

Towards green gases solutions for industry

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Abstract

Green gases represent a high potential to reduce carbon footprint for large industry emitters. GDF SUEZ is highly involved in several projects which are aimed at using syngas from biomass for industrial use or to produce 2nd generation Biomethane. Some of those new routes focused on renewable biosyngas, in addition with natural gas, will in a short term, be a helper for energy company to support their customers in lowering their dependencies on fossil fuels and GHG emissions. Direct firing of syngas into an industrial furnace for direct heating of a final product represents a very effective solution to reduce the use of fossil fuels. One of those projects ambitions is to produce a synthetic gaseous fuel coming from vineyards wood residues. The final goal is to manage to industrialize the use of biomass gasification for glass melting furnaces. A 1 MW gasifiers has been successfully installed and tested at GDF SUEZ Research Center. After combustion test on a semi industrial of the syngas produced by the gasifier, the whole installation has been transported and implemented on the industrial site. In the on-going test the gasifier will be coupled with the glass furnace. In addition to the developments on the synthetic gas, one of the key elements under investigation is the optimisation of the overall energy requirements of the integrated process.

Eventually, determination of the possible routes for the collection and preparation of the biomass resource with respect to the targeted application will allow the creation of a local and sustainable supply chain. For medium and long term perspectives, GDF SUEZ is also implicated in the development of the 2nd generation biomethane pathway with the GAYA project that aim to produce a renewable methane from lignocellulosic biomass through gasification and methanation. Those pathways are fully complementary and the aim is to propose to industry and others final users, a technology portfolio of green gases production for common uses of natural gas.

Main text

Reduce CO₂ emission in the industry

Major industrial actors recognized that solutions are needed to tackle CO₂ emissions. They have been highly proactive in improving energy use and reducing greenhouse gas emissions, and are now operating close to the limits of the set technologies. Further CO₂ reduction involves to find new routes to green the gases used in the industrial processes. Biomass is an opportunity to produce the green gases. However the use of those green gases in the industry is not yet highly developed.

Solid biomass (fresh wood, forestry bio-products, demolition wood and other woody wastes) is one of the biggest source of renewable energy around the world. Among the 13% of renewable in the primary energy consumption in 2010 in the world, biomass represents the major contributor. When it is valorized in a sustainable way, solid biomass has a high development potential. Unfortunately, a significant share of this usage is not made with high standard of both energy efficiency and low environmental impact. The main difficulty for an efficient use of solid biomass is its transportation to the place of use. In that framework, biomass gasification has a high potential for upgrading and widening biomass energy applications.

Aims

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

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

The last two applications has the advantage to respectively,

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

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

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

- BioVive with St Gobain (Verralia) for direct firing application in the glass melting industry, supported by the French Research Agency
- VéGaz supported by the French Research Agency followed by GAYA project for 2nd Generation biomethane production, supported by Ademe, the French Agency for Energy and Environment

Replacing fossil fuels with syngas from biomass in furnaces

Replacing a part of the fossil fuel by syngas requires coupling the furnace to a gasification unit. Depending on the application, treatment unit will be required to clean the syngas before firing in the process. A general overview of the integration is depicted in the Figure 1. .

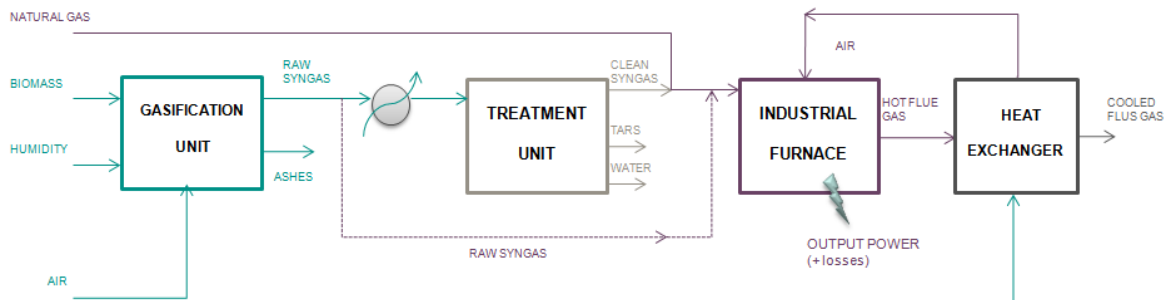


Figure 1 – Process flow of gasifier unit coupled with an industrial furnace

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

Various choices gasifiers technology for direct firing

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

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

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

Syngas contains CO, H₂, CH₄, C_xH_y aliphatic hydrocarbons, benzene, toluene, and tars (besides CO₂ and H₂O). The composition of the syngas strongly depends on the technology and the oxidant used for gasification (cf. Table 1).

% mol	H ₂	CO	CH ₄	C ₂ +	CO ₂	N ₂	NCV kWh/Nm ³
Fixed-bed downdraft composition	17	22	2	0	11	45	1,4
Fluidized bed composition (steam-blown)	38	25	11	2,6	21	2,5	3,5

Table 1 - Composition of syngas

Combustion and properties depend on the gases composition and also on the tar concentration. Tar concentration in the downdraft gasifier is low, usually around 0.015 to 0.5 g/Nm³[2]. For special application with engines, tars concentration can be strongly reduced up to less than 100 mg/Nm³ with the use of low tar technologies in the treatment unit (filtration stages, cyclones, scrubbers and cooling exchangers).

The power range of most industrial furnace is between several hundreds of kW and several tens of MW. If all of the syngas produced fire the industrial furnace, the thermal output power of the gasification unit has to match with the input thermal power of the furnace.

While steam-blown fluidized bed technologies produce syngas with higher NCV (Net calorific values) compared top fixed bed technologies, the size, power and CAPEX of those units is larger (cf. Table 2).

	NCV kWh/Nm ³	Air volume (Nm ³ air / Nm ³ fuel)	Fumes volume (Nm ³ fumes / Nm ³ fuel)
Natural Gas	10.25	9.8	10.8
Syngas (downdraft)	1.51	1.15	1.94

Table 2 - Syngas combustion properties

Major drawbacks of downdraft technologies are that it is very sensitive to the biomass particle size and requires very low humidity (< 10%). Another difficulty is that large gasifiers (> 4 MW) are not developed. However technical works are currently under way to increase the gasifier diameters and output power.

However, the simplest and the cheapest gasification technologies are the most appropriate for direct firing, especially fixed bed gasifiers. However the NCV is low. When replacing the natural gas or fuel oil on a combustion unit, the flue gas volume is largely increased and the flame temperature is decreased. Hence energy efficiency of the whole installation is reduced.

Research activities are currently under way [3] to increase the NCV with the use of oxygen instead of gasification air and therefore reduce the nitrogen concentration in the gases.

Simulation tool to assess technical feasibility

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

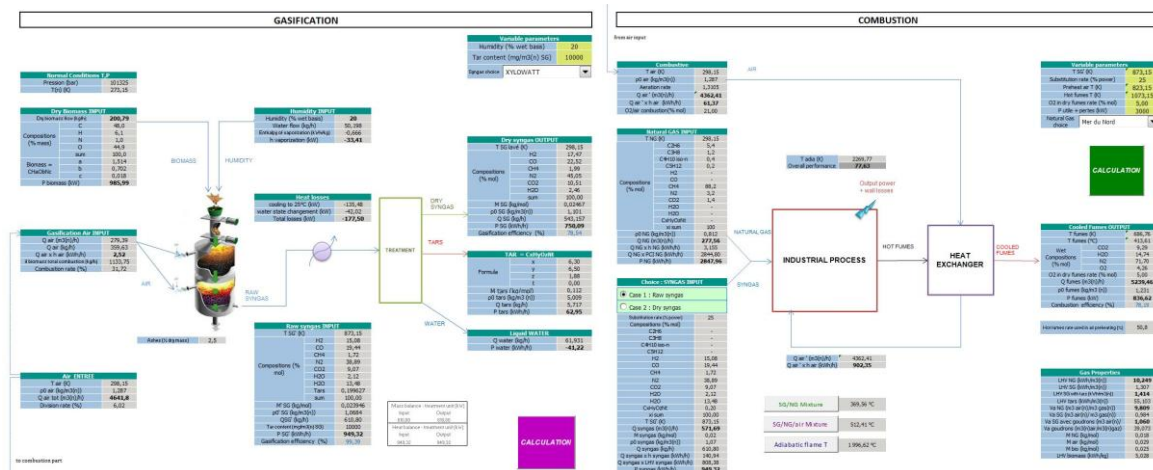


Figure 2 – Screenshots of the gasification and combustion sub-models

The model allows to achieve results on the combustion from natural gas and/or synthesis gas from a gasification unit, calculate the flow of gas and oxidizer to introduce into the industrial furnace, depending on the rate of substitution chosen and the output power of the furnace, determine the composition of syngas and the amount of biomass introduced into the gasifier from data on the clean syngas, calculate energy efficiencies in various industrial settings.

The model is able to consider two alternatives: with or without the use of a treatment unit. Without a treatment unit raw syngas is produced. If the industrial process supports it, raw syngas can be used instead of cleaned syngas. The main advantage is that raw syngas flows out of the gasifier at high temperature (around 600°C) and contains tars that can be used to increase NCV and radiation emission of the syngas. However, raw syngas contains a large concentration of water which does not participate to the combustion reaction but improve the flame radiation.

It was calculated on a reheating furnace case that compared to a fully fossil fueled combustion, energy efficiency fell by 13 and 17% at a total substitution into synthesis gas (respectively raw and clean), while overall performance fell by 14 and 35%. The volume of fumes increased from 23 and 47%. The results are affected by the configuration of the industrial furnace and the fumes temperature (which is directly linked with the temperature set point of the product to be heated).

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

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

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

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

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

A 1 MW wood gasifier has been built to produce the best suited specific syngas combustion into a glass melting furnace. It has been tested successfully at GDF Suez CRIGEN Research Center. It produces a clean syngas that could be injected into a laboratory combustion test cell representative of a slice of a glass melting furnace (cf. Figure 3 and Figure 4).

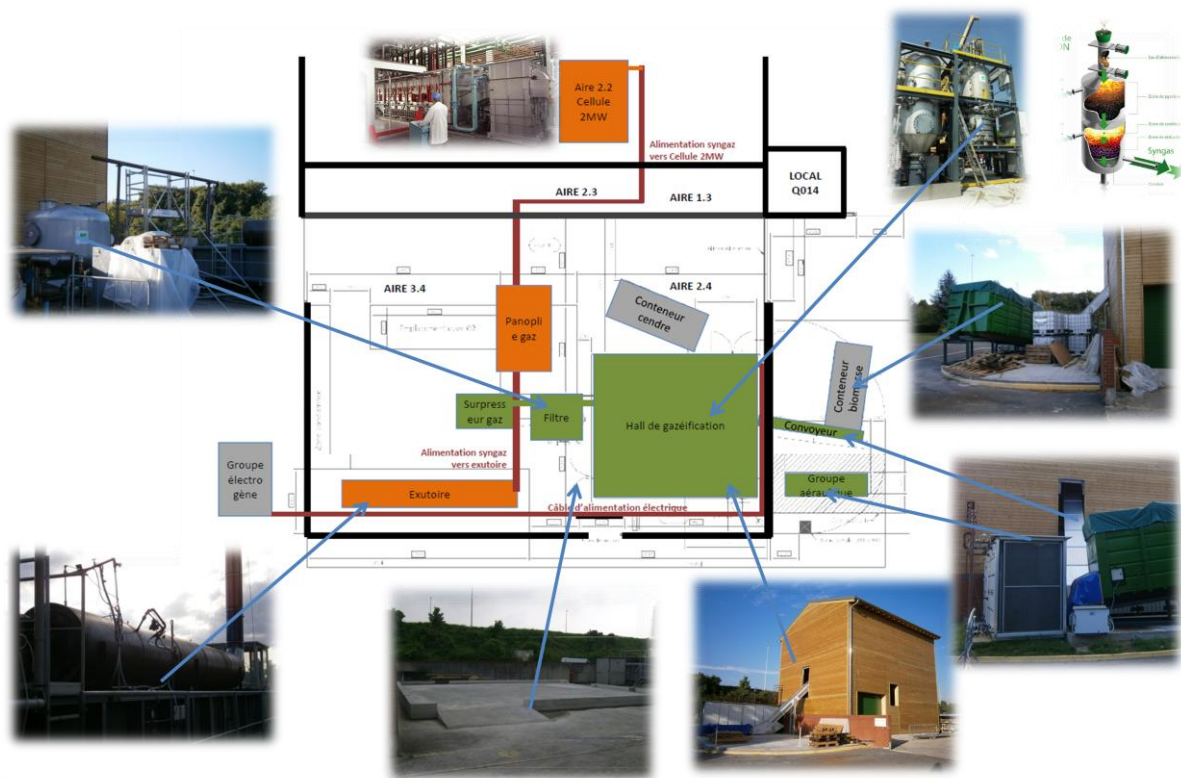


Figure 3 - Gasifier implementation on CRIGEN site

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



Figure 4 - Biomass gasifier and combustion test cell for BioVive Project

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



Figure 5 - Combustion visualization through CRIGEN furnace hub [3]

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

VeGaz project results

The VeGaz project, completed in early 2011, has demonstrated the possibility to potentially achieved high efficiency conversion of solid biomass to renewable natural gas (70%) while keeping environmental impact at minimum. In addition a comparison has been made with 2nd Generation Liquid Biofuels for both Energy Efficiency and Environmental Impact. On both criteria, biomethane has shown higher standards than 2nd generation biodiesel.

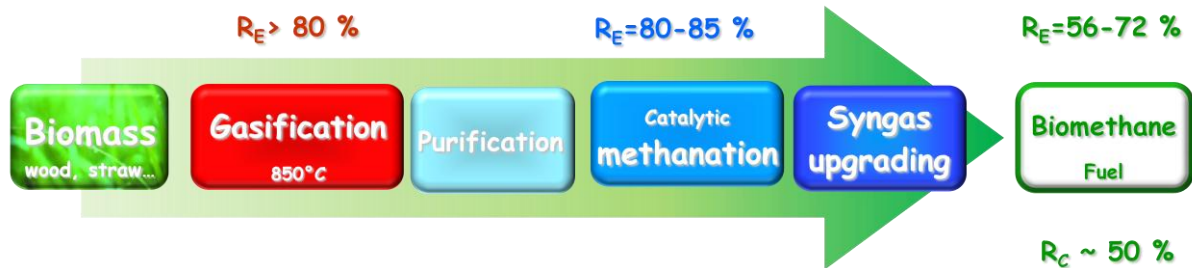


Figure 6: 2G Biomethane key figures

GAYA project results

The GAYA project has been officially launched in June 2010 for 7 years with 11 partners from upstream to downstream chain, coordinated by GDF Suez and with an overall budget of more than 40 M€. A Demonstration Platform has been engineered and will be build in 2012 at Saint-Fons near Lyon. A experimental test program has been set up to optimized the all chain for performance and costs while minimizing environmental impact. Simulation tools will be developed accordingly to be able to design future plants adapted to local available biomass and grid injection conditions.

Conclusions

Introduction of renewable fuels coming from the biomass will allow greening of the industrial processes that need to integrate policy respecting energy and environmental challenges for tomorrow. A large range of industrial processes can benefit from the environmental advantages of the syngas fuel. Keeping a subsequent input of natural gas in the mix is mandatory for most of the industrial processes, and particularly for the high temperature processes.

Transformation of solid biomass into a gas could be made into 2 different forms: as a syngas to be burnt directly into industrial furnaces or by transforming the syngas into a bio Synthetic Natural Gas (biomethane) that is injected into the gas grid. Both applications use biomass gasification technology and represents an opportunity for gas companies to green their supply while giving to their customer the opportunity to have a significant part of renewable gas in their energy mix.

A gasifier was installed in the CRIGEN labs and connected to an experimental combustion facility representative of a glass furnace. Results from the trials have brought comprehensive characterization of syngas combustion, up to 100% of syngas.

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