MAN Energy Solutions
Future in the making

Prospects for energy and maritime transport in the Nordic Region

MAN ES decarbonization options towards 2050

Michael Jeppesen
Promotion Manager, Customer Support
Malmø, 26-27th February 2020

The world's leading designer of Two Stroke Diesel Engines

Copenhagen, Denmark.

Design of Two-Stroke Engines

Production of Spare Parts

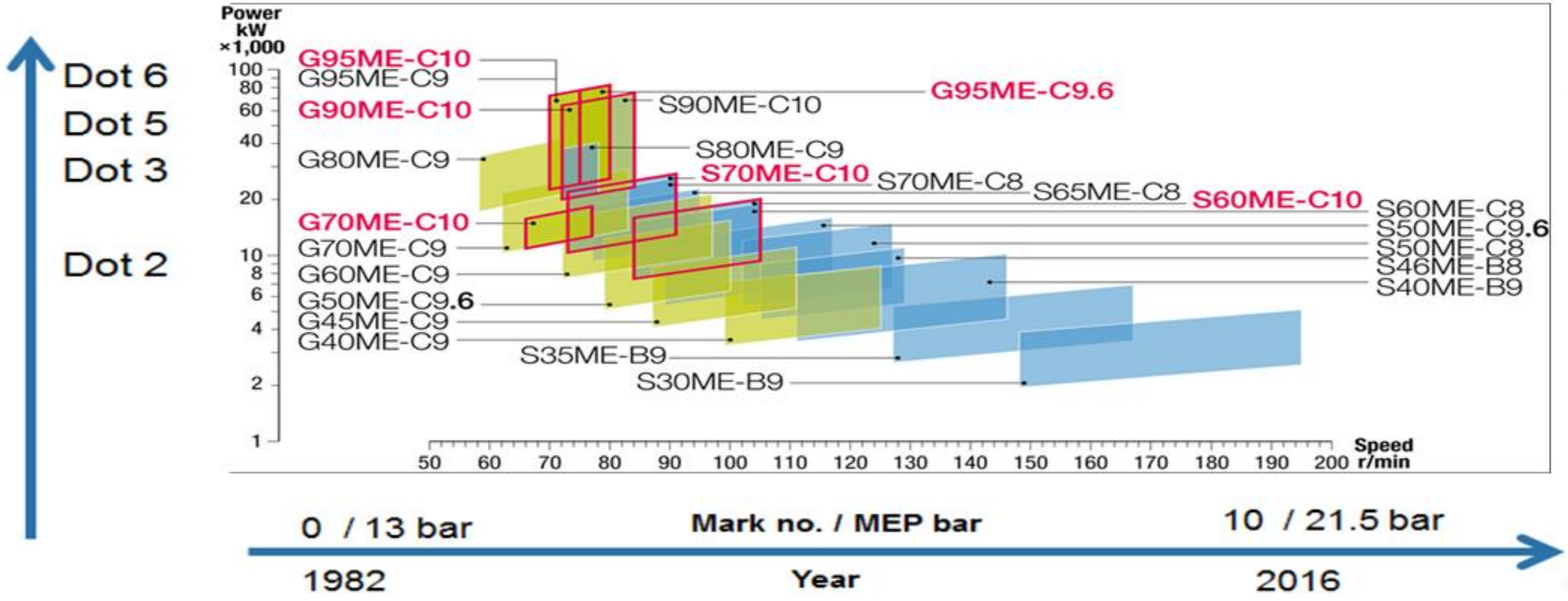
PrimeServ Academy

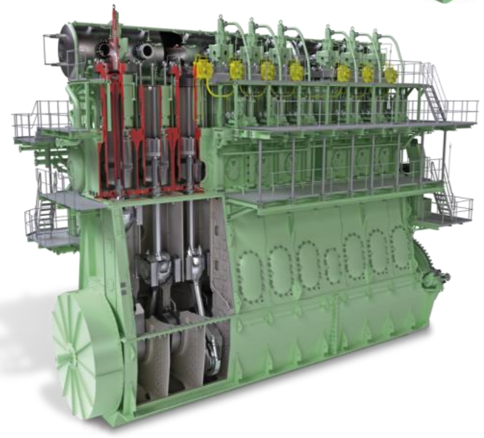
R&D Center

Diesel House

Employees CPH 1,300 (DK about 2,000)

Engine Programme Development





Mission: Meet any combination of propeller power and speed the naval architects will need

MAN Energy Solutions

1 Company Strategy, Targets, Market drivers

2 Marine Application & Decarbonization Options

3 Power to X

4 Energy Outlook

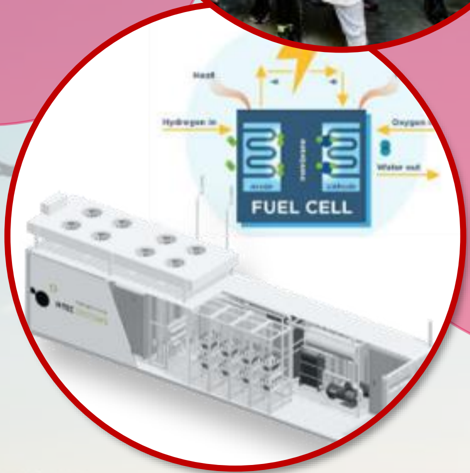
Driver of MAN-ES company strategy

Decarbonization

Calls for new technologies

- Limit global warming to below 1.5° Celsius
- Carbon neutrality by 2050

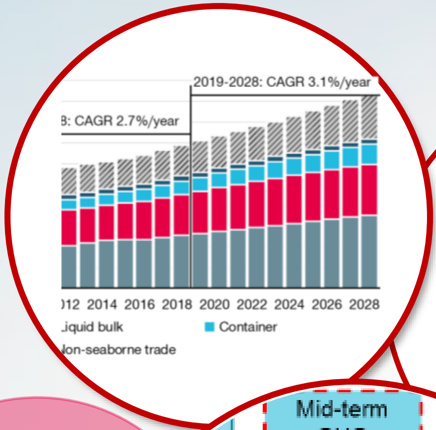
Market Drivers

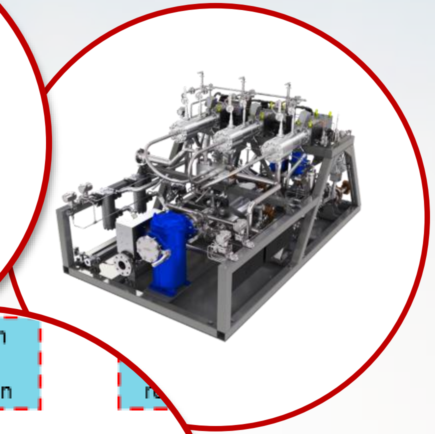


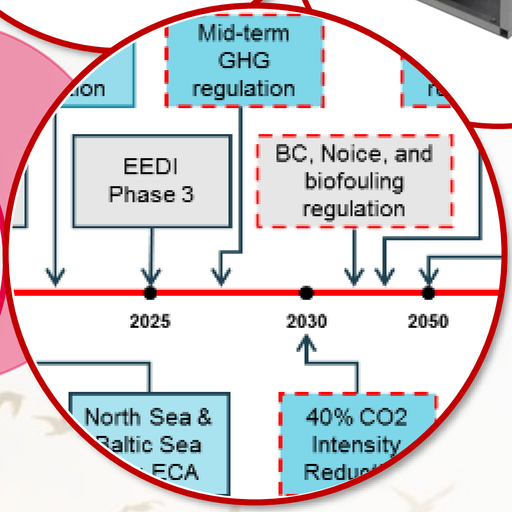
Regulations & Public Focus

Climate Change

Technology



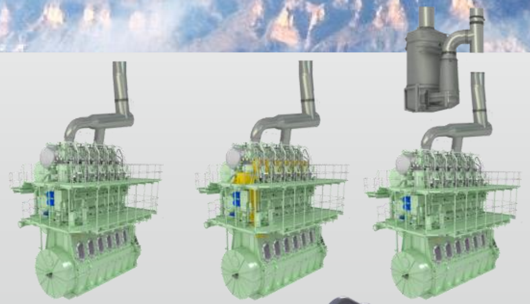




Regulation – a driving factor for engine development

SO_X

LNG
LPG
LS fuel oil
Ethane
MGO
Exhaust gas scrubber
Methanol



NO_X

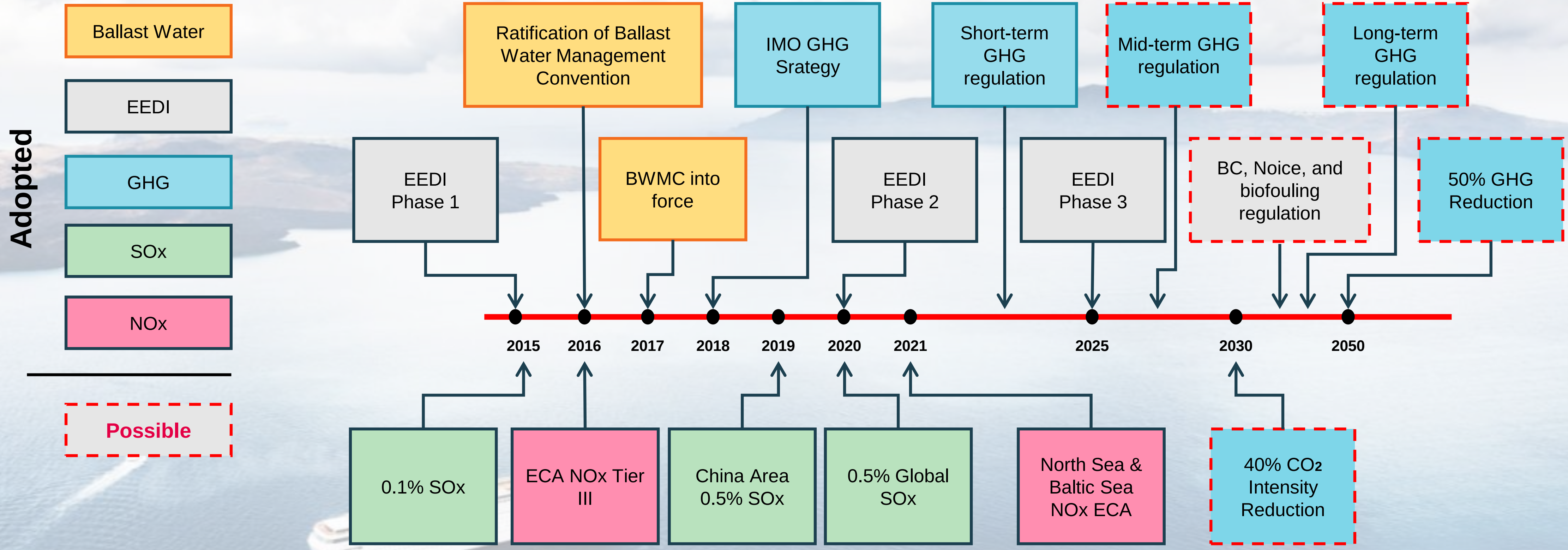
EGR
Water
SCR

GHG

Fuel
Machinery efficiency
Speed
Hull
Propeller
Ship size
Energy saving devices

Emission Regulations

Timeline overview



- NOx, SOx & EEDI regulation on the short term focus list
- Significant GHG reductions planned in the following years.

IMO resolution MEPC.304(72)

Initial IMO strategy on reduction of GHG emissions from ships

Level of ambition

Carbon intensity of ships to decline

– Strengthening of EEDI requirements for new ships

Carbon intensity of shipping to decline

– 40% reduction per transport work by 2030 relative to 2008
– 70% reduction per transport work by 2050 relative to 2008

GHG emission from shipping to decline

– 50% reduction of GHG emissions by 2050 relative to 2008

Timeline

Short-term measures: 2018–2023

– EEDI improvement (Energy Efficieny Design Index)
– SEEMP improvement (Ship Energy Efficiency Management Plan)
– Speed regulation
– Methane slip regulation
– VOC regulation (Volatile Organic Compounds)

Mid-term measures: 2023–2030

– Low-carbon/zero carbon fuels introduction
– Operational energy efficiency requirements
– Market-based measures

Long-term measures: > 2050

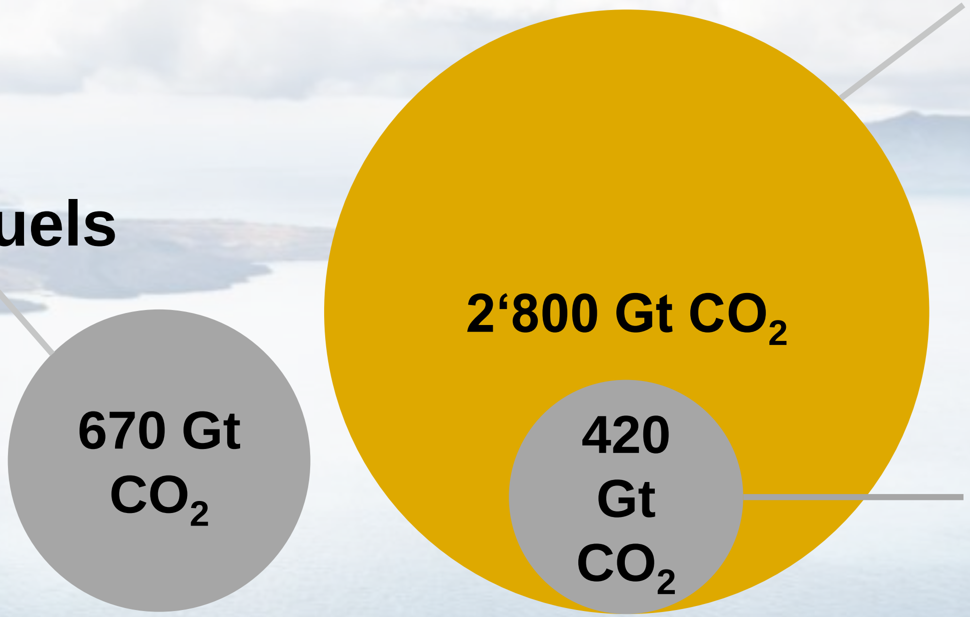
– Zero carbon/fossil-free fuels for 2050 and later

The Target: max. 2°C

CO_2 Emissions & Fossil Fuel Reserves

CO_2 emission potential of proven global fossil fuel reserves

CO_2 emissions caused by fossil fuels 1990 - 2015



Maximum amount of fossile fuel emissions until 2050 before reaching 2°C carbon budget

**The world is not running out of fossil fuel resources anytime soon.
But the environmental impact of CO_2 emissions means we cannot burn it all.**

Reference: IEA, World Energy Outlook

The Target: max. 1.5°C

COP21·CMP11
PARIS2015
UN CLIMATE CHANGE CONFERENCE

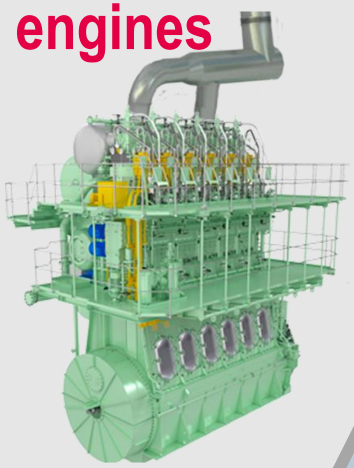
AMBITION 1.5°C
GLOBAL SHIPPING'S ACTION PLAN
13 NOVEMBER 2017

IMO draft
-50% GHG by 2050

DECARBONIZATION requires
Technologies & Infrastructure

Engine Optimization

Multi fuel engines



Alternative Fuels

Hybridization

MAN Energy Solutions

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Marine Applications

Our Solutions for

SO_x	NO_x	CO_2 / Fuel Economy
Low Sulphur Fuel (MGO, ULSF, VLSF)	Catalysts (SCR)	Efficiency optimization
De-Sulphurisation (Wet Scrubber)	Exhaust Gas Recirculation (EGR)	De-rated engines / speed reduction
	WIF (Methanol)	

Gas as Marine Fuel

PtX – Synthetic Marine Fuel

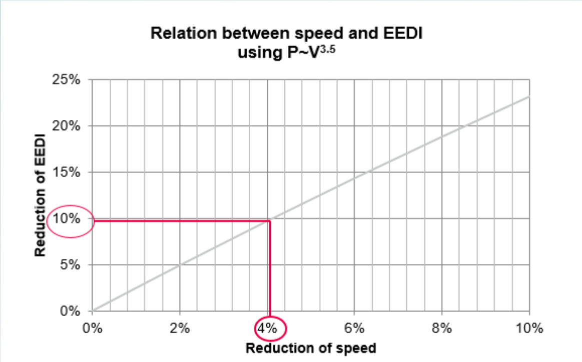
EEDI – Reduction

Ship Speed / Power / Low Carbon Fuels

$$\text{EEDI} = \frac{\Sigma P \times C_F \times SFC}{\text{Capacity} \times \text{Speed}}$$

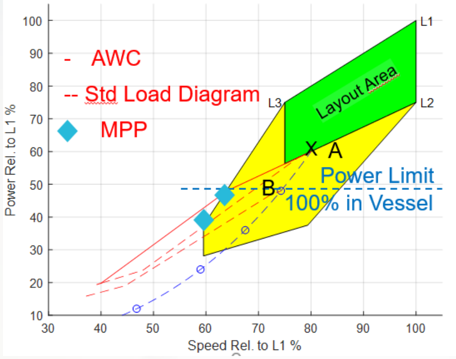
Influence of speed reduction on EEDI reduction is significant

- Due to the propeller law (speed to power relation) and
- as power is divided with speed in EEDI calculation.



Influence of engine power limitation on EEDI reduction is significant

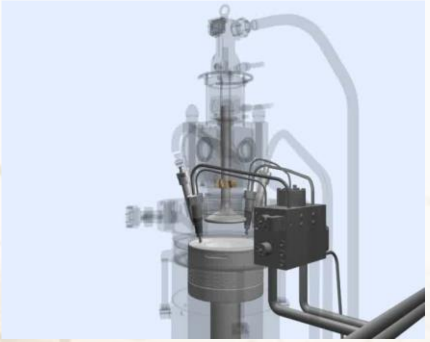
- For TIER III engines with EcoEGR tuning and
- Due to significant fuel savings



Influence of gas fuelled engines on EEDI reduction is significant

- Due to the Carbon factor C_F in the EEDI calculation
- Due to significant fuel savings

Fuel	Reduction
MDO	0%
Methanol	5%
LPG	15%
LNG	24%
Ammonia	95%



Decarbonization with Battery-propulsion & -Backup

MAN B&W 2-stroke Engines

Residual
ME/MC

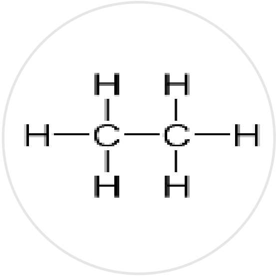
Distillates
ME/MC

ULSFO
ME/MC

Methane
ME-GI/MEGA

Methanol
ME-LGIM

LPG
ME-LGIP

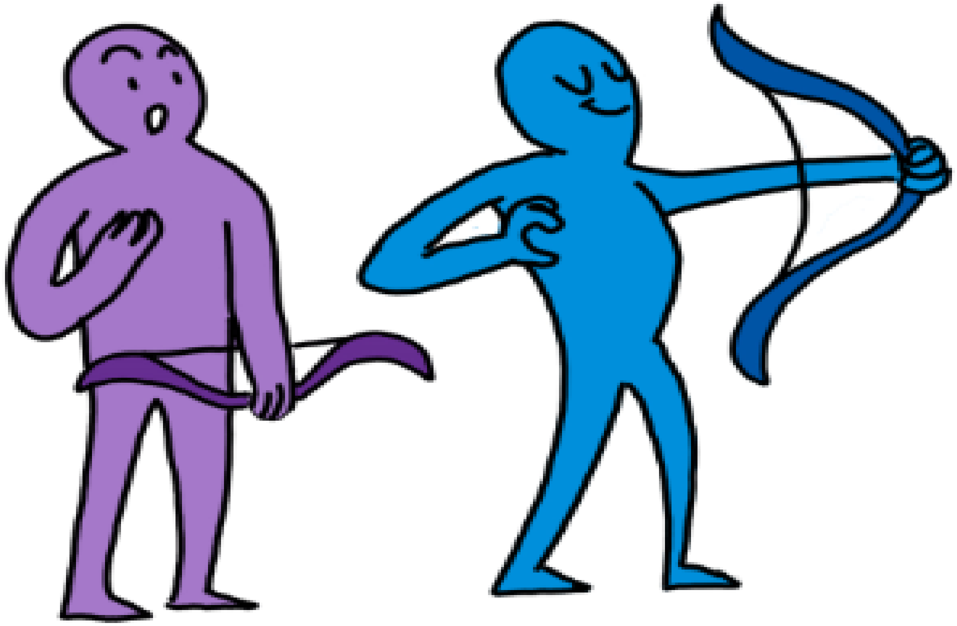


Ethane
ME-GIE

Biofuel
(2^{nd}+3^{rd} gen.)
ME/MC

MAN Energy Solutions **supports all**

MAN B&W Multifuel Engines



Today - The Dual Fuel success

4 x World's first duel fuel driven ships equipped with MAN B&W engines

World's first LNG driven ocean going ship
Owner: TOTE
Ship type: Container ship, 3,100 Teu
Capacity: Dual Fuel engine type: 8L70ME-C8.2-GI
Engine delivered in 2012

World's first ethane driven ocean going ship
Owner: Hartmann Schifffahrt
Ship type: LEG Carrier, 36,000 M^3
Dual Fuel engine type: 7G50ME-GIE
Engine delivered in 2014

World's first methanol driven ocean going ship
Owner: MOL
Ship type: Methanol carrier, 50,000 dwt.
Dual fuel engine type: 7S50ME-B9.3-LGIM
Engine delivered in 2013

World's first LPG driven ocean going ship
Owner: Exmar
Ship type: VLGC, 80,000 M^3
Dual Fuel engine type: 6G60ME-LGIP
Not yet in service

Retrofits – there is a huge existing fleet

Worldwide more than 50,000 relevant ships

Engine conversions: HFO to LNG/SNG*

Examples: Converting an 48/60B to 51/60DF

~ 99% Reduction in SO_x emissions

~ 90% Reduction in NO_x emissions

~ 20% Potential in CO_2 reduction

*) SNG = Synthetic Natural Gas

Retrofit LNG 4-stroke
Owner: Wessels (Wes Amelie)
Engine Conversion:
MAN48/60 -> MAN51/60DF

Retrofit LNG 2-stroke
Owner: Nakilat
Engine Conversion:
7S70ME-C -> 7S70ME-GI

Alternative fuels

Properties

Energy storage type	Specific Energy MJ/kg	Energy Density MJ/L	Required Tank Volume m^3. [1]	Supply pressure bar	Estimated PtX efficiency	Injection pressure bar	Emission Reduction Compared To HFO Tier II			
MGO	42,7	35	1000	7-8		950	SO_x	NO_x	CO2	PM
Liquefied natural gas (LNG -162 °C)	50	22	1590	300	0,56	300	90-99%	20-30%	24%	90%
Liquid ethane gas (LEG -88 °C)	47,8	17,1	2046	380		380	90-97%	30-50%	15%	90%
liquefied petroleum gas (LPG -42,4 °C)	46,4	23	1,521	50		600-700	90-1 00%	10-15%	13-18%	90%
Methanol	19.9	15	2333	10	0,54	500	90-97%	30-50%	5%	90%
Ethanol	26	21	1666	10		500				
Ammonia (liquid -33 °C)	18,6	11,5	3043	70	0,65	600-700	100%	Compliant with regulation	>95%	>90%
Hydrogen (liquid -253 °C)	120	8.5	4117		0,68					
Marine battery market leader, Corvus, battery rack	0,29	0,33	106.060							
Tesla model 3 battery Cell 2170*. [2]	0,8	2.5	14000							

- *1: Given a 1000 m^3 tank for MGO. Additional space for insulation is not calculated for in above diagram. All pressure values given a high pressure Diesel injection principle.*
- *2: Values for Tesla battery doesn't contain energy/mass obtained for cooling/safety/classification .*

Alternative fuels

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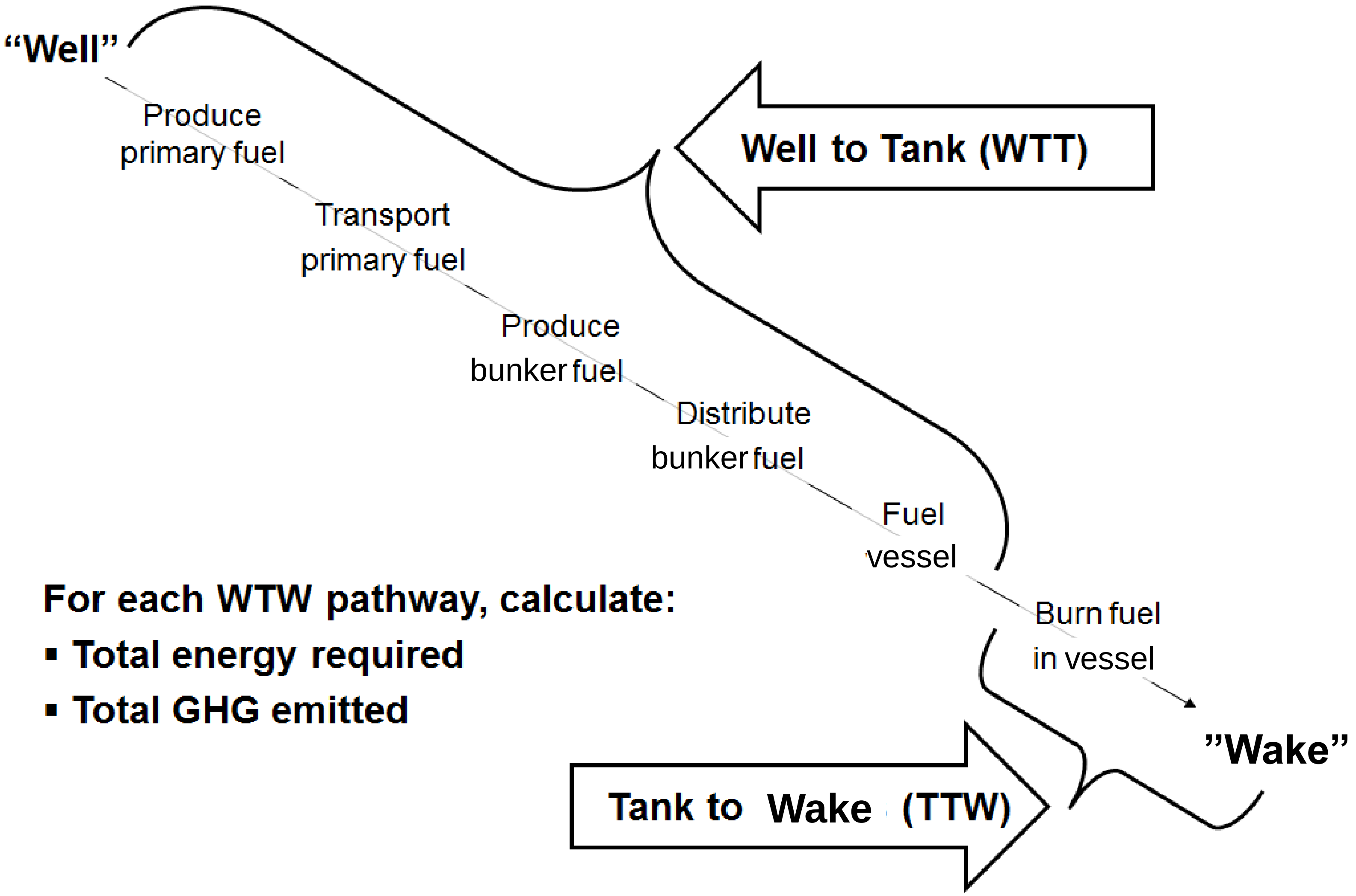
Alternative fuels

Basis for CO_2 calculation



For each WTW pathway, calculate:

- **Total energy required**
- **Total GHG emitted**

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MAN power-to-x (PtX)

MAN PtX for carbon-neutral synthetic fuel

- Energy transformation technology that converts electricity into **carbon-neutral synthetic fuels**
- **MAN PtG** (power-to-gas): Renewable energy is used to produce hydrogen via water electrolysis. Together with CO_2, the hydrogen forms synthetic natural gas (SNG) in a methanation reactor
- **MAN PtL** (power-to-liquid): Hydrogen is converted into methanol
- **MAN PtC** (power-to-chemicals): Together with nitrogen or other compounds, hydrogen forms chemicals such as **ammonia**, ethylene or propylene

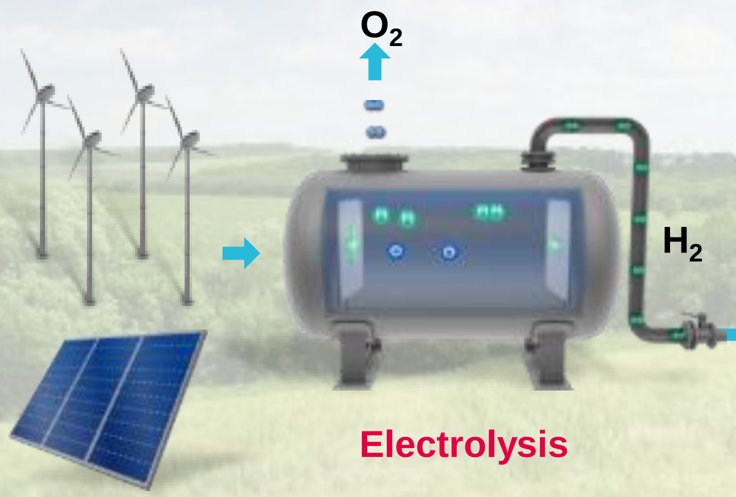
Hydrogen is now.
H-TEC SYSTEMS

PTX paths

Marine evaluation

Liquid H2

- *Gaseous, cryogenic liquefaction*
- *New infrastructure required*
- *Dedicated ships required*



Liquid synthetic Methane

- *Gaseous, cryogenic liquefaction*
- *Existing infrastructure can be used*
- *Mixing with fossil fuel possible*

Synthetic Methanol

- *Liquid*
- *New infrastructure based on broad global presence*
- *Dedicated ships required*

Synthetic Crude Oil

Petrol
Diesel
Kerosene

- *Liquid*
- *Existing infrastructure can be used*
- *Mixing possible*

Synthetic Ammonia

- *Liquid/Gaseous*
- *New infrastructure based on broad global presence*
- *Dedicated ships required*

Ammonia as fuel

NH3 as potential green fuel of the future

- Can be produced 100% from renewable energy sources
- Clean combustion without CO2 or carbon emissions
- Easy to store (liquid -33 deg C or 20 deg C at 9 bar) compared to LNG (-163 deg C) or hydrogen (-253 deg C)
- Industrial experience with ammonia (180 mill ton production per year). Used as refrigerant onboard ships

Green Power to Fuel

e-Fuels: Methane, Methanol, Ammonia & Hydrogen

Technologies are available for future projects

Top technologies for CO_2-minimization available for future projects

Production of CO_2-neutral fuels

Worldwide largest power-to-methane plant in Werlte with MAN reactor ✓

SNG = substitute / synthetic natural gas

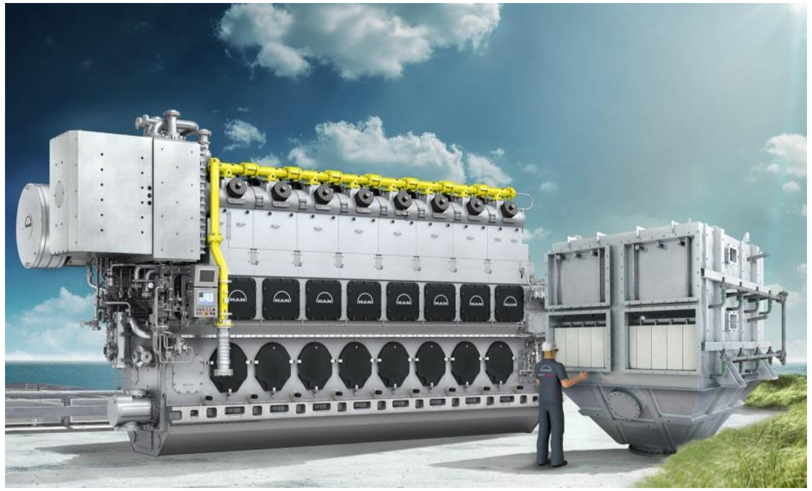
Drive technology for synth. fuels (SNG)

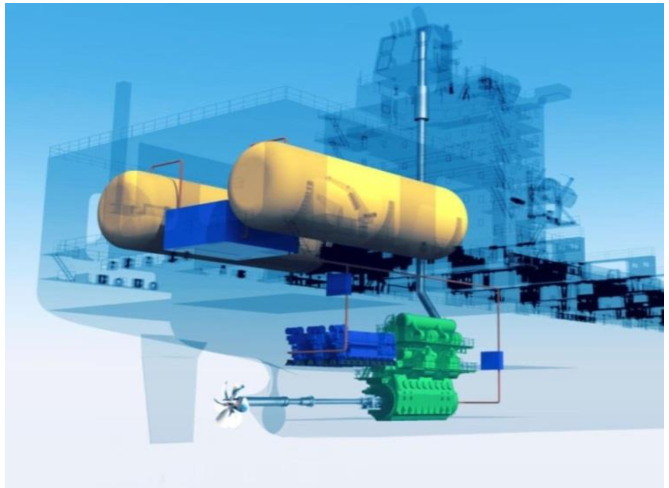
Gas- and dual-fuel engines ✓

~ 99% less SO_X emissions

~ 90% less NO_X emissions (Otto Cycle)

~ 100% potential for CO_2 reduction





ME-GI engine operating on LNG

New built ship

Ship built today

Layout for fossil LNG

→ -20% CO_2

(Over)compliant by 2020

Mix in 25% SLNG

→ -40% CO_2

Compliant by 2030

Mix in 38% SLNG

→ -50% CO_2

Compliant by 2050

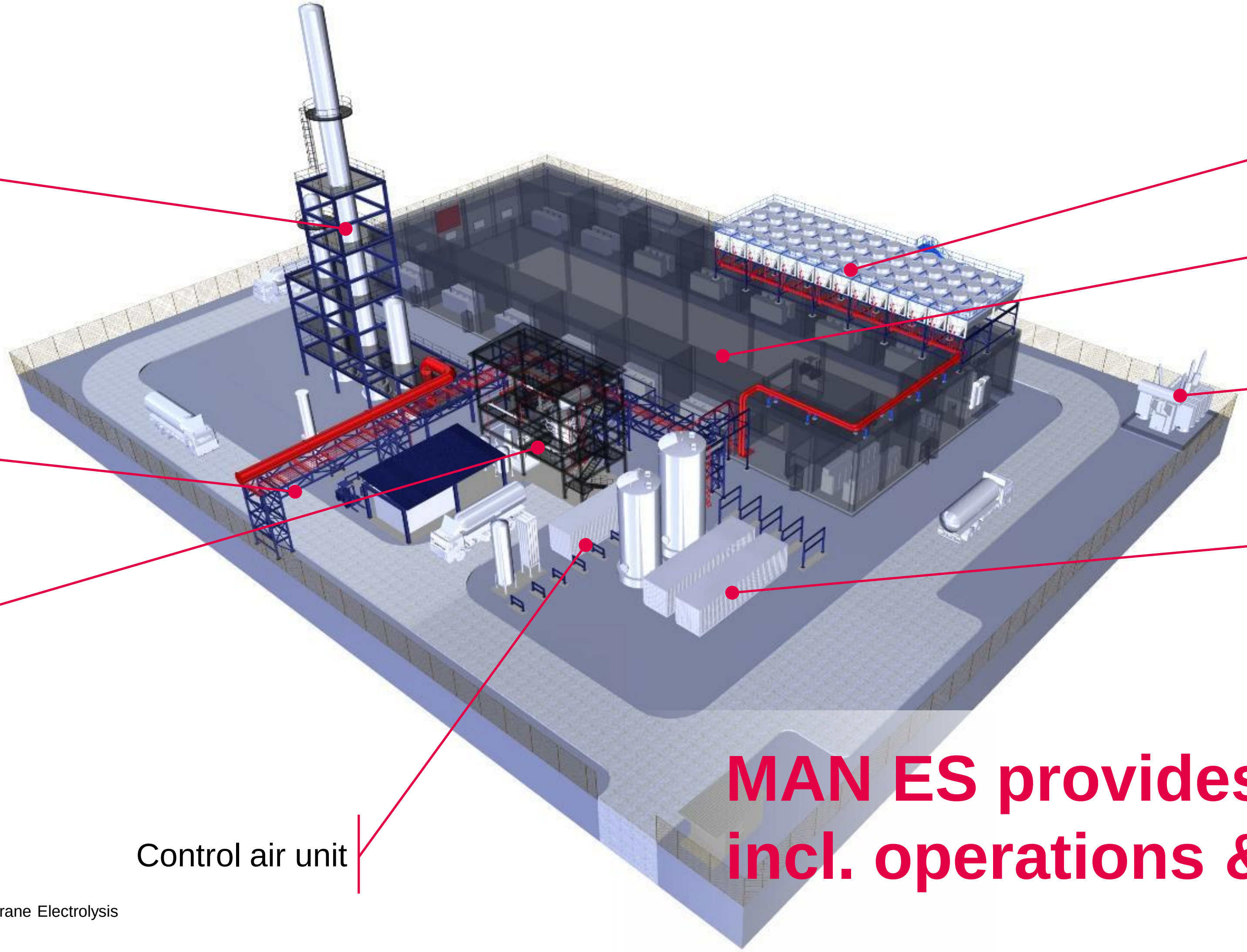
A LNG powered ship today already provides the flexibility to comply with the foreseeable CO_2 reduction targets!

ME-GI engine operating on LNG

M/V Wes Amelie – World Premiere with liquid SNG

MAN power-to-gas reference plant

MAN 50 MW PtG plant layout - preliminary



MAN ES provides full EPC incl. operations & maintenance

AEL: Alkaline Elektrolysis, PEM: Polymer Electrolyte Membrane Electrolysis

Green Marine Fuel

CO_2 neutral shipping with MAN Power to Gas

50MW Power to SNG plant

- 50 MW PtG plant at a site with excess/ renewable energy
- 21.250.000 m³ SNG at 8000 hrs./a

2 Car Carrier CO_2-neutral

- SNG use in car carrier per roundtrip: 1.490.000 m³
- SNG production per year: 21.250.000 m³
- 14 Roundtrips / 2 car carriers are CO_2 neutral

SNG: synthetic natural gas; Picture © Mac Mackay

Green Marine Fuel

Confidential

CO_2 neutral shipping with MAN Power to Gas

11,000 Teu

Typical container vessel
MAN ME-GI gas engine

28600 m3 LNG

Main fuel consumption per year,
7.5 roundtrips Dubai – Genua - Dubai

61MW

P2G plant @ 8000 hrs. /a

100% CO_2 neutrality

Source: MAN Study „11,000 teu container vessel – An ME-GI powered vessel fitted with fuel gas supply system and boil-off gas handling", 2018

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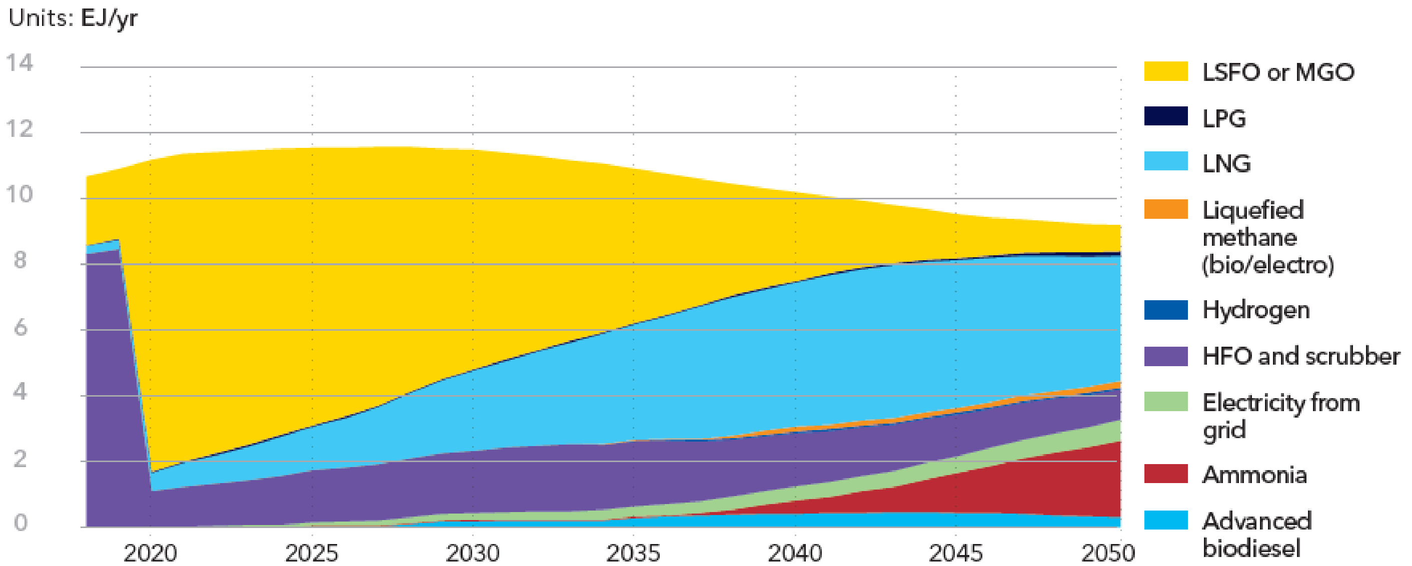
DNV forecast on maritime energy transition

Projected fuel mix

DNV GL Main indicators

- LNG and Ammonia will make up a large amount of future fuels
- LSFO and MGO will in the next 15 years remain the most popular fuel by demand

Energy use and projected fuel mix 2018-2050 for the simulated IMO ambitions pathway with main focus on design requirements



LSFO, low-sulphur fuel oil; MGO, marine gas oil; LPG, liquefied petroleum gas;
LNG, liquefied natural gas; HFO, heavy fuel oil;
Advanced biodiesel, produced by advanced processes from non-food feedstocks

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