Emission change potential of Finnish sea traffic in the Baltic Sea in transferring to use LNG

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1. Introduction

International Maritime Organization (IMO) defines Baltic Sea one of the emission control areas in the International Convention for the Prevention of Pollution from Ships (MARPOL). It includes the stringent targets on airborne emissions such as SO_x and NO_x. Therefore the continuation of ship traffic in the Baltic Sea requires modifications to ships or renewal of fleet. In order to reach the targets, one of the options is to outfit ships with more environmental friendly LNG (liquid natural gas) fuelled engines.

According to DNV 2010 (Det Norske Veritas, the advisor for the maritime industry), LNG fuelled ship reduces SO_x and particles by close to 100% and the emissions of NO_x by 85–90% compared to today’s conventional fuel. In addition, LNG fuelled ships will come with 15–20% reduction in net GHG emissions.

LNG has not been imported to Finland so far, but at the moment, there are activities going on to build LNG import terminals in Finland onto the Baltic Sea area. Transfer to LNG use in ships decreases harmful airborne emissions of ship traffic, but the open questions are related to the overall emissions of the whole value chain when also upstream emissions of producing and transporting fuels are considered. Finding answers to this is a basic target of this study.

This study was carried out in the project which is a part of the Measurement, Monitoring and Environmental Efficiency Assessment (MMEA) research program, funded by the Finnish Technology Agency (TEKES) and the natural gas service provider Gasum Oy.

The aims of the study are:

- To perform a comparison of environmental impacts of LNG and heavy fuel oil (HFO) operated ships using a passenger ferry as an example and
- To estimate roughly the potential change in emissions of Finnish sea traffic in the Baltic Sea if ships will transfer to use LNG instead of oil.

2. Problem

The environmental state in and around the Baltic Sea is worsened for several reasons. One of the reasons is heavy sea traffic and its airborne emissions. In order to improve the state of the Baltic Sea environment, the attention has also been focused on the shipping industry including emission reduction requirements.

Due to the cleaning technology, especially sulphur oxides have decreased notably in land operations. The Thematic Strategy on air pollution from 2005 concluded that if action is not taken, SO_x and NO_x

emissions from ships in EU seas are projected to be greater than all land-based emissions in 2020. Shipping is a global industry and air pollutant emissions from maritime transport can be transported over long distances and cause human health and environmental problems. Therefore global solutions are preferable. (SEC /2005/1133)

IMO has adopted the International Convention (MARPOL), which seeks to minimize airborne emissions from ships (SO_x, NO_x, ozone depleting substances (ODS) and volatile organic compounds (VOC)). MARPOL defines the Baltic Sea one of the emission control areas (ECAs), and therefore these special areas are provided with a higher level of protection than other areas of the sea, and they have stringent controls on SO_x and NO_x emissions. (IMO, 2013.) Emissions reduction requirements are being implemented gradually and in order to reduce SO_x emissions, the maximum of 0.1 % sulphur in marine fuel from 2015 are allowed. The NO_x emission limits for marine engines will have full in force in 2016. (DNV, 2010).

Heavy fuel oil (HFO) is used in the majority of the marine engines. HFO is produced from refining crude oil and thus sulphur content of HFO is dependent of the sulphur content of crude oil, which refinery streams used and how they are blended. HFO with a sulphur content of 1 % represents the most used maritime transportation fuel in the ECA area at the moment, which exceeds the limits set for sulphur content by the IMO. (Bengtsson, 2011.)

3. Methodology

Life cycle assessment (LCA) methodology (ISO 14040:2006; ISO 14044:2006; ILCD Handbook, 2010) is used to assess the environmental impacts of LNG and HFO imported to Finland and their use as ship transportation fuel. The SimaPro LCA software (SimaPro UK Ltd, 2014) is used as a calculation tool. The emissions of CO_2, NO_x, SO_x and PM (particulate matter) from the production and end use phases of the fuels are calculated. During the whole LNG value chain, leakages of methane are occurring. The methane emissions are not considered in this study, because emission reduction targets of MARPOL are not falling upon methane. As an environmental impact assessment method, we used ReCiPe midpoint method, hierarchist version, with European normalisation factors (ReCiPe, 2013). For the closer examination, we chose the impact categories of climate change, terrestrial acidification, photochemical oxidant formation and particulate matter formation.

4. Studied systems

We compare the production chains of HFO and LNG, which are both imported from Russia to Finland. The HFO production chain is based on the information that crude oil is acquired from West Siberia and transported by pipeline to Primorsk terminal. Crude oil is then transported by tanker to Naantali, Finland, where it is refined to heavy fuel oil. (Finnish Petroleum Federation, 2013; Marcon International, Inc. 2014)

LNG production chain is based on one of the import options of the natural gas in Finland. In this option, natural gas is acquired from West Siberia and transported by pipeline to nearby St. Petersburg area, where it is liquefied to LNG and transported by tanker truck to Finland.

In order to estimate the potential change in emissions of Finnish sea traffic in the Baltic Sea if ships will transfer to use LNG instead of HFO, we take an example of the passenger ferry travelling between Turku, Finland and Stockholm, Sweden. Yearly emissions and fuel consumption data is based on the confidential information (Kackur, 2014). Therefore the results are presented as relative values in this paper. The system boundaries of the production chains of HFO and LNG and data sources used in the calculation are presented in Figure 1 and Table 1.

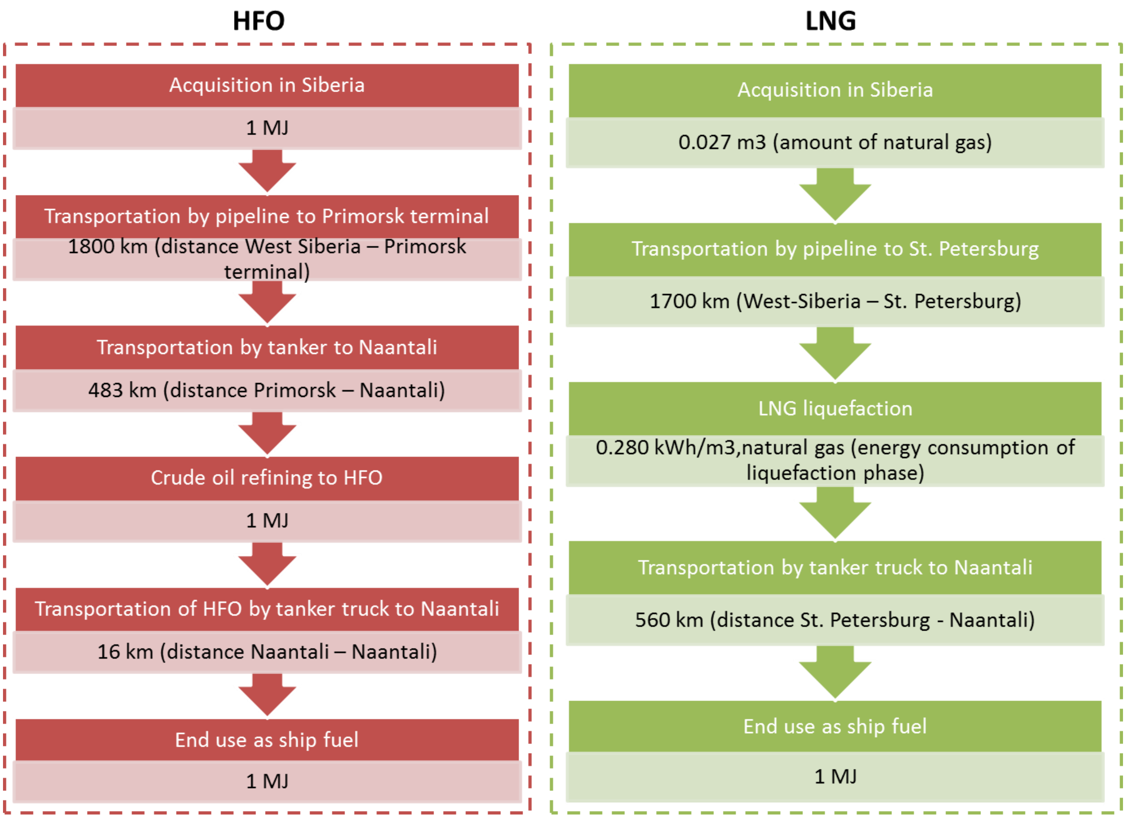

Figure 1. The system boundaries of the production chains of heavy fuel oil (HFO) and liquefied natural gas (LNG).

Table 1. Data sources used in the calculation.

Life cycle phases	Data sources
Acquisition	Ecoinvent database v.3.0
Pipeline transportation	Ecoinvent database v.3.0
Tanker ship transportation	LIPASTO 2011
Crude oil refining	Ecoinvent database v.3.0
Natural gas liquefaction	Ecoinvent database v.3.0; Karvonen, 2013
Tanker truck transportation	LIPASTO 2011
End use of passenger ferry	Kackur, 2014

5. Results

5.1. Reduction potentials

From the total emissions of HFO and LNG chains divided for the upstream (fuel production) and end use stages (Figure 2) can be seen that the approximate percentage values vary explicitly depending the type of emissions and fuel. As expected the main part of the emissions are caused by the end use of fuels, except particulates in LNG production, which are equal for upstream and end use phases.

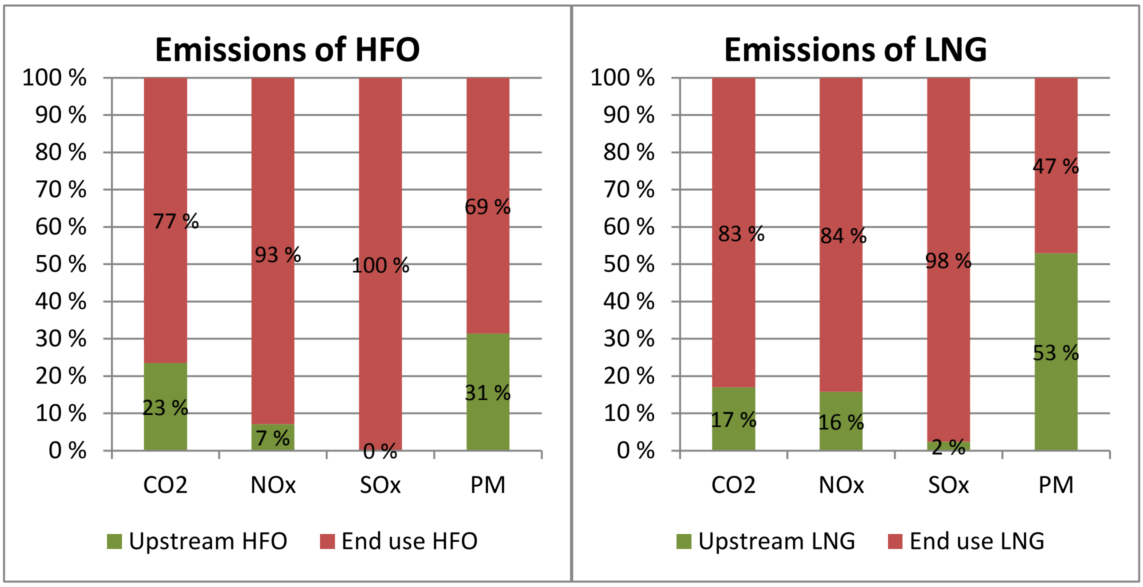

Figure 2. The shares of total emissions divided for upstream (fuel production) and end use stages of HFO and LNG chains.

The emission reduction potential of upstream and end use emissions, when passenger ship travelling between Turku and Stockholm will transfer to use LNG instead of HFO are presented in Figures 3, 4 and 5. In the figures, the value of the HFO chain is set to 1.

The production of LNG generates significantly less emissions than HFO production This is mainly caused by the onshore well operation and infrastructure of oil production. (Ecoinvent database v.3.0.) Emissions of distribution of natural gas to nearby St. Petersburg cause higher emissions than distribution of crude oil. In this case, we assumed that LNG is transported by a tanker truck from Russia to Finland, which cause higher emissions than transporting crude oil by a tanker ship from Russia to Finland. LNG could also be transported by a tanker ship from Russia. In that case the distribution emissions of LNG would presumably be in the same level or lower than distribution of crude oil. When comparing the processing phases of natural gas to LNG and crude oil to HFO, crude oil refining causes higher emissions than natural liquefaction. (Figure 3).

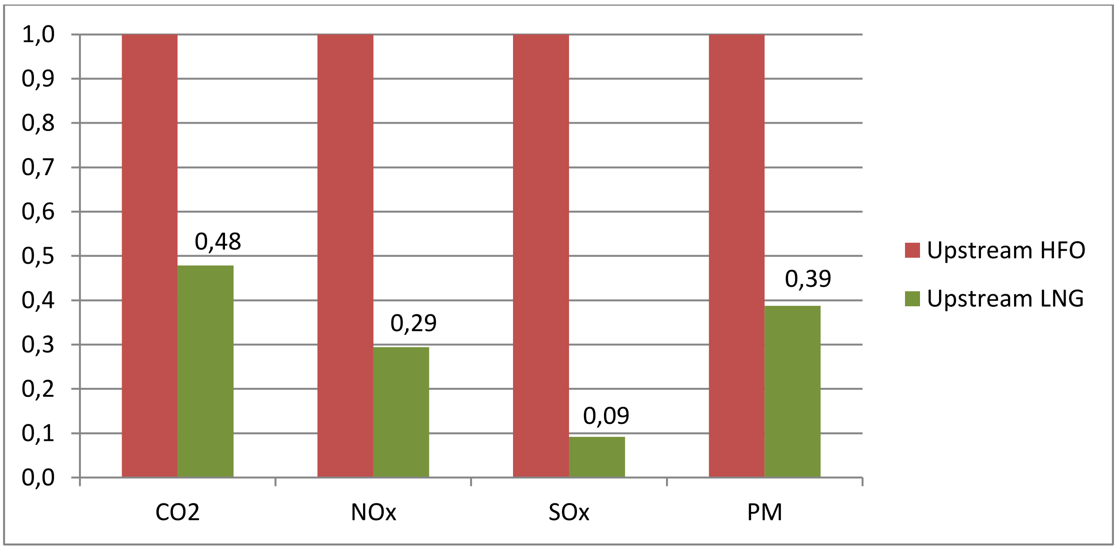

Figure 3. Emission comparison of upstream emissions of the HFO and LNG chains.

Emission reduction potentials of the end use of LNG are in line with the values concluded by DNV 2010 (Figure 4). Total emission reduction potentials in which upstream and end use emissions are summed up are presented in Figure 5.

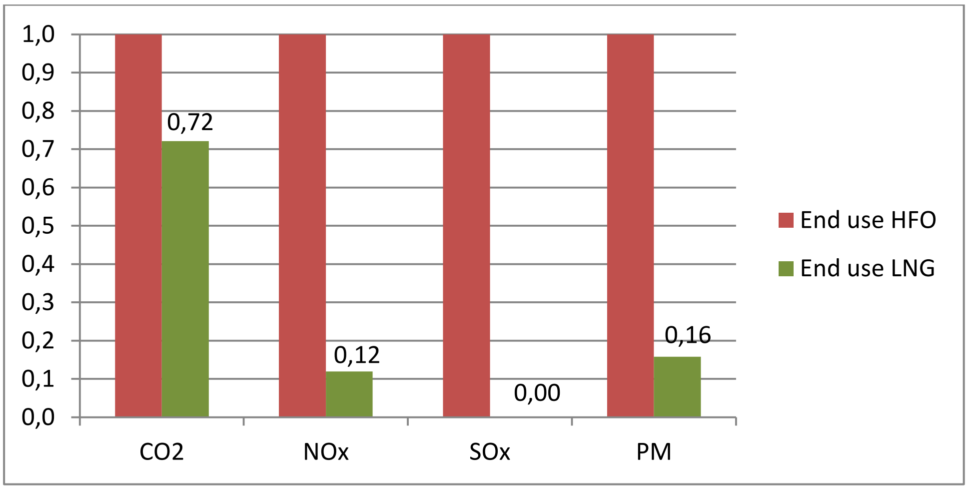

Figure 4. Emission comparison of end use emissions of the HFO and LNG chains.

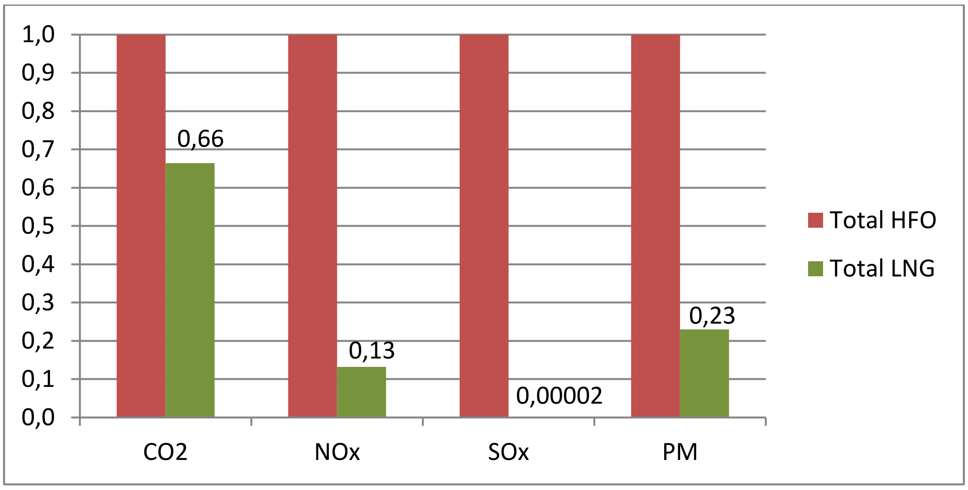

Figure 5. Total emission reduction potentials when passenger ship travelling between Turku and Stockholm will transfer to use LNG instead of HFO.

5.2. Normalised environmental impacts

In the LCA methodology, emission values are called life cycle inventory (LCI) results. In order to convert LCI results to common unit and aggregate the converted results within the same impact category, values must be characterised using characterisation factors. Characterisation factors are derived from a certain characterisation model. The aim of the normalisation is to understand better the relative magnitude for each impact category result of the studied system. In this case, normalised results are European characterised results per capita (ReCiPe, 2013).

In larger European context, normalised results indicate that the greatest benefits transferring the use of LNG can be achieved in acidification (Figure 6). The reduction in climate change impacts is not so significant.

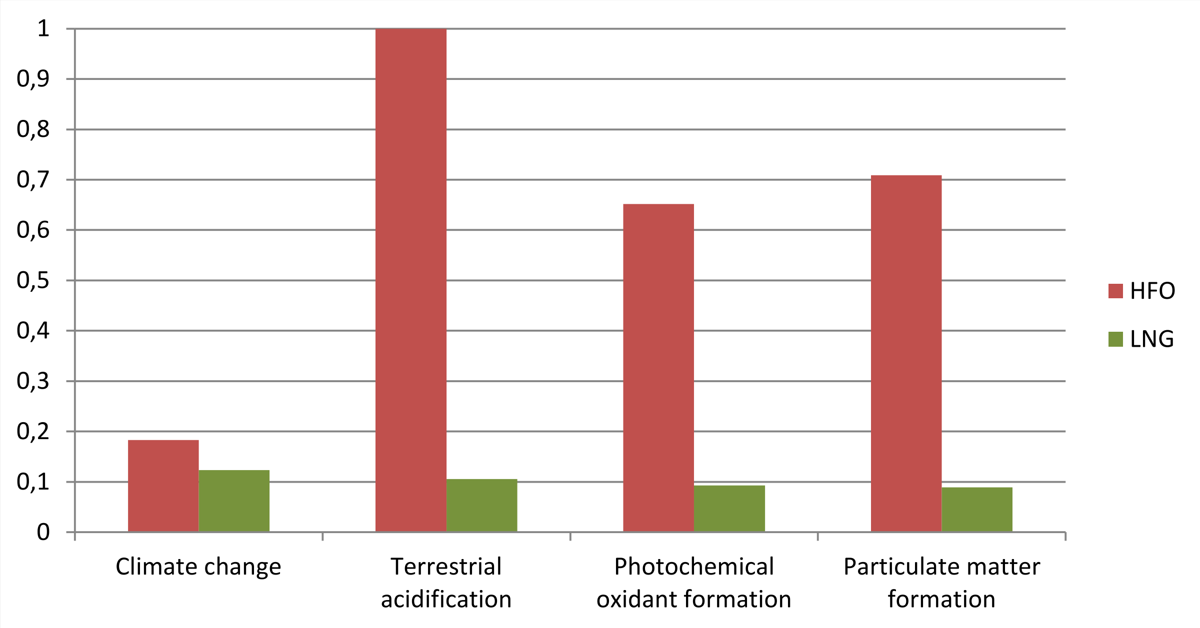

Figure 6. Normalised results of the HFO's and LNG's upstream and end use environmental impacts.

6. Emission reduction potential of Finnish sea traffic

Based on our study, rough emission reduction potentials can be estimated, if the whole Finnish fleet would transfer to use LNG. Reduction potentials can be at least equal to our results in the future, but an unequivocal method to calculate emissions of ships does not exist. If more realistic overview of the whole Finnish sea traffic would be examined, more specific calculations are needed including different types of ships. For example technology, efficiency of motors, sizes and operation modes of the ships have to be taken into account in order to calculate the ship specific emissions.

Recent studies (e.g. Bentsson et al. 2012; Burel et al. 2013), show that end use emissions of LNG fuelled ships are lower compared to ships using HFO as fuel. Based on our study, the fuel production emissions compared to end use emissions are significantly lower for emissions of CO_2, NO_x and SO_x. However, the case-specific examination for the production route of LNG and HFO is always recommended to do.

7. Conclusions

In this paper we estimated the emission reduction potentials of ship traffic using as an example one passenger ferry sailing a roundtrip (around 600 km) between two cities during a year. Based on this example, the emission reduction potentials of 34 % for CO_2, 88 % for NO_x, almost 100 % for SO_x and 77 % for PM, are possible to achieve. However, if more realistic overview of the whole Finnish sea traffic would be needed, more specific calculations are required including different types and properties of ships.

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