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MARITIME

LNG as a fuel

Future & safety – LNG application & bunkering guidelines in the light of DNV GL's Recommended Practice (DNVGL-RP-G105)

Transport Week Conference Gdańsk 2018

Jan Talaska

05 March 2018

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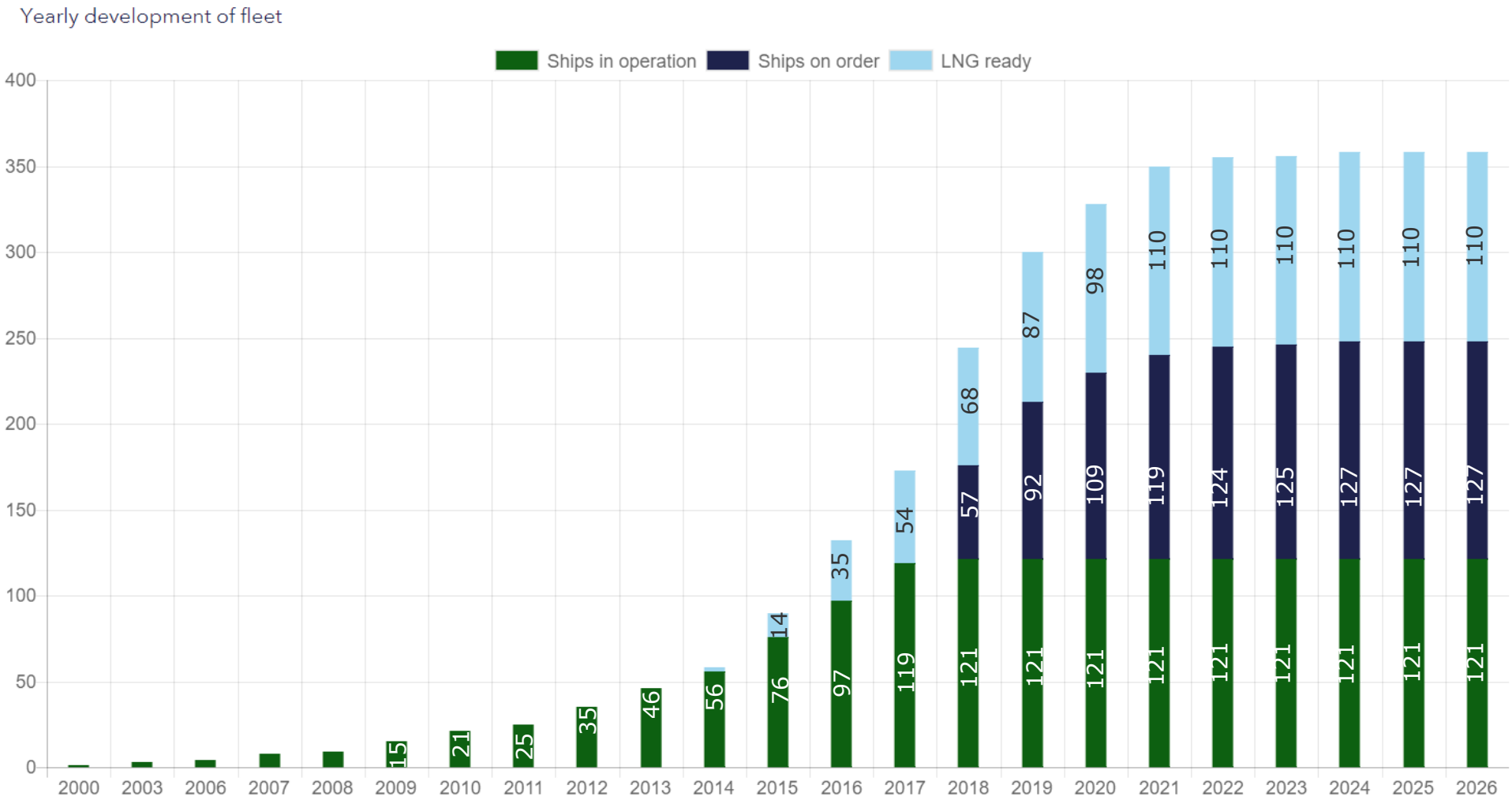
SAFER, SMARTER, GREENER

There are currently 248 confirmed LNG fuelled ships, and 110 additional LNG ready ships



Updated 1 March 2018

Excluding LNG carriers and inland waterway vessels

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Hyundai Mipo delivers world's first LNG-fuelled bulk carrier to Ilshin

The 50,000 dwt bulk carrier has also been verified to be in compliance with the International Gas Fuel (IGF) Code.

The vessel is equipped with a high manganese LNG fuel tank. The Type 'C' LNG tank with a capacity of 500m³, is located on the aft mooring deck.

Ilshin Green Iris is the first ship in service with a high-manganese steel LNG bunker tank

Gaining market share rapidly for trucking as well.....

- > 1500 truck
- > 120 LNG fuelling stations
- Total number of refuellings > 35.000
- Total amount of LNG sold > 3.500.000 kg
- Total distance > 17.500.000 km

Source: NGVA / Blue Corridors project

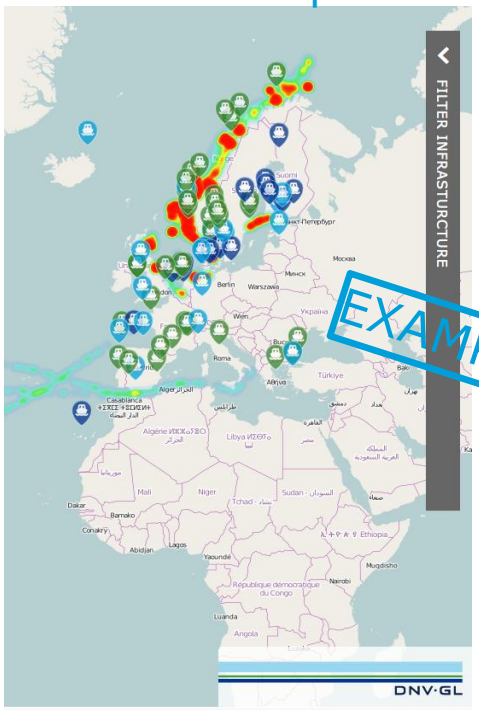
LNGi portal

LNGi provides all needed information to keep you on top of LNG bunkering for ships

LNGi - Comprehensive insights on worldwide LNG bunkering availability and market data on LNG as fuel for ships

- ✓ **Map** of LNG bunkering infrastructure with **detailed** project data
- ✓ Heat map and vessel positions of LNG fuelled fleet operating area using **AIS**
- ✓ Detailed **statistics** of LNG fuelled **fleet** development
- ✓ Scrubber + alternative fuels overview
- ✓ LNG related studies and publications

Heat map



Vessel positions

The heat map and vessel positions are based on AIS data from 01.01.2016-11.01.2016

All types of LNG supply facilities are being developed*

*Some locations have several types of facilities, which is why the number of facilities is higher than the number of locations.

- Local storage – An intermediary LNG storage
- Tank to ship bunkering – A local storage where an LNG fuelled ship can bunker directly from shore
- Truck loading facility – A terminal where LNG trucks can load LNG
- Bunker Ship loading facility – LNG terminal accessible by small LNG carriers

Updated 9 December 2016

End-use safety of LNG

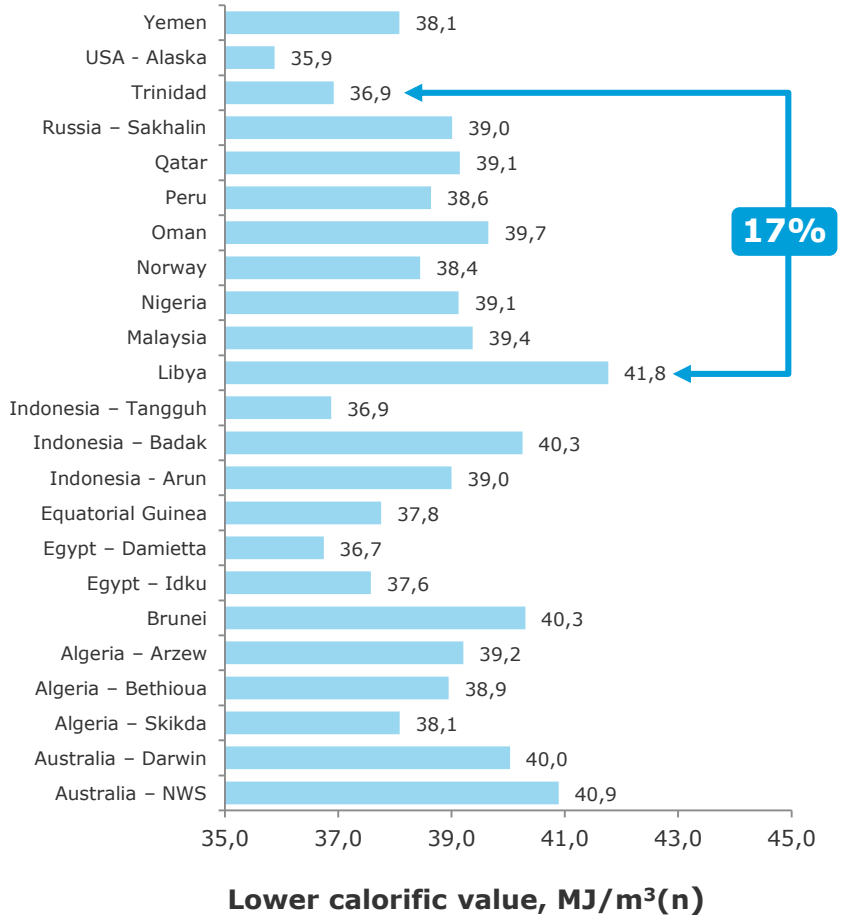
LNG has significant quality variations across the globe….

- LNG is produced at different locations around the world.
- Due to differences in natural gas sources, production technologies and the target markets for the LNG, the composition may vary substantially

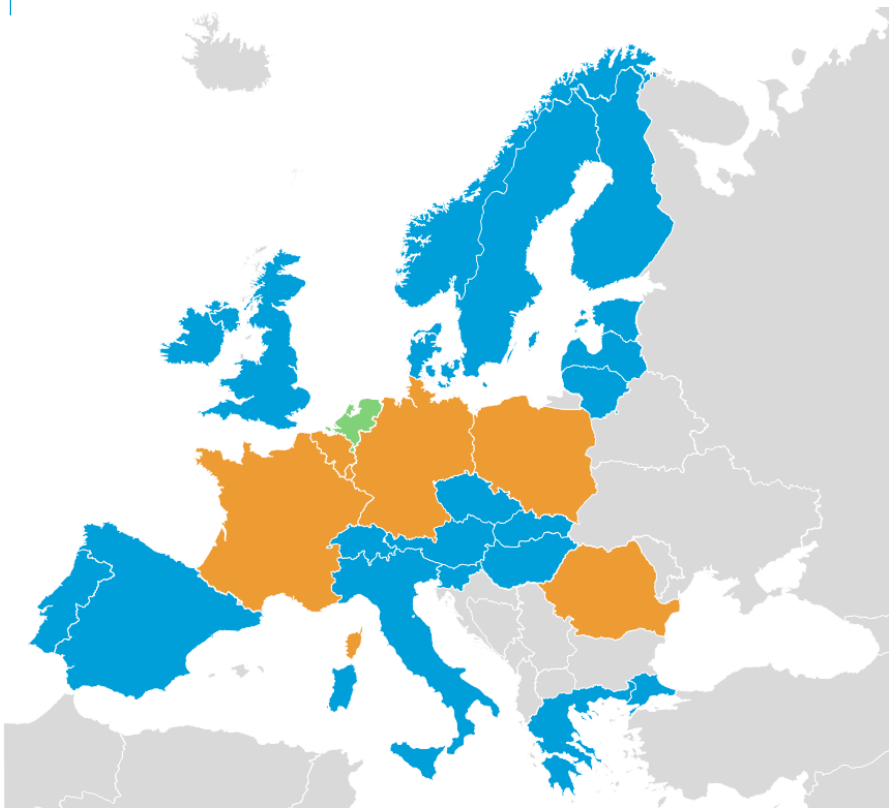
Origin	Nitrogen	Methane	Ethane	Propane	Butane
	N_2, %	CH_4, %	C_2H_6, %	C_3H_8, %	C_4H_{10}, %
Australia – Darwin	0.1	87.64	9.97	1.96	0.33
Algeria – Skikda	0.63	91.4	7.35	0.57	0.05
Algeria – Arzew	0.71	88.93	8.42	1.59	0.37
Brunei	0.04	90.12	5.34	3.02	1.48
Egypt – Idku	0.02	95.31	3.58	0.74	0.34
Indonesia – Badak	0.01	90.14	5.46	2.98	1.40
Indonesia – Tangguh	0.13	96.91	2.37	0.44	0.15
Libya	0.59	82.57	12.62	3.56	0.65
Nigeria	0.03	91.7	5.52	2.17	0.58
USA - Alaska	0.17	99.71	0.09	0.03	0.01
Bio LNG		**~ 100**			

Challenges of delivering fit-for-purpose gas for end users

LNG has significant quality variations across the globe….

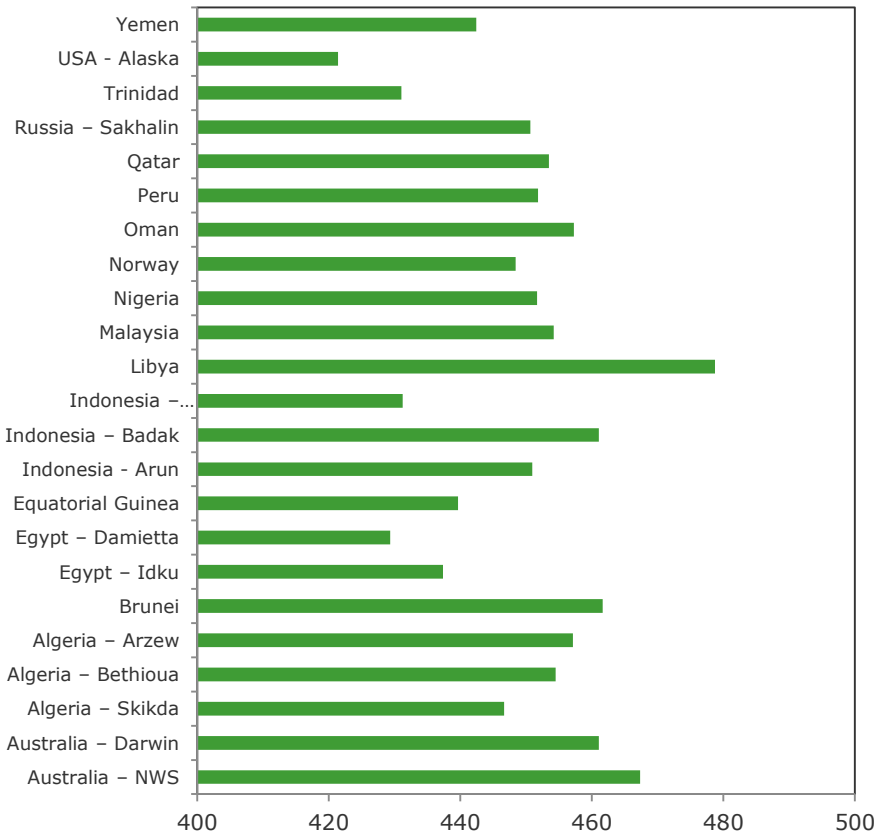


….where gas end-use is a local market with specific composition requirements



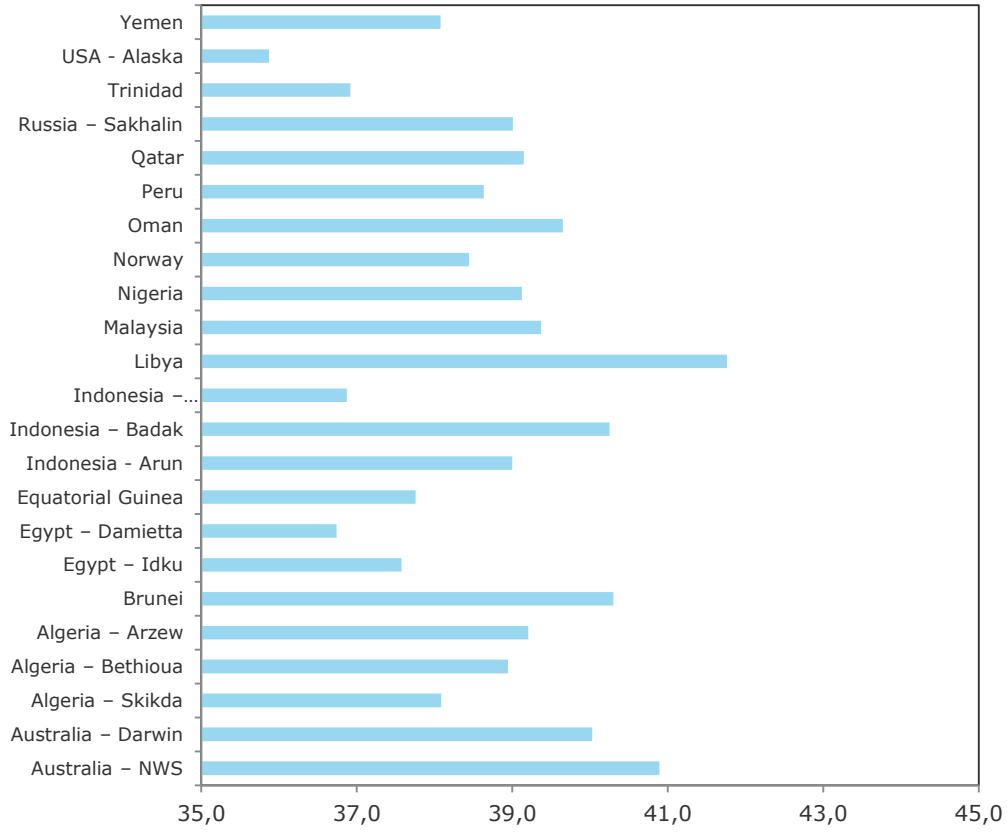
Different calorific values based on domestic appliances

The quality of commercially available LNG varies significantly across the globe



Density, kg/m³

12% variation



Lower calorific value, MJ/m³(n)

17% variation

Example – January 2016:
LNG import on hold due to not meeting specifications

Lithuania puts plans to import LNG from the United States on hold for now

VILNIUS

Jan 13 Lithuania has put plans to buy liquefied natural gas from the United States on hold because the LNG is not yet suitable for the Baltic state's gas system, its state energy company said on Wednesday.

Lithuania's system was built to use Russian gas and state energy group Lietuvos Energija said U.S. LNG was much more calorific than Russian gas.

The country opened an LNG import terminal in the Baltic Sea at the end of 2014, which allowed it to start importing from Norway and end its total dependence on gas imports from its former Soviet master, Russia.

"We are not buying gas from the U.S. at the moment, because the gas they are offering at the moment does not meet specifications needed for our gas distribution system"

"U.S. LNG is currently much more calorific than the Russian gas for which Lithuania's current gas transmission system has been built"

Weathering of LNG due to boil-off in LNG distribution chain

- A key issue in LNG transportation is the generation of Boil-Off Gas (BOG).

- The "boil-off" of the volatile components in the LNG stored leads to a change in composition of LNG

Component	Boiling point (°C)
Nitrogen	-196
Methane	-162
LNG	**-163**
Ethane	-88.5
Propane	-42
Butane	-0.5

Boil-off rate depends on:

1. Gas composition of the LNG
2. Temperature of the LNG
3. Heat transfer rate to the LNG through the tank
4. Residence time of LNG in the chain
5. Operating pressure
6. Motion

BOG generated during loading and un-loading processes

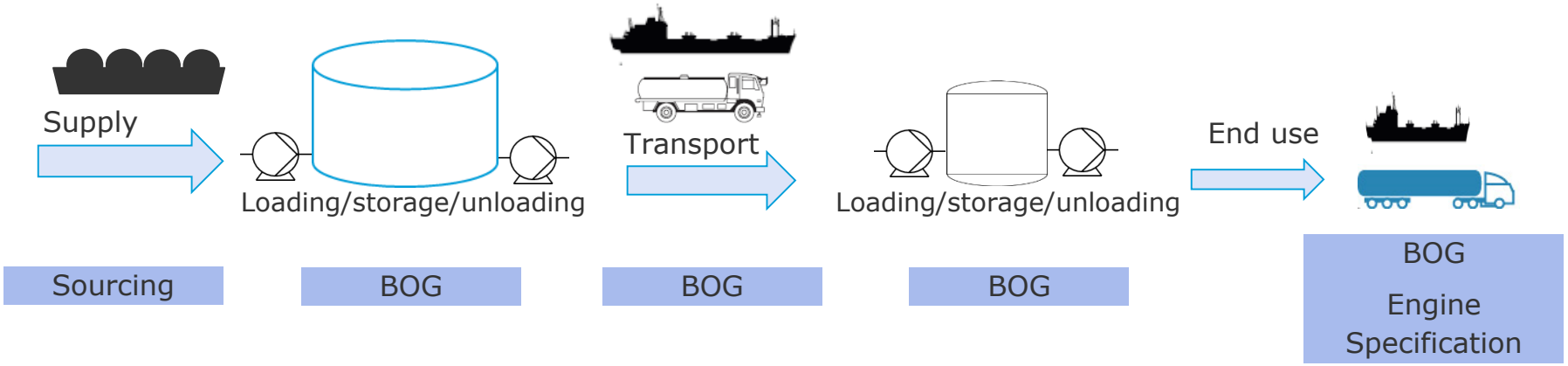
BOG generated during loading process

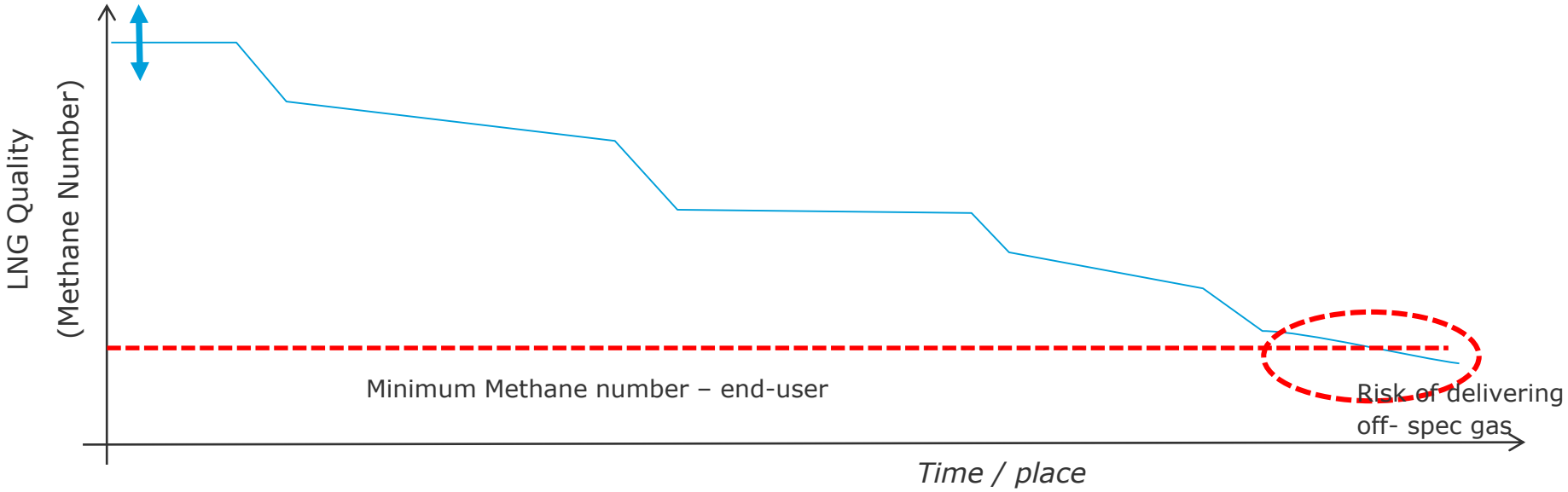
- Vapour return from ship's tanks.
- Heat transferred to LNG by loading pumps.
- Heat leak into LNG from pipes and equipment.
- Cooling down of the ship's manifold and loading arms.
- Cooling down of jetty lines prior to loading if not continuous.
- Mixing of loaded LNG with the initial amount of LNG (heel).
- Cooling down of ship's tanks if necessary.

BOG generated during unloading process

- Vapour return from ship's tanks.
- Heat transferred to LNG by loading pumps.
- Heat leak into LNG from pipes and equipment.
- Cooling down of the ship's manifold and loading arms.
- Cooling down of jetty lines prior to loading if not continuous.
- Mixing of loaded LNG with the initial amount of LNG (heel).
- Cooling down of ship's tanks if necessary.

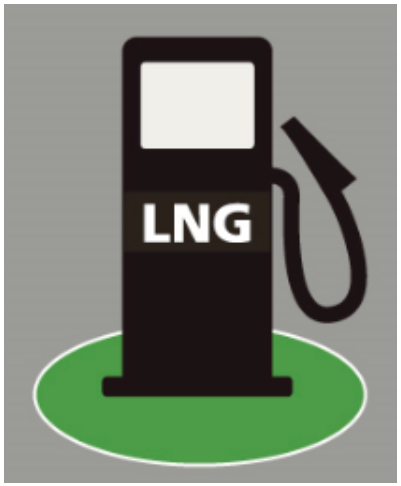
Risk of delivering "off spec" LNG in LNG value chain



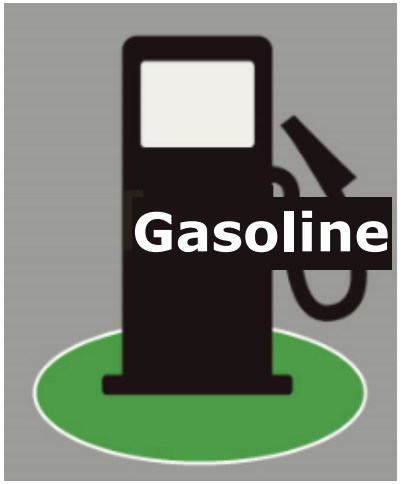


LNG as a transportation fuel

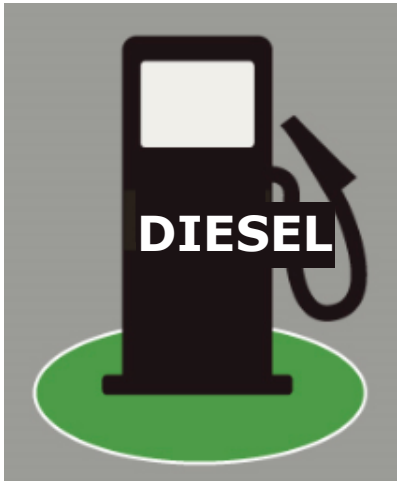
Characterization for LNG, gasoline and diesel



Methane number



Octane number

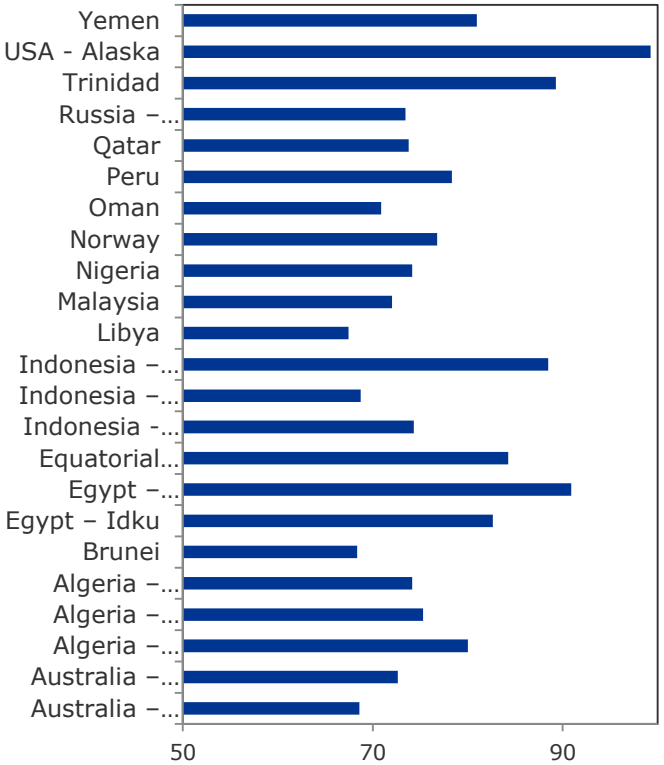


Cetane number

Currently : No European or world-wide standard ***for LNG as a fuel*** (CEN /ISO)

Determination of methane number is critical to safeguard the vehicle's safety (only relevant for Otto engines)

- The knock resistance of LNG is characterized by the methane number, which is similar to the octane number used in gasoline engines
- The global variation in methane number is **more than 32 points**
- The occurrence of engine knock leads to significant loss of performance (power reduction), engine shutdown and potential damage
- Knowledge of the knock characteristics of LNG fuels is crucial for suppliers and traders to provide reliable and efficient products and for the end user to secure optimal engine operations.
- DNV GL developed a fundamentally correct method to characterize gaseous fuels (PKI Methane Number)



Methane Number, PKI method

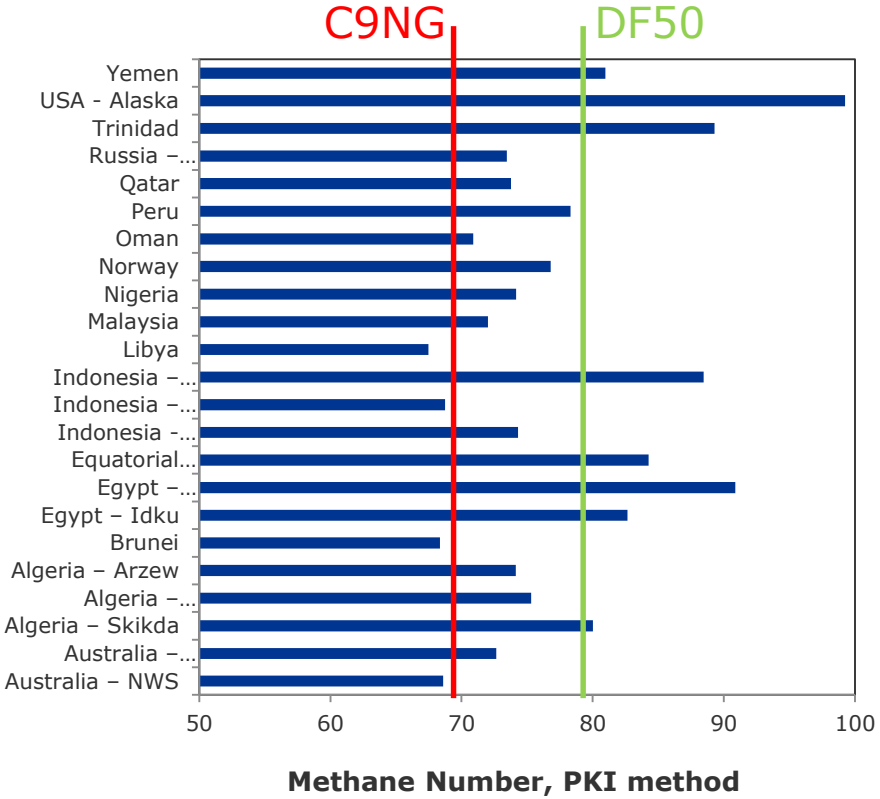
32 point variation in Methane number

Matching fuels and engines

- High performance and high efficiency (automotive) engines require high methane number (similar to Octane Number fuel)

- Engine spec examples:

Engine	Min. MN
Iveco Cursor 9 NG	70
Wärtsilä DF50	80



- If Methane Number is fixed at 80, almost 90 % of LNG downloaded in Europe does not match fuel specification, except if this is previously treated (not easy and expensive).

LNG as a fuel - PKI Methane Number Calculator

Screenshot

DNV GL Methane Number Calculator

Please fill in the LNG composition in mole % and press calculate

			N-Butane ($n\text{-}C_4H_{10}$)	0.00	%
Nitrogen (N_2)	0.00	%	2-Methylpropane ($i\text{-}C_4H_{10}$)	0.00	%
Methane (CH_4)	80	%	N-Pentane ($n\text{-}C_5H_{12}$)	0.00	%
Ethane (C_2H_6)	20	%	2-Methylbutane ($i\text{-}C_5H_{12}$)	0.00	%
Propane (C_3H_8)	0.00	%	2,2-Dimethylpropane ($neo\text{-}C_5H_{12}$)	0.00	%

Total is 100.00%. Calculate

Methane number (PKI method): 70.9

Together with the partners below DNV GL is developing dedicated Methane Number algorithms for different engine classes for LNG (Truck, Marine and CHP engines):

Key performance characteristic: Knock resistance of LNG

Now available from DNV GL: the PKI Methane Number calculator to characterize the knock resistance of LNG

Knock resistance

A characteristic of the LNG; its tendency or resistance to cause engine knock

Maintain performance

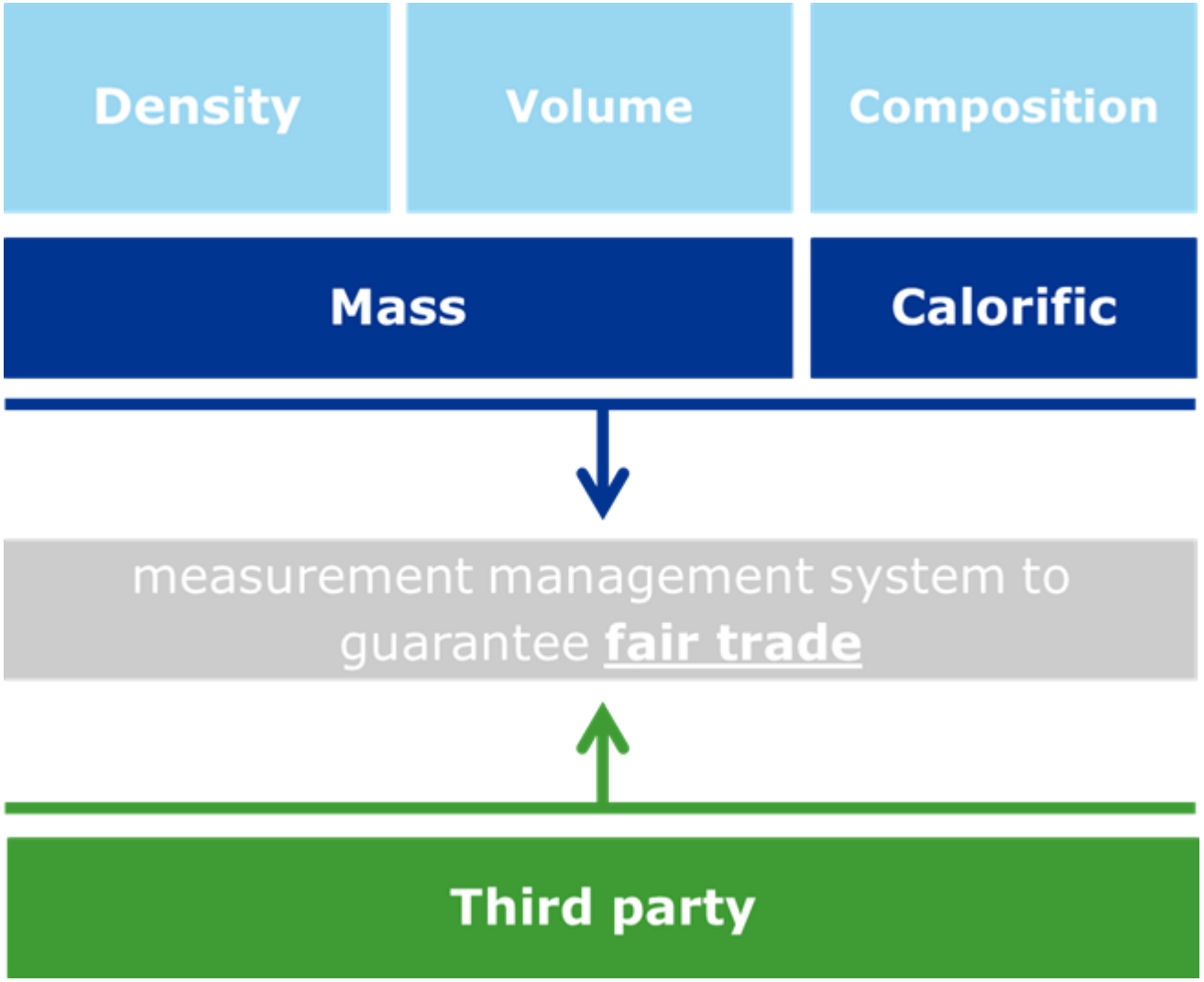
The occurrence of engine knock can lead to loss of performance, engine shutdown and damage

PKI Methane Number

The correct characterization of knock resistance guarantees that LNG and engine are matched for optimum operation

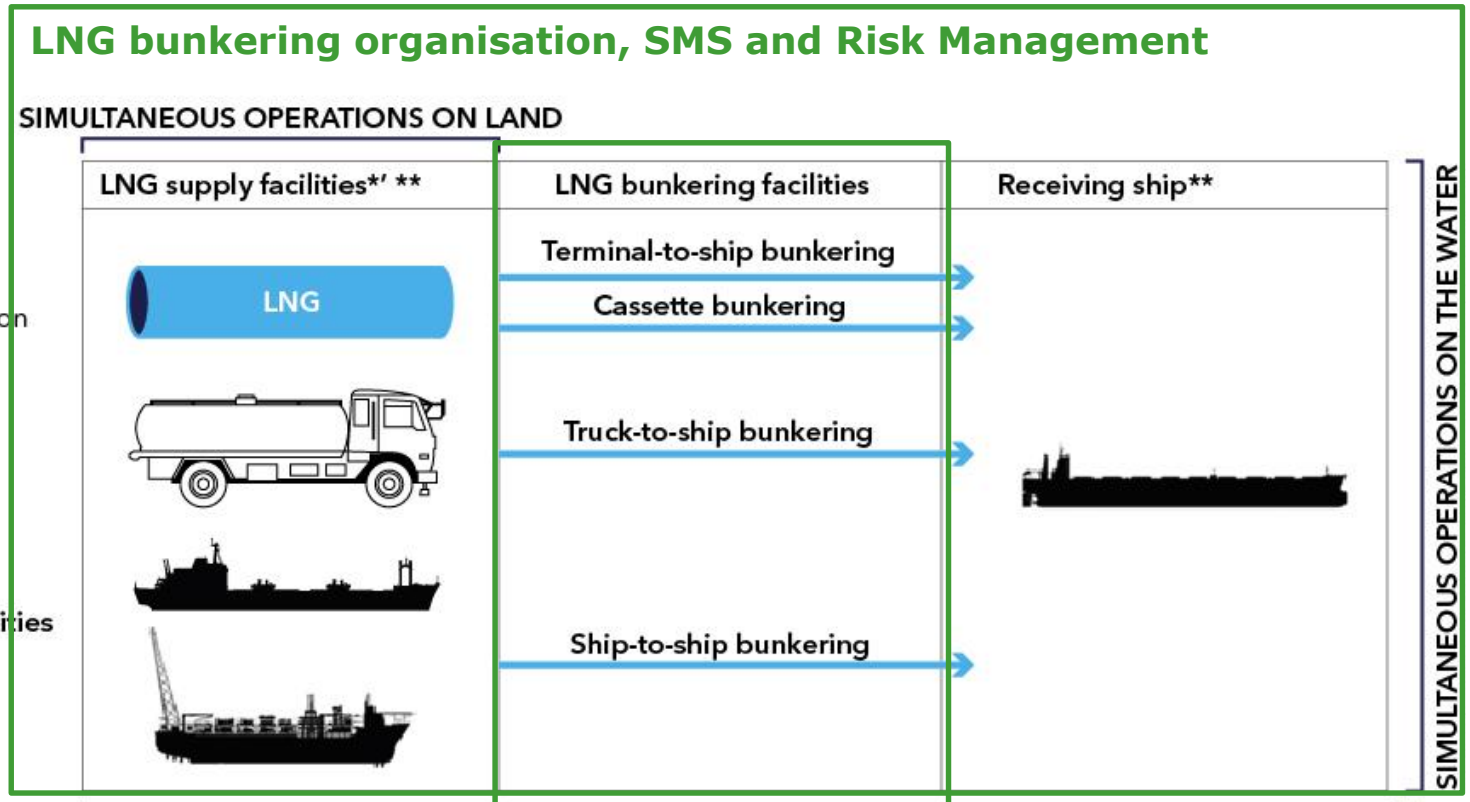
https://www.dnvgl.com/oilgas/natural-gas/fitness-for-purpose-of-lng-pki-methane-number-calculator.html

LNG billing by energy content - The RP describes several options to determine mass directly or indirectly



DNV GL Recommended Practice (G105) for LNG Bunkering

The scope of work includes guidance on risk management, fiscal metering, the bunkering organisation and functional and operational requirements for securing global compatibility



1. Shore LNG facilities:
a. Onshore permanent installation
b. Portable tanks
c. Trucks

2. Waterborne LNG supply facilities
a. LNG bunker vessel in port
b. LNG bunker vessel at sea
c. LNG offshore storage

* LNG storage facilities, trailers and containers shall be governed by secific standards or national and/or local laws. If necessary, this RP may defines additional requirements
** Supplying and receiving vessels shall be governed by specific standards

Fiscal metering, functional & operational requirements, safety zone

The RP G105 provides guidance on development and implementation of a measurement system for QUALITY and QUANTITY of LNG

- The measurement system ensures transparency in billing and safeguards both safety and fitness for purpose for using LNG as a fuel.
  - The energy content and essential properties of the transferred LNG shall be determined.
  - The receiving ship must be able to rely on the specification of fuel quality for safe use.
- The cost associated with implementing a measurement system should be proportional to the financial risk involved.

Conclusion: LNG fuel issues

- **Quality control and billing issues**
  - "boil-off" during transport and storage → composition changes over time
  - Substantial variations in density and heating value

- **Issues related to variations in engine performance with changes in fuel quality (particularly engine knock)**
  - Variation in composition w.r.t. major (hydrocarbon) species → different combustion performance (power, efficiency, emissions)
  - Different engine types/adjustment → may lead to different behaviour regarding knock

Solution: DNV GL effectively supports all stakeholders throughout their whole decision making process…

TECHNICAL SPECIFICATION ISO/TS 16901

TECHNICAL SPECIFICATION ISO/TS 18683

First edition 2015-01-15

Guidelines for systems and installations for supply of LNG as fuel to ships

Lignes directrices pour les systèmes et installations de distribution de gaz naturel liquide comme carburant pour navires

2016-04-08

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RECOMMENDED PRACTI

DNVGL-RP-G105

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RULES FOR CLASSIFICATION

Ships

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Development and operation natural gas bunkering facilit

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Part 6 Additiona

Chapter 2 Propu auxiliary systen

RULES FOR CLASSIFICATION

Ships

Edition January 2016

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RULES FOR CLASSIFICATION

Ships

Edition January 2016

Part 5 Ship types

ter 7 Liquefied gas tankers

Part 6 Additional class notations

Chapter 5 Equipment and design features

SECTION 14 GAS BUNKER VESSELS - GAS BUNKER

1.1 Introduction

The objective of this section is to outline requirements for carriers and barges intended for the transport of liquefied gas with dedicated gas fuel transfer equipment for supply of bunker for gas fuelled ships on regular basis

1.1.2 Scope

This section covers safety of the gas bunker vessel, its gas bunker related equipment and installations on-board. It outlines requirements for design, construction and required operational procedures with regard to connection and disconnection of transfer arrangements, bunker transfer and vapour return

1.1.3 Application

This section applies to the vessels with the ship type notation **Tanker for Liquefied Gas (Tanker for C)** built in compliance with Pt.5 Ch.7 and barges specifically intended for carriage of liquefied gas built in compliance with Pt.5 Ch.11

Part 6 Chapter 5 Section 14

ECTION 5 GAS FUELLED SHIP INSTALLATIONS - GAS FUELLED

General

.1 Introduction

e additional class notation **Gas fuelled** provides criteria for the safe and environmentally friendly rangement and installation of machinery for propulsion and auxiliary purposes, using gas as fuel.

.2 Scope

Part 6 Chapter 2 Section 5

… and since the regulatory framework for LNG fuelled shipping and LNG bunkering is developing fast, DNV GL support with recommendations and decision support on strategic, tactical and operational level

THE INNOVATION PARTNER TO THE GAS INDUSTRY

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MARITIME

Thank you for your attention

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