Work towards 2050 emissions and alternative fuels

Focus on the Baltic and the North Sea

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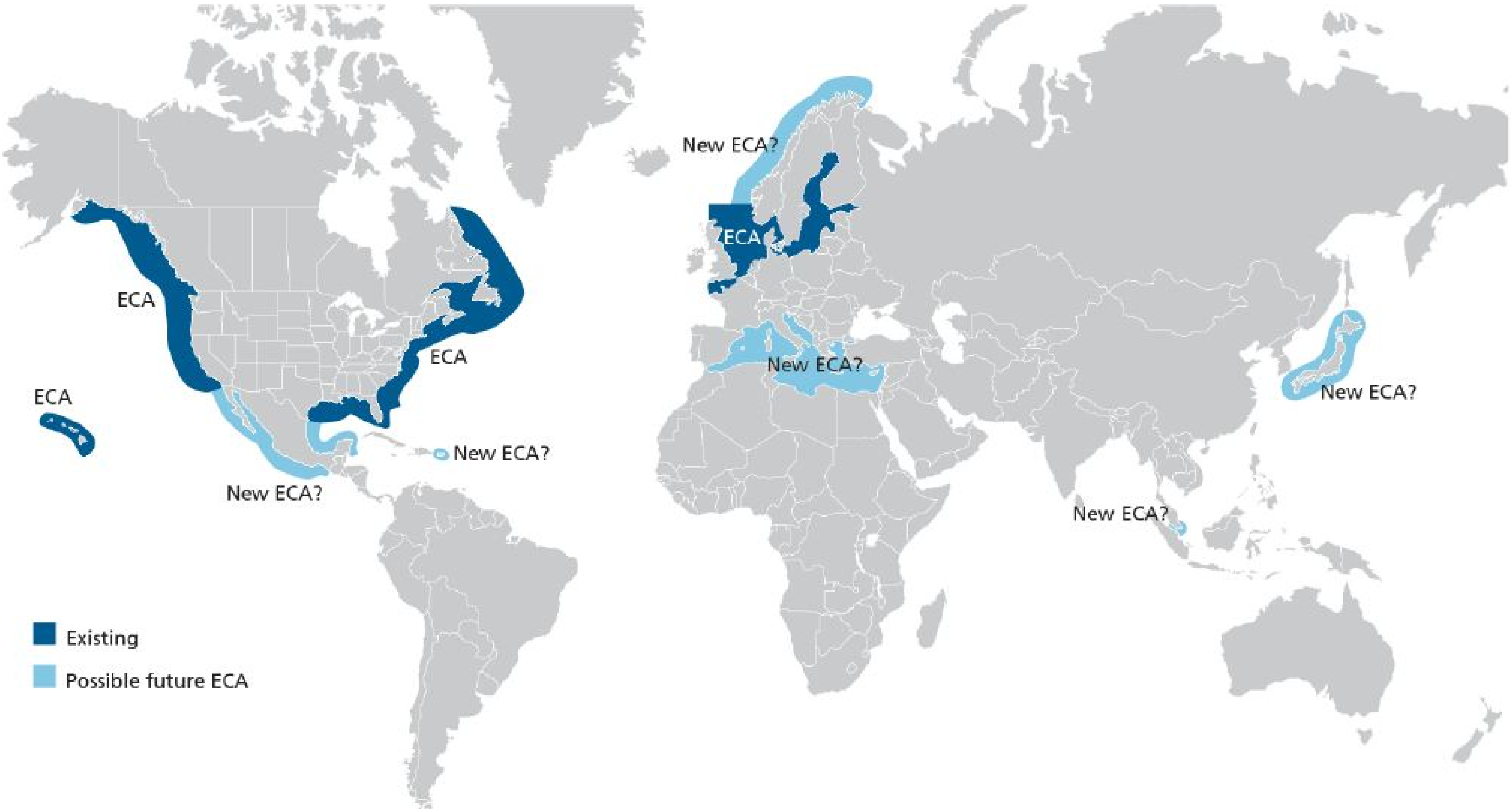
Outline

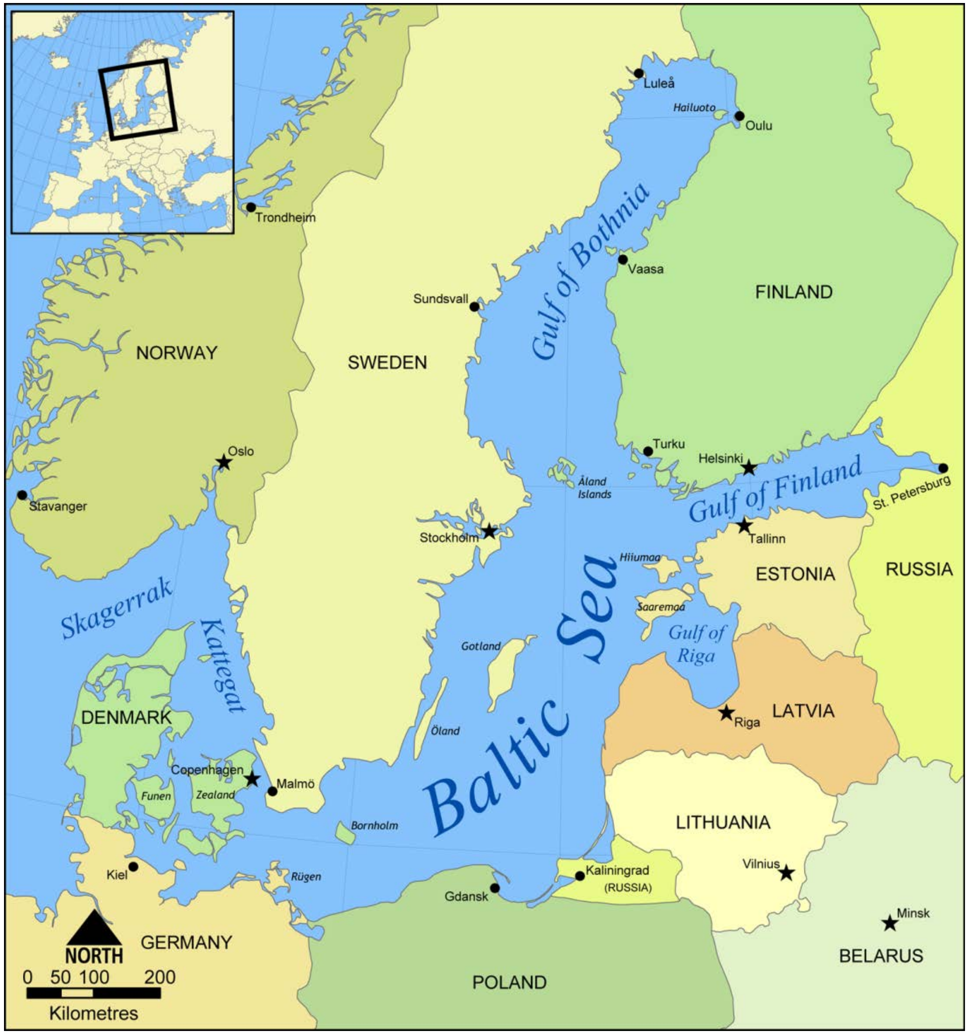
- The Baltic Sea
- Alternative Fuels Options
- Pathways to 2050 for Low Carbon Shipping

Sulphur Emission Control Areas – 2015



The Baltic Sea

- Average depth of 55 m
- The maximum depth is 459 m
- The surface area is about 377,000 km²
- The volume is about 20,000 km³
- The periphery amounts to about 8000 km of coastline
- 2000 ships operating at any time, will be 3500 in 2015
- 15% of total world trade
- ***90 mill people*** live in the catchment area



The Mediterranean Sea

- It covers an approximate area of 2.5 million km²
- Its connection to the Atlantic (the Strait of Gibraltar) is only 14 km wide
- Average depth of 1,500 metres
- The deepest recorded point is 5,267 metres
- 20% of total world trade

Imagine if the Mediterranean had similar catchment population as the Baltic Sea:

16,9 bn people

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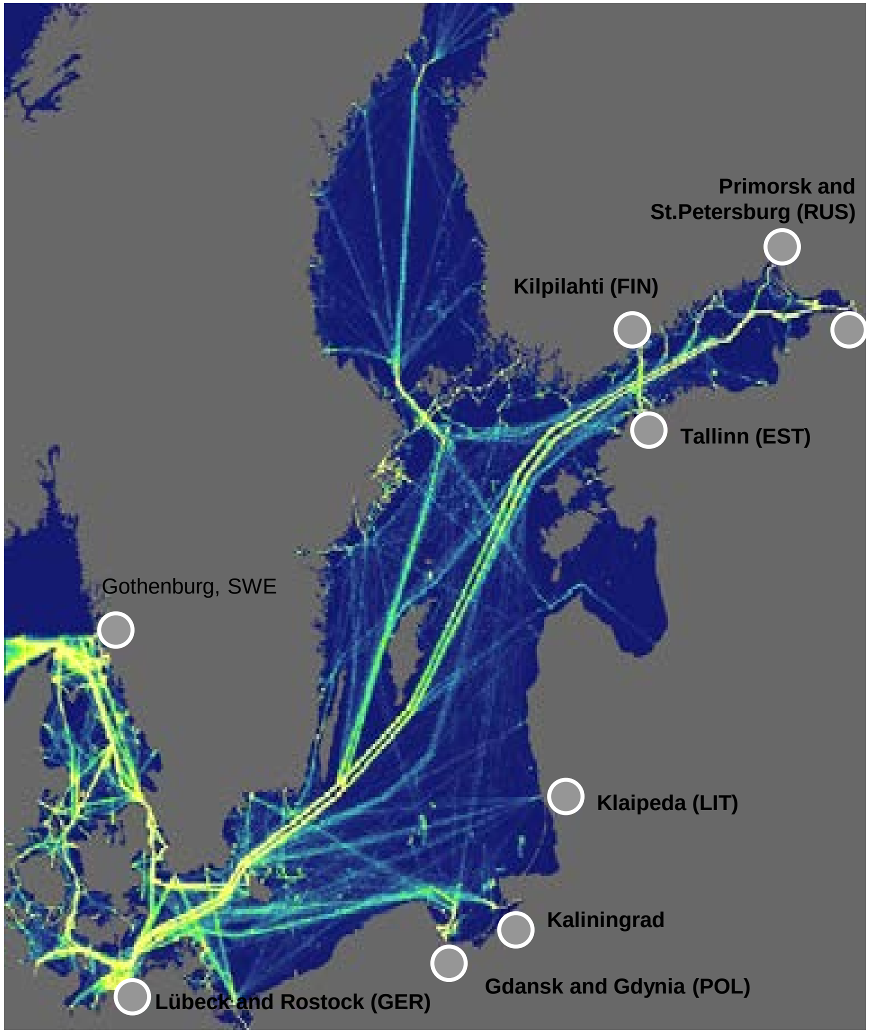
Background - the Baltic Sea

- Multiple pollution sources
  - Agricultural runoff
  - Untreated wastewater
  - Ship emissions
- Extremely vulnerable sea
  - Shallow waters
  - Low water exchange rate
  - Algal blooms caused by pollution
- More than 2,000 ships operating at any time, 10 000 ships yearly
- Annual ship emissions:
  - SOx: 135 000 tonnes
  - NOx: 400 000 tonnes
  - CO2: 19 million tonnes
- Ship emissions equals
  - all land-based NOx from Denmark & Sweden combined
  - twice the SOx emissions from Denmark and Sweden combined



Pathways to 2050

For Low Carbon Shipping

Future Greenhouse Gas Emissions from Shipping

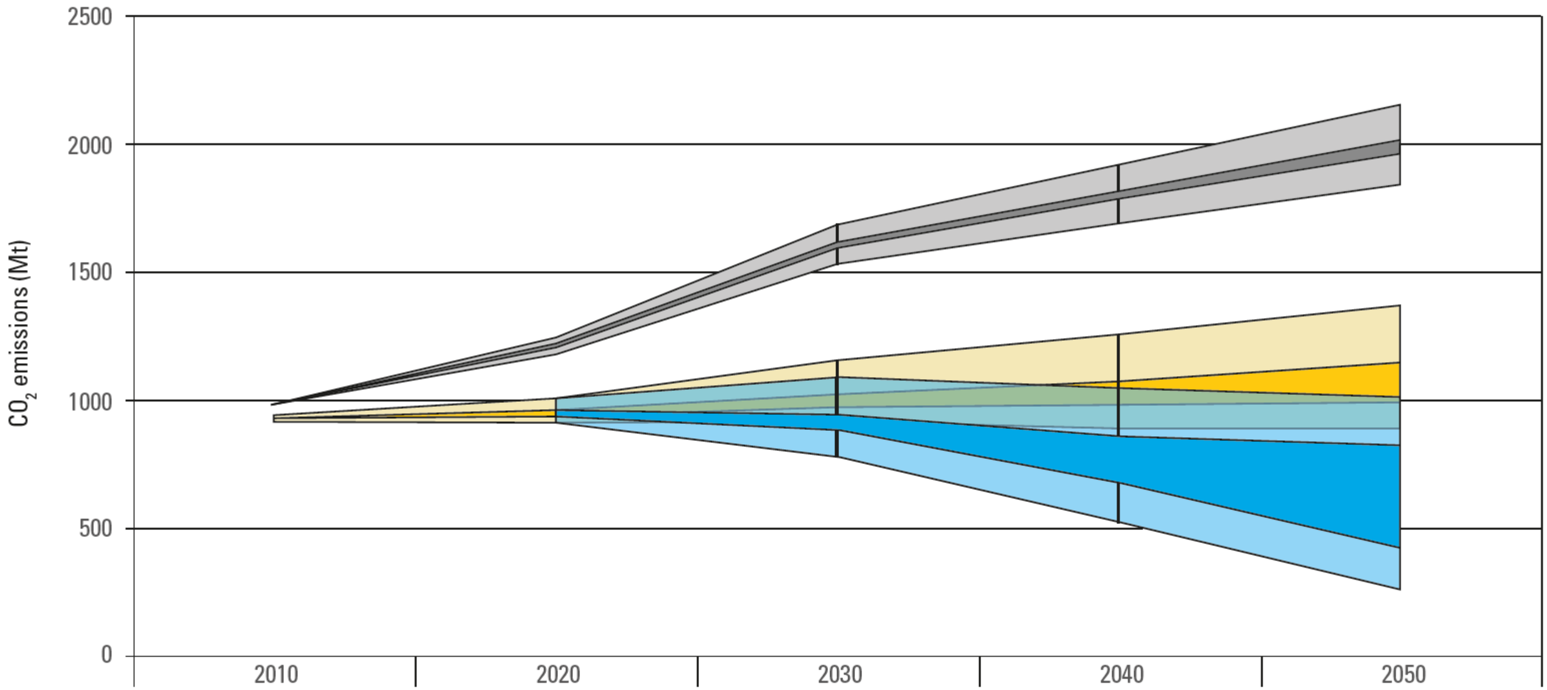


Figure 1: Baseline emissions (grey) vs. emissions including cost-effective uptake of alternative fuels. Blue sector shows potentials including uptake of nuclear, biofuel and LNG, as well as technical and operational measures. The yellow sector shows the same potential, but excludes nuclear. The achievable emission levels are illustrated, displaying the maximum, minimum, 25% and 75% percentiles of 200 model realizations; the dark shaded area covers the central 50% of the model runs.

Model Results – NO_x, SO_x Emissions

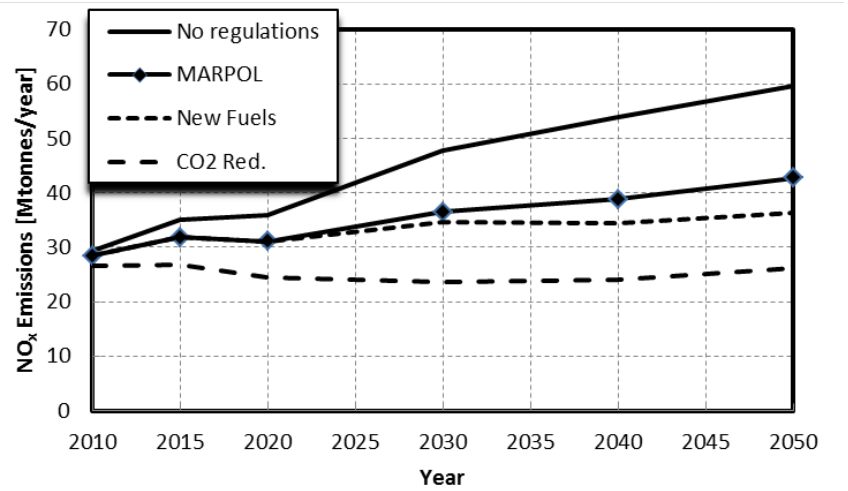
- NO_x, SO_x emissions

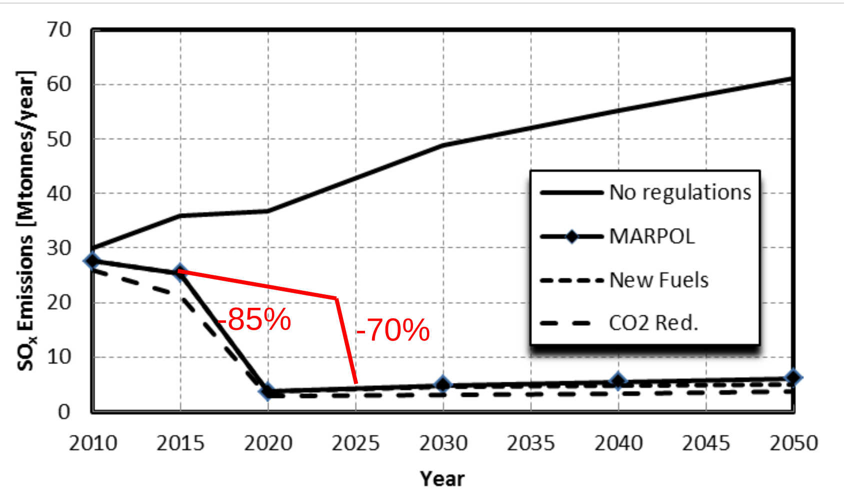
- Scenarios considered:
  - No regulations
  - MARPOL regulations

    + With New Fuels

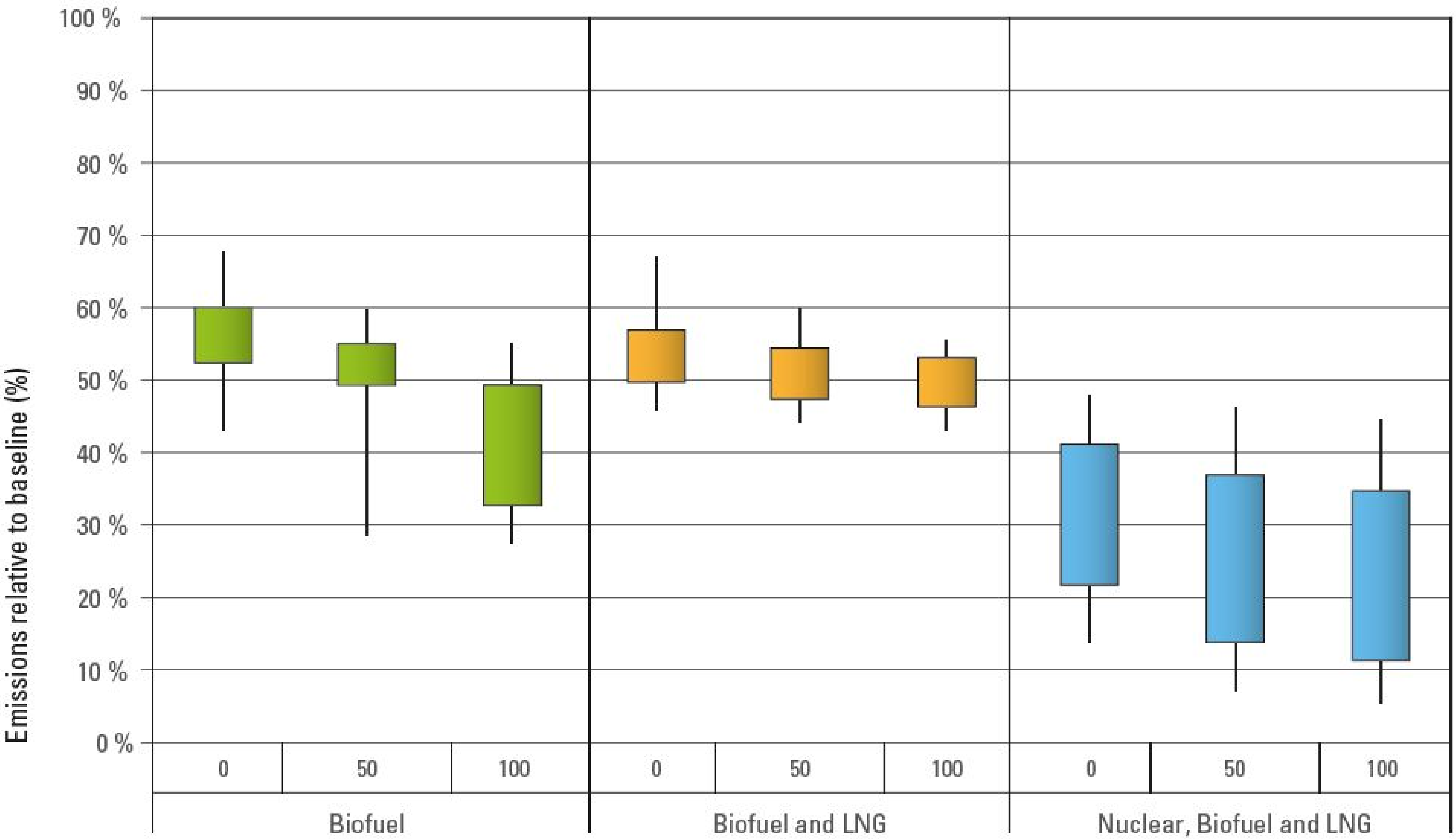
    + With CO_2 abatement measures

- Implications:
  - Price of distillates to be increased after 2020
  - LNG could become even more attractive
  - Other fuels can be introduced:
    - Biodiesel, LPG, DME, etc.





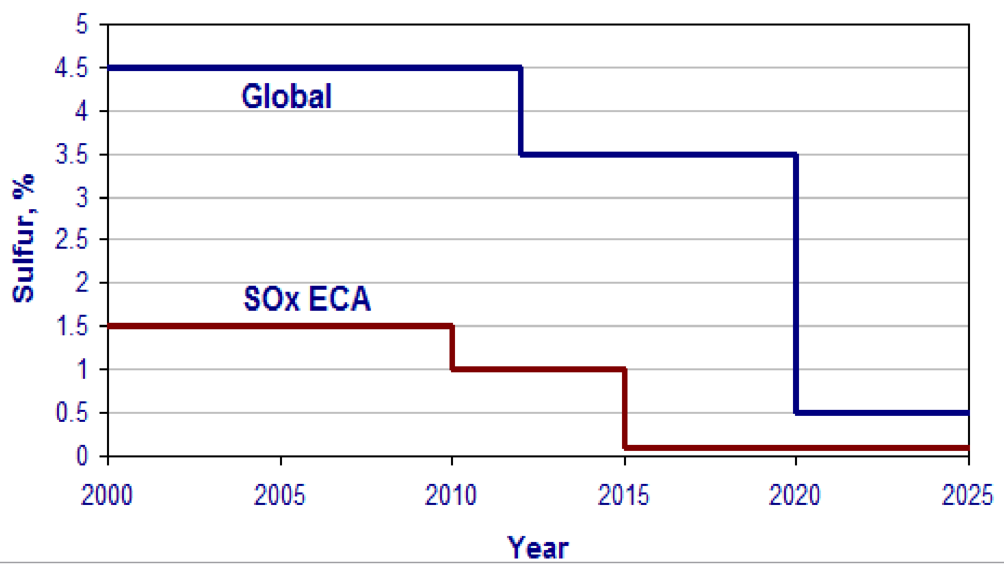
Potential for Emissions Reduction from Shipping - 2050



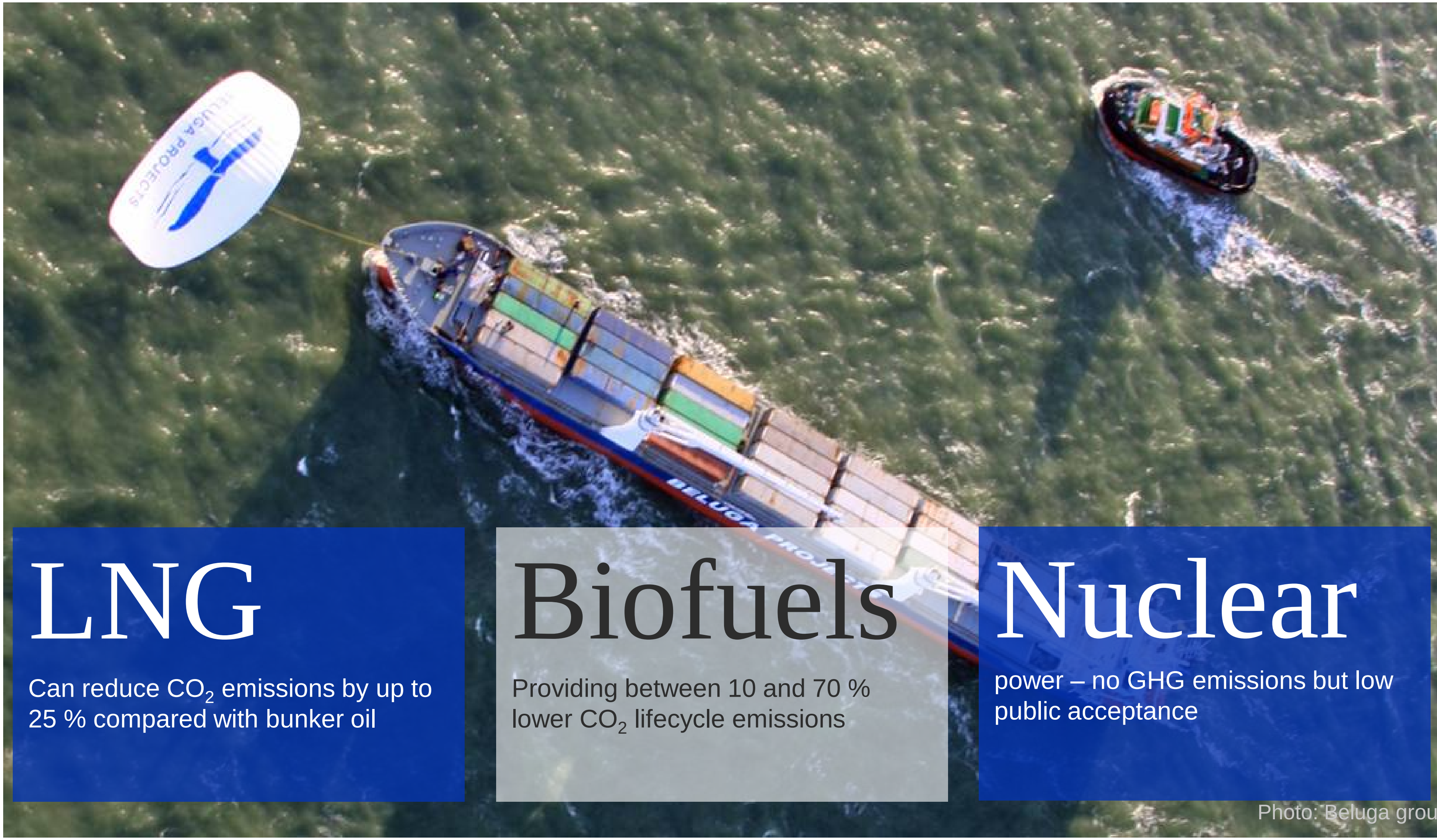
Alternative Fuel Options for Shipping

Motivation for Alternative Marine Fuels

- Greenhouse Gas Emissions
- Regulations: Pollutant Emissions
- Oil Availability – Energy Security - Cost
- Low Sulphur Fuels
  - In the ECAs (**30-50 Mt/year** today)
  - Globally after 2020 (or 2025) (≈ **300 Mt/year**)



Emissions Reduction from Shipping



LNG

Can reduce CO_2 emissions by up to 25 % compared with bunker oil

Biofuels

Providing between 10 and 70 % lower CO_2 lifecycle emissions

Nuclear

power – no GHG emissions but low public acceptance

Photo: Beluga group

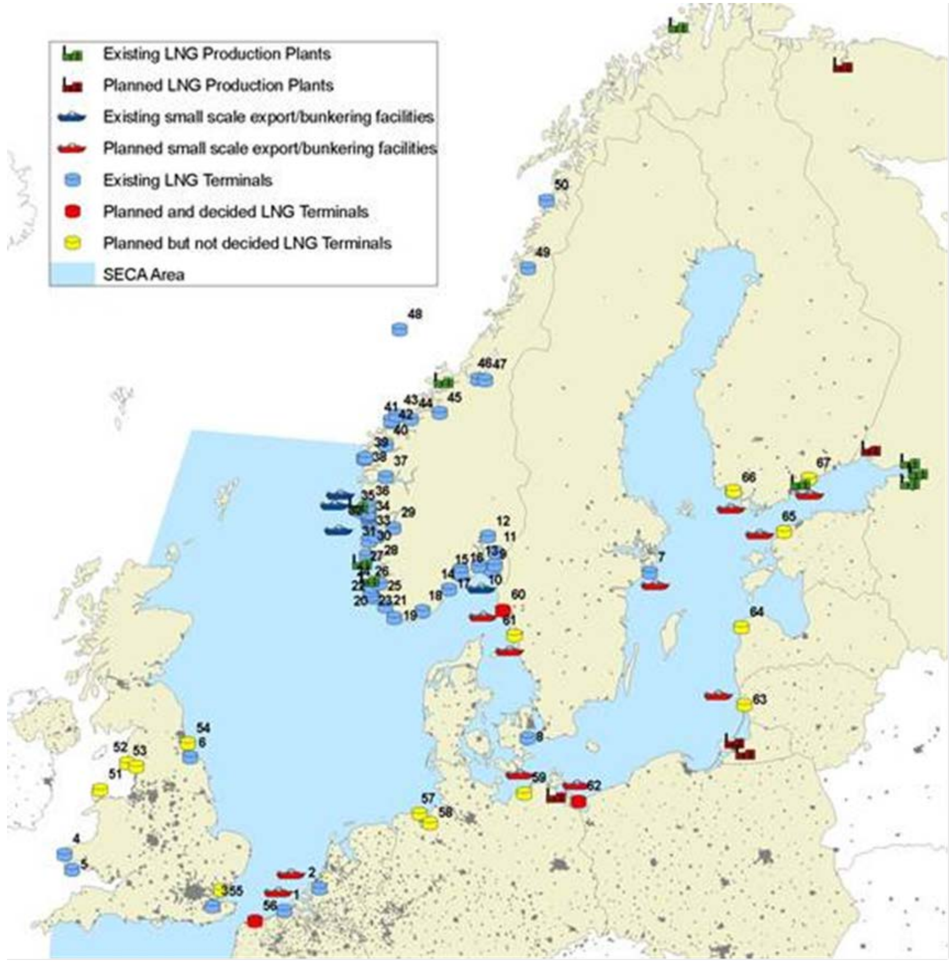
Alternative Fuel Options for Ferries

1. Liquefied Natural Gas (LNG)
2. Liquefied Petroleum Gas (LPG)
3. Methanol / Ethanol
4. Di-Methyl Ether (DME)
5. Synthetic Fuels (Fischer-Tropsch)
6. Biodiesel
7. Biogas
8. Hydrogen
9. Nuclear

- Physical & Chemical Characteristics
- Production, Availability & Cost
- Applications & Current Status
- Safety Considerations
- Emissions & Environmental Impact

Alternative Fuels

- Liquefied Natural Gas (LNG)
  - Very attractive for vessels in the ECAs
  - Expected to grow significantly in the next decade
  - Gas Engines, Dual-Fuel Engines
  - Issues with methane slip at low loads
  - Main Issue: Bunkering infrastructure
    - Feasibility studies in SE Asia
    - Facilities being developed in the North Sea, North America



38 LNG fuelled ships in operation worldwide

Ships in operation

Year	Type of vessel	Owner	Class
2000	Car/passenger ferry	Fjord1	DNV
2003	PSV	Simon Møkster	DNV
2003	PSV	Eidesvik	DNV
2006	Car/passenger ferry	Fjord1	DNV
2007	Car/passenger ferry	Fjord1	DNV
2007	Car/passenger ferry	Fjord1	DNV
2007	Car/passenger ferry	Fjord1	DNV
2007	Car/passenger ferry	Fjord1	DNV
2008	PSV	Eidesvik Shipping	DNV
2009	PSV	Eidesvik Shipping	DNV
2009	Car/passenger ferry	Tide Sjø	DNV
2009	Car/passenger ferry	Tide Sjø	DNV
2009	Car/passenger ferry	Tide Sjø	DNV
2009	Patrol vessel	Remøy Management	DNV
2009	Car/passenger ferry	Fjord1	DNV
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2010	Car/passenger ferry	Fjord1	DNV
2010	Car/passenger ferry	Fosen Namsos Sjø	DNV
2011	PSV	DOF	DNV
2011	Chemical tanker	Tarbit Shipping	GL
2011	Car/passenger ferry	Fjord1	DNV
2011	PSV	Solstad Rederi	DNV

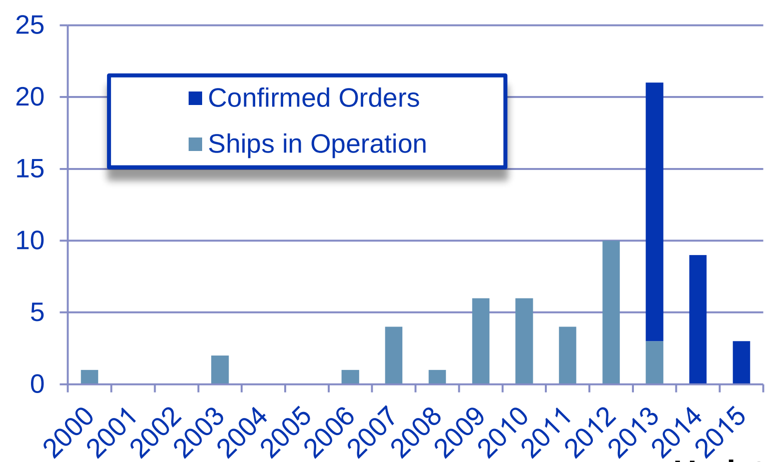
Year	Type of vessel	Owner	Class
2012	Car/passenger ferry	Fjord1	DNV
2012	PSV	Eidesvik	DNV
2012	PSV	Olympic Shipping	DNV
2012	PSV	Island Offshore	DNV
2012	General Cargo	Nordnorsk Shipping	DNV
2012	PSV	Eidesvik Shipping	DNV
2012	PSV	Island Offshore	DNV
2012	Car/passenger ferry	Torghatten Nord	DNV
2012	Car/passenger ferry	Torghatten Nord	DNV
2012	Car/passenger ferry	Torghatten Nord	DNV
2013	PSV	REM	DNV
2013	RoPax	Viking Line	LR
2013	Car/passenger ferry	Torghatten Nord	DNV

Updated 16.01.2013
Excluding LNG carriers and inland waterway vessels

30 confirmed LNG fuelled newbuilds

Confirmed orderbook

Year	Type of vessel	Owner	Class
2013	Harbor vessel	Incheon Port Authority	
2013	High speed RoPax	Buquebus	DNV
2013	Ro-Ro	Sea-Cargo	DNV
2013	Ro-Ro	Sea-Cargo	DNV
2013	RoPax	Fjordline	DNV
2013	RoPax	Fjordline	DNV
2013	General Cargo	Eidsvaag	DNV
2013	Car/passenger ferry	Norled	DNV
2013	Car/passenger ferry	Norled	DNV
2013	Ro-Ro	Norlines	DNV
2013	Ro-Ro	Norlines	DNV
2013	Tug	Buksér & Berging	DNV
2013	PSV	Harvey Gulf Int. Marine	ABS
2013	PSV	Harvey Gulf Int. Marine	ABS
2013	Patrol vessel	Finish Border Guard	GL
2013	Car/passenger ferry	Society of Quebec ferries	LR
2013	Tug	CNOOC	CCS
2013	Tug	CNOOC	CCS
2014	Car/passenger ferry	Society of Quebec ferries	LR
2014	Car/passenger ferry	Society of Quebec ferries	LR
2014	Tug	Buksér & Berging	DNV
2014	PSV	Harvey Gulf Int. Marine	ABS
2014	PSV	Harvey Gulf Int. Marine	ABS
2014	Gas carrier	SABIC	BV
2014	Gas carrier	SABIC	BV
2014	PSV	Remøy Shipping	DNV
2014	PSV	Siem Offshore	DNV
2015	PSV	Harvey Gulf Int. Marine	ABS
2015	Container Ship	TOTE Shipholdings	ABS
2015	Container Ship	TOTE Shipholdings	ABS

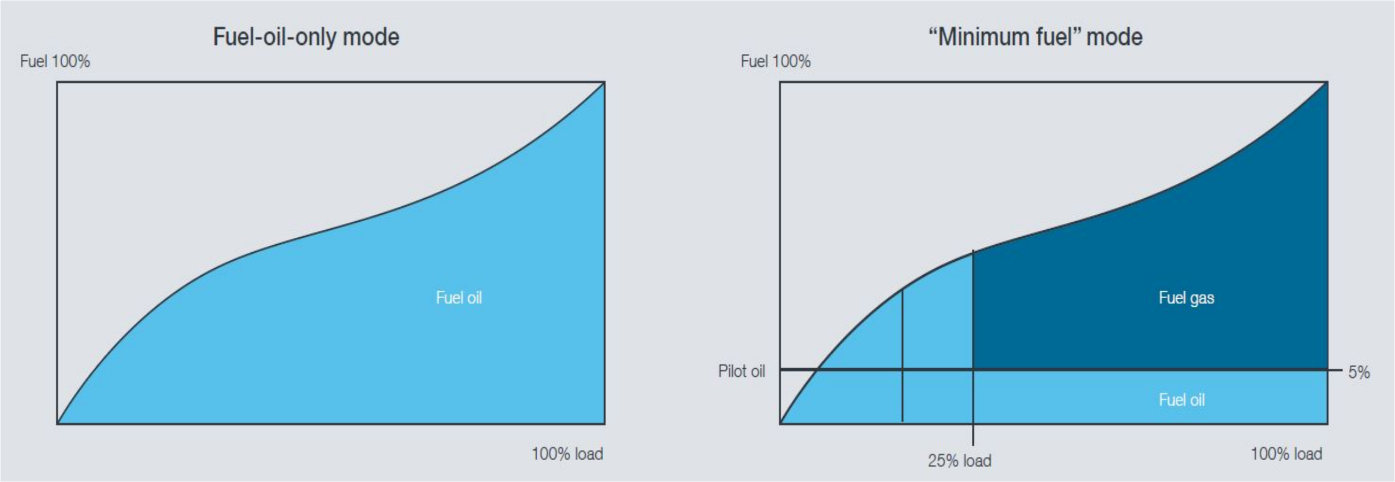


Updated 16.01.2013

Excluding LNG carriers and inland waterway vessels

Alternative Fuels

- Liquefied Petroleum Gas (LPG)
  - In use since 1912
  - Mixture of Propane & Butane
  - Production: ≈270 Mt/year, increasing
  - Safety: similar to LNG
  - Uses: domestic, chemicals, agriculture
  - MAN ME-GI: introduced in 2011
    - Also runs on DME



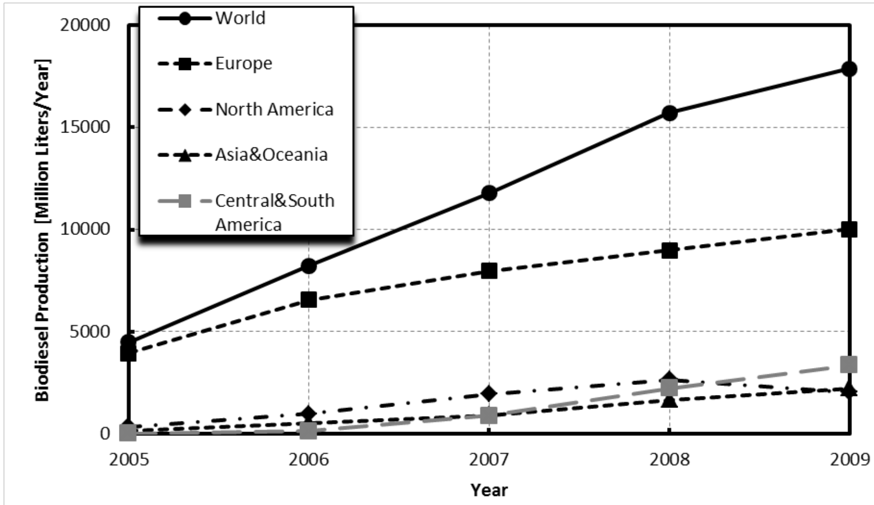
Alternative Fuels

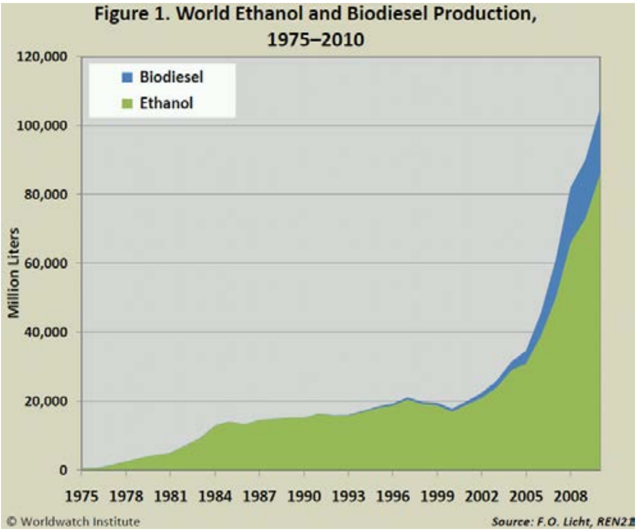
- Methanol / Ethanol
  - Production:
    - Methanol: ≈50 Mt/year + 34 Mt excess capacity
    - Ethanol: ≈100 Mt/year
  - Scania in Sweden uses Ethanol with an additive to make it suitable for heavy duty Diesel engines
  - Possible to use in dual fuel engines
  - Safety: low flashpoint ⇒ safety requirements similar to LNG
  - **Rules** already exist for storage
    - **Under development for use as fuel**
  - Less toxic emissions than oil-based fuels

- Application of Methanol
  - Stena Line: ferry operator in Scandinavia
  - Retrofitting one vessel for 2014
    - Stena Germanica: RoPax
    - 300 cars, 1300 Passengers
  - Methanol → DME on board
  - Plans for 25 more vessels up to 2018

Alternative Fuels

- Biodiesel
  - Can be used in blends: B10, B50, …, B100
  - In Europe: spare capacity of ≈11 Mt/year
  - Strict regulations on sustainability in the EU
  - Applications:
    - US Navy (algae-based fuels)
    - Maersk Line (30t Rapeseed oil, 30t algae-based)
    - Maersk: Involved in fuel development research programme
  - Regulatory issues:
    - MARPOL Annex VI
    - ISO 8217:2010
  - Cost: currently ≈ 10-20% more expensive than distillate fuels





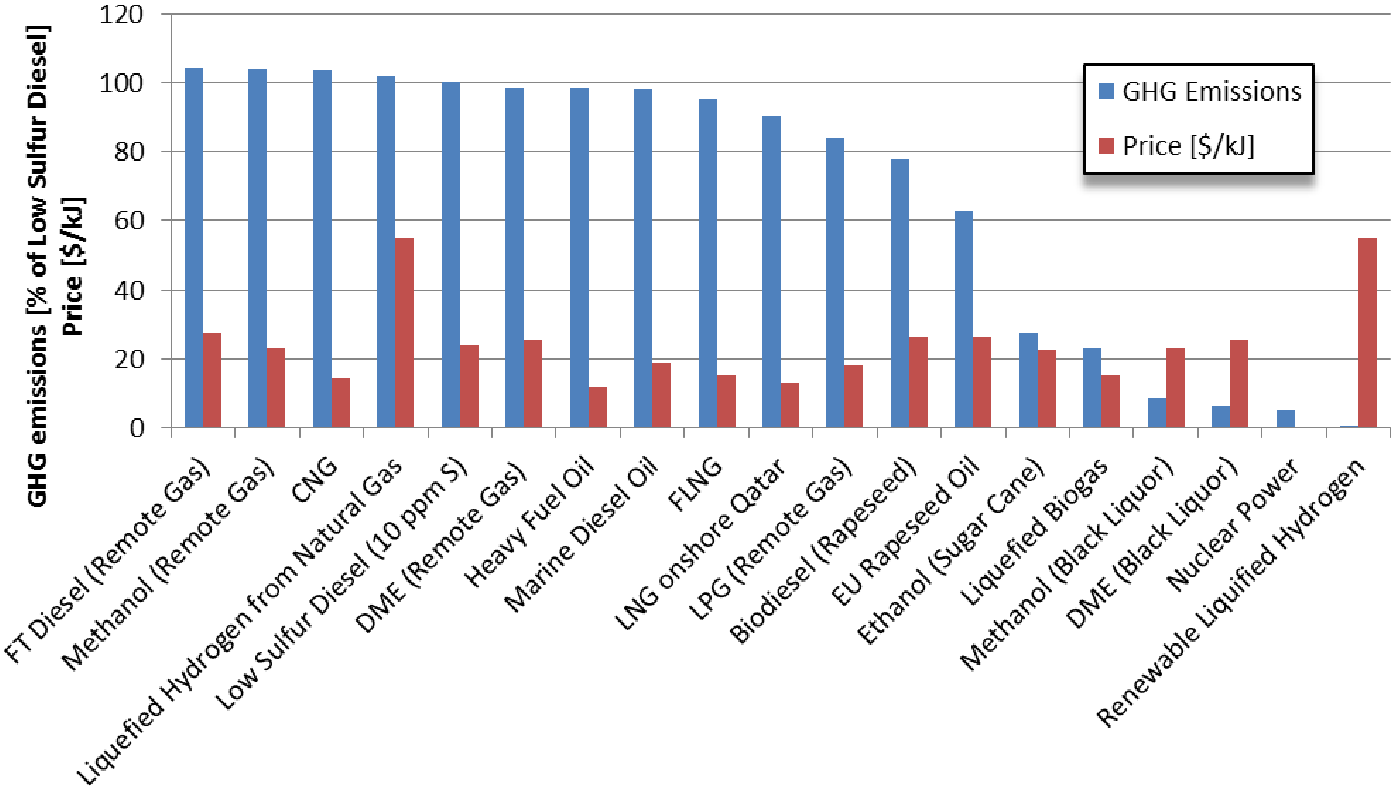
Availability of Alternative Fuels

Fuel	2010 Total consumption (million TOE/year)
Oil-based	4,028*
Natural Gas	2,858 (LNG: 250-300)
LPG	275
Methanol	23
Ethanol	58
DME	3-5
Fischer-Tropsch	15
Biodiesel	18-20
Biogas	Very low
Hydrogen	Very low

* Approximately 7-8% for shipping

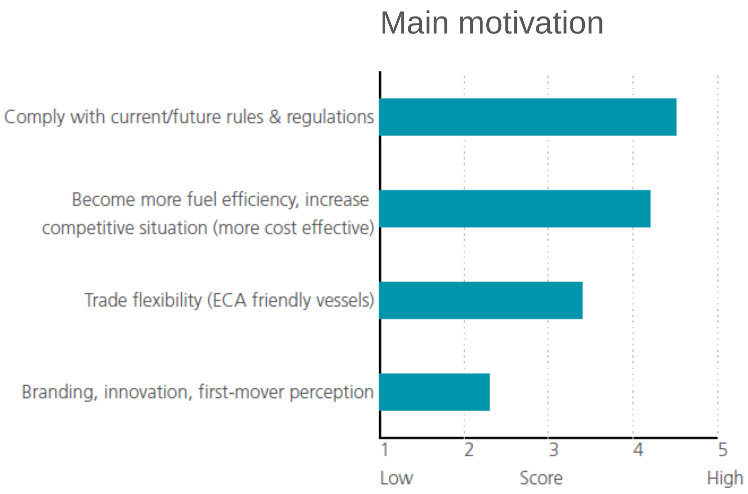
Sustainability and cost of Alternative Fuels

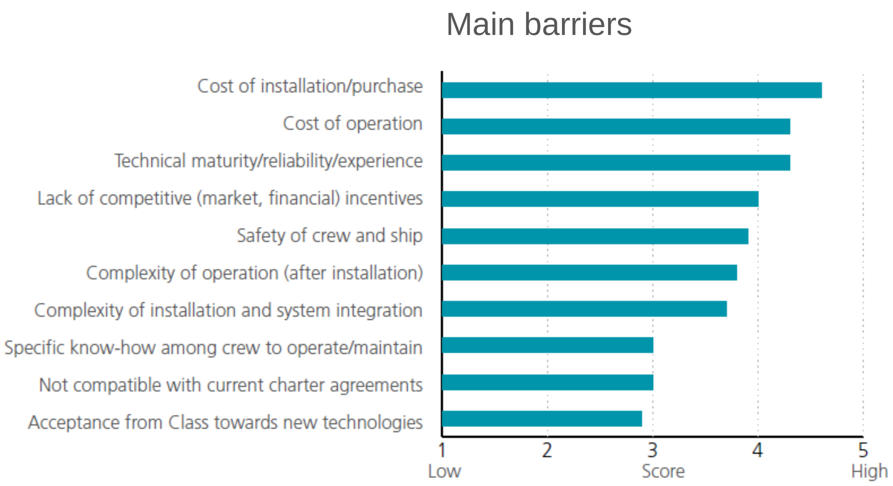
- Well-to-Propeller CO_2 Emissions
  - Tank-to-Propeller (combustion) emissions assumed to be equal to CO_2 absorbed by the plant during its lifetime



Ship owner survey – motivation and barriers

Main Motivation: Compliance and fuel efficiency
Main Barriers: Cost and technology maturity

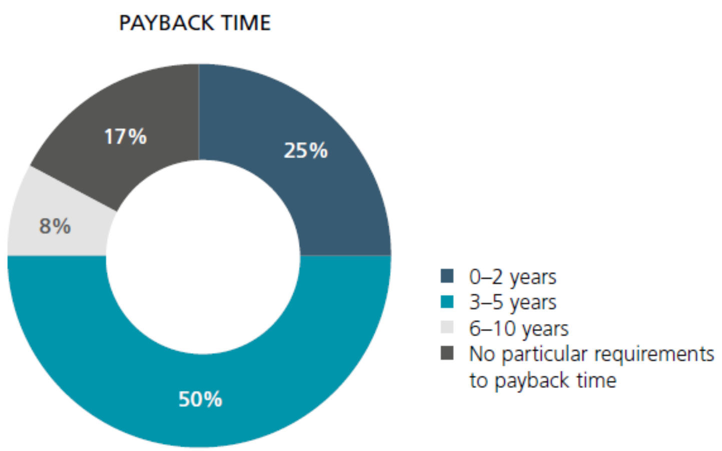


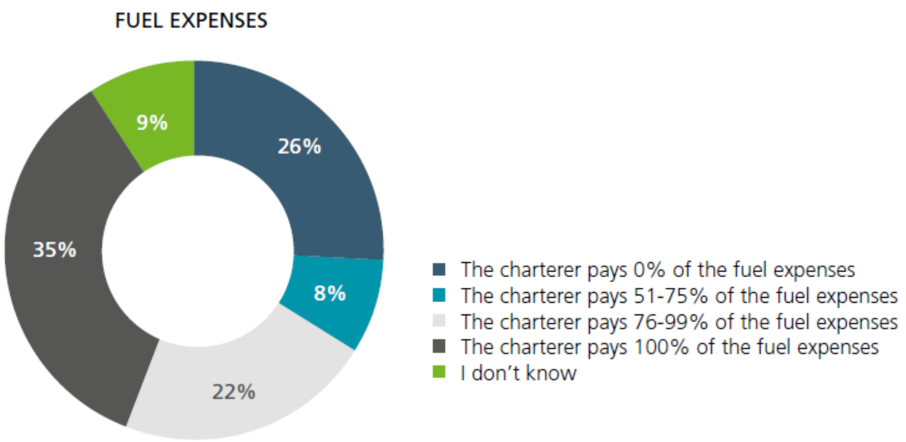


Source: DNV survey (23 respondents)

Ship owner survey – investment preferences

Investment horizon (payback requirements) and how much of the fuel cost is paid by the ship owner impact the cost-effectiveness of many measures





Source: DNV survey (23 respondents)

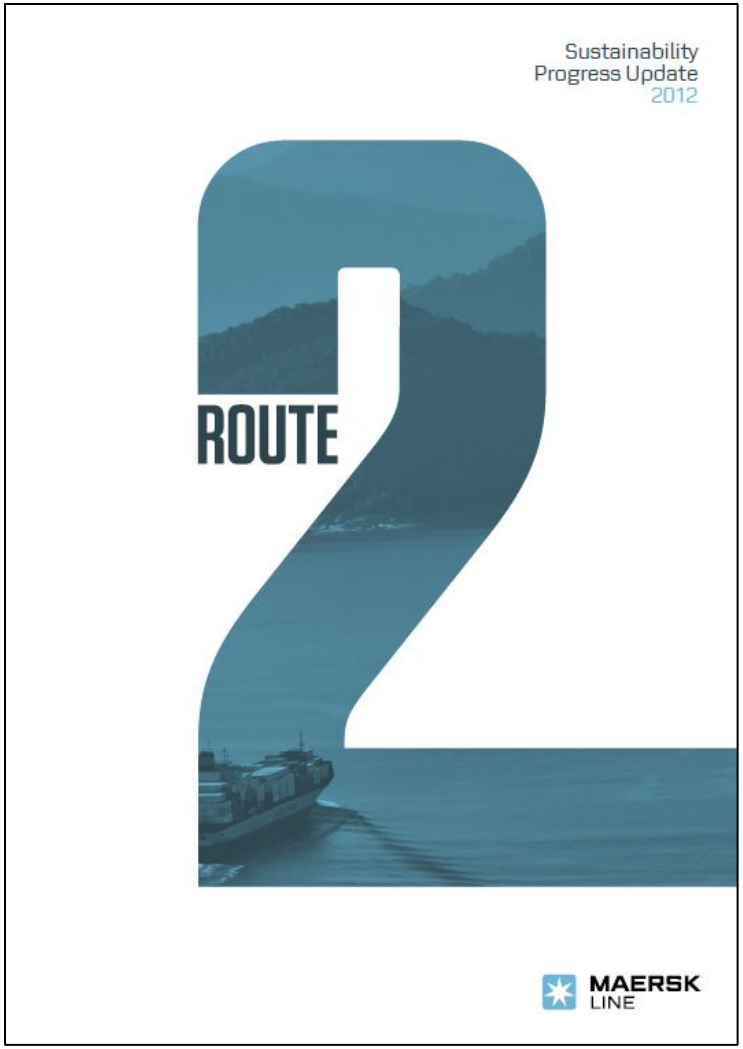
Selandia – first diesel powered ocean going vessel - 1912

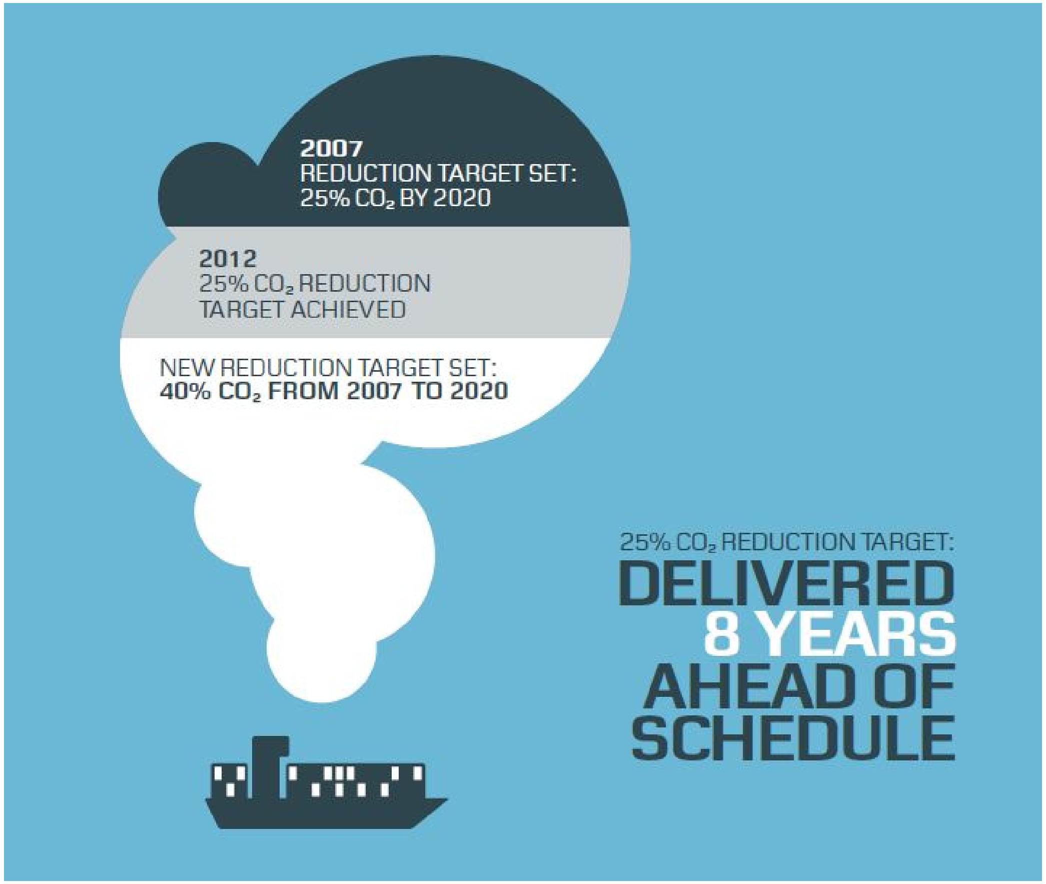
Selandia had to bunker for a voyage from Europe to Singapore because no bunkering was available at that time.
Building diesel-powered ships did not take place for another 20 years.

Safeguarding life, property and the environment

www.dnv.com

Is it possible to reduce emissions?





Biofuel Feedstocks

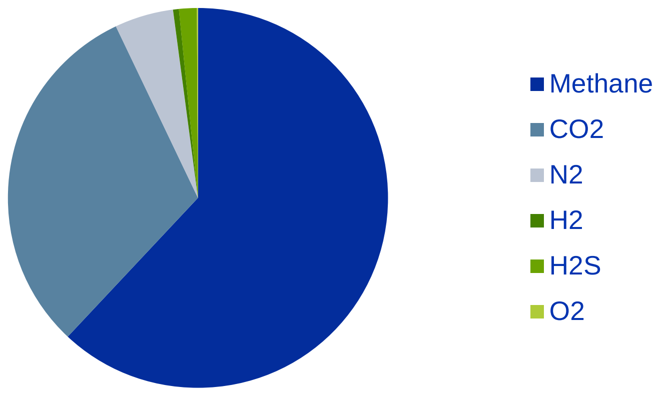
	Examples	Processing
Sugar Crops	Sugar Cane, Sugar Beet	Extract Saccharose and ferment to ethanol
Starch Crops	Corn, Wheat, Cassava	Hydrolyze enzymatically to sugar solution, then ferment
Pure Plant Oil	Palm, Soybean, Rapeseed, Sunflower	Transesterification to biodiesel
Waste Vegetable Oil	Cooking oil, Animal fat	Refinement, then transesterification
Lignocellulosic (inedible plant material)	Waste (forestry, farm, municipal), Switchgrass, Miscanthus, Poplar	Break down lignin to reach sugar/starches
Jatropha	Nut crop with 27-40% inedible oil	Transesterification to biodiesel
Algae (Micro & Macro)	Diverse group, some up to 60% oil by dry weight	Transesterification to biodiesel or fermentation to ethanol

Biofuel Production Potential

Feedstock	Area [km^2] for production of 50 M TOE	% of Arable Land*	Fuel Type
Sugar Cane (Brazil)	135,038	0.98%	Ethanol
Maize USA	197,152	1.43%	Ethanol
Miscanthus	118,310	0.86%	Ethanol
Palm Oil (Malaysia)	118,193	0.86%	Biodiesel
Algae	22,400	0.16%	Biodiesel

Alternative Fuels

- Biogas
  - Typical composition:
    - Methane 50-80%
    - CO_2 20-50%
    - N_2 0-10%
    - H_2 0-1%
    - H_2S 0-3%
    - O_2 Traces
  - Production can be integrated in farms and food-processing facilities
  - Applications: heat generation, electricity production, substitute for LNG
    - Widely used in vehicles in Sweden and Norway
    - Can be used in LNG or Dual-Fuel engines by Wärtsilä, MAN, GE (from 100 kW to 9.5 MW)
  - Same safety precautions as LNG
  - It averts CH_4, VOC emissions from farming, landfills



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