Life Cycle Assessment of the European Natural Gas Chain – A Eurogas-Marcogaz Study

By M. Papadopoulo, S. Kaddouh, E. Dridi-Dastrevigne, A. Cigni and D. Hec

Life cycle assessment (LCA) is a method aimed at assessing and accounting for the specific impacts of all the contributions from all the activities/processes needed for the production of a particular good or service in the whole chain ("from cradle to grave").

Initially, LCA was developed by and for industry in order to make strategic decisions concerning the environment and was broadly used in the 1990s to manage global environmental problems. According to the ISO 14040 and 14044 standards, LCA is a global environmental assessment method to evaluate the environmental burdens (global warming, resource depletion, etc.) associated with a product or activity over its life cycle. Considering the whole life cycle helps to ensure that no environmental burdens are shifted to other phases or among different impacts.

Until now, however, the European natural gas industry has not developed a detailed LCA. Only IGU has produced a worldwide LCA, which was presented at the 23rd World Gas Conference in 2006.

Aims

In a context of development of life cycle oriented regulations and the launching of the European Reference Life Cycle Data System (ELCD) project supporting business and policymaking in Europe with reference data and recommended methods on LCA, the Eurogas-Marcogaz Joint Group "Environment, Health & Safety" decided to set up a working group on this topic and to establish an LCA of the European natural gas chain in order to determine the environmental footprint of the whole natural gas chain, utilisation included.

The Eurogas-Marcogaz LCA covers all steps of the natural gas chain – a gas-fired combined cycle power plant under construction in Kårstø, Norway.

Scope of the study

The Eurogas-Marcogaz LCA covers all steps of the natural gas chain for the year 2004: from production to utilisation, including transport by pipelines and tankers, liquefaction, gasification and distribution of natural gas. Three different utilisations based on the best available technologies (BAT) are considered [reference 1]:

1. Electricity production with a natural gas combined cycle;
2. Heating with condensing boilers (domestic and commercial use);
3. Combined heat and power production (domestic and commercial use).

Substances and impacts considered

It was decided to focus on the main environmental impacts of the systems studied, for which Marcogaz can provide a real added value regarding the data quality [3]. The following substances have therefore been considered:

- Atmospheric emissions: greenhouse gases (CO_2, CH_4, CO, N_2O), acidifying emissions (NO_x, SO_x), particulate matters, non methane volatile organic compounds;
- Energetic consumptions: natural gas, oil, coal, uranium, hydropower.

  The associated impacts used in Eurogas-Marcogaz LCA are the following:

- Global warming potential (GWP);
- Acidification potential (AP);
- Non-renewable energy demand.

Results and conclusions

A confirmation of the good performances of natural gas

The results of the Eurogas-Marcogaz LCA confirm the good performances of natural gas as a fuel (*see Figure 1*). One kWh of useful heat produced from natural gas with a best available technology generates about 230 grams of CO_2-equivalent on its whole life cycle; the kWh of electricity produced with a natural gas combined cycle emits 393 grams of CO_2-equivalent. Generally the results support the figures used in existing generic LCA databases [2] for global warming and non-renewable energy resources depletion although both impacts are slightly lower in this study.

A low contribution of the natural gas upstream chain to the total GWP of heat and electricity supply

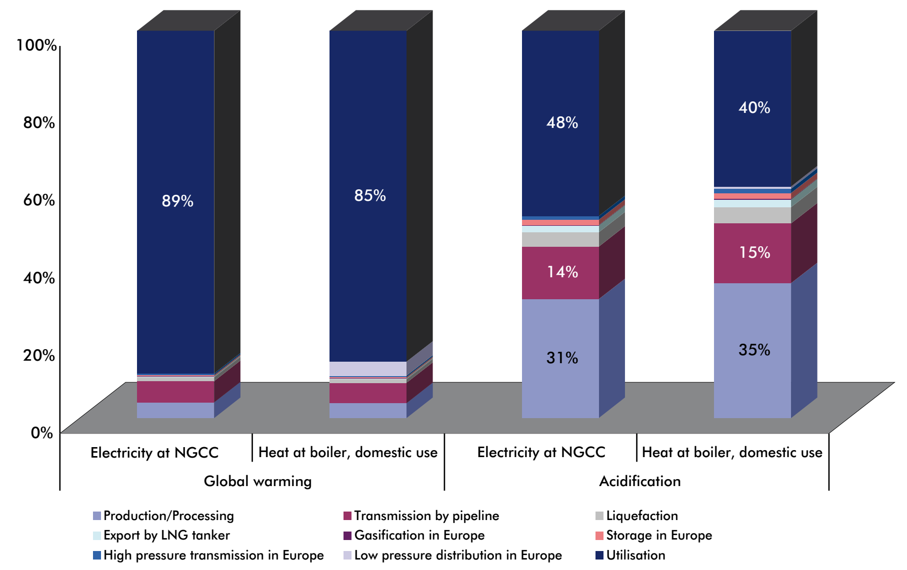
The utilisation phase (combustion at power plant or boiler) is predominant in terms of greenhouse gas emissions: its contribution exceeds 85% of the total GHG emissions. CO_2 is by far the main sub-

LEFT
Figure 1.

RESULTS OF THE EUROGAS-MARCOGAZ LCA

For 1kWh	*GWP (geq CO_2)*	*AP (mg eq SO_4)*	*Non renewable energy depletion (kWh)*
Heat at boiler – domestic use	236	129	1.12
Heat at boiler – services and buildings	224	120	1.09
Heat at CHP – domestic use	243	168	1.15
Heat at CHP – services and buildings	232	189	1.07
Electricity at CHP – domestic use	243	168	1.15
Electricity at CHP – services and buildings	228	186	1.06
Electricity at combined cycle plant	393	257	1.90

CONTRIBUTION OF EACH STEP TO GLOBAL WARMING AND ACIDIFICATION FOR ELECTRICITY PRODUCTION WITH A COMBINED (NGCC) CYCLE AND HEAT PRODUCTION WITH A DOMESTIC BOILER



ABOVE
Figure 2.

stance contributing to climate change, accounting for about 95% of the GHG emissions, while methane emissions account for the remaining 5%.

In terms of acidification, utilisation (40 to 53%), production/processing (27 to 35%) and international pipeline transmission (12 to 15%) are the main steps contributing to this impact. NO_X emissions occurring during natural gas combustion in power plants and boilers and in compressor drivers (for liquefaction and pipeline transmission) account for about 80% of the acidifying emissions, SO_X emissions representing the other 20%. Those are mainly emitted during production/sweetening of the sour natural gas produced in Russia and Germany, as well as during LNG transport through the use of heavy fuel oil as propulsion energy. (See *Figure* 2.)

A possibility to identify differences between the supply chains

This LCA also allows the assessment of the environmental performances of the different supply chains of natural gas arriving in Europe[1] (see *Figure* 3) as is illustrated in the following examples:

- The production of heat with a condensing boiler from natural gas coming to Europe as LNG emits about 27% more GHG than heat production with natural gas coming from European countries through conventional pipelines. This is mostly due to the high energetic consumption of existing liquefaction units and shows the strategic importance of investing in highly efficient liquefaction plant projects, such as the Snøhvit liquefaction plant in Norway, which should be two times less energy-consuming than existing liquefaction plants.
- Heat production from Russian natural gas emits about 20% more GHG than heat production with natural gas coming from European countries. This is mainly due to the distance covered from the Siberian fields to the EU-25 (about 5000 kilometres); in comparison, the distance covered from the European production fields is 1000 kilometres on average. The choice of a specific leakage rate on the Russian export pipeline systems has a low impact on the final results: a sensitivity analysis showed

1 European gas chains: mix of natural gas coming from Norway, Great Britain, Germany and The Netherlands to EU-25. LNG chains: mix of natural gas coming as LNG from Algeria, Qatar and Nigeria to EU-25. Russian chain: natural gas coming from Russia to EU-25.

that the use of the highest value found in the literature (0.43%/1000 kilometres against 0.18%/1000 kilometres for the baseline case [4]) resulted in an increase of barely 2% of the total GWP.

PRODUCTION OF HEAT WITH A DOMESTIC CONDENSING BOILER – REPARTITION OF THE GHG EMISSIONS AMONG THE DIFFERENT LIFE CYCLE STAGES

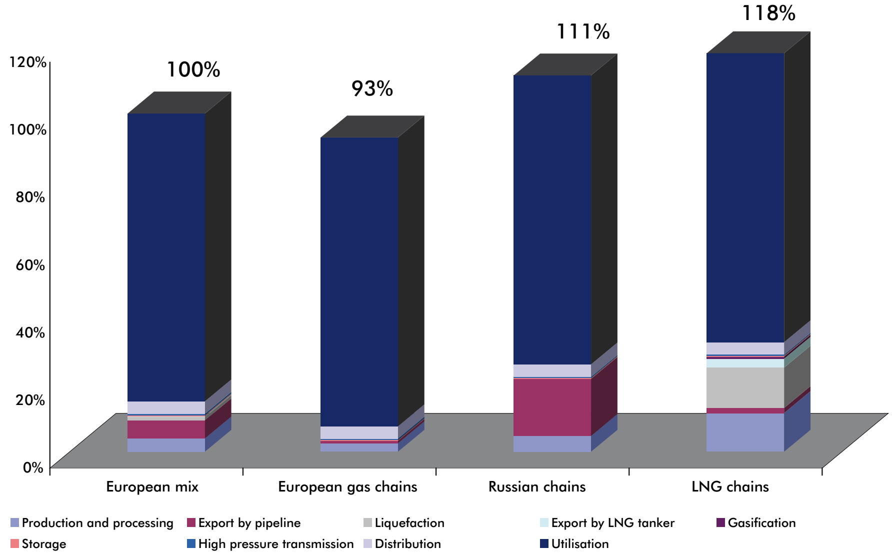


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Figure 3.

A need for more specific and up-to-date data

Important differences with existing generic LCA databases [2] have been noticed particularly for CH_4 and SO_X emissions, which are generally overestimated in the upstream chain.

Indeed, methane emissions on the transmission and distribution grids are much higher in existing databases than the rates measured on the networks of different European companies (eight and two times higher on the transmission and respectively the distribution grids [3]). This results in a reduction by a third of total methane emissions associated with the domestic systems assessed in this study.

Moreover the ecoinvent model for the European natural gas supply was based on a sour gas share of 10.2%, representing the average European supply in 2000. However, in 2004, the estimated proportion of sour gas only reached 3.4%. This explains that the domestic systems assessed in this study emit less SO_X in their whole life cycle than the corresponding systems in the ecoinvent database.

These differences show the importance of not basing environmental decisions on generic databases without first assessing their relevance and applicability.

Marion Papadopoulo and Emilie Dridi-Dastrevigne are project managers and Salam Kaddouh is a research engineer at GDF SUEZ, while Alessandro Cigni is the Technical Adviser and Daniel Hec is the Secretary General of Marcogaz.

REFERENCES

1. Paul Scherrer Institut. Life Cycle Assessment of New Natural Gas Conversion Systems in France (2007).
2. Ecoinvent v2 database.
3. Marcogaz internal data (2004).
4. Wuppertal Institut, Greenhouse Gas Emissions from the Russian Natural Gas Export Pipeline System (2005).