

# POLLUTANT EMISSIONS FROM LNG FUELED SHIPS

## Assessment and Recommendations

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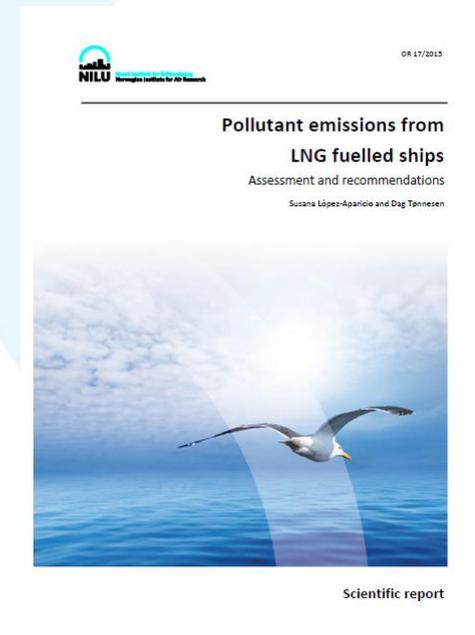
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# Introduction

Project: “Developing the programme of measures for the Estonian marine area in compliance with the requirements of the EU Marine Strategy Framework Directive, including feasibility study on using LNG as an alternative ship fuel to reduce pollution”

NILU’s role:

- Contribute to the development of scenarios for using LNG based on the feasibility study of using LNG as a ship fuel;
- Assess and propose the pollutant emissions factors for ship using LNG;



# Introduction and Motivation

## Emission Control Areas (ECA)



Distribution of existing and possible future Emission Control Areas (ECA).

The Annex VI “Regulations for the prevention of Air Pollution from ships” of the International Maritime Organization (IMO, 2013).

Limit the sulphur content in marine fuel:

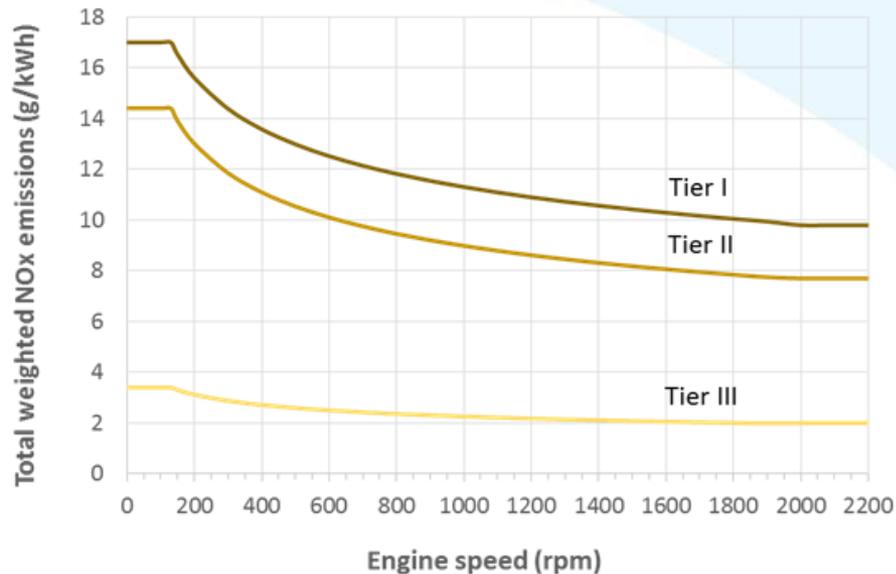
- 4.5 % m/m prior to 1<sup>st</sup> January 2012
- 3.5 % m/m on and after 1<sup>st</sup> January 2012
- 0.5 % m/m on and after 1<sup>st</sup> January 2020

and it imposes stricter regulation in ECA:

- 1.5 % m/m prior to 1st July 2010
- 1.0 % m/m on/after 1st July 2010
- 0.1 % m/m on/after 1st January 2015

# Introduction and Motivation

## MARPOL Annex VI NO<sub>x</sub> emission limit (IMO 2013)



Regulation number 13 of Annex VI (IMO 2013) concerns **NO<sub>x</sub> emissions**:

- Tier I (current limits) affects diesel engines installed on ships from 1st January 2000 to 1st January 2011.
- Tier II: affects diesel engines installed on ships constructed on or after 1st January 2011.
- Tier III: this limitation affects ships constructed on or after 1st January 2016 and operating in ECA.

# Introduction and Motivation

**Aim:** to contribute to the tasks to be performed in the project regarding emissions under different scenarios of implementations of LNG as fuel in vessels operating in Estonian waters.

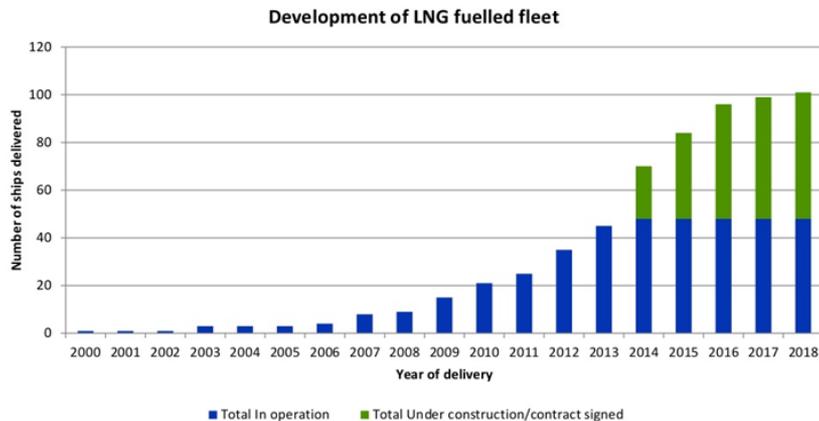
**Method:** Critical review of the information available in the literature regarding emission of different compounds from LNG-fuelled vessels

## Typical ships operating in Estonian waters

Type of vessels	Gross tonnage (GT)	Engine (kW)	#Calls (2013)	Average time (h)
Passenger Ship	5 000 – 5 999	1400	20 722	13 566
Passenger Ship	30 000 – 39 999	40000 (ME); 2000 (AE)	3 511	10 533
Tankers	10 000 – 19 999	8775 (ME); 1200 (AE)	129	516
Dry Bulk Carrier	2 000 – 2 999	975 (ME); 225 (AE)	356	3 680
Container Ship	10 000 – 19 999	10890 (ME); 1500 (AE)	208	832

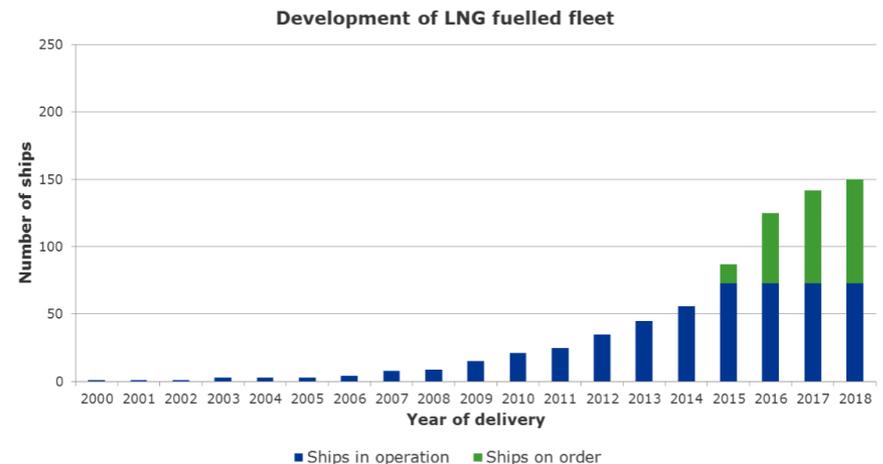
# LNG as fuel for ships

- Liquefied natural gas (LNG) is predominantly natural methane gas (CH<sub>4</sub>) which has been converted into liquid.
- The number of LNG fuelled vessels is growing globally



*Lopez-Aparicio and Tønnesen (2015) after DNV (2014)*

**There are currently 153 confirmed LNG fuelled ship projects**

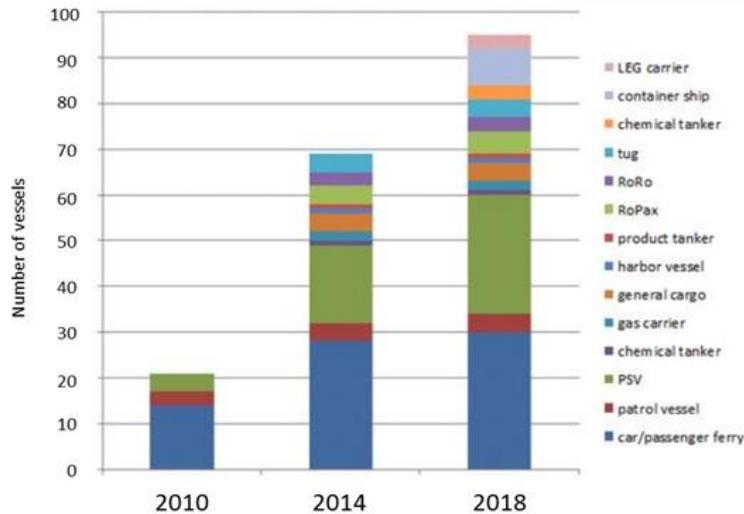


*DNV (2015)*

[https://www.dnvgl.com/Images/World%20LNG%20fuelled%20fleet\\_Oct\\_2015\\_tcm8-5550.pdf](https://www.dnvgl.com/Images/World%20LNG%20fuelled%20fleet_Oct_2015_tcm8-5550.pdf)

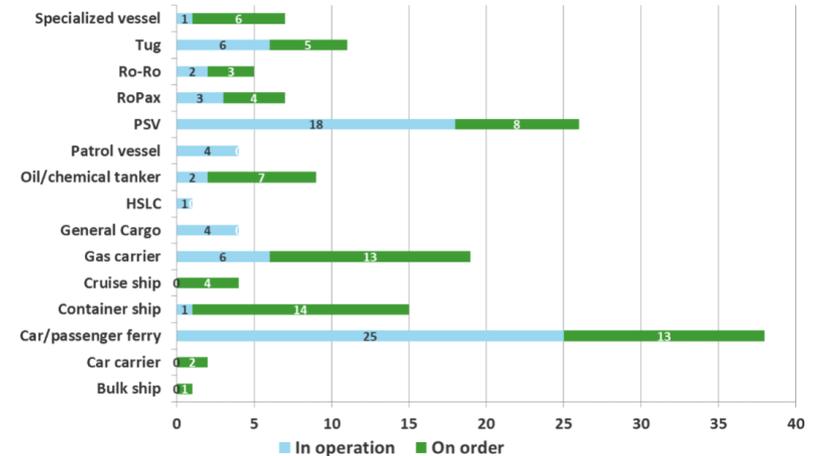
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Lopez-Aparicio and Tønnesen (2015) after DNV (2014)

## LNG uptake by vessel segment



Updated 23 October 2015

DNV (2015)

[https://www.dnvgl.com/Images/World%20LNG%20fuelled%20fleet\\_Oct\\_2015\\_tcm8-5550.pdf](https://www.dnvgl.com/Images/World%20LNG%20fuelled%20fleet_Oct_2015_tcm8-5550.pdf)

# Emission factors for LNG fuelled vessels

Summary of emission factors based on literature review

Reference	Emission factors (g/kWh)				
	TUT (2015)	Nielsen and Stenersen (2010)		CNSS 2013	Verbeek et al. (2011)
SO <sub>2</sub>	0.004				0.51 * 10 <sup>-3</sup>
NO <sub>x</sub>	1	1.1			1.3 – 3 <sup>a</sup>
CO <sub>2</sub>	426			421	
PM	0.00036				0.02 – 0.21 <sup>a</sup>
CH <sub>4</sub>		8.5 <sup>*</sup>	15.6 <sup>¥</sup>	8.5 <sup>§</sup>	

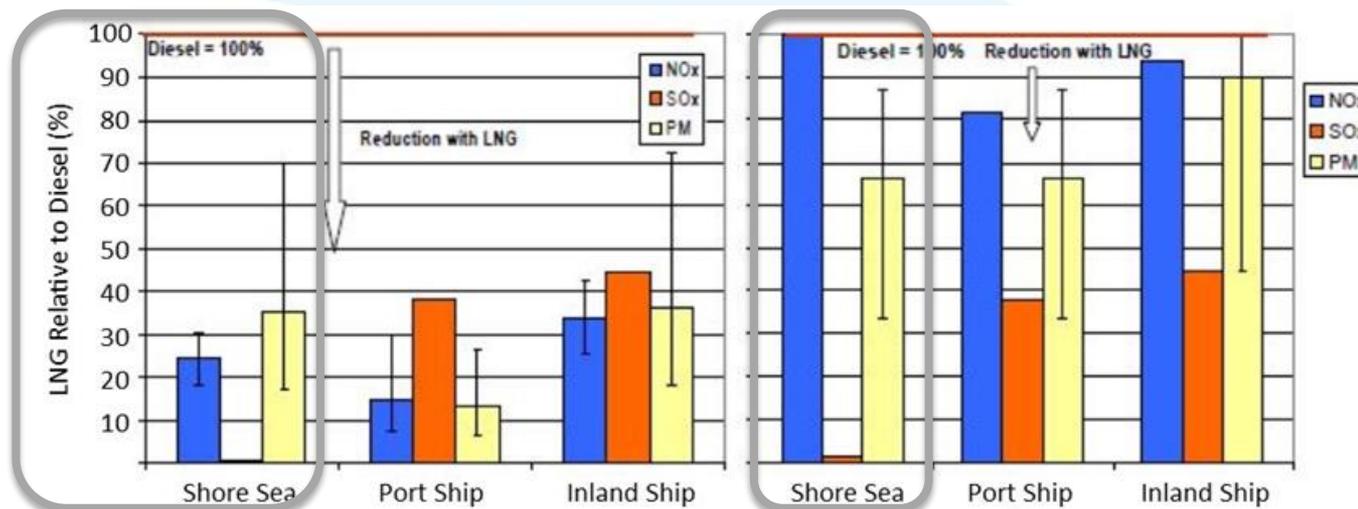
## LIMITATIONS



- Emission tests are very limited
- Information about emissions per type of vessel is very limited
- No information about emissions per type of movement

# Emission factors for LNG fuelled vessels

Annual Tank to Propeller (TTP) air pollutant emissions (Verbeek et al., 2011)



Diesel engines (2011-2015)

Diesel engines (2016 and later)

# Recommendations

## Emission factors for vessels operating in Estonian waters

EF NO <sub>x</sub>	Type of Vessels	NO <sub>x</sub> emission factors (g/kWh)	Source
	<b>Passenger Ship<sup>a</sup></b>	1.1	Nielsen & Stenersen 2010
	<b>Passenger Ship<sup>b</sup></b>	1.1	Nielsen & Stenersen 2010
	<b>Tankers</b>	1.3 – 3 [2.15]	Verbeek et al., 2011
	<b>Dry Bulk Carrier</b>	1.3 – 3 [2.15]	Verbeek et al., 2011
	<b>Container Ship</b>	1.3 – 3 [2.15]	Verbeek et al., 2011

EF SO<sub>2</sub> EF SO<sub>2</sub> = 0.51 \* 10<sup>-3</sup> g/kWh  
 SO<sub>2</sub> depends on the sulphur content in the fuel, therefore the same emission factor is recommended for the different vessels. (Ref. Verbeek et al., 2011)

EF PM EF = 0.02 to 0.21 g/kWh (Ref. Verbeek et al., 2011)

EF CO<sub>2</sub> EF = 421 - 426 g/kWh (Ref. TUT 2015; CNSS 2013)

EF CH<sub>4</sub> EF = 8.5 – 15.6 g/kWh (Nielsen and Stenersen, 2010)

# Conclusions

- This report summarizes and evaluates the information published in the literature regarding pollutant emission factors for ships using LNG.
- The number of studies on emission factors for LNG fuelled vessels is very limited.
- It becomes challenging to select emission factors for different pollutants, different types of vessels and even more for different operational modes (e.g. cruising, manoeuvring, at berth).
- More research (theoretical and measurements) is needed to characterize emissions from LNG fuelled vessels.

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### Thank you for your Attention

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