Energy Policy Studies

1(2) / 2018

IGNACY LUKASIEWICZ
ENERGY
POLICY
INSTITUTE

Cover design: Aku Studio

Typesetting: Aleksandra Szewczyk

Proofreading: Robin Gill

Publisher: Ignacy Lukasiewicz Energy Policy Institute

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http://www.instytutpe.pl/en/eps-en/

e-ISSN: 2545-0859

The electronic version of the journal is the original version.

Rzeszów 2018

Ministry of Science and Higher Education
Republic of Poland

"Energy Policy Studies – English language e-edition as a tool for disseminating science" and "Energy Policy Studies – transfer of the best foreign pracities and echange of experience" – the tasks financed as part of contract 687/P-DUN/2018 with the resources of the Minister of Science and Higher Education for science promotion activity.

LEAKING AWAY THE FUTURE: THE ROLE OF METHANE EMISSION AND NATURAL GAS SUPPLY CHAINS IN GLOBAL WARMING

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Abstract
Natural gas is being considered as a "bridging fuel" that plays a crucial role in implementing the transition to a low-carbon economy and society. This study reviews an aspect of the natural gas industry that has been neglected for far too long, in spite of the growing importance of countering global warming and climate change. Reducing methane emissions from natural gas production, processing, transportation and consumption is becoming a more and more important aspect of reducing greenhouse gas emissions, and may contribute significantly to the goals of the United Nations Climate Change Conference of 2015. The key question this study aims to answer is to what degree does a stronger emphasis on natural gas consumption contribute to the fulfilment of the climate goals of the Paris Agreement per se? Is promoting natural gas consumption really the key to avoid a climate catastrophe? Is there sufficient time left to avoid such a catastrophe?

Keywords: natural gas, global warming, climate change, greenhouse gases, methane

Introduction

In December 2015 at the United Nations Climate Change Conference in Paris world leaders once again agreed – just as they did before, in Cancun, Copenhagen, Kyoto and Rio de Janeiro – to try to put a halt to climate change and its constantly aggravating consequences. The 196 signatory states of the Paris Agreement committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations Framework Convention on Climate Change, 2015:2). But, despite the global understanding that urgent steps are needed to avert the worst-case scenarios of climate change, the world remains on track towards further global warming and, along with it, suffering from increasingly unpredictable and extreme weather conditions. According to the United Nations Environment Programme (UNEP), even if all of the current Paris pledges are kept, the world will still warm up by more than 3°C (UNEP, 2016:7).

The main reason behind this continuing failure to meet the challenge of climate change is the world's insatiable dependence on and appetite for fossil fuels: coal, oil, and natural gas. Almost every country burns these hydrocarbons at an accelerating pace, which gives incentives to the fossil fuel industry to explore for more. Yet there is a visible shift underway in global energy politics: although investments in coal and oil remain strong, over the last decade there has been an investment boom in natural gas, which led to a global increase in natural gas extraction and consumption. It started with the shale gas boom in the late 2000s in the United States whereby the level of natural gas production of the US increased from 543,2 billion cubic meters in 2000 to 734,5 billion cubic meters in 2017. This was accompanied by constantly growing natural gas consumption globally. Today, the five biggest natural gas consumers are the United States, Russia, China, Japan and Iran, accounting for almost half of all global natural gas consumption, with 1736,2 billion cubic metres out of 3670,4 billion cubic meters of total consumption worldwide in 2017 (British Petroleum 2018, p. 28).

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Since combustion of natural gas emits 50 to 60 percent less carbon dioxide (CO_2) when combusted in efficient natural gas power plants as compared to the emissions from a typical new coal plant, the image of natural gas extraction became strongly coupled with the fight against global warming and the goal of less pollution (National Energy Technology Laboratory 2010, p. 41-43). Thus, based on political, economic and environmental reasons, more and more countries plan to increase the share of natural gas as compared to other fossil fuels. The best example for this is the European Union as a whole, where natural gas plays a crucial role in the establishment of the so-called Energy Union, an ever-closer cooperation of member states with the aim of boosting energy security, creating a fully integrated internal energy market, improving energy efficiency, and pursuing the goal of decarbonisation (European Commission 2016b).

However, the question arises: *To what degree does a stronger emphasis on natural gas consumption contribute to the fulfilment of the climate goals of the Paris Agreement*? Is promoting natural gas consumption really the key to avoid a climate catastrophe until mankind finds a way to overcome its addiction and dependence on fossil fuels in energy generation and transport? Is there sufficient time left?

The severe consequences of climate change

It has been shown by scientists that a 2°C rise in temperatures worldwide can have devastating effects on the local and global scales, hitting the most vulnerable the hardest, and affecting tens of millions of people mainly in Africa, the Middle East and Asia. Even a 1.5°C rise in average global temperatures carries major risks, by threatening the very existence of some small island states, such as Tonga, Tuvalu, Palau, and the Solomon Islands, and low-lying coastal regions of Vietnam, Bangladesh, The Netherlands, and Japan through the accelerated melting of polar ice.

According to the National Oceanic and Atmospheric Administration (NOAA) and NASA, since record-keeping began in 1895, the hottest year on record worldwide was 2016. In that year, the Earth's surface temperature was one-degree Celsius warmer than the average across the entire 20th century. Before 2016, 2015 and 2014 were the warmest years on record, globally. According to NASA, 16 out of the 17 warmest years on record occurred since 2001 (NASA 2017).

Climate dynamics often strongly affect some regions more than others, so not every part of Earth experienced above-average temperatures in the last years. However, some outstanding anomalies should be mentioned. The last years have brought numerous reminders that the world is drifting towards a climate emergency. Floods in South Asia, heavy storms in the Atlantic Ocean region, severe drought in East-Africa, and island states in the Pacific Ocean region starting to disappear because of rising sea levels. All this shows the devastating impact of climate change on human lives and livelihoods, particularly in the poorest and most vulnerable countries. Hurricanes Harvey and Irma – the strongest ever recorded in the Atlantic region –

devastated large parts of the Caribbean, and Texas and Louisiana in the US, showing that even the most-developed countries are vulnerable to climate disasters.

There is evidence of climate change in Europe and its vicinity as well. Europe experienced the "Lucifer heatwave" in August 2017, which affected millions and saw temperatures as high as 42°C in Croatia and 44 °C in Spain.

CO2 is not the only problem

As mentioned earlier, burning natural gas instead of oil or coal where and when possible can significantly reduce the emissions of carbon dioxide (CO_2) and thereby contribute to a lessened greenhouse effect. However, CO_2 is not the only problem when it comes to natural gas that contributes to global warming. Significantly less attention is paid to the fact that natural gas production is also responsible for large amounts of methane emissions. Methane, one of the components of natural gas, is also a potent greenhouse gas that contributes to global warming and climate change. Though more short-lived in the atmosphere than CO_2, it still contributes to approximately 20% of the anthropogenic warming impact on the climate (Anderson and Broderick 2017, p. 20).

With the amount of natural gas extracted, the level of methane emission is also steadily increasing. According to Anderson and Broderick, increases in atmospheric methane concentrations have been observed since 2006, as well as regional increases in emissions. These are in line with the most pessimistic of the Intergovernmental Panel on Climate Change's[2] emissions scenarios for future greenhouse gas emission levels (Anderson and Broderick 2017, p. 20-23).

Methane is a potent greenhouse gas, with a global warming potential 34 times higher than CO2 on a 100-year time horizon, and 86 times higher for a 20-year timeframe. Although it degrades over a period of about 12 years, and thereby has a relatively short half-life in the atmosphere as compared to CO_2 (of which between 65 and 80% dissolves into the ocean over a period of 20–200 years), the persistently high emissions of methane will replenish this loss and maintain the initial warming effect. This leads to a continuous wave of additional short-term temperature increases, which add to the warming effect of CO_2 (Anderson and Broderick 2017, p. 31-32).

Due to its longer lifespan in the atmosphere, CO_2 emission will remain the main catalyst of global warming, and the reduction of methane emissions can have a significant short to medium-term impact. As Schwietzke et al. conclude, "reducing methane emissions now will reduce climate forcing in only a few years – it takes much longer for CO_2. And since fossil fuel methane emissions are higher than previously thought, the potential to reduce climate forcing from this specific source is also greater" (Schwietzke et al. 2016, p. 90). This means that if mankind wants to limit global warming to below 2°C and avoid the worst-case scenarios of climate change, it must reduce CO_2 and methane emissions at the same time.

[2] See more about this: Intergovernmental Panel on Climate Change:Global Warming of 1.5°C– Special report

Main sources and types of methane emission

Methane is emitted by numerous, diverse sources into the atmosphere. These can be grouped by their provenience – natural or anthropogenic (man-made) origin, - or by the emitting process – thermogenic, biogenic, pyrogenic. (Saunois et al. 2016, p. 702-703).

– *Thermogenic methane* is formed due to the pressure and heat deep in the Earth's crust by the breakdown of buried organic material. It reaches the surface during natural gas and oil extraction or coal mining through geologic seeps.
– *Biogenic methane* is the by-product of the decomposition of organic matter predominantly in swamps, landfills, marine sediments, landfills, rice paddies, and waste-water facilities.
– *Pyrogenic methane* is produced by the incomplete combustion of biomass. The main sources of it are biofuel usage, biomass burning and peat fires.

However each of the three process categories can have both anthropogenic and natural components. According to estimates, aproximately 40% of the total methane emission comes from biogenic sources, while the other 60% are anthropogenic (Saunois et al. 2016, p. 702). The main source of anthropogenic methane emissions is agriculture, followed by industrial activity, and fossil fuel use. The oil and gas sector contribute roughly a quarter of the world's methane emissions.

If we look at the main types of methane emission, three categories can be identified.

– *Vented emission* is the intentional release of methane into the athmosphare mainly due to operational procedures, technical design, or safety deliberations. The most common form of vented emmission is the flaring of naural gas as a byproductof oil extraction.
– *Fugitive emissions* is the consequence of unintentional methane "leaks" from not sufficiently insulated valves and gas taps, or acures do to pipeline damage. These sources of methane emission are the most challenging to detect and quantify, because of the size and complexity of the netural gas infrastructure.
– *Un-combusted emission* derives from un-combusted methane in the exhaust of equipment in the production, processing and transmission segments.

Stages of natural gas flow and methane emission

Greenhouse gas emissions occur across the full supply chain of natural gas, from its exploration to its consumption. Generally, the natural gas life cycle can be broken down into three parts of which each has separate sub-stages with separate sources of emissions. Production can be divided into three activities, namely exploration, extraction and processing. The second stage is transport, which consists of four activities: transmission through pipelines, LNG (Liquefied Natural Gas), storage, and distribution. The third stage is end-usage, referring to residential or industrial consumption.

Production

In the production or upstream stages of natural gas production, three main sources of methane emissions can be identified (Le Fevre 2017, p. 16):

- Emission during well completion
- Fugitive emission from gathering pipelines
- Flaring is also a prominent sources of methane emission though it primarily steams from the gas accompininig oil production that is not gathered and utilised. Therefore it could be considered as not a direct result of natural gas production and supply, it nevertheless plays an important role in methane gas emission.

Howarth notes that because on average 3,6 – 7,9 per cent of shale gas escapes into the atmosphere it has a larger green house gas footprint than coal if used in power generation (Howarth 2011, p. 681).

Transmission and distribution

During the transmission stage methane emission mainly arises from above ground installations such as gathering and long distance transport pipelines, compressor and pressure regulation stations and liquified natural gas terminals. In all cases the age of the infrastructure and the level of maintenance is crucial with regards to the levels of fugitive methane gas during operations. The highest amount of emissions arising during maintanence and repair operations of gas in pipelines occurs when natural gas is vented to the atmosphere prior to work commencing. In 2015 Gazprom reported 1.3 million tonnes of methane emission of which 77 per cent arose from venting during repairs pf pipelines and other transport infrastructure (Gazprom 2016, p. 22). Leakage rates can vary widely however. A recent study by DBI (2016) assessed leakage rates for gas exported by Russie trough Ukraine as 0.38 per cent of sales gas. At the same time an European transmission operator reported a reduction in measured pipeline leakage from 0.024 per cent of sales gas to 0.01 per cent after a major repair programme was carried out between 2015 and 2017 (Le Fevre 2017, p. 17).

If we look at the distribution segment the main source of methane emission can be tracked back to the composition and insulation of pipelines. Methane leakages are more common in the case of older, metallic mains compared to polyethylene pipelines. In the case of metallic pipelines methane leakages typically arise from cracks in the iron, or from leaking joints and valves with old, worn out gaskets.

Table 1. Stages and sources of methane emission during the natural gas live cycle

Stage	Source	Example
Pre-extraction	Drilling and hydraulic fracking	Gas vented to atmosphare while drilling
	Well construction	Gas vented during the completion process

Extraction	Flaring	Unburned methane
	Workovers	Intentional venting
	Fugitive	Leaks caused by insufficient sealing
Processing	Flaring	Unburnd methane
	Fuel production	Unburned methane leaking to atmosphare
	Fugitive	Equipment failure
Transmission and distribution	Fuel	Unburned methane leaking from engines
	Fugitive	Unsufficient equipment sealing
Utilisation	Leakages	Unburned methane leaking during residential and industrial activity

(Balcombe 2015, p. 8).

Europe is involved in all of the stages of the natural gas life cycle, which also means that it has to deal with methane emissions from all three dimensions of the gas industry. However, the biggest and most important segment of it is transportation.

The Netherlands and the United Kingdom are the largest producers of natural gas in the European Union, representing approximately 70% of production. However, most gas consumed in the EU is imported, with an energy dependency ratio of approximately 70%. Currently, four sources dominate imports: pipeline gas from Russia (42% of imports to the EU in 2016), Norway (34%), Algeria (11%) and Liquified Natural Gas (13%) from diverse regions but mainly from Qatar, Algeria and Nigeria (European Commission 2016a).

According to Anderson and Broderick, the greenhouse gas emissions in the European natural gas supply chain, from lowest to highest, are: 1) conventional North Sea production, 2) short-distance pipelines, 3) LNG, 4) long distance pipelines (from Russia). The additional emissions of LNG and long-distance pipelines are approximately double those from short-distance conventional production. However, more factors must be considered when comparing and calculating the greenhouse gas emissions of different types of natural gas transportation. According to Abrahams (Abrahams 2015, p. 3239), upstream emissions from Russian production and transmission have an additional 3% methane leakage over US gas (speaking in average terms) and concludes that LNG exports from the US to Europe are more favourable than long-distance pipelines. Heath (Heath 2014, p. 3169) identified pipeline distance and pipeline leakage rate as the dominant factor of emissions, whereby a doubling of distance would lead to a 30 to 35 percent increase in greenhouse gas emissions. Balcombe (Balcombe et al. 2017, p. 8-10) suggest that the additional energy required for liquified natural gas (for liquefaction, cooling, shipping, transportation, and regasification) increases total emissions of LNG by about 20%.

End use accounts for the largest share of the climate change impact from natural gas, except for the very highest end of the liquefied natural gas range. As to transportation, the *lowest* absolute emissions of pipelines range from 94% to 53%, versus 86% to 43% for the *highest* absolute emissions for LNG, respectively.

Totalling 8%, transmission, storage and distribution are next on the list of sources of harmful emissions, followed by processing at 7%. All other stages of the natural gas supply chain represent less than 1% of total absolute emission (Anderson and Broderick 2017, p. 11).

However, supply chains with poorly regulated and enforced production and transportation standards – especially in the case of the long-distance pipelines from Russia – may still have the highest leakage rates.

LNG and climate change

The fracking boom in the US and high levels of natural gas consumption in the European Union between 2003 and 2010, and from 2014 onwards, have contributed to the rise of a new source of threat for the climate. The revival and constant output growth of the LNG industry has significantly contributed to global greenhouse gas emissions. Natural gas is more easily and cost-effectively transported across great distances in liquid form than through pipelines, but the climate impact of LNG has received little attention so far.

LNG creates additional methane emissions through the additional steps that are needed to produce it, ranging from liquefaction to the special processes and arrangements needed for transport and the regasification process. To make LNG, natural gas first needs to be cooled down to minus 160°C, and then warmed up again to convert it back to its gaseous form. Both procedures are highly energy-intensive, and therefore emissions-intensive. Anderson and Broderick conclude that although "there are large uncertainties in the emissions associated with natural gas supply chains, the additional emissions of LNG and long-distance pipelines are approximately double those of short distance conventional production" (Anderson and Broderick 2017, p. 39). According to Balcombe et al. (Balcombe et al 2017, p. 9) there is "greater confidence in the conclusion that the additional energy required for LNG transportation (for liquefaction, shipping and regasification) adds a burden for LNG of approximately an additional 20% over emissions from combustion and short-distance pipeline transport." Research firm Wood Mackenzie estimates that with the present year-on-year growth of the liquefied natural gas sector of around 5%, it will be the biggest source of carbon emissions growth for the world's top oil and gas companies by 2025 (Wood Mackenzie 2017). All this makes LNG a particularly dangerous kind of energy source for the climate; one which sees increases in investments from both exporting and importing countries, because they see it as a way of strengthening their energy security and diversifying their energy mix.

Conclusion

Climate change is driven by the continuously high amount of fossil fuel production, distribution and consumption needed to power our everyday lives. If we are to achieve the objectives of the Paris Agreement – to hold global average temperatures to below 2°C above pre-industrial levels – it is essential that within the coming three to four decades massive steps be taken in the direction of full global decarbonisation. This means that there is no room for the current consumption of high-level greenhouse gas emitting fossil fuels, such as coal and oil. Neither of these energy sources ought to play a substantial role on the global scale beyond 2035.

Methane emissions from the gas industry are a threat to the climate, and especially to people most at risk from the adverse effects of climate change. Whether produced and consumed domestically, or exported by pipeline or by ship as LNG, the gas industry contributes significantly to climate change by uncontrolled methane leaks.

Even though there is no reliable data on how extensive and how dangerous these leaks are, cutting methane emissions is nonetheless a necessary step to cut greenhouse gas emissions. Given the extent of existing greenhouse gas emitting infrastructure, it is highly unlikely that the Paris 2°C commitment is a viable mitigation objective.

Whereas currently carbon dioxide may be the main source of, and contributor to, climate change. However, methane released during natural gas production, distribution and consumption, means that, in the long run methane has a much greater warming effect. Its amount is greatly influenced by factors such as locations, production technologies, and the type and length of transportation infrastructure. Since recent trends allow for the projection of a further increase in the production and shipping of LNG, this also implies an additional greenhouse gas emission burden for the environment.

Therefore, natural gas cannot be considered as a short- or medium-term solution to climate change. Decades of political inaction has led to the urgent need for action today. Time is running out fast for a fossil fuel-based transition to renewable energy resources, which could avert a catastrophic climate change. The world needs to act and cut back significantly on its fossil fuel dependency before it is too late to do so.

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