ENVIRONMENTAL FOOTPRINT OF GAS TRANSPORTATION: LNG VS. PIPELINE

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Overview

The share of natural gas has been steadily growing in the European energy mix: from 17,8% in 1990 to 23,2% in 2013 (Eurostat, 2015). Natural gas attracts increasing attention because of higher efficiency and a low CO_2 impact in comparison to coal and oil. In May 2015, Norway overtook the Russian position of the main gas supplier to Western Europe. Most of the Norwegian gas is transported via an extensive export pipeline system to Europe, and a small fraction (less than 4%) is exported in liquid form (LNG) by special ocean-going tankers to the US, Europe, Japan, etc. The need for new gas transport infrastructure on the Norwegian continental shelf (NCS) and strict environmental policy targets justify a study of the environmental performance of alternative modes of gas transportation. The aim of this study is to estimate emissions of CO_2 and NO_x caused by processing and transportation of a unit of dry gas in either a gaseous form via a pipeline, or as LNG with ships from the NCS to relevant markets.

Methodology

Due to the fact that the wellstream to a certain extent is processed on platforms the processing related emissions cannot be fully separated from the production related emissions. Therefore, this study also includes the emissions related to production, excluding emissions related to the drilling of production wells. Exploration (seismic surveys by special ships, exploration drilling) and support activities provided by supply vessels and helicopters are also excluded from the analysis, based on the assumption that these activities are common to the pipeline and LNG chains. The emissions of pipelines chains are estimated through adding up emissions from production, processing, and pipeline transportation segments. The analysis of the LNG chain includes emissions from production, processing, liquefaction, sea-shipping, and regasification. The analysis is based on publicly available industry data, mainly annual reports of the operators on the NCS to the Norwegian Ministry of Climate and Environment (2014). It gives this study an advantage of using field- and facility-specific emission factors and values measured at site, instead of theoretical parameters. The estimates are adjusted for the associated oil and condensate production.

In order to perform a reasonable comparison, we consider seven pipeline chains (Table 1), because technologies of the pipeline gas processing are not uniform on the NCS. The differences are determined by numerous factors such as the composition of the gas, the type of well, the distance from the shore, sea depth, and transportation solutions available. At the Åsgard, Statfjord, Troll, Kvitebjørn, and Aasta Hansteen fields, the water and parts of natural gas liquids (NGLs) are separated from the wellstream at the offshore platform, the remaining rich gas is transported via rich gas pipelines to onshore facilities for further processing. When the remaining NGLs are removed, dry gas (methane and some ethane) is transported via dry gas pipelines to Europe. At the Sleipner Øst field, the wellstream is processed offshore, dry gas is sent directly to the continental Europe via the transmission pipelines, while NGLs and condensate are shipped by vessels. The Ormen Lange field does not have any processing steps offshore – the unprocessed wellstream is directly sent via a field-dedicated multiphase pipeline to the processing facility onshore. Some fields (Ormen Lange and partially Troll) are connected to the main electricity network onshore, the majority use gas turbines for power generation. All processing plants (Kollsnes, Nyhamna, and Kårstø) use power from the main grid; however, the Kårstø plant uses gas turbines for export compression.

There is only one LNG chain on the NCS, which produces gas from the Snøhvit field. As the estimates are sensitive to the distance over which LNG is shipped, we consider two existing shipping routes: to the Iberdrola terminal in Spain and to the Cove Point terminal on the western USA; and one hypothetical route to Zeebrugge in Belgium (which represents a close comparison to the pipeline alternative).

Results

The description of the considered chains and total specific CO_2 and NO_x emissions are presented in Table 1.

Table 1. The environmental footprint of LNG and pipeline gas processing and transportation

Field (start year)	*Upstream gas transport*	*Processing facility*	*Export gas transport, destination point*	*Kg CO_2/ Sm^3 oe*	*Kg NOx/ Sm^3 oe*
Åsgard (1999)	Åsgard Transport (707 km)	Kårstø (1985)	Europipe II (658 km) to Dornum, Germany	126,374	0,151
Statfjord (1979)	Statpipe Rich Gas (308 km)		Statpipe (228 km) – Draupner S – Statpipe/ Norpipe (643 km), to Emden, Germany	349,846	1,125
Troll (1995)	Field-dedicated rich gas pipeline (65 km)	Kollsnes (1996)	Zeepipe IIA (299 km) – Sleipner R – Zeepipe (813 km), to Zeebrugge, Belguim	20,283	0,081
Kvitebjørn (2004)	Kvitebjørn Gas Export (147 km)			14,356	0,063
O.Lange (2007)	Field-dedicated multiphase pipeline (120 km)	Nyhamna (2007)	Langeled N (627 km) – Sleipner R – Langeled S (543 km), to Easington, UK	1,972	0,002
A.Hansteen (2017)	Polarled (481 km)			33,718	0,029
Sleipner Øst (1993)	Offshore		Langeled S (543 km,), to Easington, UK	87,589	0,393
Snøhvit (2007)	Field-dedicated multiphase pipeline (145 km)	Hammerfest LNG(2007)	Cove Point,US (4072 nm) Iberdrola, Spain (2019 nm) Zeebrugge, Belgium (1375 nm)	400,325 324,746 301,491	0,460 0,371 0,343

Generally, pipeline transportation outperforms LNG supply chains with respect to emissions. An exception is the Statfjord pipeline chain. The comparatively high specific emissions for this chain are due to the offshore production segment. 85,1% of the CO_2 and 96,8% of NO_x emissions are related to this activity. This can be explained by the age of the field – it is one of the oldest on the NCS, with much lower energy efficiency compared to newer fields. At the offshore production stage, 82,1% of CO_2 and 94,5% of NO_x emissions are attributed to the power generation by gas turbines. Similar considerations are related to the other fields connected to the Kårstø plant, the Åsgard chain: offshore production causes 66,4% of the CO2 and 80,8% of the NO_x emissions, most of which are due to the power generation. Such proportions are explained by the high energy requirements of the gas transportation over the long distances to the processing plant. The other pipeline chains, which include the Kollsnes plant, show significantly better results. The fields are rather close to the shore, requiring less power for transportation to the processing plant. Another reason is that gas compression for export to Europe is driven by energy from the main grid, as opposed to the Kårstø plant, where export compressors are driven by gas turbines. The «cleanest» of the pipeline supply chains is the Ormen Lange chain. It is due the proximity of the field to the shore and a technology with a subsea installation, which allowed avoiding any processing offshore. The Nyhamna plant uses the hydroelectric power from the main grid, producing emissions only due to gas flaring for the safety reasons and some gas combustion in processing equipment. However, this chain is rather an exception. Another field connected to the Nyhamna plant is Aasta Hansteen, a mid-size field, which comes on stream in 2017. Because of the distance from the shore, it requires energy production on site, which causes 94,2% of CO_2 and 93,1% of NO_x emissions.

The Hammerfest LNG facility, which receives the unprocessed wellstream from the Snøhvit field, produces power for processing and liquefaction by gas turbines. For the Cove Point chain, this segment causes 55,3% of CO_2 and 25,7% of NO_x, shipping for the 4072 nautical miles adds 37% of CO_2 and 38% of NO_x, the remaining 7,7% of CO_2 and 36,3% of NO_x are due to regasification.

Conclusions

Several important aspects are left out of the scope of this paper. Among them are the differences of the CO_2 content in the dry pipeline gas and LNG, which lead to different emission intensities of the combustion for the final use. Another aspect is the indirect emissions associated with construction and decommissioning of the infrastructure, which, however, might be negligible because of a long life-time of the facilities and high production volumes. The obtained results represent the main picture and allow drawing some conclusions. Though a pipeline itself does not produce any emissions during normal operations, as opposed to the LNG shipping, the environmental impacts of the pipeline transportation are not negligible. The scale of environmental advantages of the pipeline transportation over the LNG strongly depends on the location of the field, technology applied, and the energy source used for export compression. Though, according to the regulation, each project on the NCS is assessed for the opportunity to get power from the main grid, in many cases it is either technologically not possible or economically not viable due to the distances to the shore, leading to considerable emissions from both for the pipeline and the LNG transportation alternatives.