Aligned with your needs.

Alternative Maritime Fuels

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ALION
SCIENCE AND TECHNOLOGY

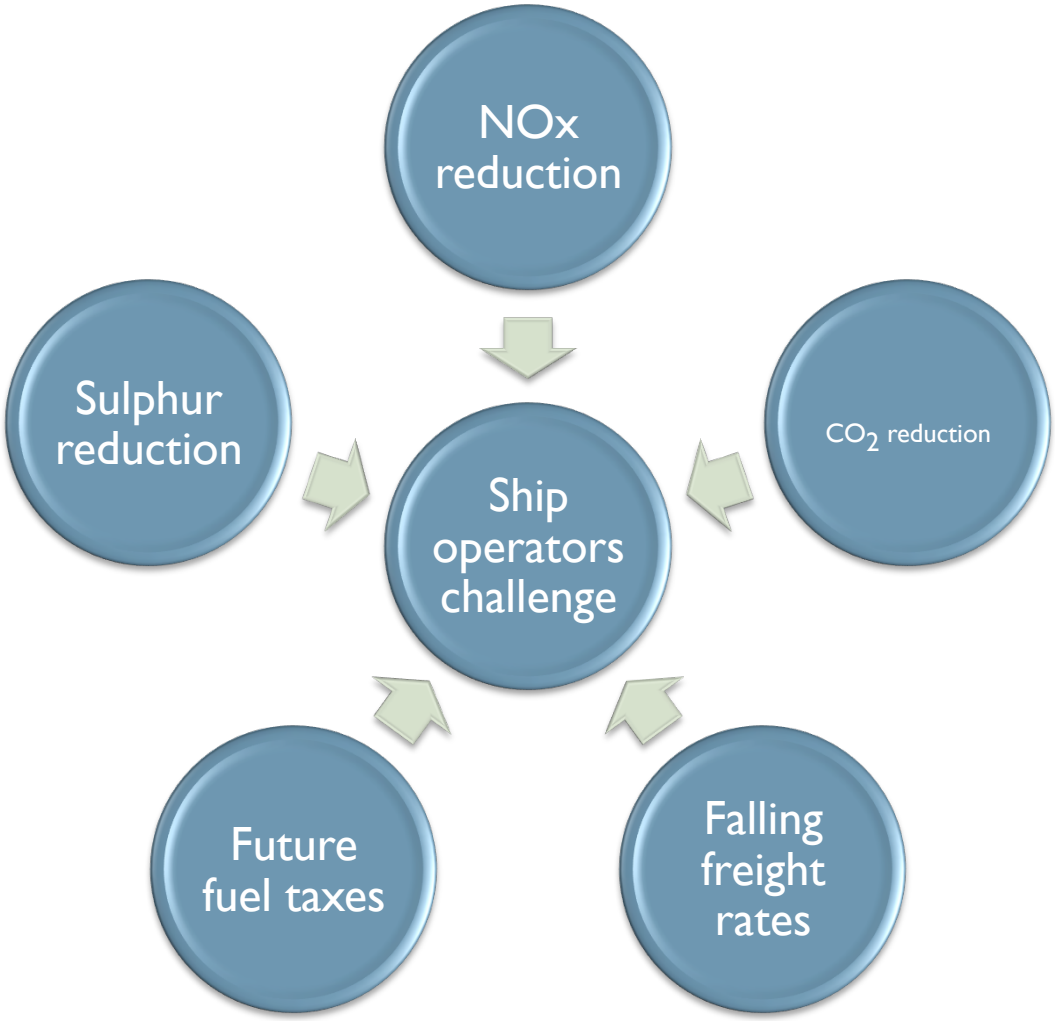
Alion Science Alternative Fuels Experience

- *Evaluating and Testing Alternative Fuels for Marine use since 2002*
  - *SF Water Transit Authority – Working Paper on Alternative Propulsion and Fuel Technology*
  - *US Navy Alt Fuel Specification Development and Testing*
  - *US Coast Guard Alt Fuel Selection, Test Plan Development and Demonstration*
  - *Transport Canada Future Marine Fuels Study*
  - *IEA-AMF Future Marine Fuels*
  - *Royal Canadian Navy Alt Fuels Study for Military Marine Applications*
  - *Transport Canada After Exhaust Treatment Waste Disposal*

IEA-AMF Future Marine Fuels Report

- *Alion Provided Majority of Research and Developed the Report Under Contract from Fuels, Engines and Emissions Consulting*
- *DTI major contributor with European Experience and Economic Data*
- *Reviewed by Lloyd's Register for copyright permission*
- *Report concentrates on compliance options using fuels or exhaust treatment for Diesel Engines on Large Commercial Ships – (Largest Users)*
- *Report available on IEA-AMF Website*
  - http://www.iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_41.pdf

Marine Shipping Industry Challenges



Environmental Control Areas (ECAs)

- *ECAs – Present and Future*

ECA and Global Fuel Sulfur Limits

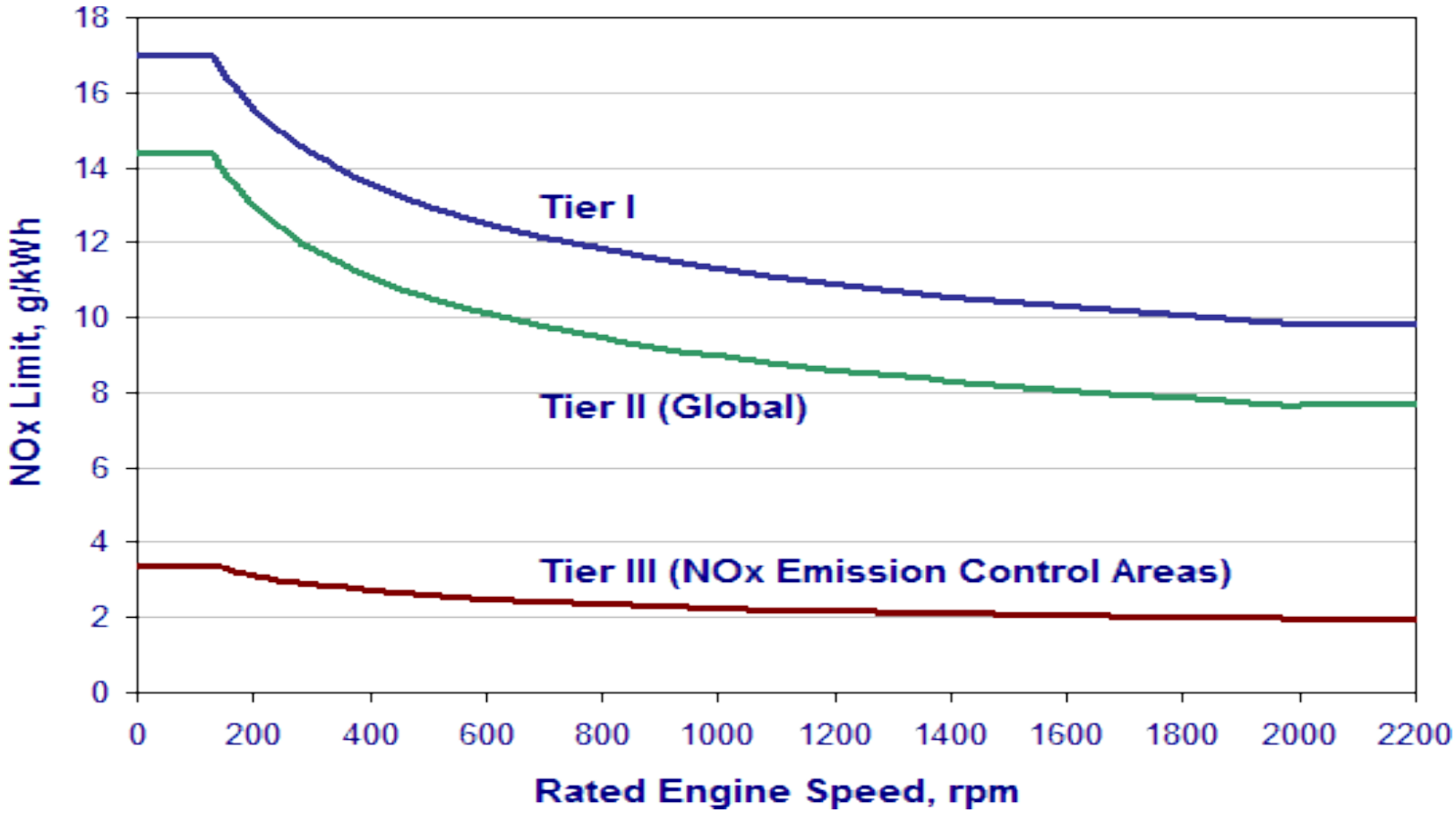
- *MARPOL Annex VI Marine SOx Emission Reduction Areas (SECA) with Fuel Sulfur Limits*

European SECAs	Year	Fuel Sulfur (ppm)	Fuel Sulfur (%)
North Sea, English Channel	Current Limits	10,000	1
	2015	1,000	0.1
Baltic Sea	Current Limits	10,000	1
	2015	1,000	0.1
North American ECAs			
United States, Canada	2012	10,000	1
	2015	1,000	0.1
Global	2012	35,000	3.5
	2020*	5,000	.5

- * *Alternative date is 2025, to be decided by a review in 2018*

MARPOL NOx Limits

- *NOx Emission Limits*



NOx Limit Timelines

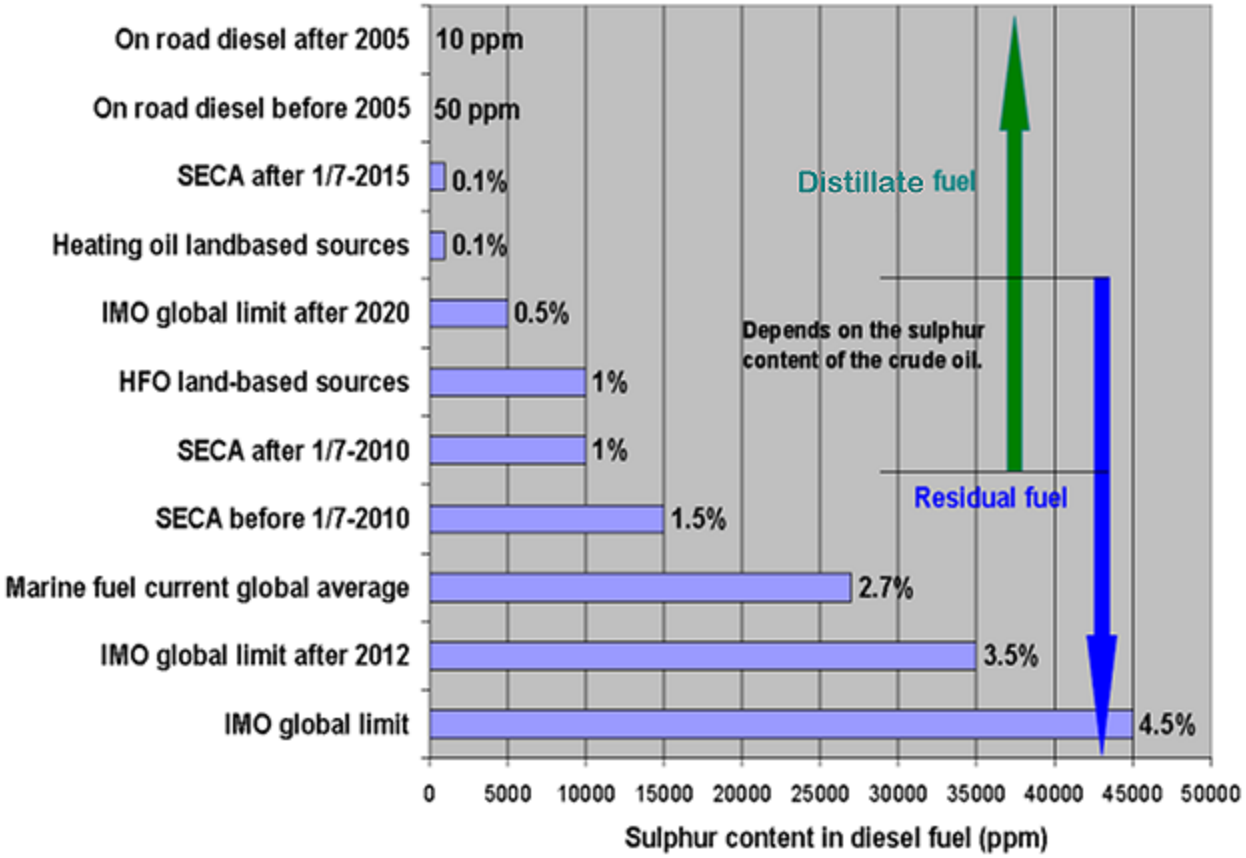
- *After 1 Jan 2011 Marine Diesel Engines must comply with Tier II Standards*
- *Tier III Marine Diesel Engines for ships constructed on or after 1 January 2016 and operating in designated NOx ECAs*

Current Situation

- *Global marine fuel usage >300 Megaton/year*
- *77 % residual fuel (low price, low quality)*
  - *Also referred to as heavy fuel oil (HFO)*
  - *Must be heated to flow properly*
- *Almost entirely consumed by cargo ships*
- *Average HFO fuel sulfur level 2.7%*
  - *Current allowable 4.5%*
- *Challenge to get to ECAs and Global Sulfur limits*

Current Situation

- *Comparison of Fuel Sulfur Levels*



Compliance Options

- *Low sulfur fossil fuels*
  - *Residual or distillate*
- *Alternative liquid biofuels*
  - *From vegetable oils and animal fats, hydrogenated, esterified or straight, other processes*
- *Gaseous Fuels*
  - *Biogas, Natural gas, LPG (Propane)*
- *Exhaust Gas Treatment Systems*
  - *Scrubbers for SOx removal*
  - *NOx Reducing Devices*

Future Marine Fuels

- *Alternative Fuel Incentives*
  - *Price Fluctuations of Fossil Fuels*
  - *IMO-MARPOL Annex VI*
    - *SOx and NOx Limits*
    - *Regulations for GHG reductions in CO_2, EEDI (Energy Efficiency Design Index)*
  - *Emission Control Areas (ECAs)*
    - *SOx and NOx limits*
    - *Canada, USA, North Sea, Baltic Sea and future ECAs*
  - *USA*
    - *Renewable Fuels Standard (RFS)*
  - *Global Fuel Sulfur limits*

Future Marine Fuels

- *Future Marine Fuel Characteristics*
  - *No Engine or Fuel System Modifications*
    - *Drop in Liquid Fuel*
  - *Lowers Emissions*
  - *Competitively priced*
  - *Available worldwide or regionally for bunkering*
  - *Can mix with current fuels*
  - *No degradation of Engine performance*
  - *Safe*

Future Marine Fuels

- *Alternative Marine Fuels*
  - *Low Sulfur Marine Fossil Fuels for SOx*
    - *Ultra Low or Low Sulfur Diesel (ULSD and LSD)*
    - *Low Sulfur Residual Fuel (LSRF)*
  - *Biofuels*
    - *Biodiesel (FAME)*
    - *Algae Fuels (not yet available)*
    - *Hydrogenation-Derived Renewable Diesel (HDRD)*
    - *Methanol*
    - *Dimethyl-Ether (DME)*
    - *Bio Crude (Pyrolysis oil)*

Future Marine Fuels

- *Marine Alternative Fuels (Con't)*
  - *Gaseous Fuels for SOx, NOx, PM, CO_2*
    - *Biogas (Compressed, Liquefied)*
    - *Natural Gas (Compressed, Liquefied)*
    - *Propane*

Future Marine Fuels

- *Liquid Fuels (Advantages, Disadvantages)*
  - *Low Sulfur Marine Fuels (ULSD, LSD,LSRF)*
    - *Advantages*
      - *Compatible with engines and fuel systems*
      - *Lower SOx Emissions*
      - *Safe to use*
      - *Commercially available*
    - *Disadvantages*
      - *Cost*
      - *Different characteristics (Lower Viscosity) can cause fuel system operational problems and loss of propulsion*

Future Marine Fuels

- *Liquid Fuels (Advantages, Disadvantages)*
  - *Biofuels (Biodiesel (FAME))*
    - *Advantages*
      - *Lower SOx Emissions*
      - *Safe to use, Environmentally friendly*
      - *Commercially available*
      - *Cost Competitive*
      - *Can be blended or used as neat fuel*
      - *Produced to ASTM and EU Specifications*
      - *Advanced Biofuel*
      - *Marine engines certified to burn biodiesel*

Future Marine Fuels

- *Liquid Fuels (Advantages, Disadvantages)*
  - *Biofuels (Biodiesel (FAME))*
    - *Disadvantages*
      - *Low Temperature Operation (High Cloud Point)*
      - *Fuel System and Engine compatibility (Seals, Hoses, Gaskets, some metallics)*
      - *Storage limitations affects fuel stability (Duration)*
      - *Can clog fuel filters when first used -Solvent action loosens deposits, etc.*
      - *Price fluctuations depending on feedstock*
      - *Not readily available to marine market*

Future Marine Fuels

- *Liquid Fuels (Advantages, Disadvantages)*
  - *Hydrogenation-Derived Renewable Diesel (HDRD)*
    - *Advantages*
      - *Compatible with engines and fuel systems*
      - *Lower SOx Emissions*
      - *Safe to use*
      - *Similar to conventional marine fuels (drop in fuel)*
      - *Produced to diesel fuel specifications*
    - *Disadvantages*
      - *Limited availability*

Future Marine Fuels

- *Liquid Fuels (Advantages, Disadvantages)*
  - *Biofuels (Algae Fuels)*
    - *Advantages*
      - *Compatible with engines and fuel systems*
      - *Lower SOx Emissions*
      - *Safe to use*
      - *Similar to conventional marine fuels (drop in fuel)*
      - *Military Specification for 50-50 blend*
    - *Disadvantages*
      - *Availability*
      - *Cost*
      - *Lower heating values and aromatics*

Future Marine Fuels

- *Gaseous Fuels (Advantages, Disadvantages)*
  - *Natural Gas (Compressed (CNG) or Liquefied (LNG))*
    - *Advantages*
      - *Good availability- Abundant*
      - *Cost competitive*
      - *Lower SOx, Nox, PM and CO_2 emissions*
      - *Rules for gas fueled ships are in place (DNV, LR, others)*
      - *Dual fuel or single fuel gas engines available*

Future Marine Fuels

- *Gaseous Fuels (Advantages, Disadvantages)*
  - *Natural Gas (Compressed (CNG) or Liquefied (LNG))*
    - *Disadvantages*
      - *Modifications to Existing Engines*
      - *Infrastructure for marine bunkering limited*
      - *Increases the cost of new ship construction*
      - *Fuel storage space more then for conventional fuel oil (LNG better than CNG)*
      - *Lower heating value than conventional HFO*
      - *Increased Safety requirements*

Future Marine Fuels

- *Vessels Using Alternative Fuels*
  - *Majority using ULSD, LSD or LSRF*
    - *US – 2012 all Marine Diesel Fuel is ULSD*
    - *Ships entering ECAs or Low Sulfur zones switch to ULSD, LSD or LSRF*
  - *Natural Gas (Compressed (CNG) or Liquefied (LNG))*
    - *Small – Medium*
      - *Offshore Supply Vessels (OSVs), Ferries, Patrol Vessels, Inland River Cargo Vessels and Tugs*
    - *Large*
      - *LNG Carriers (Cargo Boil Off)*
      - *214 meter Passenger Ship*
      - *Numerous Contracts for Short-Sea Container Vessels*
      - *Society Approved Designs for Trans Atlantic LNG Fueled Container Ships*

Future Marine Fuels

- *Vessels Using Alternative Fuels (Con't)*
  - *Interest worldwide in LNG as marine fuel*
    - *Construction of new LNG fueled vessels*
    - *Conversion of existing vessels to LNG*
  - *22 Vessels using LNG in spring of 2011*
  - *100+ LNG Fueled Ships Announced March 2014*
    - *48 Operating, 53 New Builds*
  - *Approximately 42 vessels in North America under construction or evaluation for conversion to LNG*
    - *New construction OSVs, Container Ships and Ferries*
    - *Conversion of Ferries and RO-RO ships*

Future Marine Fuels

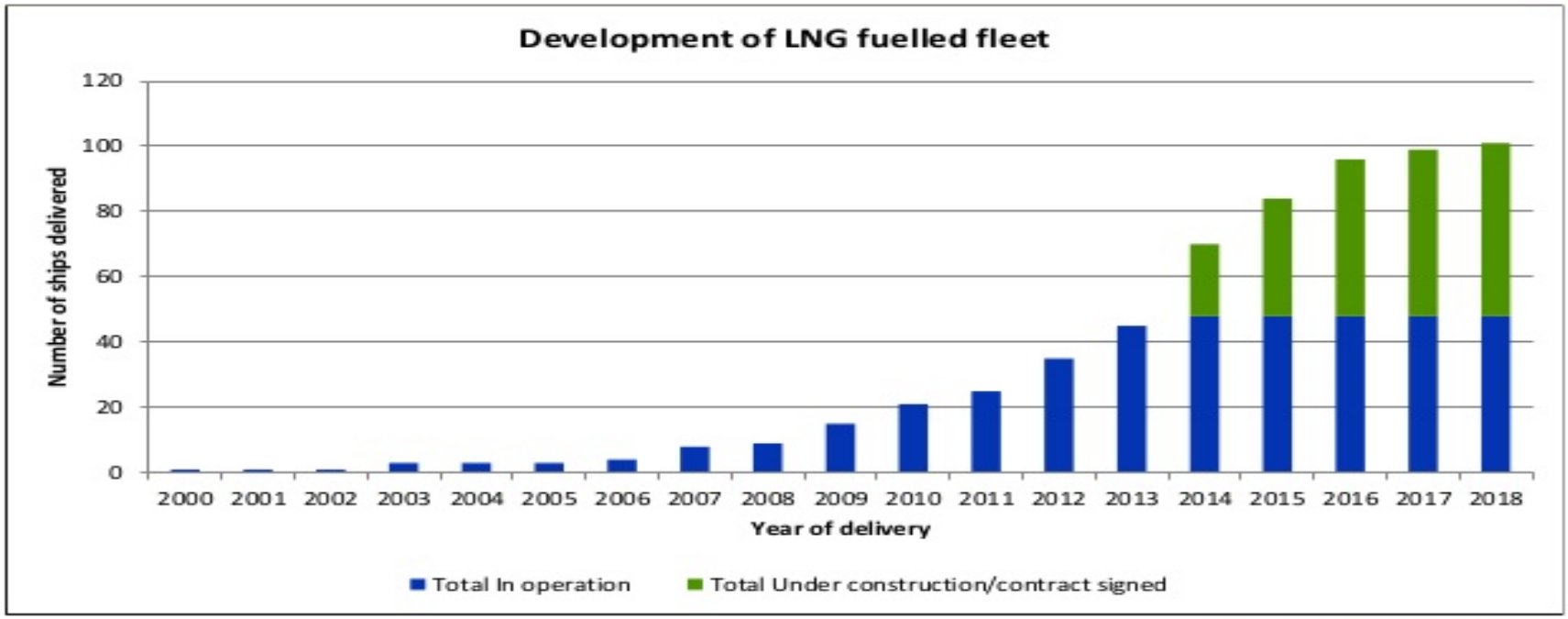
- *Vessels Using Alternative Fuels (Con't)*
  - *DNV estimates as many as 1,000 ships will have capability for using LNG as a fuel by 2020*
  - *Currently most LNG fueled ships are in Coastwise, dedicated or short sea routes (US to Puerto Rico or Hawaii).*
  - *Most have dual-fuel engines capable of running on LNG or Diesel.*

Future Marine Fuels

- *Vessels Using Alternative Fuels (Con't)*
  - *Methanol*
    - *Stena Lines - Pilot project early 2015*
      - *Stena Germanic with one Main Engine modified*
      - *Modification minor and 1/3 cost of LNG modifications*
      - *Liquid fuel similar to HFO handling, distribution*
    - *Metahnex order for seven methanol tankers to run on methanol*
      - *Two Stroke MAN engines*
    - *Cheaper to convert to methanol than LNG*
    - *Engines are available for methanol as a fuel*

LNG Fueled Ships

There are currently 101 confirmed LNG fuelled ship projects



Updated 07.03.2014
Excluding LNG carriers and inland waterway vessels

4 DNV GL © 2013

DNV·GL

Vessels Converted to LNG Fuel

- *Bit Viking Chemical Product Carrier Converted to LNG*

New Construction LNG Vessels

LNG Vessels Planned

Progress on LNG Bunkering Facilities

- *LNG Fueling*
  - *Four Methods of Bunkering*
    - *Truck, Barge, Fixed or Portable Tanks*
  - *Safety Practices promulgated by IMO, Classification Societies and US Coast Guard*
    - *Draft of Recommended Practices by DNV-GL*
    - *Report by ABS*
  - *Several LNG Bunkering Facilities available in Europe*
  - *Construction of facilities planned in Europe by EU*
  - *Construction of facility started in US*
    - *Port Furchon, Louisiana, ($25 Million)*

LNG Information as Ship's Fuel

- *Recent Website Focused on LNG as shipping Fuel*
  - *Developed by World Ports Climate Initiative (WPCI)*
  - *Overview of LNG as ship's fuel, technical requirements, bunkering infrastructure, vessels under development, engine types, and business case for LNG*
  - *Emphasis on bunkering (Check Lists)*
  - www.lngbunkering.org

Exhaust Gas Treatment Systems

- *Scrubbers*
  - *Alternative to Low Sulfur Fuels*
  - *Allows use of cheaper HFO*
  - *Proven technology in shore side installations*
    - *98% or better SOx removal*
  - *Technology has been adapted to and proven in marine installations*
    - *DFDS Passenger Car Ferry*
    - *Pride of Kent and the Ficaria Seaways*
  - *Ship owners/operators are building and ordering ships with scrubbers*

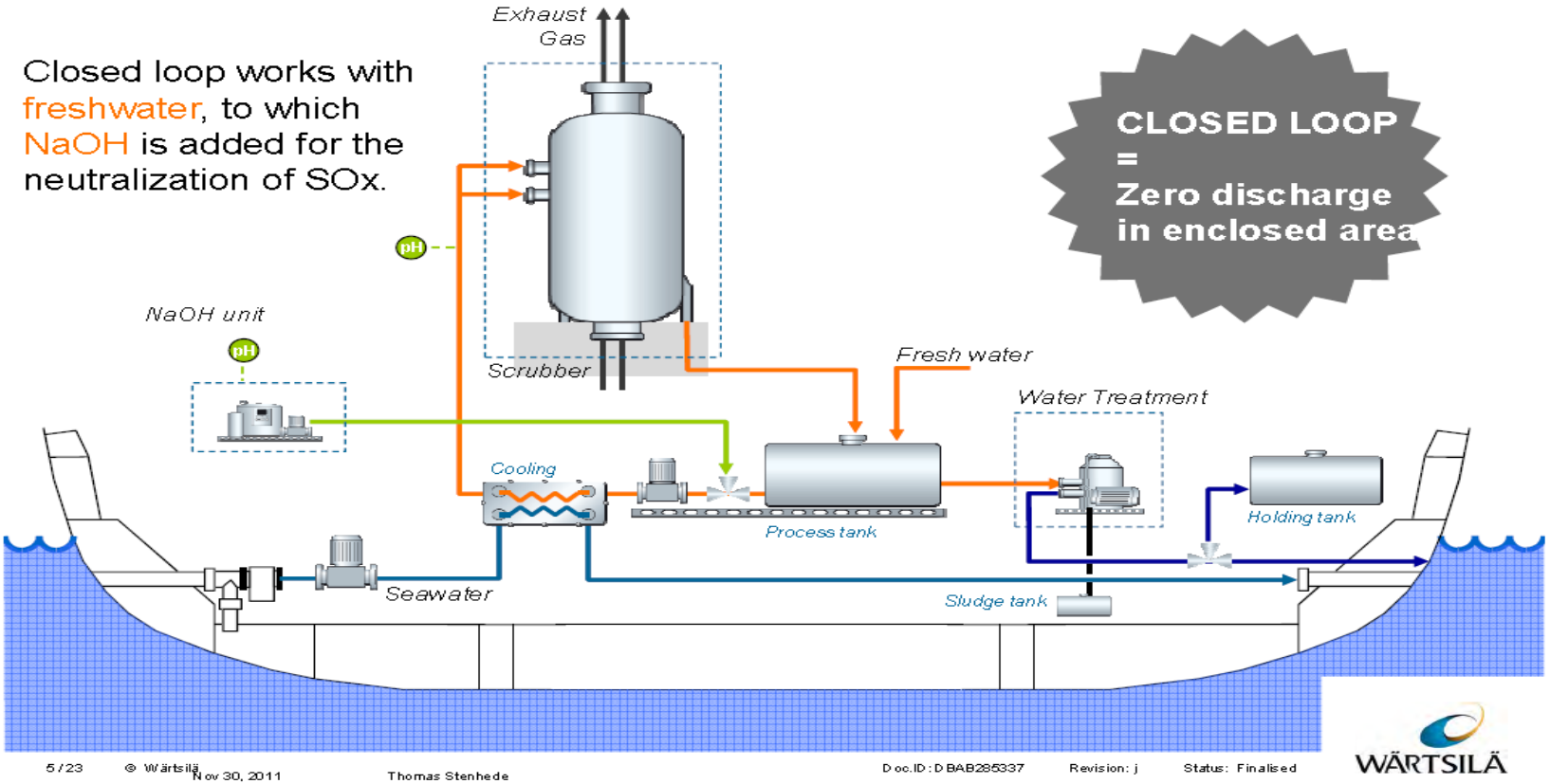
Exhaust Gas Treatment Systems

- *NOx reducing devices*
  - *For ships built after 1 January 2016 to operate in ECAs designated for NOx emission control*
  - *NOx requirement is not retroactive*
- *For Detailed description of EGTS*
  - *Lloyd's Register publication, "Understanding Exhaust Gas Treatment Systems, Guidance for Shipowners and Operators, June 2012"*

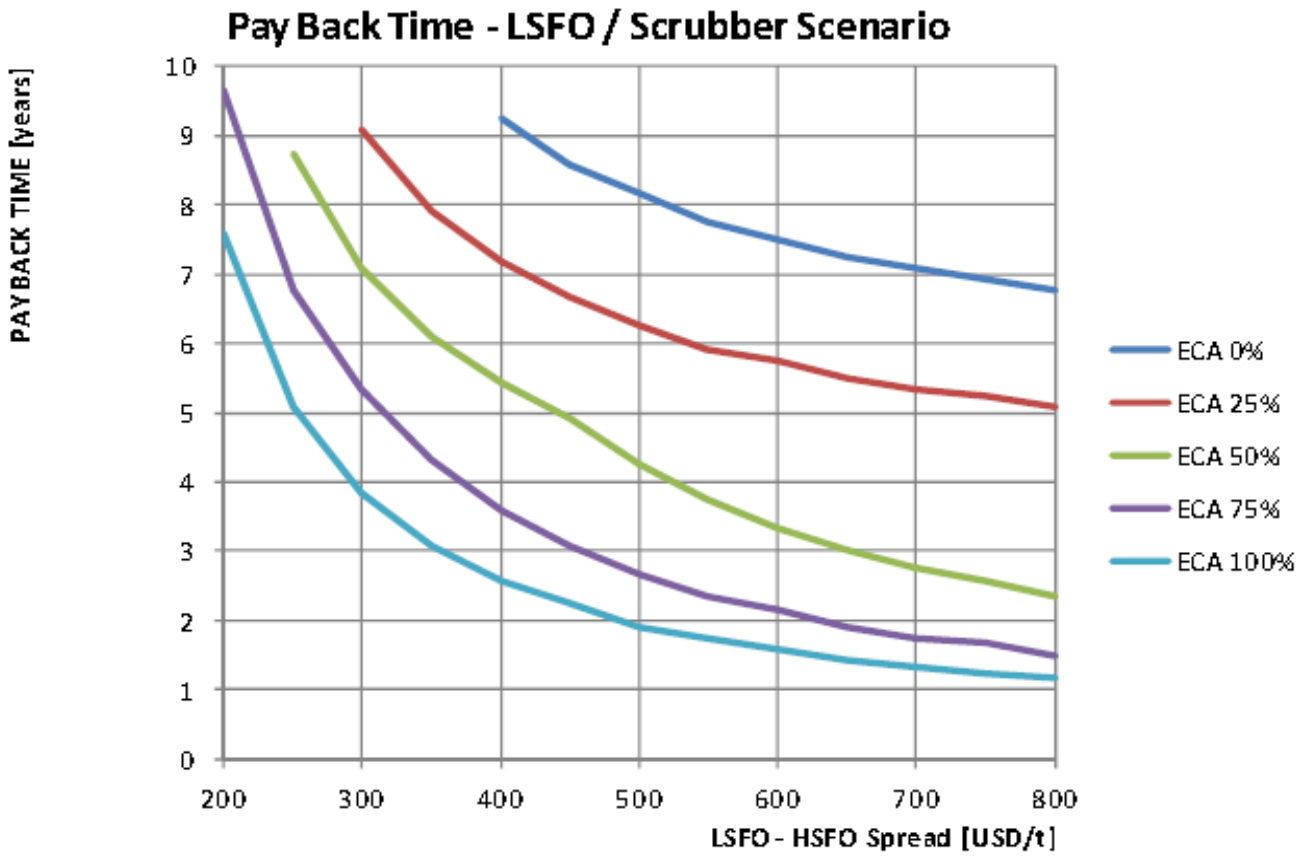
Exhaust Gas Treatment Systems

Marine Fresh Water Scrubber System

Closed loop works with freshwater, to which NaOH is added for the neutralization of SOx.



Scrubber Pay Back Time



Viable Future Marine Fuels

- *Viable Future Marine Fuels*
  - *ULSD, LSD and LSRF*
    - *Currently Availability is good*
    - *NOx reduction will require engine modifications or aftertreatment*
      - *Or installation of emission compliant engines*
  - *More Costly Than HFO (Next Slide)*

Marine Fossil Fuel Prices

- *Marine Fuel Prices July 2012 in USD/Metric Ton (MT)*

Grade/ Port	High Sulfur Heavy Fuel (IF 380)	Low Sulfur Heavy Fuel (LS 380) (1% S)	High Sulfur Heavy Fuel (IF 180)	Low Sulfur Heavy Fuel (LS 180) (1% S)	LSMGO (0.1 % S)	MDO
Copenhagen	$597.50	$658.50	$630.00	$683.50	$907.50	$865.50
Rotterdam	$580.00	$631.50	$602.00	$653.00	$865.00	-------

Viable Future Marine Fuels

- *Natural Gas (Compressed (CNG) or Liquefied (LNG))*
  - *Viable current and future fuel for SOx, NOx, and CO_2 reduction*
  - *Availability is good*
  - *Cost is competitive*
  - *Gas or dual fuel engines available*
  - *Rules for LNG ship design and safety published*
  - *Development of bunkering facilities may facilitate increased number of ships using this fuel*
  - *CNG not viable due to extensive refueling times, loss of cargo space and limited range*

Viable Future Marine Fuels

- *Biodiesel*
  - *Limited use of Biodiesel (FAME)*
  - *Second generation (HDRD) Biodiesel fuels may be viable if:*
    - *Production scales up*
      - *US Capacity – 297 Million Gallons*
      - *Europe – Neste Oil – 800,000 Metric Tons (273 Million Gallons)*
      - *Capacity being added*
    - *Fuels are Cost competitive (with diesel fuel, but not competitive with residual fuels)*

Viable Future Marine Fuels

- *Methanol*
  - *Currently in test trial on a Stena ferry*
  - *Metanex has ordered seven methanol carriers with methanol fuel*
  - *Engines available*
  - *Society Rules for Low Flash Point Fuels published*

Evaluation summary

	IFO	LSFO	MGO/GTL/ BTL	HVO/SVO/ FAME	MeOH	DME/LPG	LNG/LBG
Engine and fuel system cost	Drop-in	Drop-in	Drop-in	Drop-in	Dual fuel	Gas tank	Dual fuel Cryo tanks
Projected fuel cost		Refining	Refining	Land use		Infra-structure	Infra-structure
Emission abatement cost	SOx, NOx, PM, CO_2	NOx, PM, CO_2					
Safety related cost					Flash point	Ventilation	Press/temp
Indirect cost				Ethics	Cargo space	Cargo space	Cargo space

Serious impediment

Significant cost

Feasible solution available

Conclusions

- *Compliance with emission and fuel sulfur limits are forcing changes in the marine fuel mix*
  - *No longer one size fits all*
- *Fossil fuels are seen as dominate through 2020 with transition to mostly distillate fuel*
- *Biofuels do not seem to be a strong alternative with their limited availability and cost*

Conclusions

- *Natural Gas as LNG is viable alternative propulsion fuel for ships*
  - *Has been demonstrated and is in use on vessels on fixed and coastal trade routes*
  - *Appearing in new builds and conversions with LNG fuel systems and gas engines*
  - *Development of a global LNG bunkering system is critical to the expansion of LNG as a fuel for the large ships that travel on international routes*

Conclusions

- *Projected Fuel Mix 2020*

Vessel types	Small vessels, ferries etc.	Cargo ships with sulfur removal	Cargo ships without sulfur removal	Total
No. of vessels	55.000	30.000	20.000	105.000
HFO [Mton/yr]	-	204	-	204
LSFO [Mton/yr]	-	-	110	110
MGO/MDO [Mton/yr]	44	-	25	69
LNG [Mton/yr]	15	-	-	15
Biofuels etc. [Mton/yr]	1	-	1	2
Total fuel [Mton/yr]	60	204	136	400
Market per cent	15%	51%	34%	100%

Conclusions

- *Exhaust scrubbers are viable alternative to using lower sulfur fuels*
  - *Shown effective in marine installations*
  - *March 2014 Wartsila has 45 ships contracted for total of 94 Exhaust Gas Scrubbers*
  - *Other Vendors (Alpha-Laval, Clean Marine) have sold and installed scrubbers*
  - *Exhaust Gas Cleaning Association Reports about 160 sold by all vendors – Mostly for new builds.*
- *Compliance with the new emission requirements will raise construction and operating costs for ship owners*

Conclusions

- *NOx compliance in 2016 for new ships in ECAs will be achieved with after treatment devices to reduce NOx emissions*
  - *Ships with gas fired engines may comply without NOx after treatment*
- *Of note is lack of a low cost fuel to replace HFO*

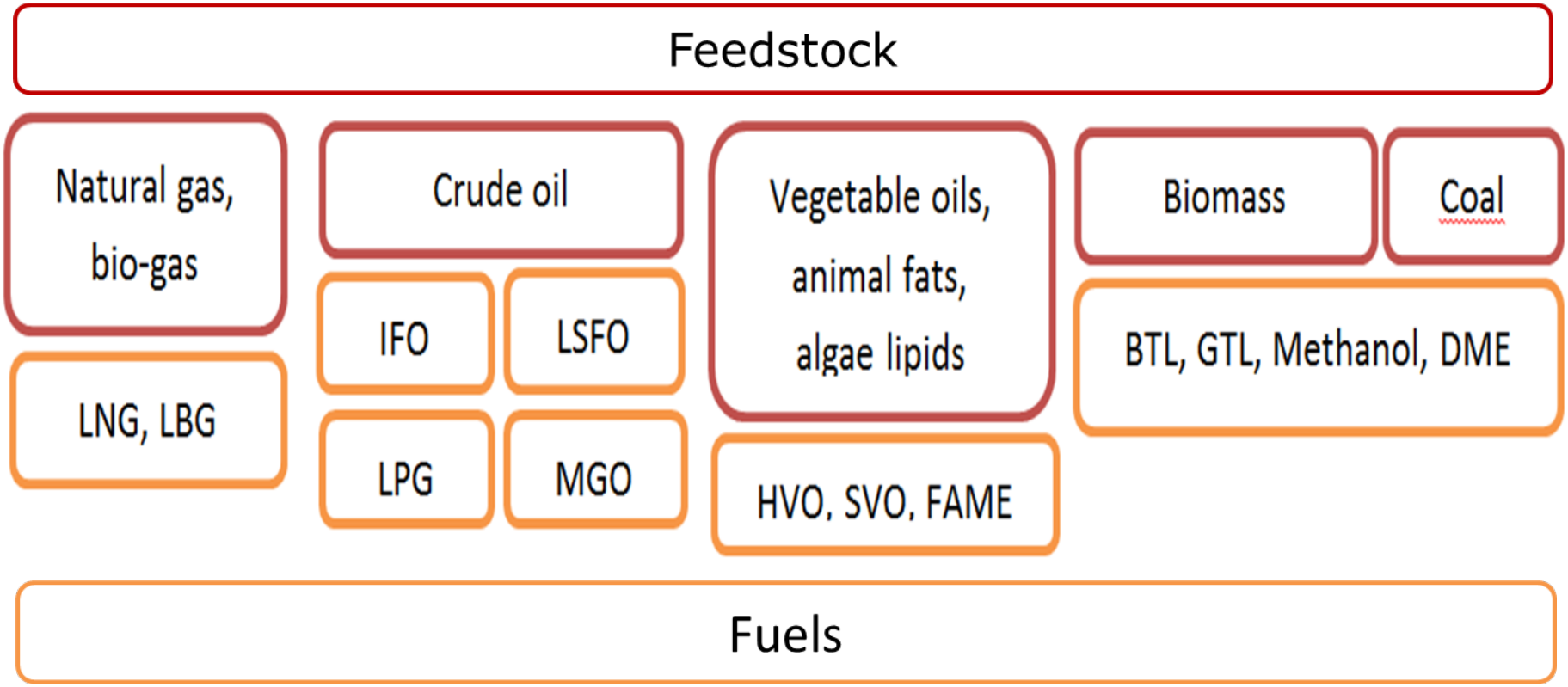
Recommendations

- *Continue this study for compliance trends as more ECAs come into force and the 2015 low sulfur and 2016 NOx limit dates approaches*
- *Monitor the progress of large LNG fueled ships coming into the shipping mix*
- *Monitor establishment of marine LNG bunkering facilities*
- *Monitor biofuel producers and their ability to produce low cost high volume fuels for the marine shipping industry*

Alternative Maritime Fuels

Backup Slides

Selected Marine Fuels for Evaluation

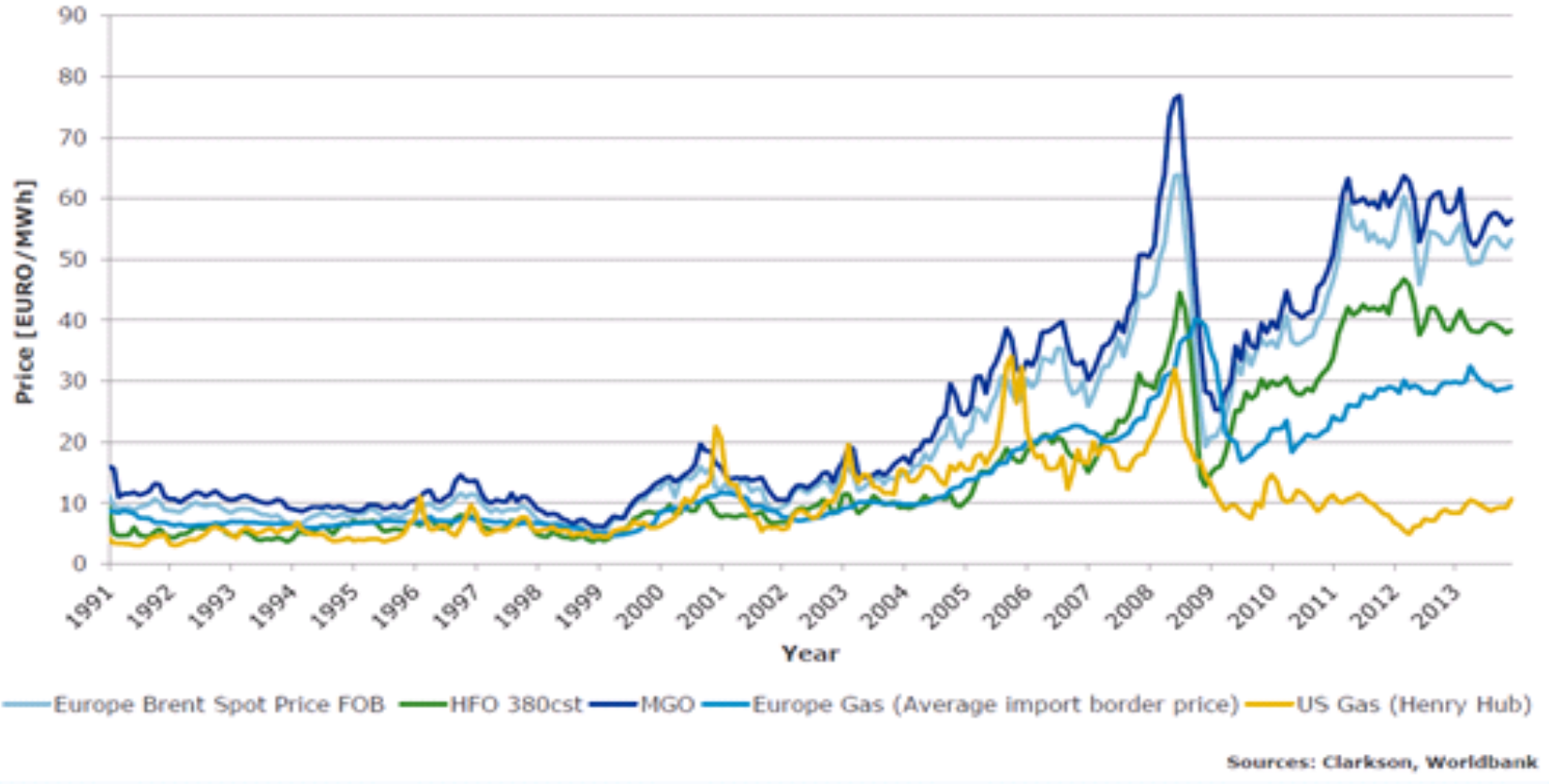


November 2013 LNG Prices

- *World LNG Price*

Ship Fuel Prices

- *Historical LNG, MGO, and HFO Prices*



Evaluation criteria (1of 3)

- *Engine and fuel system cost, including*
  - *New vessel on-cost*
  - *Retrofit investments*
  - *Increased maintenance cost*
- *Projected fuel cost, including*
  - *Projected fuel price per MJ*
  - *Availability and cost of infrastructure*
  - *Long term world supply*
  - *Fuel consumption penalty (e.g. due to lesser efficiency, boil off)*

Evaluation criteria (2 of 3)

- *Emission abatement cost, including*
  - *PM port compliance (e.g. fuel change)*
  - *SOx SECA (e.g. scrubber)*
  - *NOx SECA (e.g. SCR, EGR)*
  - *CO_2 EEDI (e.g. slow steaming, heat recovery)*
- *Safety related cost, including*
  - *Approvals (classification)*
  - *Additional insurance cost*
  - *Crew training and education*

Evaluation criteria (3 of 3)

- *Indirect cost, including*
  - *Reduced range between bunkering*
  - *Reduced cargo capacity*
  - *Increased waiting time in ports*
  - *Ethics, sustainability*