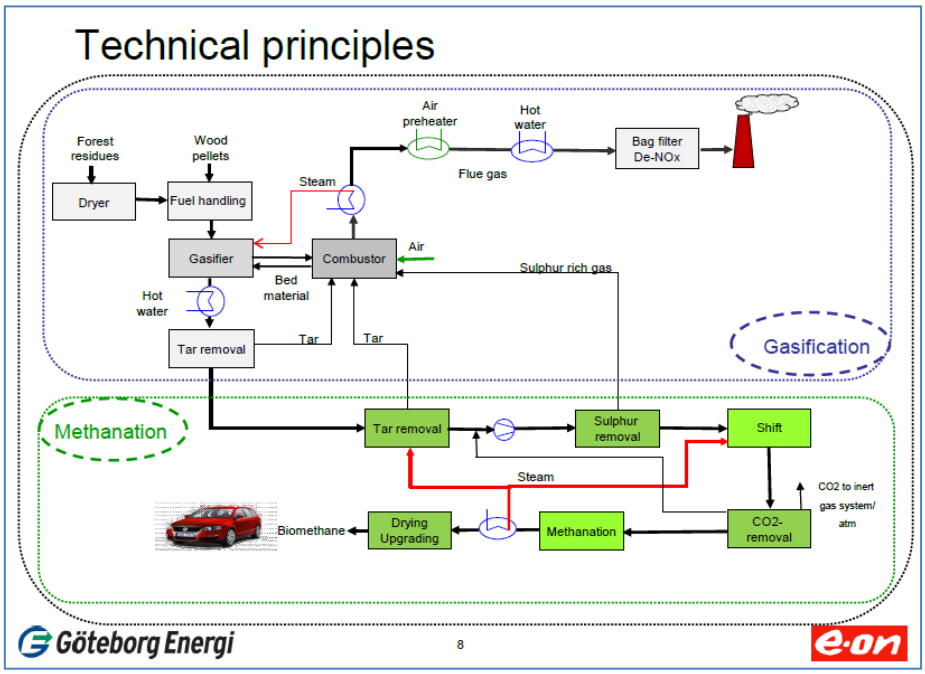


Fig 8: Technical principles of GoBiGas process

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 %.

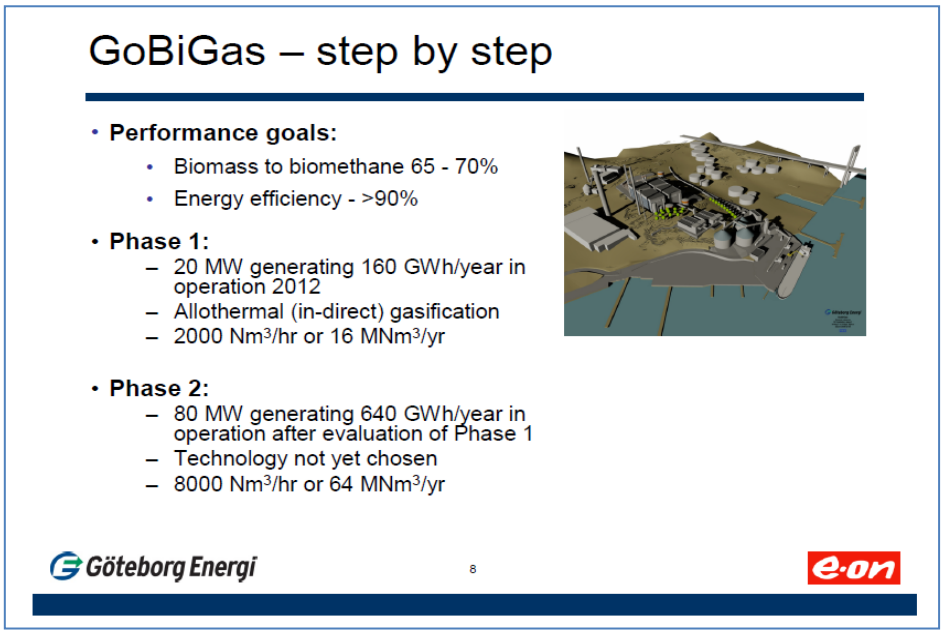


Fig 9: A deployment step by step

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.

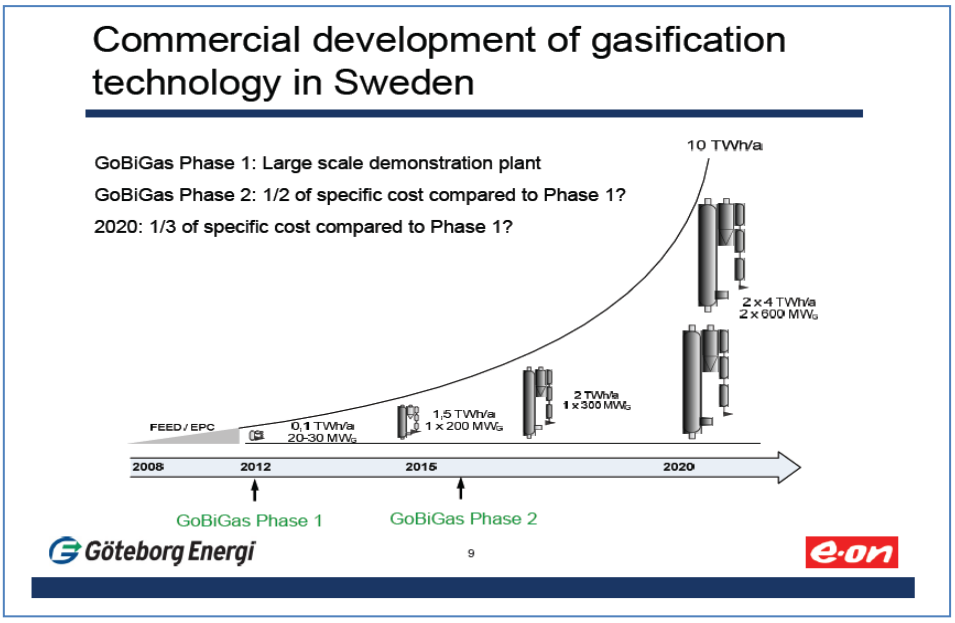


Fig 10: perspectives of technology deployment in Sweden

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.

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

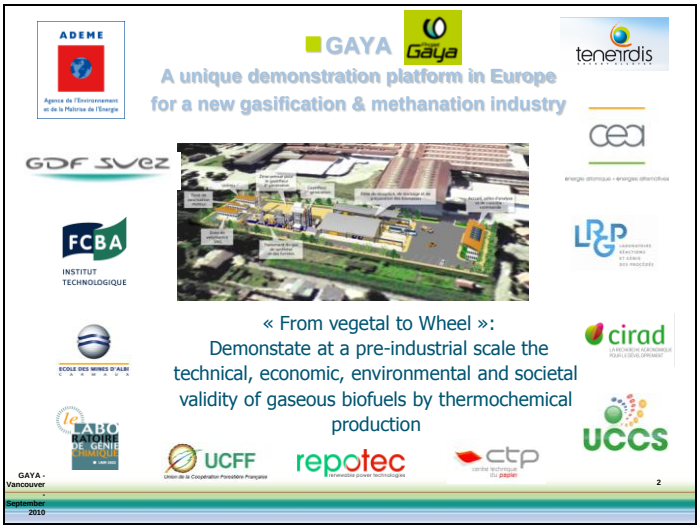
Context

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 gasification + methanation processes 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.

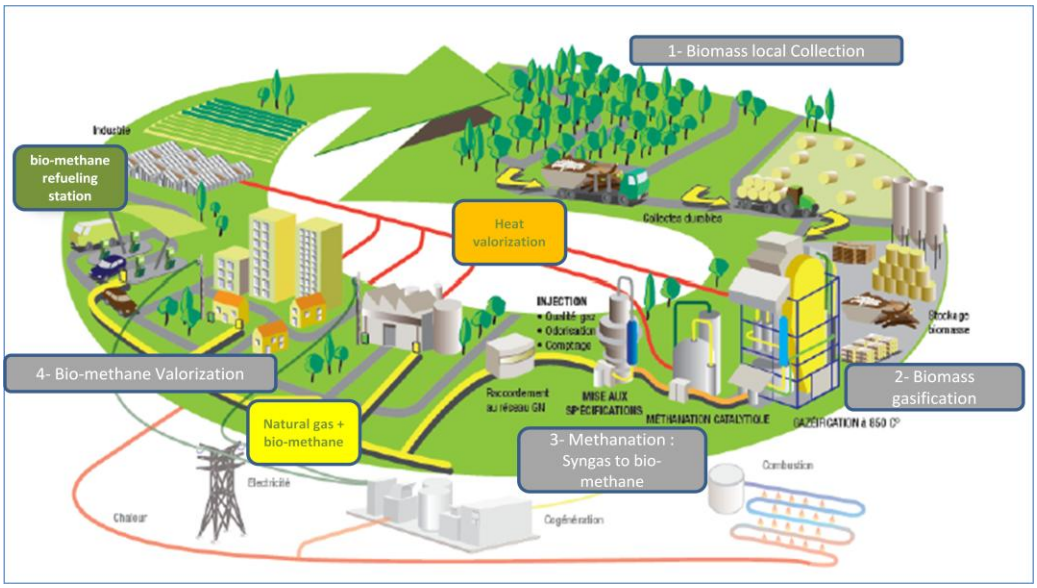


Fig 11: Project Gaya – territory integration of bio-methane production

GAYA process (Gasification + méthanation) 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 %. The coupling of Gasification process with methanation process (Gaya technology) is therefore in a context of diversification and optimization of biomass conversion.

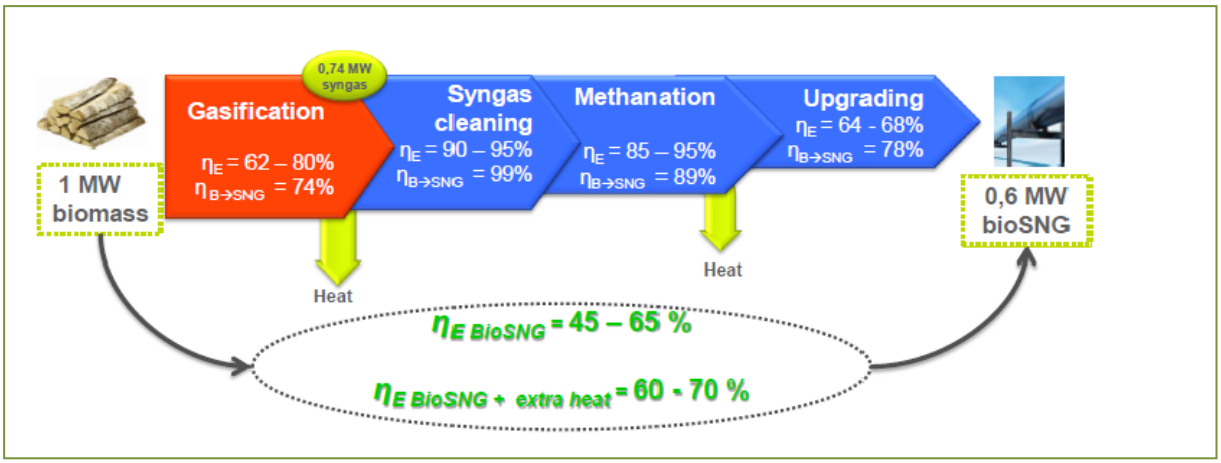


Fig. 12: GAYA technology chain choose for biomass to energy conversion

Project GAYA – a proven technology

Gasification process:
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 7000 h /year during 5 years. Syngas quality produce after gasification is well adapted to methanation (~10% CH4) due to the high level of methane contains.

Methanation process:
For methanation process, several technologies are available at industrial scale or Pilote scale. The technology for Gaya project was choose in order to have the best compromise between adaptation to gasification process, capacity to provide Bio-methane with NG Grid specifications and best economical ratio. This technology is based on fluidized bed reactors.
Fluidized beds are known to be suitable for large-scale operations of heterogeneous catalyzed reaction with high exothermicity. The mixing of the fluidizing solids leads to an almost isothermal condition in the reactor, which allows simple and easy control of the operation. Heat and mass transfer is higher compared to fixed bed reactors. Easy remove, add and recycle catalyst continuously during the process is also possible with this reactor technology

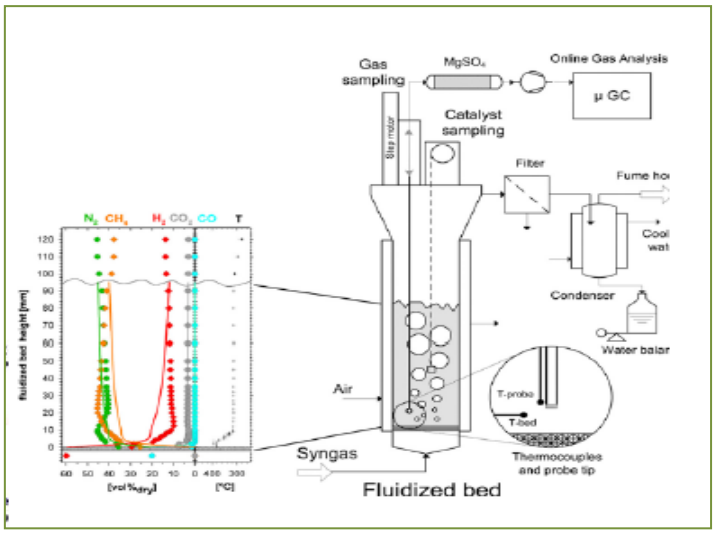


Fig. 13: Fluidized bed process proposed by PSI/CTU and studied in Vegaz project

Fig 14: Repotec FICFB gasification process – Güssing cogeneration units and méthanation pilot plant

Energy integration:

Gasification and methanation steps produce high and low temperature heat which may be integrated to the process or purchased as steam (by neighbouring industries, for instance). Heat production and energy needs of the SNG process chain are strongly influenced by biomass characteristics, in particular moisture (with a possible preliminary wood drying process), and lower heat value.

The diagram aside shows heat duty and production by the process for four different biomass types (for a 20 MW SNG-plant).

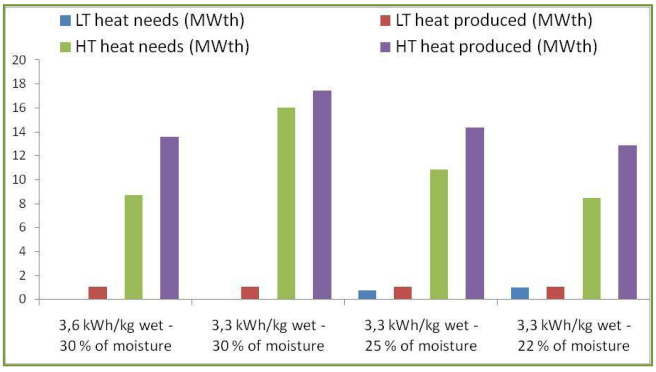


Fig 15: Basic energy integration on the whole process chain.

Results on LCA analyse of Gaya Bio-methane Supply chain:

During the Vegaz[4] R&D project (Research National French Agency project - preparation project for GAYA) a Life Cycle Analyze was done for this Bio-methane supply chain.
The LCA method was composed of 4 steps and allows:

- Identifying the hot spots of the system from an environmental point of view and the improvement opportunities;
- Avoiding a pollution shift from one step to another or from one impact to another.

The main goal of this study is to realize a simplified assessment of the environmental burdens of the supply chain and final use of the Bio-SNG. The impact indicators considered are: climate change, eutrophication, acidification and non renewable energy consumption. The biomass conversion GAYA conversion process (gasification and methanation) is the main contributor of the whole life cycle with more than 55% of all impacts.
These results can be explained by the fact that:

- More than the third of the eutrophication and the acidification (38% and 35 %) are attributable to the direct emissions of gasification (NOx and SOx);
- The rapeseed biodiesel consumption, used for the syngas scrubbing, has a significant contribution to eutrophication and acidification (43% et 25%), due to its conventional agricultural origin;
- More than 35% of the non renewable resources consumption is due to the process electricity consumption, especially for the compressors (81 % of the total consumption).

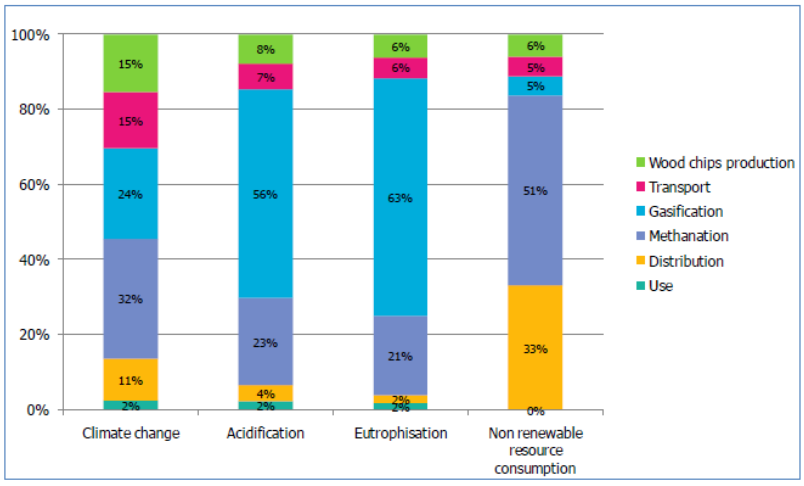


Fig. 16 : Contribution of the different stage of the life cycle to the impacts

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

4 Vegaz project.- towards a green natural gas efficiënt pathway through biomass gasification and méthanation – O. Guerrini and M. Perrin – GDF SUEZ Research and innovation –CRIGEN

- 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.

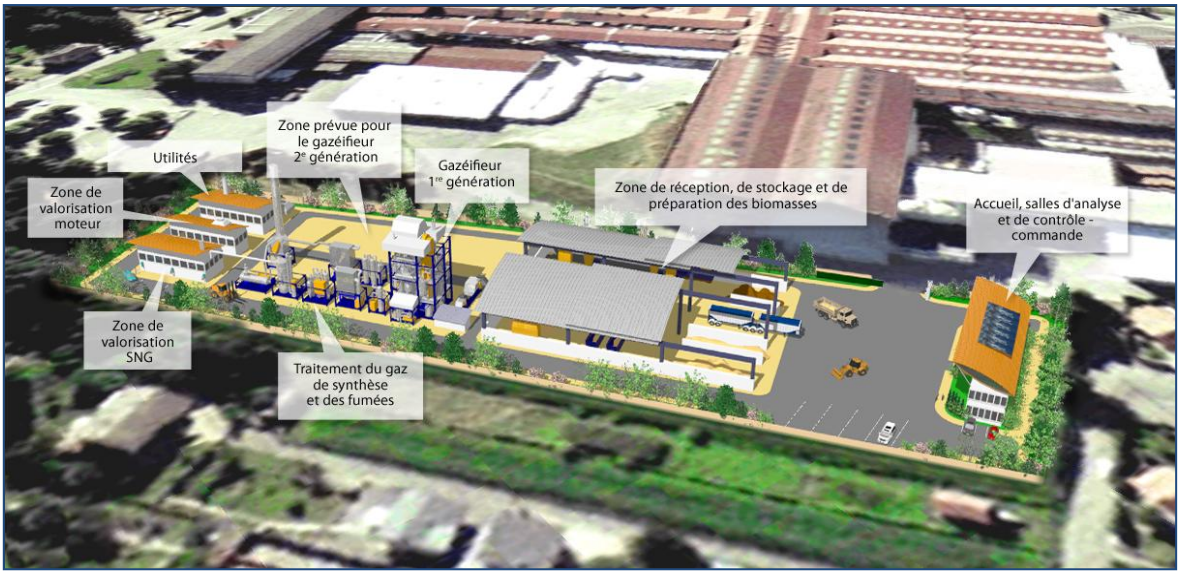


Fig 17: GAYA project - Virtual view of the demonstration and R&D platform which will be installed near Lyon town France

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 French marhet, 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. 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 and Cities authorities 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, reduce their CO2 foot-print and to be in conformity with new environmental and energy regulations. To reach this objective, they will need competitive solutions on the both topics energy efficiency and massive introduction of renewable energy in their energy master plan. This means development of tools and industrial solutions for:

- 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 **implementation of renewable energy, especially bio-fuel gas, in the energy mix.**

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, bio fuel-gases…), 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, for natural gas Companies to be involve in innovative offers providing. The range of solutions will be from sale of green gas; consulting services to outsourcing services for energy integration in energy mix of such renewable energy or renewable technologies.

Somme of these businesses related to Green gas energies supplying, will be completely new and some very close of more classical business models like mass production of electricity or CHP plants. The figures hereunder give some example of type available of business models for this new supply chain.

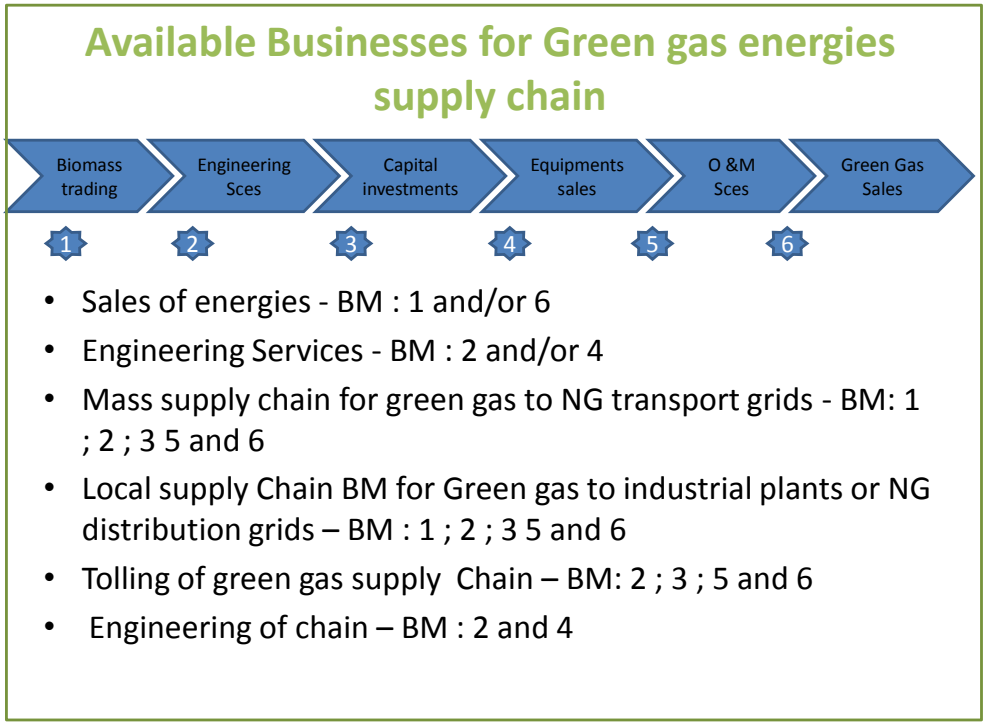


Fig 18: Examples of Business Models for Green Gas suplying

In this paragraph we will quickly review some of these examples and what could be the opportunities of new business or new offers for the next future.

a. Sales and Trading of Bio fuel-gas or 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 on “Free CO_2 “ gas sales , 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 white 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 to 200 TWh per year, in 2020, with a minimum for Bio-methane of roughly 20 TWh per year. If we take a regulated bio fuel-gas price for grid injection between 90 to 130 €/MWh, the potential turn over for Bio-methane selling is roughly between 1 to 3 Billion of Euros per year, with a potential turn over in Europe 6 to 10 times greater.

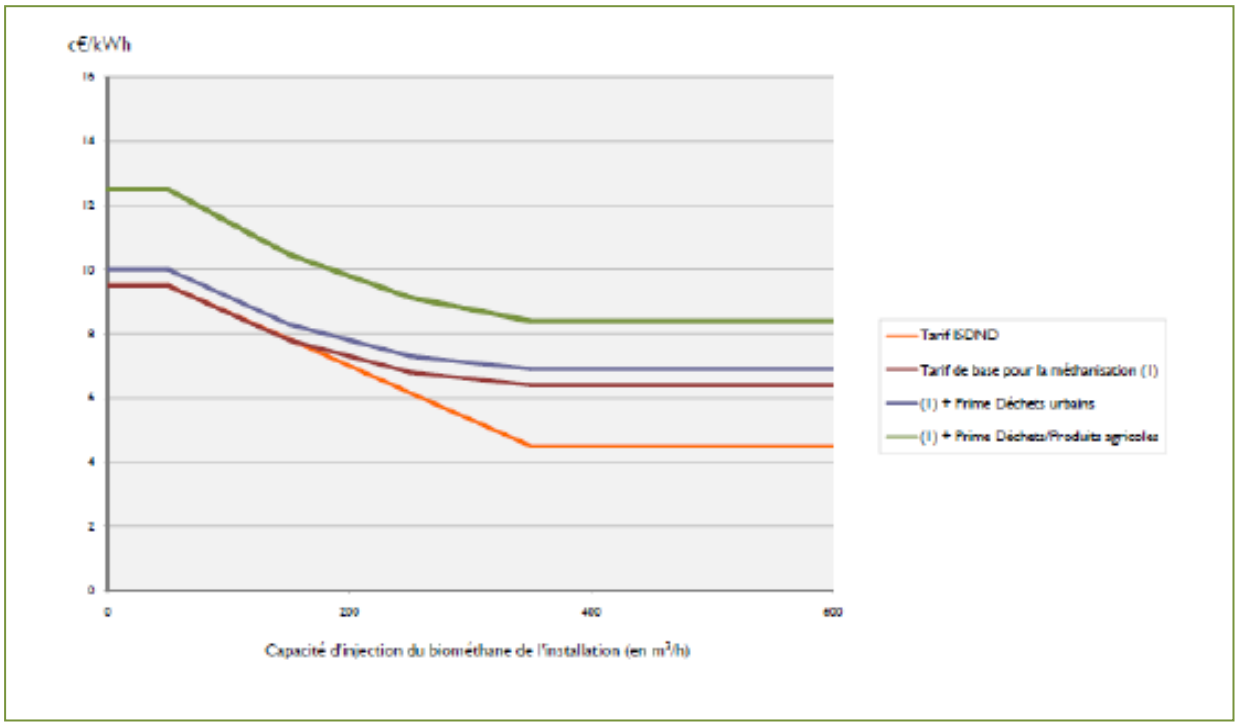


Fig 19: example of regulated Purchasing prices for Bio-methane
for injection into NG Grids

This rapid estimation of the potential market shows clearly the interest for natural gas companies and more if we take account that in many case Bio fuel-gas will be use in substitution of natural gas.

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 directly to end user, and selling of associated heat to industrial plat-form or big cities.

- Collect of biomass in the country and/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.

For example: If we think about a units with a production capacity of 2 to 4 TWh/y of bio-methane the turnover of the units will be around 180 to 240 MEuros /year. In front of those revenues, in this kind of plants, we can estimate that 40-60 % of costs are related to Biomass purchasing, 8 to 12 % related to O&M services and 10 to 15 % for capex.

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 local cities, 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 their own activities or 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).
- Collect of local biomass in the territory to provide raw materials to the unit (See Gaya project business model).

This global service including: the collection 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 CHP plants.

For example for a medium size unit producing 250 to 350 GWh/y of bio-methane, the total Turnover will be between 30 to 40 MEuros/y. Added value could be done to this global services with introduction of advanced control-command services on optimization of local energy grid “local smart grid appliances” function of reduction of energy consumption, production rate; emissions of GHG regulation….).

d. Tolling or O&M Services of these industrial plants

Sometimes industrial customers or City authorities, wants to keep the control of their energy production. In this case natural gas companies could propose some energy tolling services or O&M services for the plant. For the first type that means to have capability to control Collect of biomass or purchasing of biomass and sale of green energy. For the second, energy services subsidiaries are required. In these cases, resulting turnover will be lower with a magnitude around 30 to 20 % of the green energy sales (5 to 20 MEuros/y) but probably with long term (15 to 20 years).

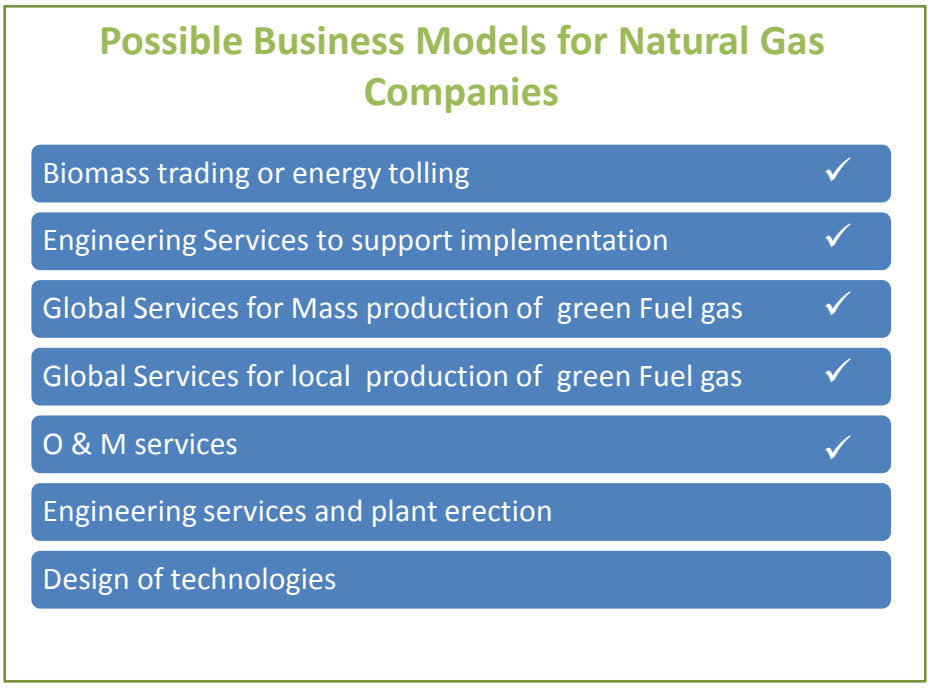


Fig 20: Possible business models for Natural Gas Companies

6. Conclusions

All over the world, due to the new energy contexts and involvement of countries in the fight against climate changes, you will see that we have two main opportunities of new business in:

- Reduce energy consumption for example in Europe (France) significant progresses have been made in energy efficiency of industrial processes.
- Introduce renewable energy especially bio-fuel gas in the energy mix of countries, cities and industrial plants

Bio fuel-gas production is becoming more and more attractive, thanks to the introduction of regulatory restrictions and incentive rules. The production and valorisation is booming in Germany and has become Europe's fastest growing renewable energy sector.

Bio-fuel gas production for renewable gas or green gas is possible, through thermo-chemical process call gasification. You get Syngas, and after upgrading the final product is called bio-SNG gas or bio-methane or through Anaerobic digestion and after upgrading you get also bio methane. As we try to demonstrate in this article, through few examples (GoBiGas, Gaya Project...), many new developments in course will give in the next future years, large available quantities of these free carbon fuel-gas. In this context, 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. And naturally, natural gas companies, due to their heavy experience with natural gas traditional businesses, have to take these opportunities to re-invent their business models in order to bring response to this demand and be the major partner of industrials, Cities and countries for the development of new concepts like Eco-design quarter or cities and industrial plants.

7. References

[1] Biogas barometer – EUROBSERVER – NOVEMBER 2010

[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

[3] Göteborg Energi web site – GoBiGAs project.

[4] Ingemar Gunnarsson,**Göteborg Energi AB**. Status of the GoBiGasProject

[5] BIOMASS GASIFICATION FOR PRODUCTION OF "GREEN ENERGY" (COMBINED HEAT AND POWER, GREEN METHANE…) - Véronique MAMBRE – GDF SUEZ CRIGEN - Research & Innovation Department – France; Co-author :Maud IMBERTY ;Olivier GUERRINI ;Maïlys GUERQUIN

[6] ” TOWARDS A GREEN NATURAL GAS EFFICIENT PATHWAY THROUGH BIOMASS GASIFICATION AND METHANATION - Bamarni J. 1, Bassil G.5, Boissonnet G.2, Capela S.1, Chambrey S. 4, Dreillard M. 1, Fatah N.4, Fongarland P.4, Jarry A.1, Jayabalan T.3, Jose J.5, Khodakov A.4, Kara. Y. 1, Lautier A.1, Legrand F. 1, Marchand B.1, Mambre V.1, Mokbel I.5, Pale M.1, Pierre A.1, Poli P.1, Prieur A. 1, Pré P.3, Setier PA.2 and Guerrini O.1*

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- 4 - UCCS, Université des Sciences et Technologie de Lille Cité Scientifique 59655 - Villeneuve d'Ascq Cedex - France
- 5 - LSA, Bât. Curien (CPE) - 43, Bd du 11 novembre 1918, 69622 Villeurbanne Cedex - France

[7] Étude des marchés de la Méthanisation et des valorisations des biogaz – ADEME ; GrDF , MEEDTL - Olivier THEOBALD – ADEME – Direction Consommation Durable et Déchets ; Claire BRECQ – GrDF – Direction Stratégie

[8] Bolhar-Nordenkampf, Rauch, Bosch, Aichernig, Hofbauer, “Biomass CHP Plant Güssing – Using Gasification for Power Generation“

[9] Fercher, Hofbauer, Fleck, Rauch, Veronik, “Two years experience with the FICFB-gasification process“

[10] Hofbauer, Bosch, Siefert, Aichernig, Tremmel, Voigtlaender, Koch, Lehner, “Steam gasification of biomass at CHP plant Güssing – status of the demonstration plant”

[11] Hofbauer, Rauch, Bosch, Koch, Aichernig, “Biomass CHP Plant Güssing – A Success Story“

[12] Hofbauer, Rauch, Loeffler, Kaiser, Fercher, Tremmel, “Six years experience with the FICFB-gasification process”

[13] Kopyscinski, Schildhauer, Biollaz, “Employing catalyst fluidization to enable carbon management in the SNG-production from biomass

[14] Energy efficiency Recipe for success – World Energy Council –Full report 2010