Optimising the life cycle

Gas is in demand. One of the many reasons for its popularity is its environmental performance compared with other fuels, but to stay ahead in changing global markets, life-cycle management may prove a vital strategy. By Maartje Sevenster and Harry Croezen, CE Delft consultancy, in collaboration with the IGU's programme committee A

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A NEW CONCEPT is finding its way into environmental management and policy: life-cycle thinking. Considering the potential environmental effects of a product throughout its life cycle is the key to finding the most effective and efficient way to limit those effects. For example, by designing a more energy-efficient light bulb, energy consumption by the end user may be more easily influenced than by expecting the end user to use less lighting.

Life-cycle thinking integrates all product stages into a single framework that considers environmental effects. While traditional policies deal separately with climate change, polluting emissions and acidification, these effects are intricately linked and cannot be tackled effectively in isolation. By focusing environmental action on single issues, without attention to the life cycle, it is easy to overlook effective abatement options, or even to cause additional environmental effects at other stages. Being effective, and cost-effective in particular, is one of the main drivers behind life-cycle thinking.

Life-cycle assessment

Life-cycle assessment (LCA) is the tool that accompanies life-cycle thinking and life-cycle management. It comprises a data-inventory phase and an impact-calculation phase that together yield the quantitative information industry needs for decision making. LCA is used for a variety of purposes, such as environmental product design, comparison between alternatives for a given functional need, or identification of potential improvements in a single product system.

Although many individual studies, compilations and public databases exist, these do not form a complete and consistent source of information on natural gas. In 2005, the International Gas Union's (IGU) programme committee on sustainable development undertook an LCA (conducted by the consultancy CE Delft) on the gas-production life cycle around the world. Together with a European gas life-cycle study by Eurogas-Marcogaz, the IGU project was one of the first attempts to construct a large-scale industry database for gas. (The Marcogaz project performed an LCA on the basis of 1 cubic metre (cm) of gas consumed in Europe.)

A global life-cycle data inventory (LCI), such as that initiated in this project, would yield a general basis that could be used in a wide range of applications: to identify opportunities for process improvement, for benchmarking and for strategy development, for example; or as input for specific life-cycle analyses, as a service to stakeholders and for public LCA practitioners.

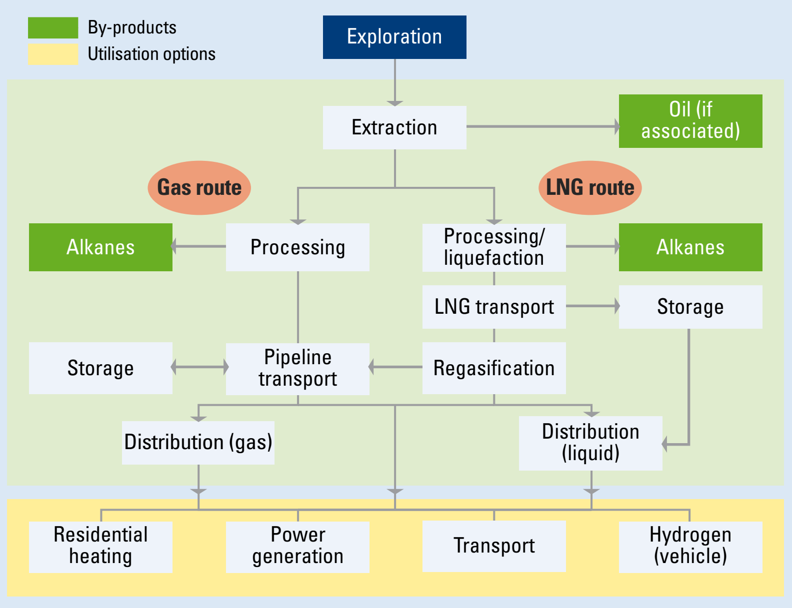
Such a project would be very ambitious, but not the first of its kind. The International Stainless Steel Forum (ISSF) is facilitating a worldwide LCI to provide data on a variety of products. On a somewhat smaller scale, Plastics Europe provides public access to elaborate life-cycle data on many chemicals and products.

The gas life cycle

The gas life cycle, or system (see Figure 1), comprises the following main stages: exploration; extraction; processing (treatment); transport; storage; distribution; and application (utilisation, combustion). Because of LCA methodological issues, exploration, as well as the various utilisation options, have a slightly different status from the other stages. As the figure shows, the life cycle is not as linear as suggested by the above list. There are two parallel routes, gaseous and liquid (LNG), and at several stages by-products split off, or a side step may be made to storage.

Extraction and processing are hard to disentangle as processes, as some or all processing may be conducted at the extraction site. In practice, envi-

Figure 1: Schematic of the natural gas life cycle



ronmental data generally relate simultaneously to extraction and processing, often referred to simply as production. By definition, freshly extracted gas does not match the specifications required for transportation or end consumers and is, therefore, processed into either pipeline quality gas or LNG. In both routes, processing involves separating out the contained water, acid gases, nitrogen and heavier hydrocarbons – the latter are valuable by-products.

Processed gas is consumed mainly within the producing country and is transmitted by compressor-driven pipelines to regional pipeline-distribution systems supplying industrial and domestic consumers. Increasingly, mismatches between (preferably continuous) gas production and (seasonal variations in) consumption are modulated, or balanced, by temporary storage in depleted oil or gas fields, aquifers or specially designed and engineered caverns.

Around 20% of global gas output is exported, 75% through international pipelines and the rest as LNG – primarily to Asia-Pacific countries, but increasingly to Europe and the US as well. Exports, especially of LNG, are rising because of the ever-growing demand for energy, but also because gas is seen as a relatively clean fuel, with a more limited influence on global climate and air quality during the use phase than petroleum products or coal.

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Supplied gas is consumed for a variety of purposes: transport (compressed natural gas); residential heating and cooking; electricity production, or co-generation; industrial uses (such as drying, heating, powering); hydrogen production; and non-energy use, such as feedstock for the chemicals industry.

Worldwide, around 35% of gas is used for power generation, according to the International Energy Agency (IEA), and 25% for residential and commercial heating and cooking. Within the OECD, only about 3% of gas supply is used as a transport fuel. The remaining third goes primarily to energy and non-energy (5-10%) applications in industry. In each of these applications, natural gas competes with a range of alternative products, including: coal or nuclear fuel (power generation); gasoline or biofuels (transport); biogas (heating); and oil (non-energy uses).

Gas and the environment

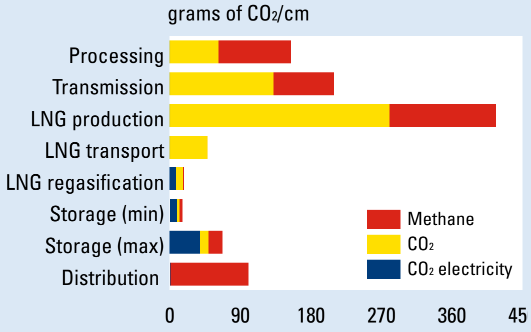
All the links in the gas cycle, from wellhead to consumer, create environmental pollution, primarily in the form of:

- Combustion emissions – carbon dioxide (CO_2), nitrogen oxides, sulphur dioxide (SO_2) – from turbines, boilers or engines as well as flares, at the processing and the utilisation stages; and
- Emissions of methane (CH_4) and other volatile organic compounds as a result of venting, or fugitive emissions at several stages along the life cycle.

Energy requirements for turbines and boilers are generally covered by gas itself, although in more densely populated regions electricity from the grid may be used to power compressors and other items.

The environmental burden per 1 cm of supplied gas can vary significantly, owing not only to large differences in gas quality, but also to differences: in the distance between source and end consumer; between LNG and pipeline transport; in gas treatment and co-products; and in equipment sophistication (best available, versus obsolete technology).

Figure 2: Global-warming potential of the gas life cycle



Source: CE Delft

CO_2 and CH_4 are the greenhouse gases (GHGs) best covered by the data. Data on SO_2 emissions are not generally available, partly because they are very low for natural gas. For climate change, the results of the IGU's CE Delft study yield the following picture (see Figure 2):

- On average, LNG processing is less environmentally efficient than gas processing without liquefaction; although
- In the transport phase, LNG transportation performs better than pipeline transmission. The climate effect of pipeline transmission is determined largely by fugitive emissions, which may vary by over a factor of 100/cm, depending on, among other things, transmission distance.

Increased efficiency

Analysis of LNG production capacity under construction shows that new plants will be considerably more efficient than the average shown in Figure 2 for existing capacity. The climate impact of standard gaseous processing is influenced primarily by the quality of the raw gas; the more processing that is required, the more energy is consumed.

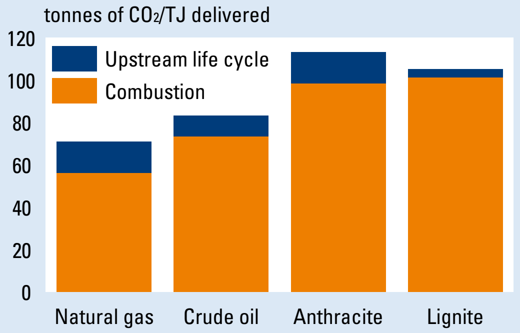
Overall, an important factor in climate impact is that the gas, CH_4, is a potent GHG with 23 times the global-warming potential of the CO_2 arising during combustion. In terms of climate change, therefore, venting and fugitive emissions have a much greater effect than flaring, although the same amount of gas is lost in the process.

Figure 2 does not include the utilisation phase – combustion. The so-called emissions factors used by the International Panel for Climate Change for fossil fuel combustion are shown in Figure 3, together with estimates for life-cycle emissions (basically, the sum of the emission factors shown in Figure 2). Gas has relatively low combustion emissions of CO_2, but relatively high upstream emissions of GHGs, especially when expressed as a fraction of total life-cycle emissions.

The dialectics of progress

This assessment, together with the available literature, shows that in terms of life-cycle environmental effect, natural gas remains the fossil fuel of choice in many applications. But there are opportunities for improvement at several points in the life cycle. These may lie in measures to limit fugitive emissions and venting. These CH_4 emissions not only lead to significant losses of valuable product – possibly about 1% – but also have a significant greenhouse effect. The total volume of these emissions is similar to the figure reported for global paddy rice production, another known source of CH_4 emissions. Another opportunity would be to focus on using best available technology in new LNG production capacity.

Figure 3: Climate impact of energy delivered



Source: CE Delft, Wuppertal Institute **YES?**

Continuous improvement is always a key element of environmental management, but it is especially important if gas is to retain its good environmental reputation, as several developments may change the favourable environmental profile of the fuel. These are partly technical in nature and partly related to changing global markets.

One technical development is the use of CO_2 capture and sequestration to create zero-emissions power generation. Because it is combustion emissions that will be captured, coal-fired plants have much to gain in terms of environmental performance. The technology can also be applied to gas-fired plants – the first plant to utilise CO_2 capture and sequestration will be a gas-fired facility in Norway. If this technology becomes commonplace, however, gas will lose some of its head start.

The global gas market is also undergoing dynamic change. Traditionally, it consisted of a number of separate, fairly coherent regions, among which trade flows have been fairly constant and bilateral. However, with production capacity shifting to new areas and demands on flexibility becoming higher in a globalising market, LNG is expected to increase its share of trade.

In 2004, LNG accounted for only 6% of the global gas market and 26% of international trade flows. By 2030, however, the IEA expects over half the international gas trade to be as LNG. Another likely development, geared to increased flexibility of the supply chain, is increased use of gas storage. These two developments may well increase the net environmental effect of 1 cm of gas delivered. These developments, along with continuing technological improvements in the life cycles of other fossil fuels, will reduce gas' lead unless improvements are made to the gas life cycle.

Planning for the future

Costs and environmental effects are important motives for evaluating the gas life cycle. Environmental impact is set to become an increasingly important issue for industry policy and strategy. Gas lost through fugitive emissions and venting or flaring has a major global-warming effect – reducing losses leads to improved environmental, as well as economic performance. While venting or flaring may be difficult to avoid, fugitive emissions can, in principle, be reduced significantly, as shown by the US' Gas Star programme – a voluntary government/industry initiative that reduced CH_4 emissions by 9.6bn cm between 1993 and 2003. The energy efficiency of processing can also be improved – most of the energy used for this purpose is provided by gas itself, resulting in a loss of product.

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The link between costs and environment can be made even more explicit by expressing environmental impacts in financial terms. There are several methods for calculating the shadow price of these effects and their use in cost-benefit analyses is gaining popularity in several countries. In some industries, shadow budgets that include environmental entries are assessed alongside direct budgets to determine corporate strategies.

Many opportunities exist for economic and environmental gain to go hand in hand. This means efforts to keep a favourable environmental profile with respect to other fuels and work with governmental and non-governmental organisations on implementing environmental policy may lead to economic benefits instead of costs. Ultimately, both industry and stakeholders will benefit from the availability of consistent and authoritative data on all stages of gas' life cycle. ■