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.
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

Prospects for energy and maritime transport in the Nordic region
Regulation – a driving factor for engine development

**SO\textsubscript{x}**
- LNG
- LS fuel oil
- Ethane
- Exhaust gas scrubber
- Methanol

**NO\textsubscript{x}**
- EGR
- Water
- SCR

**GHG**
- Fuel efficiency
- Speed
- Propeller
- Ship size
- Energy saving devices
**Emission Regulations**

**Timeline overview**

- **Ballast Water**
- **EEDI**
- **GHG**
- **SOx**
- **NOx**

### Possible

- 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 Efficiency 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

MAN Energy Solutions
Prospects for energy and maritime transport in the Nordic region
The Target: max. 2°C

CO₂ Emissions & Fossil Fuel Reserves

CO₂ emissions caused by fossil fuels 1990 - 2015

The world is not running out of fossil fuel resources anytime soon. But the environmental impact of CO₂ emissions means we cannot burn it all.

Reference: IEA, World Energy Outlook

CO₂ emission potential of proven global fossil fuel reserves

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

2'800 Gt CO₂

670 Gt CO₂

420 Gt CO₂

The world is not running out of fossil fuel resources anytime soon. But the environmental impact of CO₂ emissions means we cannot burn it all.
The Target: max. 1.5°C

IMO draft -50% GHG by 2050

DECARBONIZATION requires Technologies & Infrastructure

Engine Optimization

Multi fuel engines

Alternative Fuels

Hybridization

Prospects for energy and maritime transport in the Nordic region
MAN Energy Solutions

1 Company Strategy, Targets, Market drivers
2 Marine Application & Decarbonization Options
3 Power to X
4 Energy Outlook
## Marine Applications

### Our Solutions for

<table>
<thead>
<tr>
<th>SO\textsubscript{x}</th>
<th>NO\textsubscript{x}</th>
<th>CO\textsubscript{2} / Fuel Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Sulphur Fuel (MGO, ULSF, VLSF)</td>
<td>Catalysts (SCR)</td>
<td>Efficiency optimization</td>
</tr>
<tr>
<td>De-Sulphurisation (Wet Scrubber)</td>
<td>Exhaust Gas Recirculation (EGR)</td>
<td>De-rated engines / speed reduction</td>
</tr>
<tr>
<td></td>
<td>WIF (Methanol)</td>
<td></td>
</tr>
<tr>
<td>Gas as Marine Fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PtX – Synthetic Marine Fuel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EEDI – Reduction
Ship Speed / Power / Low Carbon Fuels

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

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDO</td>
<td>0%</td>
</tr>
<tr>
<td>Methanol</td>
<td>5%</td>
</tr>
<tr>
<td>LPG</td>
<td>15%</td>
</tr>
<tr>
<td>LNG</td>
<td>24%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>95%</td>
</tr>
</tbody>
</table>

$$EEDI = \Sigma P \times C_F \times SFC$$

Capacity x Speed
Decarbonization with Battery-propulsion & -Backup

Engineering Innovative Solutions
AKA is a Canadian electrical systems integrator with over 20 years of experience in the power and propulsion industry.
MAN B&W 2-stroke Engines

MAN Energy Solutions supports all

- Residual ME/MC
- Distillates ME/MC
- ULSFO ME/MC
- Methane ME-GI/MEGA
- Methanol ME-LGIM
- LPG ME-LGIP
- Ethane ME-GIE
- Biofuel (2nd+3rd gen.) ME/MC

Prospects for energy and maritime transport in the Nordic region
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 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 ethane driven ocean going ship**
Owner: Hartmann Schifffahrt
Ship type: LEG Carrier, 36,000 M3
Dual Fuel engine type: 7G50ME-GIE
Engine delivered in 2014

**World’s first LPG driven ocean going ship**
Owner: Exmar
Ship type: VLGC, 80,000 M3
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 SOₓ emissions

~ 90% Reduction in NOₓ emissions

~ 20% Potential in CO₂ 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

<table>
<thead>
<tr>
<th>Energy storage type</th>
<th>Specific Energy MJ/kg</th>
<th>Energy Density MJ/L</th>
<th>Required Tank Volume m³</th>
<th>Supply pressure bar</th>
<th>Estimated PtX efficiency</th>
<th>Injection pressure bar</th>
<th>Emission Reduction Compared To HFO Tier II</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGO</td>
<td>42,7</td>
<td>35</td>
<td>1000</td>
<td>7-8</td>
<td>0,56</td>
<td>950</td>
<td>SOₙ, NOₓ, CO₂, PM</td>
</tr>
<tr>
<td>Liquefied natural gas (LNG -162 °C)</td>
<td>50</td>
<td>22</td>
<td>1590</td>
<td>300</td>
<td>0,56</td>
<td>300</td>
<td>90-99%, 20-30%, 24%, 90%</td>
</tr>
<tr>
<td>Liquid ethane gas (LEG -88 °C)</td>
<td>47,8</td>
<td>17,1</td>
<td>2046</td>
<td>380</td>
<td>0,56</td>
<td>380</td>
<td>90-97%, 30-50%, 15%, 90%</td>
</tr>
<tr>
<td>Liquefied petroleum gas (LPG -42,4 °C)</td>
<td>46,4</td>
<td>23</td>
<td>1,521</td>
<td>50</td>
<td>0,56</td>
<td>600-700</td>
<td>90-100%, 10-15%, 13-18%, 90%</td>
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<tr>
<td>Methanol</td>
<td>19,9</td>
<td>15</td>
<td>2333</td>
<td>10</td>
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<td>26</td>
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<tr>
<td>Ammonia (liquid -33 °C)</td>
<td>18,6</td>
<td>11,5</td>
<td>3043</td>
<td>70</td>
<td>0,65</td>
<td>600-700</td>
<td>100%, Compliant with regulation &gt;95%, &gt;90%</td>
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<tr>
<td>Hydrogen (liquid -253 °C)</td>
<td>120</td>
<td>8,5</td>
<td>4117</td>
<td></td>
<td>0,68</td>
<td></td>
<td></td>
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<tr>
<td>Marine battery market leader, Corvus, battery rack</td>
<td>0,29</td>
<td>0,33</td>
<td>106,060</td>
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<td></td>
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<tr>
<td>Tesla model 3 battery Cell 2170*</td>
<td>0,8</td>
<td>2,5</td>
<td>14000</td>
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- **1**: Given a 1000 m³ tank for MGO. Additional space for insulation is not calculated for in above diagram. All pressure values given a high pressure Diesel injection principle.
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**MAN Energy Solutions**

Prospects for energy and maritime transport in the Nordic region
Alternative fuels
Basis for CO\textsubscript{2} calculation

For each WTW pathway, calculate:
- Total energy required
- Total GHG emitted

"Well"
- Produce primary fuel
- Transport primary fuel
- Produce bunker fuel
- Distribute bunker fuel
- Fuel vessel

Well to Tank (WTT)
- Burn fuel in vessel

"Wake"
- Tank to Wake (TTW)
MAN Energy Solutions

1 Market drivers, Emission Regulations, Targets
2 Marine Application & Decarbonization Options
3 Power to X
4 Energy Outlook
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 CO₂, 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
**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**
  - Liquid
  - New infrastructure based on broad global presence
  - Dedicated ships required

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

- **Petrol**
  - Liquid
  - Existing infrastructure can be used

- **Diesel**
  - Mixing possible

- **Kerosene**
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
Technologies are available for future projects

Top technologies for CO\textsubscript{2}-minimization available for future projects

**Production of CO\textsubscript{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\textsubscript{X} emissions

~ 90% less NO\textsubscript{X} emissions (Otto Cycle)

~ 100% potential for CO\textsubscript{2} reduction
ME-GI engine operating on LNG

New built ship

- Layout for fossil LNG → -20% CO₂
  - (Over)compliant by 2020

- Mix in 25% SLNG → -40% CO₂
  - Compliant by 2030

- Mix in 38% SLNG → -50% CO₂
  - Compliant by 2050

A LNG powered ship today already provides the flexibility to comply with the foreseeable CO₂ 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

Amine gas treating / CO₂ separation

Main plant media interface (gas grid, water, O₂, etc.)

Methanation unit incl. SNG treatment

Control air unit

Cooling system

Electrolysis building (AEL or PEM)

Step down transformer (opt.)

Water treatment & storage tanks

MAN ES provides full EPC incl. operations & maintenance

AEL: Alkaline Elektrolysis, PEM: Polymer Electrolyte Membrane Electrolysis

MAN Energy Solutions

Prospects for energy and maritime transport in the Nordic region
Green Marine Fuel
CO₂ neutral shipping with MAN Power to Gas

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

- 2 Car Carrier CO₂-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 CO₂ neutral

SNG: synthetic natural gas; Picture © Mac Mackay
Green Marine Fuel

CO₂ 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% CO₂ 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
1 Company Strategy, Targets, Market drivers
2 Marine Application & Decarbonization Options
3 Power to X
4 Energy Outlook
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

Units: EJ/yr

- **LSFO or MGO**
- **LPG**
- **LNG**
- **Liquefied methane (bio/electro)**
- **Hydrogen**
- **HFO and scrubber**
- **Electricity from grid**
- **Ammonia**
- **Advanced biodiesel**

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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Thank you for your attention