Biofuels for the Marine sector: New opportunities and challenges

Claus Felby (cf@ign.ku.dk)
University of Copenhagen
Faculty of Science
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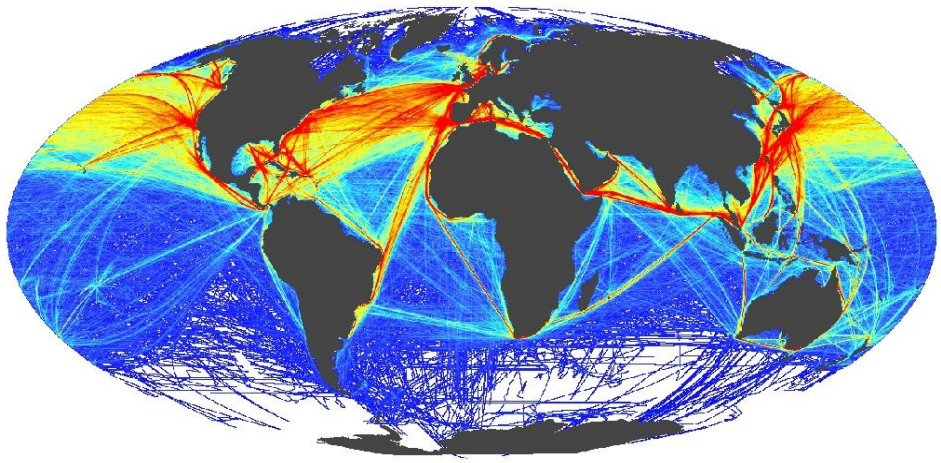
Biofuels for marine diesels
-The biofuel developers dream?

- A 330 Mton fuel market
- A market and fuel technology in transition
- Only a handful of filling stations
- (Almost) Anything that is carbon-based, liquid, stable and low in sulphur will work

The global shipping sector

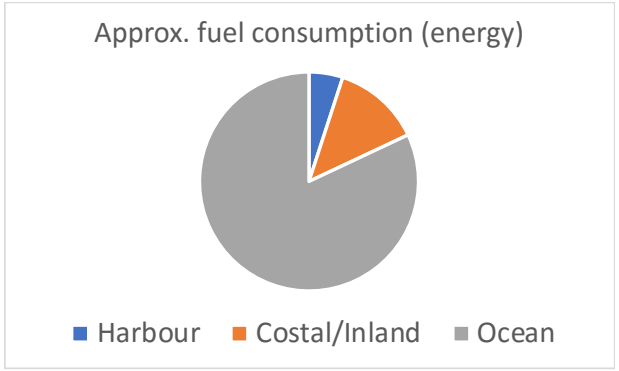


- Merchant shipping responsible for 90% of international trade
- Small and medium sized vessels make up the largest percentage of the fleet by number, but large vessels consume 70% of the fuel
    - Demand for shipping fuel approx 330 MT a year (2016)
- Energy efficient way of transporting goods, accounts for 2-3% of global CO_2 emissions
- Shipping industry is expected to grow with increasing demand for traded goods
- ***New climate/emission regulations -The sector needs new fuels***

The ships are big!

Modern ocean-going container ship

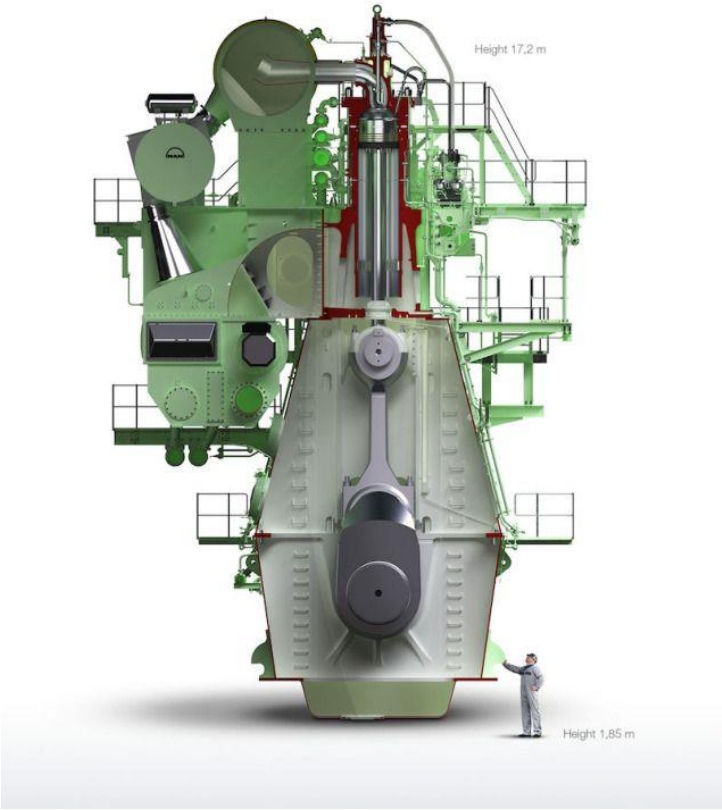
- Holds 15,000+ containers (165,000 DWT)
- Two-stroke diesel engines
- Designed for slow steaming at 19 knots (35 km/h)
- Storage capacity of 10-14 kilotonnes of fuel



- Consumes 200-250 tons of fuel per day (refuelling every 40 days)
- Lower GHG emissions than road and aviation transport
- High SOx and NOx emissions due to fuels used

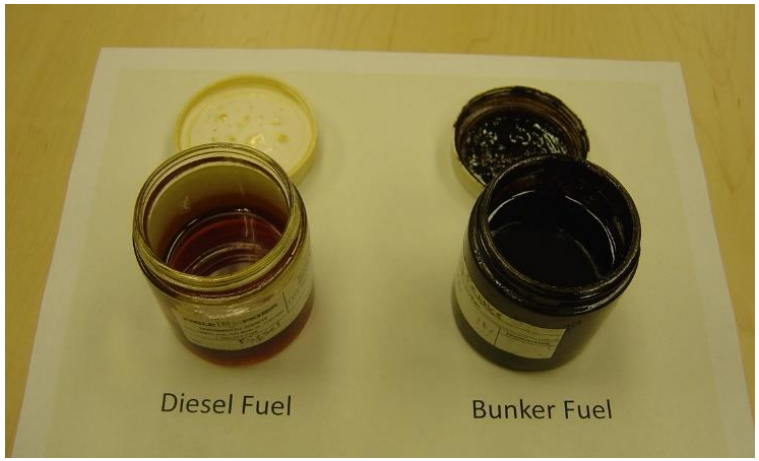
Marine diesel engines

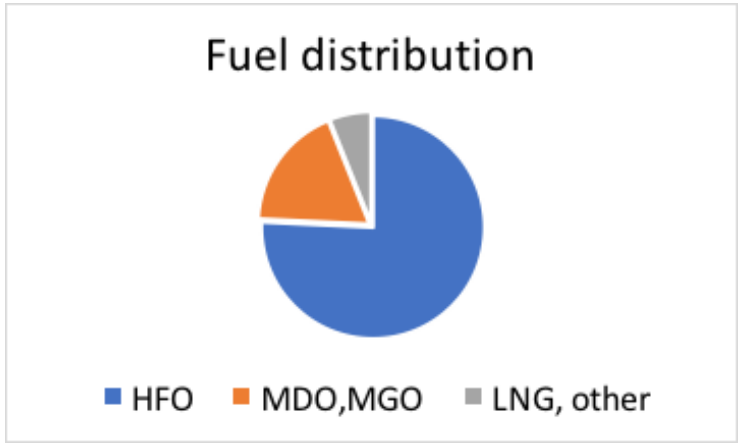
- 2-stroke compression engine
- 100,000 HP, constant revolutions, very high efficiency 60%
- Will burn anything that has carbon, both residues and distillate fuels
- Highly flexible on fuel requirements
- Can run on (almost) anything that has carbon and is low on inorganics
- Flex-fuel engines running on both liquid and gaseous fuels are introduced
- Long life-time 25-40 years



Marine fuel charachteristics

- In general two types of fuel: distillate and residual fuel
- Main fuel used is low-cost residual bunker fuel (HFO)
- Marine gas oil (MGO) and marine diesel oil (MDO) are higher quality distillates or residuals
- Liquefied natural gas (LNG) mainly used on gas tankers or ferries
- Fuel makes up to 50% of shipping vessel operational costs
- Lower quality and price of marine fuels compared to other transportation fuels





Fuel specifications

Marine fuels vs. biodiesel and Jet A

	HFO Heavy fuel oil	**MDO** Marine diesel oil	**MGO** Marine gas oil	**FAME** Biodiesel	**HVO** Hydrotreated vegetable oil	**Jet A** Kerosene-type jet fuel
Kinematic viscosity (mm^2/s)	<380	2 – 11	2 – 6	4.2 – 4.5	2.5 – 3.5	<8 at -20°C
Heating value (MJ/kg)	40.5 – 43	42 – 48	44 – 45.3	37.3 – 39.8	44 – 47.3	43.02
Density at 15°C	<991	<900	<890	880 – 920	770 – 790	775-840
Flash point (°C)	>60	>60	>60	110 – 195	>61	38
Pour point (°C)	>30	0 – 6	-6 – 0	-4 – 6	-5 – -25	-55
Sulfur (mass %)	<3.5	0.3-2.0	0.1-1.5	0	0	0
Price $/mt 20 Oct 2016	**290**	**482**	**471**	**1040**	**920**	**487**

- Biofuels initially substitutes MDO and MGO
- HVO is also a feedstock for bio jetfuels
- Feedstock competition between marine and aviation fuels

Something just happened….

50 Percent CO2 Cut by 2050: Governments Must Acknowledge Enormity of Historic IMO Agreement

in International Shipping News,Shipping: Emission Possible 27/04/2018

International Chamber of Shipping

Speaking yesterday (26 April) at Singapore Maritime Week, the Chairman of the International Chamber of Shipping (ICS), Esben Poulsson, said the adoption by the UN International Maritime Organization (IMO) of a comprehensive strategy to phase-out shipping's greenhouse gases "should be more than su
advocate regional measu
and would not be effective in helping shipping

ENVIRONMENT APRIL 13, 2018 / 10:16 AM / 16 DAYS AGO

U.N. shipping agency reaches deal to cut CO2 emissions

Growing support for ban on ships carrying high-sulphur fuel

Published on February 6, 2018 - 12:00

IMO agrees on CO2 deal Maersk calls "ambitious"

BY TOMAS KRISTIANSEN
Published 13.04.18 at 16:31

IMO: No Turning Back on Fuel Sulfur Cap

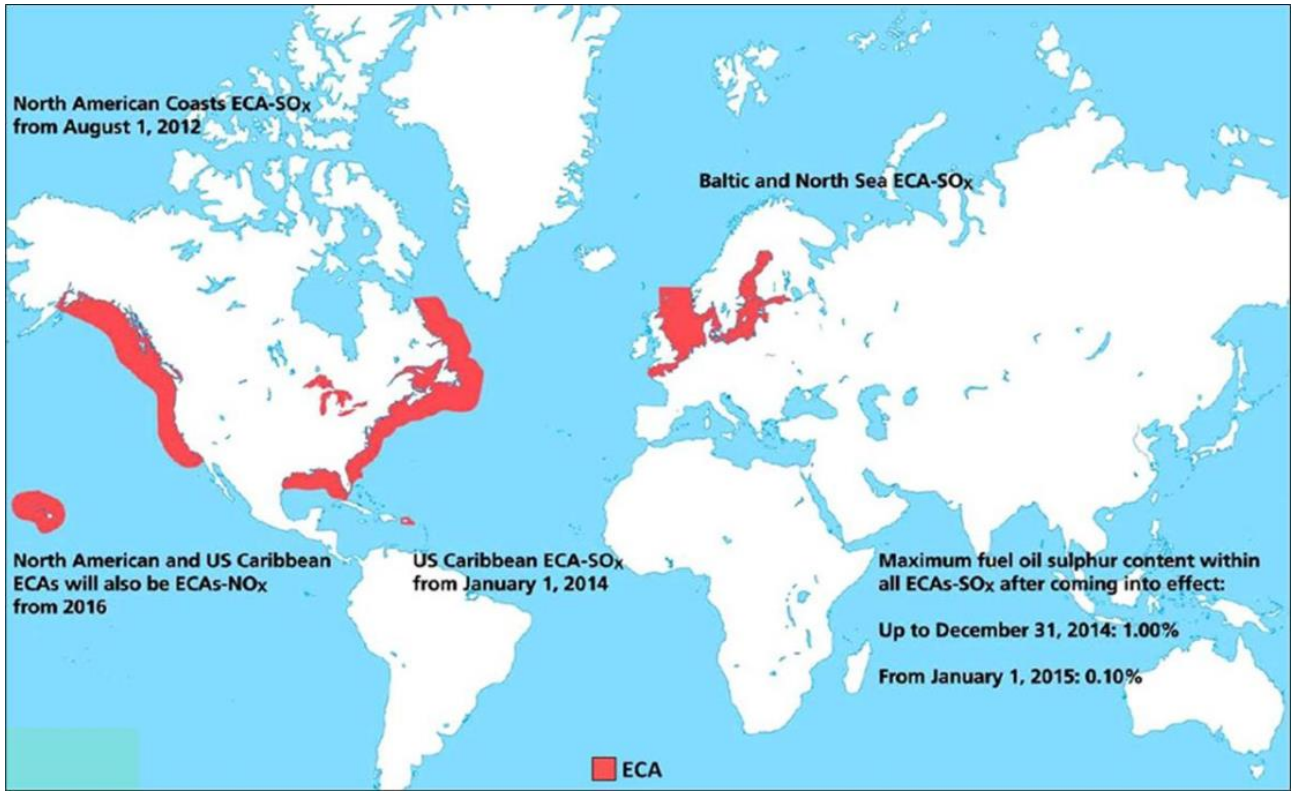
The maritime sector needs LOW SULPHUR biofuels

IMO regulation of CO_2 emissions

- IMO is the International Maritime Organisation, a legal body under the UN.
- Emissions should peak as soon as possible
- Reduce the total GHG emissions by at least 50% by 2050
- Pursue efforts towards phasing GHG emissions out entirely.
- Binding targets
- Mandatory reporting on fuel consumption
- CO_2 monitoring already implemented by ECSA - The European Community Shipowners' Associations.
- MRV -monitoring, reporting and verification scheme. Reporting will be cargo related

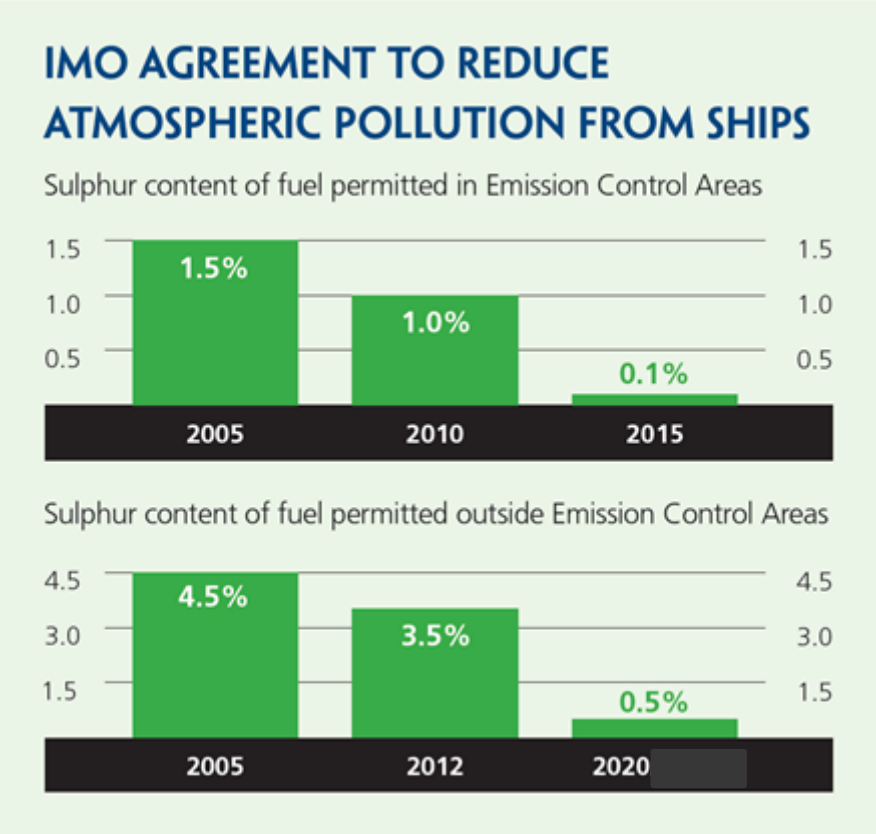
SOx and NOx regulations

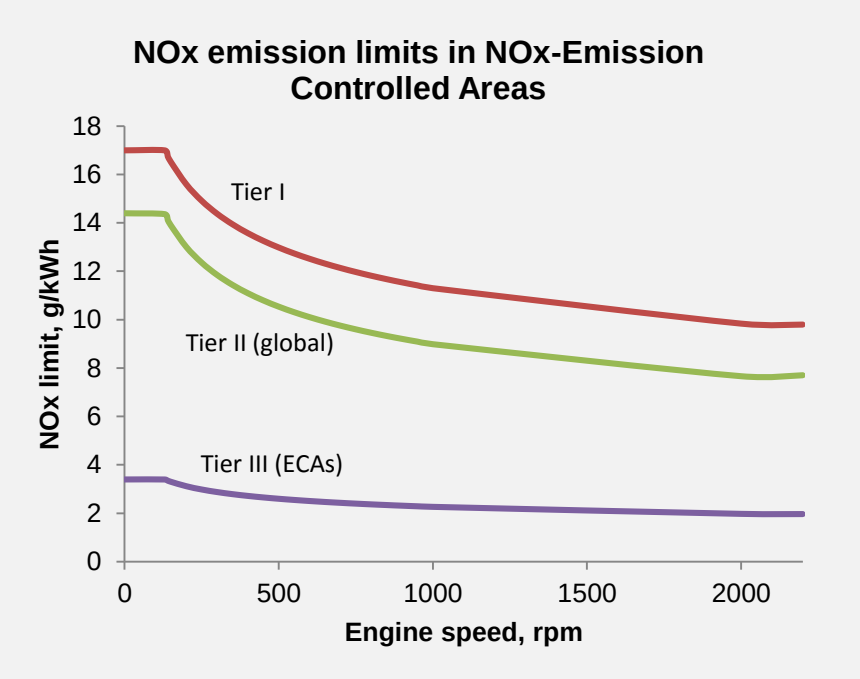
MARPOL established emission control areas (ECAs) on SOx, NOx, and particulate matter to minimize airborne emissions from ships. From 2020 also regulation outside ECA



Komar & Lalić (2015)

International fuel regulations will tighten
-Sulfur and nitrogen oxide limits for shipping fuels





NOx restrictions are only applicable in the North American ECA on vessels built later than January 2000 (Tier I), January 2010 (Tier II), or January 2021 (Tier III)

80% of current fuels/engines needs to be modified

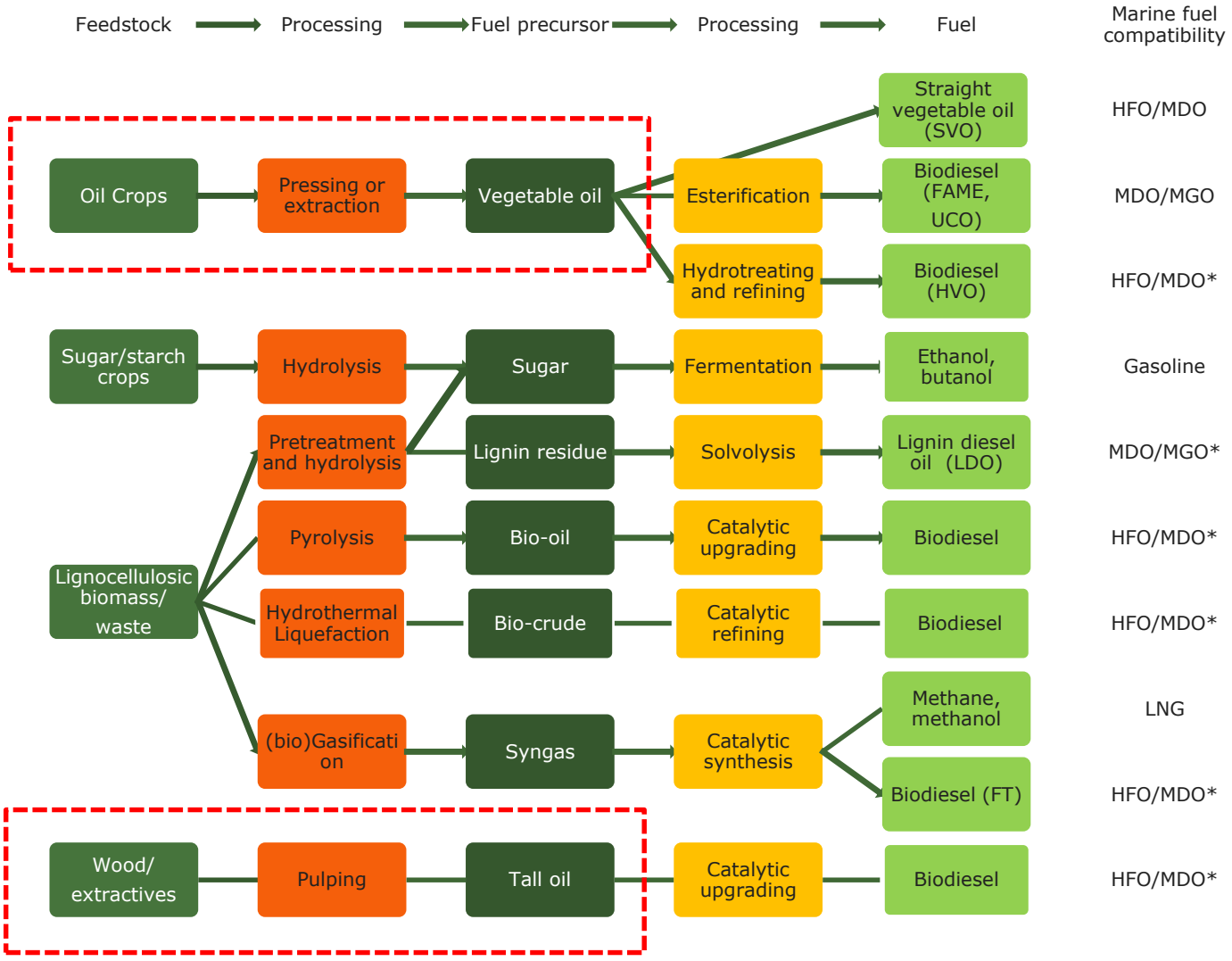
How to comply with new regulations?

- Change to low sulphur fuels, -extra cost of 100-200 USD/ton
- Switch fuel to LNG –pressurised tanks and engine modification needed, takes up cargo space.
- Install scrubbers to clean exhaust for sulphur. Installation 20-30 mio USD. Takes up cargo space. Emissions collected in tanks.
- But what about biofuels, they also reduce the GHG emissions?

Fuel development for marine diesels requires scale!

- Small test engine 200 l
- Engine test bench 2000 l
- One-cylinder large-scale test 20-200 tons
- 1 very large container-ship consumes 100 mio l/year

Current biofuel technologies
-only few are run at commercial scale



* Can be blended with conventional fuels or used as a drop-in fuel

Potential marine biofuel production technologies

Conventional diesel type fuels

- Biodiesel (FAME) (limited supply)
- Hydrotreated waste cooking oils and animal fats (limited supply)
- Hydrothermal liquefaction of biomass (no commercial scale)
- Hydrotreated tall oil from pulp and paper (limited supply)

New fuels

- 2nd generation bioethanol and lignin (new industry)
    - Lignin-based fuels under development. Ethanol (& methanol, butanol) can be used in new multi-fuel diesel engines
- Thermal conversion of lignocellulosics for drop-inn diesel fuels
- Alcohols may become a significant marine fuel
- Biogas for bioLNG

Marine biofuel testing and market penetration

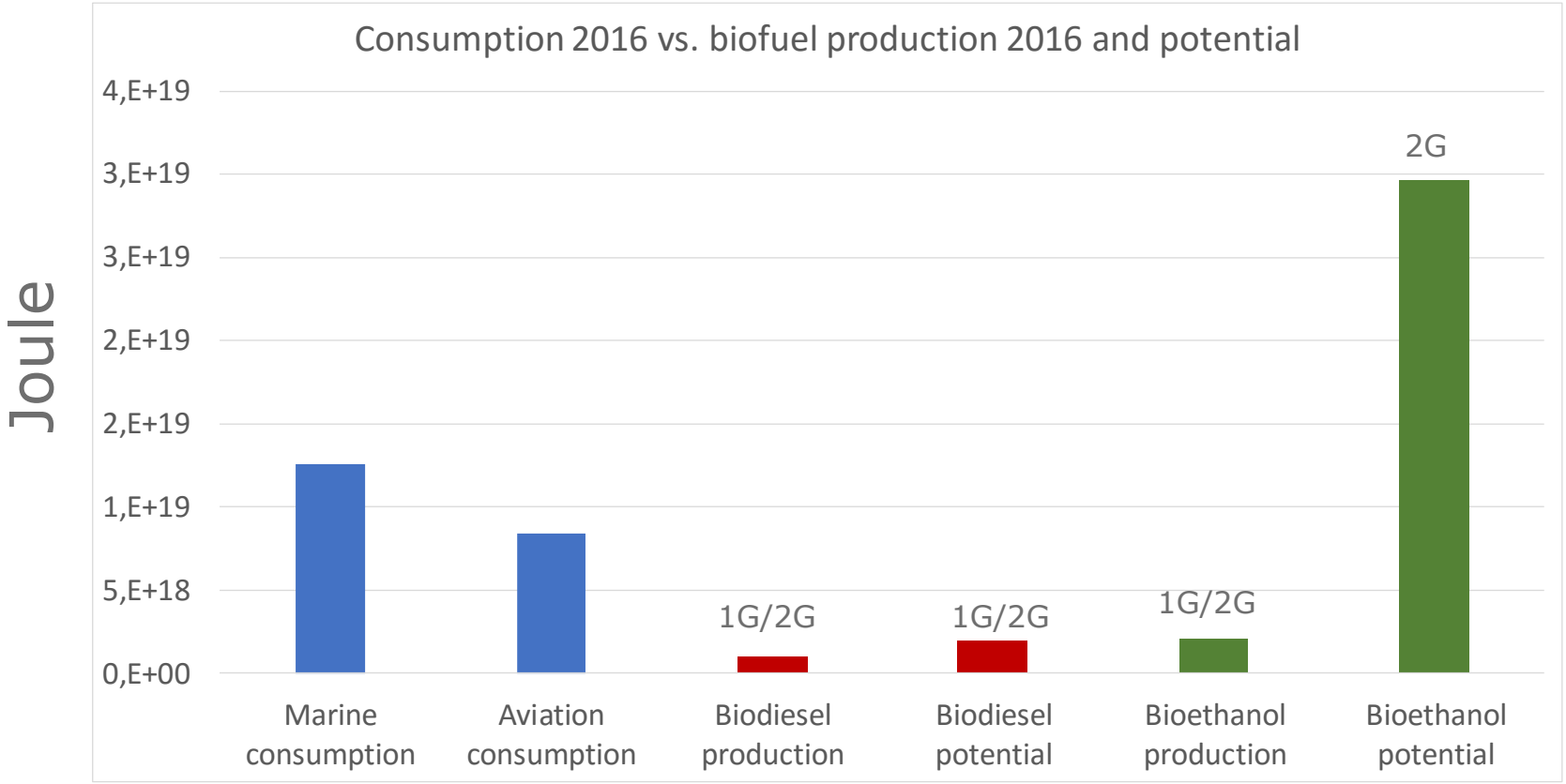
US Navy's Great Green Fleet initiative: 50% renewable alternative energy to power the Navy's fleet by 2020

- Collaborations with Mærsk, Solazyme, Renewable Energy Group, Amyris, and the Australian Navy
- 50% biofuel blend trials with HVO or FAME biodiesel have been successful
- The goal will not be met. Future policies are not known

GoodFuels Marine:

- Marine biofuel provider offering 2nd generation biofuels from waste.
- Partnered with the Port of Rotterdam, Boskalis, and Wärtsilä to accelerate the development of marine drop-in fuels in the supply chain

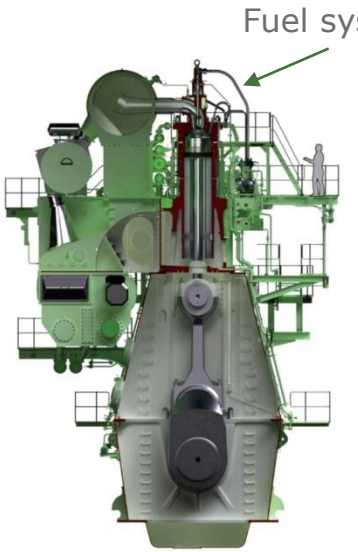
How much biofuel is available, what are the potentials?



Biofuel potentials based on agricultural production and consumption. Note distinction between 1st and 2nd generation biofuels

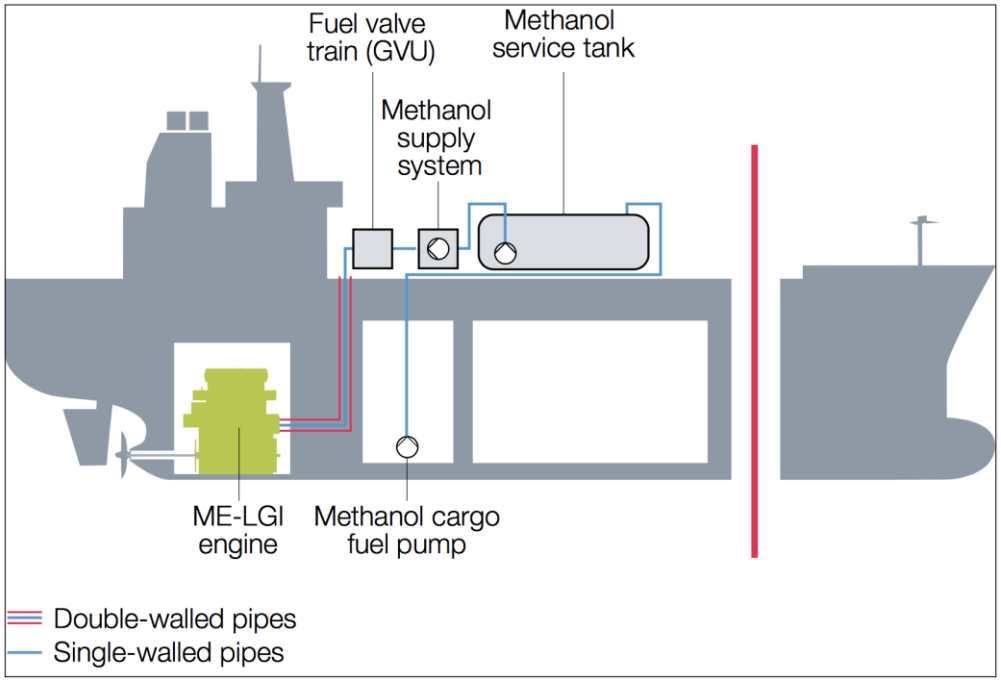
New engine technologies –multifuel engines

- LGI multifuel engines can run both heavy oil, LNG, methanol and ethanol in a **diesel cycle**



Large-scale use of alcohol fuels

- LGI engines are currently used on chemical tankers for methanol as well as on 1 ferry
- Other alcohols; ethanol and butanol can be used in the same type of engine.
- Methanol and ethanol may simply use the hull as fuel tank
- Currently only a small number of vessels have LGI engines
- No infrastructure present for e.g. ethanol bunkering



Keep-it-simple fuels
Lignin ethanol oil (LEO)

- Hydrolysis lignin dissolved in ethanol at 190-200 deg. C.
- 1 l ethanol may contain 40% w/w lignin
- Stable preparation from 0-60 C (tenside needed)
- Salt content at a very low level,
- Energy density 30-32 MJ/kg
- This is a dumb (simple) and potentially cheap fuel

Comparison of scale for laboratory preparations of lignin diesel oil (LDO) made by lignin solvolysis in ethanol and lignin ethanol oil (LEO) made by solubilizing lignin in ethanol

Stable LEO: 32 % lignin, 30 MJ/kg, silica <<100 ppm

2G lignin + tween 80 (0,2%)

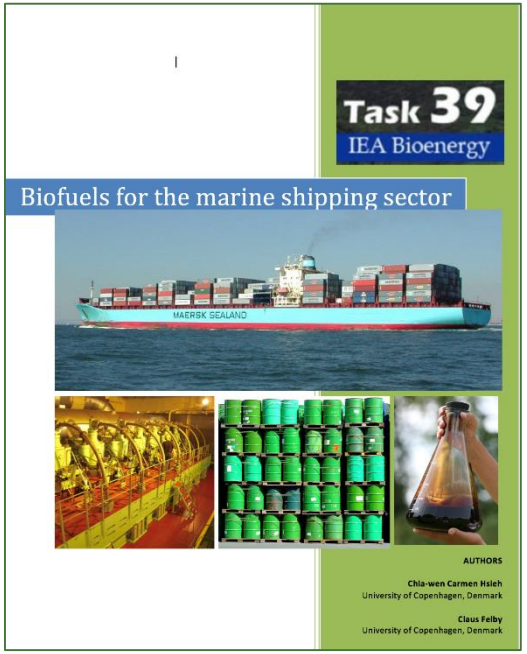
Conclusion -the case for marine biofuels

Strengths
- Feedstocks contain no sulfur
- Abundant lignocellulosic feedstocks
- Marine biofuels do not need intensive refining
- Biodiesels compatible with infrastructure

Weaknesses
- No long-term fuel testing data for marine biofuels
- Concerns about storage and oxidation of the fuel
- High biofuel volumes required
- Strong competition on biodiesel with aviation

Opportunities
- Fuel regulations. Sulfur reduction mandatory.
- Agreement on CO_2 emissions
- Drop-in biofuels has potential to replace part of the fuel mix
- New engines for alcohols

Threats
- Biofuels unknown, requires combined effort of engine manufacturers and ship owners
- LNG slowly increasing
- Competing technologies - scrubbers
- Low price of oil delays biofuel introduction



IEA report available for download

http://task39.sites.olt.ubc.ca/files/2013/05/Marine-biofuel-report-final-Oct-2017.pdf

Conclusions -Looking ahead

- Biofuels has a large technical potential, but can they deliver?
- Oleochemical fuels can only supply a minor fraction of the demand
- The sector has an immediate need –it will take decades+ to develop and scale thermal fuels
- Biogas is a technical option, but expensive
- Bioethanol has the potential for a 100% supply, but requires cheap cetane enhancers or introduction of LGI engines
- Supplier-consumer partnerships are needed for viable business cases
- Think integration!
  -Thermal, biochemical and e-fuels