

Impending Natural Gas Supply Glut and Biogas Developments in Europe: Economic and Environmental Implications

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Abstract

The recent trend in the global energy consumption as a result of growing demand from rapidly industrializing countries such as China, India, Brazil, etc. have called for an urgent need to find an alternative and economical source of energy. Natural gas from various sources (conventional, non-conventional) has long been touted as a potential replacement for heavily-polluting crude oil and coal. The recent development in natural-gas production has seen output from non-conventional sources such as shale bed increasing significantly in countries with substantial investment in pipeline and technology for the exploitation and production of gas from this new source such the US. This has created a gas boom in countries with a head-start in tapping into this economical but environmentally controversial source, as well as a slump in global natural-gas prices. In Europe, there has been a stiff opposition to gas production from non-conventional sources such as shale gas on environmental ground, and the focus here is on securing gas supply from existing conventional sources through long-term contracts with major gas suppliers as well development of environmentally friendly alternatives such as biogas from biomass. This paper examines the effects of the impending natural-gas supply glut in the global energy market with respect to biogas developments in Europe and environmental aspects of both sources of energy.
Keywords: Natural gas; Biogas; Shale gas, Substrates.

1. Introduction

Natural gas is primarily comprised of hydrocarbons of which methane (CH_4) is the major component. The other components include ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and heavier, more complex, hydrocarbons. In addition to hydrocarbons, natural gas also contains impurities such as nitrogen (N_2), carbon dioxide (CO_2), hydrogen sulphide (H_2S), and water vapour (H_2O). These impurities do not add any calorific value to natural gas. However, these impurities can be neutral such as nitrogen (N_2), can cause harmful effects such as corrosion (CO_2, H_2O) or poisoning (H_2S) (Kelkar, 2008).

Natural gas has long been favoured in the campaign against climate change because it is the least polluting fossil fuel with a relatively lower carbon footprint when compared to petroleum and coal. Historically, the production of natural gas is often associated with oil production, and as such, most of the petroleum-rich countries also have substantial natural gas deposit. Nowadays, natural gas is produced from increasingly diverse sources such as conventional and unconventional deposits, biologically-derived sources such as biomass, sewage sludge, landfill, etc. The utilization of so-called biogas produced from diverse biologically-derived materials has been gaining popularity in recent times, and with the upgrading facility to remove carbon dioxide (CO_2) and other impurities, biogas can be processed to natural-gas quality which then allows it to be distributed through existing natural-gas network (Jensen & Jensen, 2000).

Table 1. Key numbers for gas and flue gas, for natural gas and biogas. (*Jensen & Jensen, 2000*)

Key Numbers	Natural-gas	Biogas
CH_4 (methane) [Vol%]	91.0	55-70
C_2H_6 (ethane) [Vol%]	5.1	0
C_3H_8 (propane) [Vol%]	1.8	0
C_4H_{10}(butane) [Vol%]	0.9	0
C_5H_{10} (pentane) [Vol%]	0.3	0
CO_2 (carbon dioxide) [Vol%]	0.61	30-45
N_2 (nitrogen) [Vol%]	0.32	0-2
H_2S (hydrogen sulphide) ppm	~1	~500
NH_3 (ammonia) ppm	0	~100
Water dew point [℃]	<-5	saturated
Net calorific value [MJ/nm^3]	39.2	23.3
Net calorific value [KWh/nm^3]	10.89	6.5
Net calorific value [MJ/kg]	48.4	20.2
Density [kg/Nm^3]	0.809	1.16
Relative density[-]	0.625	0.863
Wobbe index [MJ/nm^3]	54.8	27.3
Methane number [-]	73	~135
Stoichiometric mixtures		
Air requirement [nm^3/nm^{3}gas]	10.4	6.22
Flame temperature* [℃]	2040	1911
Water dew point (flue gas) [℃]	59.7	59.2
Water vapour (flue gas) [Vol%]	18.8	19.3

**Adiabatic flame temperature*

2. Natural-gas sources

1.1 Conventional sources

This refers to gas reservoirs in which buoyant forces keep hydrocarbons in place below a sealing caprock. Reservoir and fluid characteristics of conventional gas reservoirs typically permit oil or natural gas to flow readily into wellbores (Schlumberger, 2012). The term is used to make distinction from shale and other unconventional reservoirs in which gas might be distributed throughout the reservoir at the basin scale, and in which buoyant forces or the influence of water column on the location of hydrocarbons within the reservoir are not significant.

1.2 Unconventional sources

This is a term commonly used to refer to low-permeability reservoir that produces mainly dry natural-gas. Many of the low-permeability reservoirs that have been developed in the past are sandstone, but significant quantities of gas are also produced from low-permeability carbonates, shales, and coal-bed methane. It can also be described as a natural-gas that cannot be produced at economic flow rates or in economic volumes of natural-gas unless the well is stimulated by large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbore or some other techniques to expose more of the reservoir to the wellbore (NPC, 2007). The equation below known as Darcy's law relates many physical factors in a gas reservoir.

$$q = \frac{kh(\bar{p} - p_{wf})}{141.2\ \bar{\hat{a}}\tilde{\imath}\left[\text{In}\left(\frac{r_e}{r_w}\right) - 0.75 + s\right]} \quad (1)$$

q is the flow rate m^3/s, k permeability m^2, h net pay thickness m, $\bar{p}$ reservoir pressure N/m^2, p_{wf}, flowing pressure N/m^2, r_e drainage area, r_w wellbore radius m, and s skin factor (USNPC, 2007).

1.3 Biologically-derived sources

These are also known collectively as biofuels, which refers to fuels (*including biogas*), derived from dead or living biological organisms, in other words, that are derived from biomass. Biomass such as lignocellulose materials, crops, grasses, animal wastes, and biogas are combustible renewable energy sources (Demirbas, 2009).There is a growing interest especially in Europe in this type of renewable energy source and the production of biogas from biowaste is becoming popular with the potential of cutting the amount of biowaste going into the landfill and incineration plants. Biogas as a secondary energy carrier can be produced from different kinds of organic materials and its options for utilization can equally be versatile. Biogas can be used to generate electricity, heat or used in vehicles as biofuels (EBA, 2009).

3. Natural gas demand and supply

Almost half of the world's recoverable natural-gas reserves are "unconventional" comprised mainly of shale gas, and also tight gas and coal bed methane. The International Energy Agency (IEA) reckons global gas demand will increase by more than half between 2010 and 2035, and unconventional gas will make up 32% of the total supply up from 14% today. While Russia and the Middle East hold the largest reserve of conventional gas, available sources of unconventional gas are spread around the world, and can be found in countries that are currently net importers, such as China and America (Economist, 2012).

Global reserves have been steadily increasing for at least 30 years. According to a report from the Massachusetts Institute of Technology (MIT), published in 2011, world production has grown significantly too, rising by two-fifths between 1990 and 2009, twice as fast as that of Oil. Only half a decade ago it looked as though the world might have 50 or 60 years-worth of gas. Now shale and other unconventional as well as new conventional gas finds have increased that period to 200 years or more, by some estimates. The unconventional gas boom has roughly doubled the gas resource base, a measure of the total gas in the ground rather than what might be economically recoverable. In 2009 the IEA estimated the "long-term global recoverable gas resource base" at 850 trillion cubic meters (tcm), against 400tcm only a year earlier. The main reason for the rethink was shale gas and other unconventionals. Not just America but parts of Europe, China, Argentina, Brazil, Mexico, Canada and several African countries, among others, sit atop as yet unknown quantities of gas that could transform their energy outlook (Economist, 2012).

The global energy demand is likely to continue its upward trend as emerging economy countries continue to expand in the years ahead. The supply side of the equation is expected to hold up as new conventional deposits are found in addition to green sources of natural gas. The combination of the demand and supply projections is likely to result in a gradual fall in the price of natural gas, as already observed in the US.

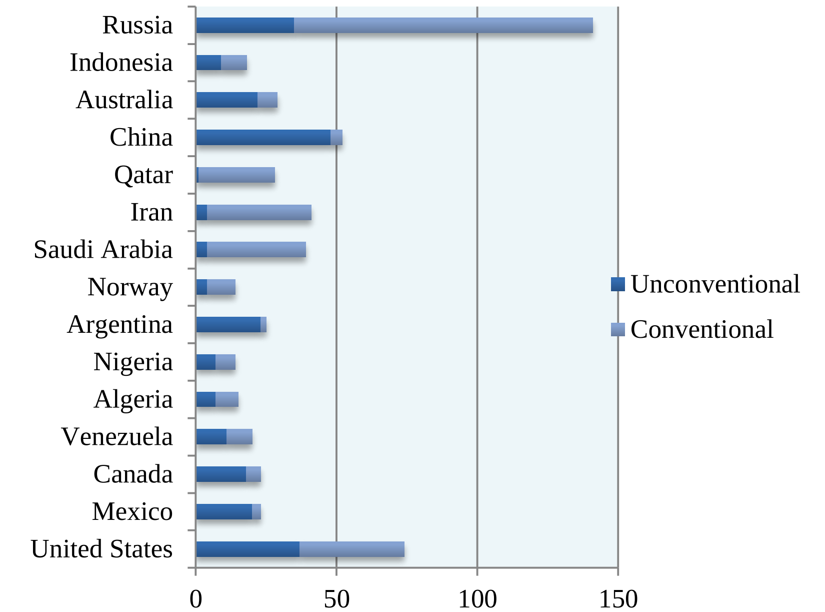

Figure1. Remaining recoverable natural-gas reserves as a share of world primary energy (IEA, 2012)

4. Shale gas production from shale bed

Shale gas is a form of natural gas produced from unconventional sources, which also include coal-bed methane, gas from tight sandstones (‘*tight gas’*) and methane hydrates. Although the existence of shale deposits across the world has been well-known for many years, most shales have not been regarded as potential sources of commercial quantities of natural gas as they have insufficient natural permeability to permit significant fluid flow to a well bore. The transformation in thinking about the shale gas potential that has occurred in recent years is not attributable to the discovery of new resources or the re-assessment of old resource estimates but to the development and application of new technologies that in effect ‘create a permeable reservoir’ and achieve high rates of production (WEC, 2010).

The recent surge in shale gas production and distribution in the US has been predicted to have a huge impact globally. The most expected impact is a significant reduction in the US natural-gas imports as the gas supply at home increases. As a proportion of America’s overall gas production shale gas has increased from 4% in 2005 to 24% today. The shock waves of America’s gas boom are being felt elsewhere. Development of Russia’s vast Shtokman gasfield, in the Barents Sea – a $40 billion project which was intended to supply America with LNG – has stalled. Qatari LNG, once earmarked for America, is going to energy-starved Japan. Yet a bigger change is expected, with the possibility of large-scale shale-gas production in China, Australia, Argentina, and possible in some European countries such Poland and Ukraine (Economist, 2012).

5. Biogas production from biological feedstock

Biogas composed primarily of methane and other undesirable impurities which are produced by bacterial conversion of organic matter under anaerobic (*oxygen free*) conditions (Raven & Gregersen, 2005). The technical terms such as biomethanization or bio-hydrogen refer to anaerobic digestion of the organic fraction of suitable substrates. This is accomplished by a series of biochemical transformation of the substrate (Forster-Carneiro et al., 2012). Nowadays, biogas is increasingly produced from a large variety of substrates while many more are being developed.

There is a high level of expertise in biogas production within the EU and in particular in the northern part of Europe. Germany, Denmark and Sweden for example have many thriving biogas plants that produce biogas of comparable quality to natural gas from a wide range of substrates. Biogas can be used to generate electricity, heat or used in vehicles as biofuels. In addition, the fermentation residues can be used, for example as a fertilizer in or soil conditioner.

Table 2. Primary production of biogas in the European Union 2010 in Ktoe (EurObserv'ER, 2012)

Countries	Landfill gas	Sewage sludge gas†	Other biogas‡	Total
Germany	232.5	402.6	6034.5	6669.6
UK	1499.4	272.8	0.0	1772.2
Italy	383.8	7.0	87.7	1478.5
France*	323.7	41.6	48.0	413.3
Netherlands	36.7	50.2	206.5	293.4
Spain	119.6	12.4	66.7	198.7
Czech Rep.	29.5	35.9	111.3	176.7
Austria	5.1	22.5	143.9	171.5
Belgium	41.9	14.6	70.9	127.4
Poland	43.3	63.3	8.0	114.6
Sweden	35.7	60.7	14.8	111.2
Denmark	8.1	20.1	74.0	102.2
Greece	51.7	15.0	1.0	67.7
Ireland	44.2	8.6	4.5	57.3
Finland	22.7	13.2	4.5	40.4
Hungary	2.6	12.3	19.3	34.2
Portugal	28.2	1.7	0.8	30.7
Slovenia	7.7	2.8	19.9	30.4
Latvia	7.9	3.3	2.2	13.3
Luxembourg	0.1	1.2	11.7	13.0
Slovakia	0.8	9.5	1.8	12.2
Lithuania	2.0	3.0	5.0	10.0
Estonia	2.7	1.1	0.0	3.7
Romania	0.0	0.0	1.1	1.1
Cyprus	0.0	0.0	0.2	0.2
Total EU	**2929.2**	**1075.2**	**6938.3**	**10943.3**

**Overseas departments not included †Urban and industrial ‡ Decentralized agricultural plants, municipal solid waste, methanation plants, centralized codigestion and multi-product plants.*

6. Environmental aspects of shale gas and biogas

It has been proven that all energy sources have impacts on the environment throughout their lifecycle from production to final utilization (Riva et al., 2006). While the environmental benefits of biogas are quite evident in terms of its low carbon footprint, the same cannot be said of shale gas with its huge water consumption, emissions, and pollution threat to the groundwater. Even environmentalists are beginning to question the sustainability of biogas produced using food crops as substrates as their cultivation increases their overall carbon footprint and poses a threat to global food security.

The future of global shale-gas development remains unpredictable as there is a huge concern in Europe concerning 'fracking'— that is the term used to describe the process of producing shale-gas. In addition, many have questioned the sustainability of the whole process considering the huge amount of water used up during fracking, but many countries (*especially those that are energy-starved*), will still consider the risk worth taking as long as they have the resource at their fingertip.

7. Implications for biogas developments in Europe

The development and production of biogas as an alternative green fuel has always been favoured as a means of utilizing biodegradable waste coming from a variety of sources in Europe. Capturing the resulting methane artificially as compared to when biowaste are allowed to biodegrade in the open air has a double effect. It can be used to generates energy and prevent the release of methane which is a greenhouse gas into the atmosphere (Economist, 2012). The process of artificial conversion of biowaste known as anaerobic digestion is constantly been improved in the UK, Germany, and Sweden and presently substantial amount of electricity is being generated from sewage sludge.

The European waste directive has an ambitious target of cutting the amount of biowaste going into the landfill significantly and biogas production is naturally seen as one of the means of meeting this target. In Germany, the number of biogas plants has increased during the past few years following a government support handed out for the installation of plants. Infact the number has tripled from 850 plants connected to the electricity network in 1999 to 2700 plants in 2006 (Deublein & Steinhauser, 2008).

Energy security has often been a sensitive topic in Europe partly because of the fact that Europe cannot meet its energy demands and has had to rely on foreign energy imports. In recent times, policy makers in Europe have seen investment in alternative pipeline projects (*such as Nord stream, Nabucco, and South stream*) to bring natural gas from different sources as a way to secure Europe's future energy supplies (Economist, 2010). In addition, alternative forms of energy especially renewables such as wind and biomass are being harnessed and actively promoted in many countries across Europe.

As the pace of shale-gas production accelerates globally, and with many countries in Europe reluctant to grant exploratory license for shale-gas, coupled with the expected price volatility in the global gas market, European policy makers will need to have a rethink on the present energy policy. Europe will therefore needs to make a delicate balancing in the years ahead regarding environmental sustainability and the economics of natural-gas demand and supply .The opening up of the arctic is another development that will fundamentally alter the natural-gas landscape in Europe and around the world as discussed in the next section.

8. Arctic developments and future scenario

The arctic is one of the least explored and last wild places. Since 1951 it has warmed roughly twice as much as the global average temperature change. Since 1951 the arctic has warmed roughly twice as much as the global average. There is no serious doubt about the basic cause of the warming. It is, in the arctic as everywhere, the result of an increase in heat-trapping atmospheric gases, mainly carbon dioxide released when fossil fuels are burned (Economist, 2012).

A considerable amount of the world's oil and gas production in the foreseeable future will come from hydrocarbon deposits in the Arctic and Subarctic regions. Mainly because of the severe climatic conditions and their remoteness from markets, these Polar Regions are among those least affected by human activities (IUCN, 1993).

There is therefore no doubt about the resource scrambling that is about to happen, as the Polar ice melts and the Arctic becomes more accessible. This informed cooperation between Canada, Denmark, Finland, Iceland, Norway, Sweden, Russia, and the United States in developing the Arctic Environmental Protection Strategy *(also known as Finnish Initiative)*. The Strategy calls for management, planning and development activities to provide for the conservation, sustainable use and protection of natural resources for the benefit and enjoyment of present and future generations (Arctic Council, 2012).

9. Conclusions and discussions

The emergence of shale gas might be a positive development in terms of energy economics. It will reduce significantly the energy bills of high energy-consuming countries and will also accelerate the popularity of natural gas-fueled vehicles. On the other hand, the environmental concerns surrounding the production of shale gas especially "fracking", the process by which it is produced will not go away overnight and needs to be addressed. The melting of the polar ice and the mineral resource scrambling that will likely ensue in the years ahead will certainly calls for a global rethink in the way our world will be powered by the future generations.

There is still a long way to go in the search of an environmentally acceptable way to meet the global energy needs and renewables such as solar, bioenergy, wind, geothermal etc. certainly has the potential to meet this goal. The urgent priority should be investment and research into ways of tapping this unlimited potential to power our world out of looming environmental catastrophe.

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