PLATFORM

SCHEEPSEMISSIES

Welkom
Seminar `SOx`
‘Innovatie en slim ondernemen’

Jan Smits

15.00	- 15.30	Ontvangst	
15.30	- 15.40	Welkom en inleiding	Jan Smits *HME*
15.40	- 16.05	De zwavelrichtiijn van de EU en IMO	David Anink Scheepsbouw Nederland
16.05	- 16.30	Modelshift of Modelshift back=	Paul Altena KVNR
16.30	- 16.55	Bunker fuels of 2015 and beyond: a shared challenge	Cor Nobel *Shell Marine Products*
16.55	- 17.20	Scrubber technologie oplossing voor nu?	Rene Biks *Alfa Laval Aalborg*
17.20	- 18.00	Pauze en licht broodjesmaaltijd	
18. 00	- 18.20	LNG installatie als economisch alternatief	Dan Veen *Wärtsilä Netherlands BV*
18.20	- 18.40	LNG keten analyse; een korte blik	Ruud Verbeek1 *TNO*
18.40	- 19.20	Forumdiscussie: Uitdagingen voor Nederlandse toeleveranciers en reders	
19.20	- 20.30	Netwerkgelegenheid	


Surveyor 2
14

Achtergrond

- Platform Scheepsemissie wil emssie onderwerpen naar de voorgrond brengen
- Confrontatie regelgeving en maritieme industie
- Verrichtte studies en aankaarten noodzaak acties
- Consumenten worden kritischer
- Bewustwordingsproces
- Inzicht in laatste stand van zaken
- Inzicht in mogelijke oplossingen
- Overdracht van ervaring en kennis
- Mogelijkeheden tot samenwerking en projectontwikkeling

Doel Scheepsemissie Platform seminars

- Inzicht in de stand van zaken
- Samenkomen van partners om nieuwe ideeën te lanceren
- Toekomstige uitdagingen en knelpunten aan te pakken
- Nederlandse industrie moet voorop lopen met ontwikkelingen

- Het platform stelt zich ten doel de bewustwoording en samenwerking in de maritieme sector op het gebied van scheepsemissies te bevorderen.

Wat komt er aanbod?

- Welke Sox regelgeving geldt er nu ?
- Wat gaat er vernaderen?
- Wat zijn de mogelijke gevolgen voor de scheepvaart?
- Welke uitdagingen zijn er?
- Wat zijn de mogelijkheden mbt soort brandstoffen?
- Is nageschakelde techniek een haalbare oplossing?
- Wat kan men aan boord doen?
- Is LNG een haalbaar en betaalbaar alternatief en welke voor- en nadelen zijn er?
- Wat moet u nu doen?

Market trend

- Scheepvaart steeds meer onder de aandacht van diverse organisaties
- Scheepvaart in ‘ survival’ mode ivm slechte vrachtprijzen en overcapaciteit
- Opkomende regionale regelgeving: EU maar ook in USA worden de milieueisen aangescherpt.
- Niemand is bereid om nu te investeren en rekening door te belasten.
- Diverse organisatie argeren tegen opgelegde regelgeving

Stellingen

- Hieronder volgen een paar stellingen voor de forumdiscussie:
  - Zolang de verlader er niet voor betaald worden investeringen nagelaten
  - Scheepvaartindustrie moet zich meer met de keten bemoeien en plek binnen die keten goed duidelijk maken
  - De scheepvaart moet hun verplichtingen nakomen omdat voor de andere mobiliteiten ook steeds strengere regelgeving geldt.


www.scheepsemissies.nl
Hartelijk dank voor uw aandacht
en graag tot het volgende
seminar op 15 december 2011
CO2

Zwavelregels van de EU en IMO

Door David Anink

Inhoud

1. Zwavelemissies, waar doen we het ook al weer voor
2. EU 1999/32
3. EU 2005/33
4. MARPOL Annex VI
5. Herziening van richtlijn in 2011
6. Zwavel en NOx
7. Kansen voor de maakindustrie

- Bij de verbranding van zwavel ontstaan zwaveloxides. Wanneer zwavel aanwezig is in een brandstof, zal bij de verbranding van deze brandstof ook de verbranding van zwavel optreden
$S + x\ O_2$ ——> SO_x Zwaveloxides zijn de hoofdveroorzaker van het verschijnsel dat we kennen onder de naam "zure regen". Door "zure regen" worden (oude) gebouwen, maar ook heel belangrijk, de natuur aangetast.
- Zwavel is een soort gif voor katalysatoren. Vrijwel alle auto's zijn uitgerust met een katalysator. Deze zorgt ervoor dat de uitlaatgassen van de auto gereinigd worden. Maar zwavel vervuild de katalysator, zodat deze zijn werk niet goed meer kan doen. Dit is ook de reden waarom de laatste jaren de maximale hoeveelheid zwavel in bijvoorbeeld diesel verlaagd wordt van 350 ppm in 2000 naar 10 ppm in 2007.

"Ships fast becoming the biggest source of air pollution in EU" DG ENV website

- Largest EU transport mode; 77% of freight volume
- 30% man-made global NOx from shipping
- 2020 EU shipping > EU land-based SOx/NOx TSAP 2005
- Average Ship fuel world's dirtiest (S, heavy metals)
- 50,000+ premature deaths annually in EU J Brandt et al. www.CEEH.dk 2011

  = 12% (€61bn) of total health costs of Europe air pollution in 2020
- CO_2 + 90% since 1990; 6% of global 2020; trebled by 2050
- 12-18% 2°C carbon budget by 2050 - IMO 2009

EU richtlijn 1999/32

- Eerste zwavel richtlijn 26 april 1999
- Stelde algemene eisen aan de zwavel norm: v.a. 2003 1% zwavel in zware olie
- Stelde geen eisen aan de zwavel in Zware stookolie scheepvaart
- Gasolie: 2000: max 0,2 %S, 2008: max 0,1%S
- Reeds eenmaal maal herzien

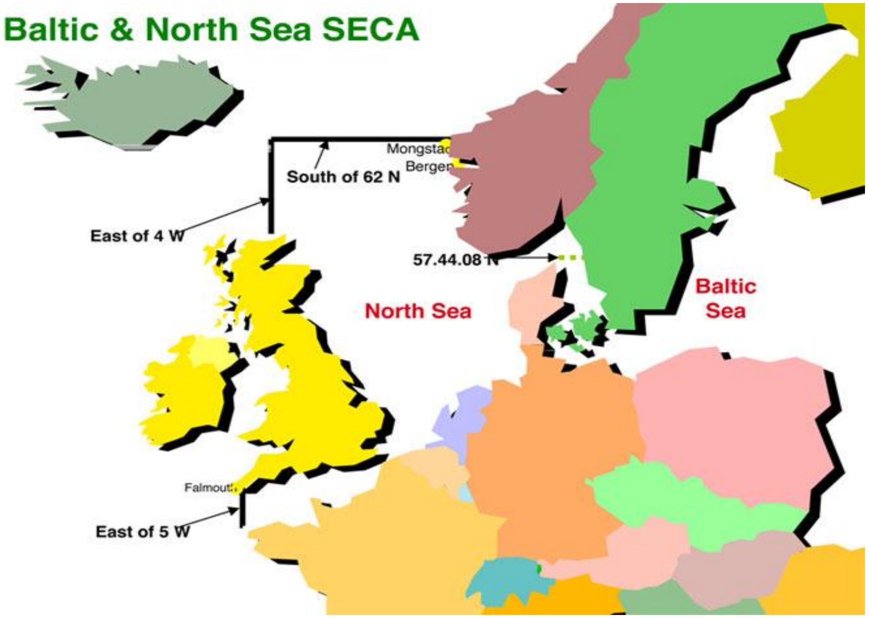
EU richtlijn 2005/33

- Eerste eisen aan zwavel in scheepsbrandstof
- Geen hoogzwavelige gas olie in kustwateren en binnenwateren van de EU (0,1%)
- Invoering van SECA normen (1,5% zwavel)
- Gebruik van nabehandeling toestaan
- Pax schepen van en naar EU zelfde eisen als in de SECA's
- 0,1 % zwavel in brandstof voor de kade vanaf 1 januari 2010

MARPOL Annex VI

- Annex VI 2005 van kracht, Herziend in 2006 en 2008
- Gefaseerde verlaging van zwavelemissies door scheepvaart.
- Invoering van SECA's
- Invoeren van wereld norm
- In Nederland vastgelegd in

Wvvs en Bvvs



Emission control Area

Special areas Annex VI

Area	Adopted	Entry Into force	In effect from
Baltic Sea (SOx)	26 Sept 1997	19 May 2005	19 May 2006
North Sea (SOx)	22 July 2005	22 Nov 2006	22 Nov 2007
North America (SOx and NOx)	26 March 2010	1 August 2011	1 August 2012

Huidige MARPOL Annex VI eisen

- SECA: nu 1 %
  - 2015: 0,1 %
- Buiten SECA:
  - 3,5%
  - 2020 0,5%
- Nabehandeling toegestaan.

Nabehandelingssyetemen

Regulation 4:

The administration of a Party may allow any fitting, material, appliance or apparatus to be fitted in a ship or other procedures, alternative fuel oils, or compliance methods used as an alternative to that required by this anex if such fitting, material, appliance or other procedures, alternative fuel oils, or compliance methods are at least as effective in terms of emission reductions as that required by this anex, including any of the standards set forth in regulation 13 and 14

Guidelines for exhaust gas cleaning systems

- Compliance should be demonstrated on the basis of the SO_2 (ppm)/CO_2(% v/v) ratio values:

Fuel oil supher content (% m/m)	Ratio emission SO_2(ppm)/CO_2(%v/v)
4,50	195,0
3,50	151,7
1,50	65,0
1,00	43,3
0,50	21,7
0,10	4,3

Guidelines for exhaust gas cleaning systems (2)

Approval and compliance:

- Scheme A – EGC system approval, survey and certification using parameter and emission checks
- Scheme B – EGC system approval, survey and certification using continuous monitoring of SOx emissions

Guidelines for exhaust gas cleaning systems (3)

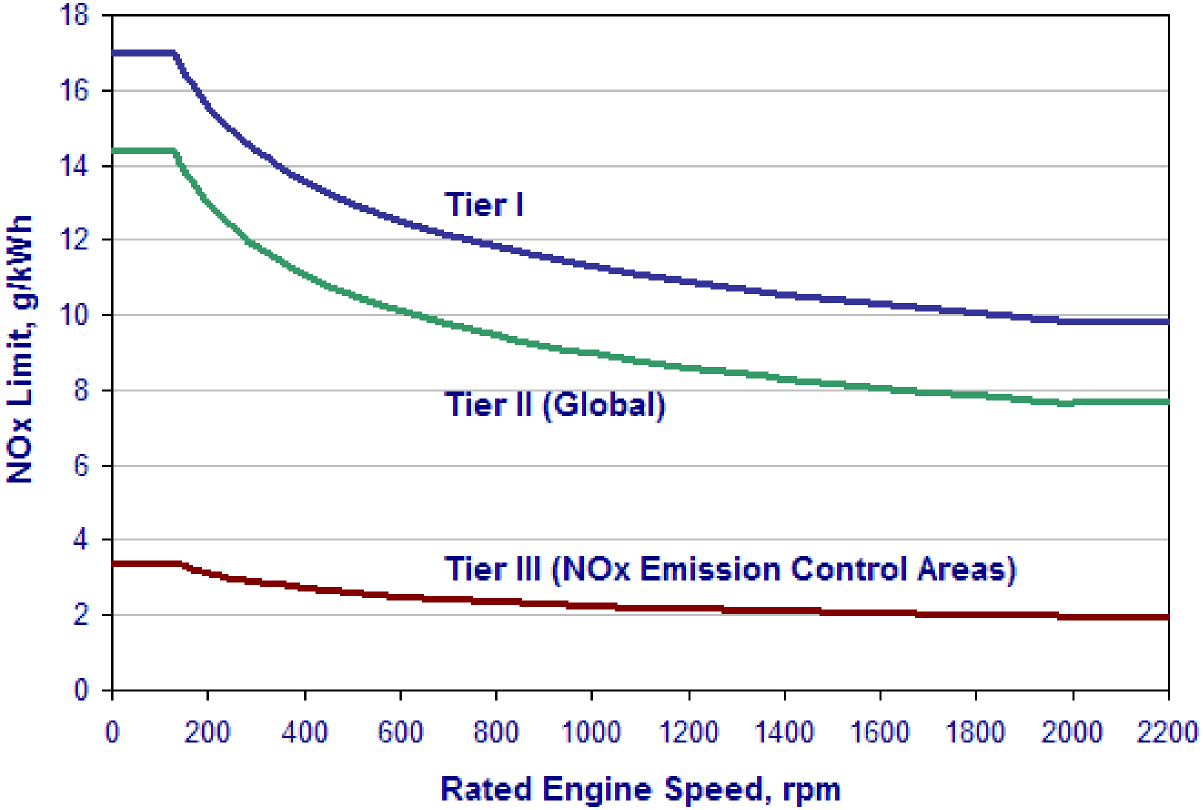
- SOx Emissions Compliance Plan (SECP)
- Washwater discharge criteria
- Continious monitoring of pH, PAH, turbidity and temperature in harbours or estuaries

Herziening richtlijn 1999/32

- In lijn brengen met IMO regels
- Aanpassen van normen voor passagiersschepen van en naar EU waters. Deze worden naar SECA normen gebracht
- Passagiersschepen buiten SECA krijgen wel 5 jaar meer de tijd
- Toelaten van nabehandelingssystemen

MARPOL Annex VI reg 13

- NOx technical code
  - Gefaseerde aanpak voor bestaande en nieuwe motoren



Eisen en de maakindustrie

- Strengere eisen bieden nieuwe uitdagingen
- Biedt mogelijkheid tot ontwikkeling van nieuwe producten
- Naast regels zou ook ondersteuning van marktgang essentieel zijn
- Vroegtijdige samenwerking tussen reders en maakindustrie essentieel

Nieuwe technologieën

- Nabehandelingssystemen
- Laag zwavelige brandstoffen
- LNG / CNG etc.
- Fuel cells
- Walstroom
- Etc..

Vragen?

Bunker Fuels From 2015 and Beyond: A Shared Challenge!

Platform Scheepsemissies

8 September 2011, Putten

Cor Nobel

Shell Marine Products

Disclaimer Statement

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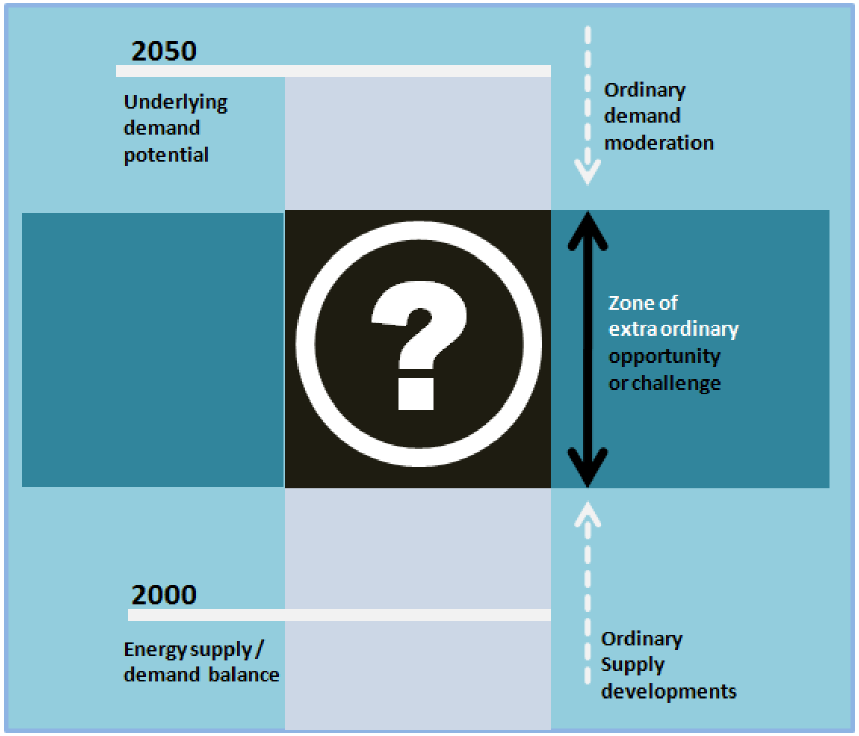
Key Energy Challenges to 2050

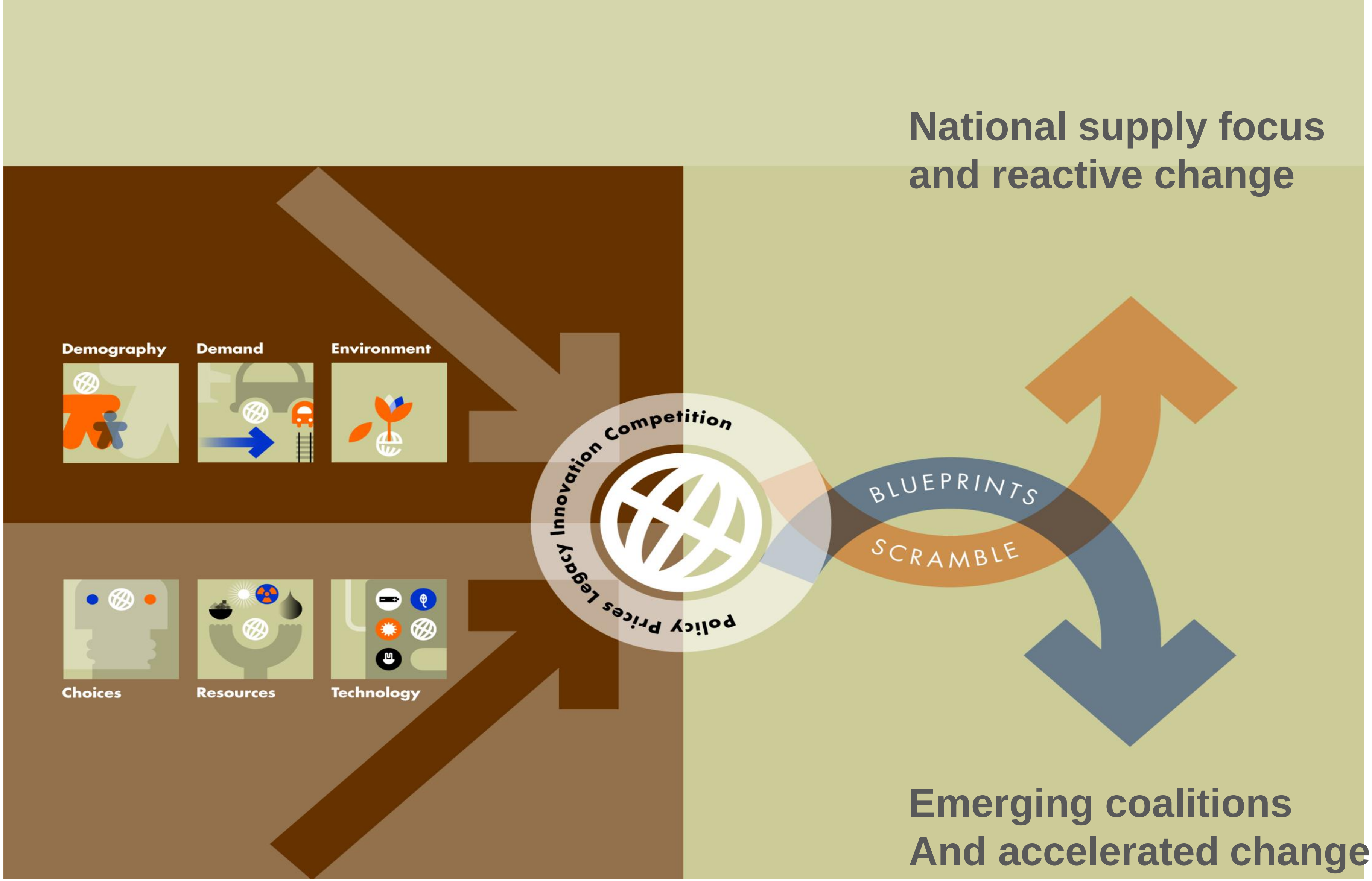
1. Surge in energy demand

2. Supply will struggle to keep pace



3. Environmental stresses are increasing – need to reduce CO_2

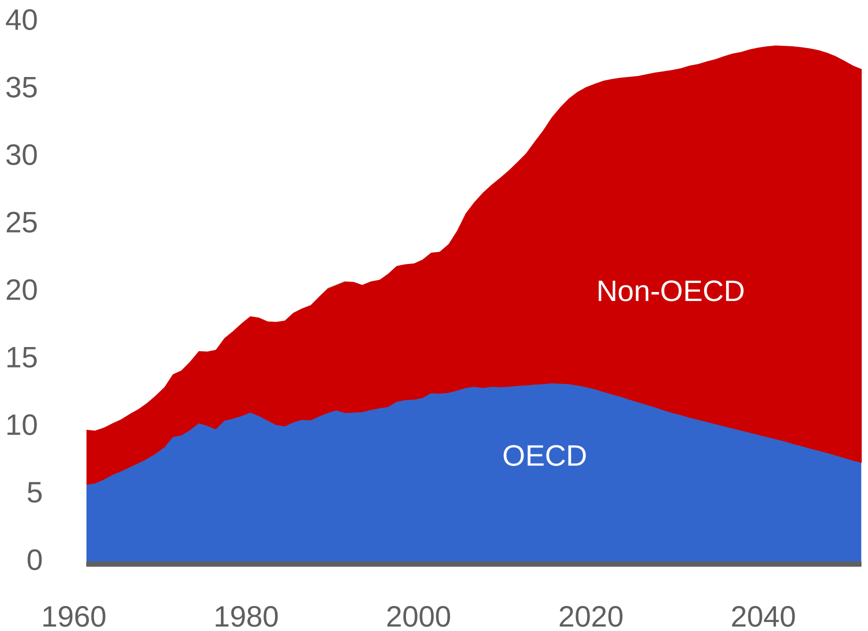
Shell Energy Scenarios: very different futures are possible



CO_2 Emissions: What's Desirable? What's Doable?

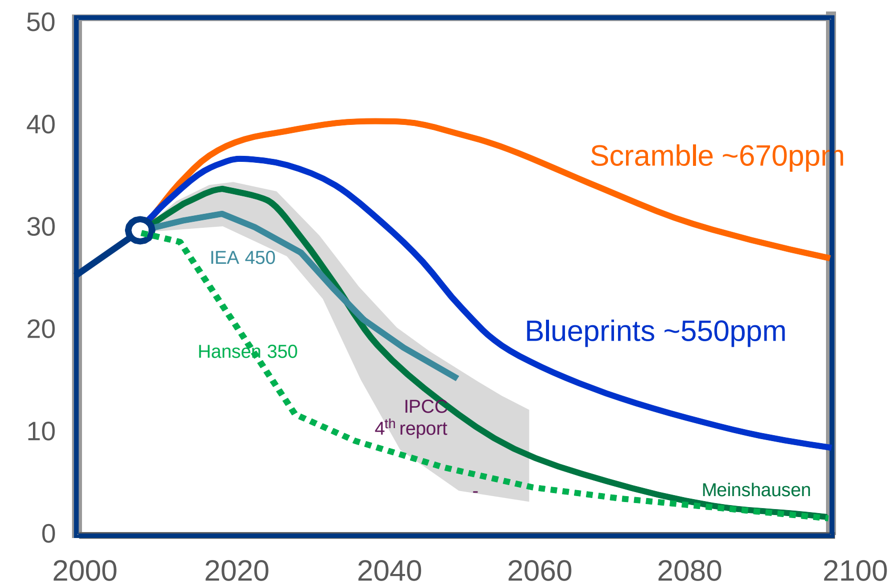
CO_2 EMISSIONS FROM ENERGY

Gigatonnes CO_2 per year



CO_2 PATHWAYS

Gigatonnes CO_2 per year



- Non-OECD emissions have overtaken OECD emissions and will be 80% of total by 2050

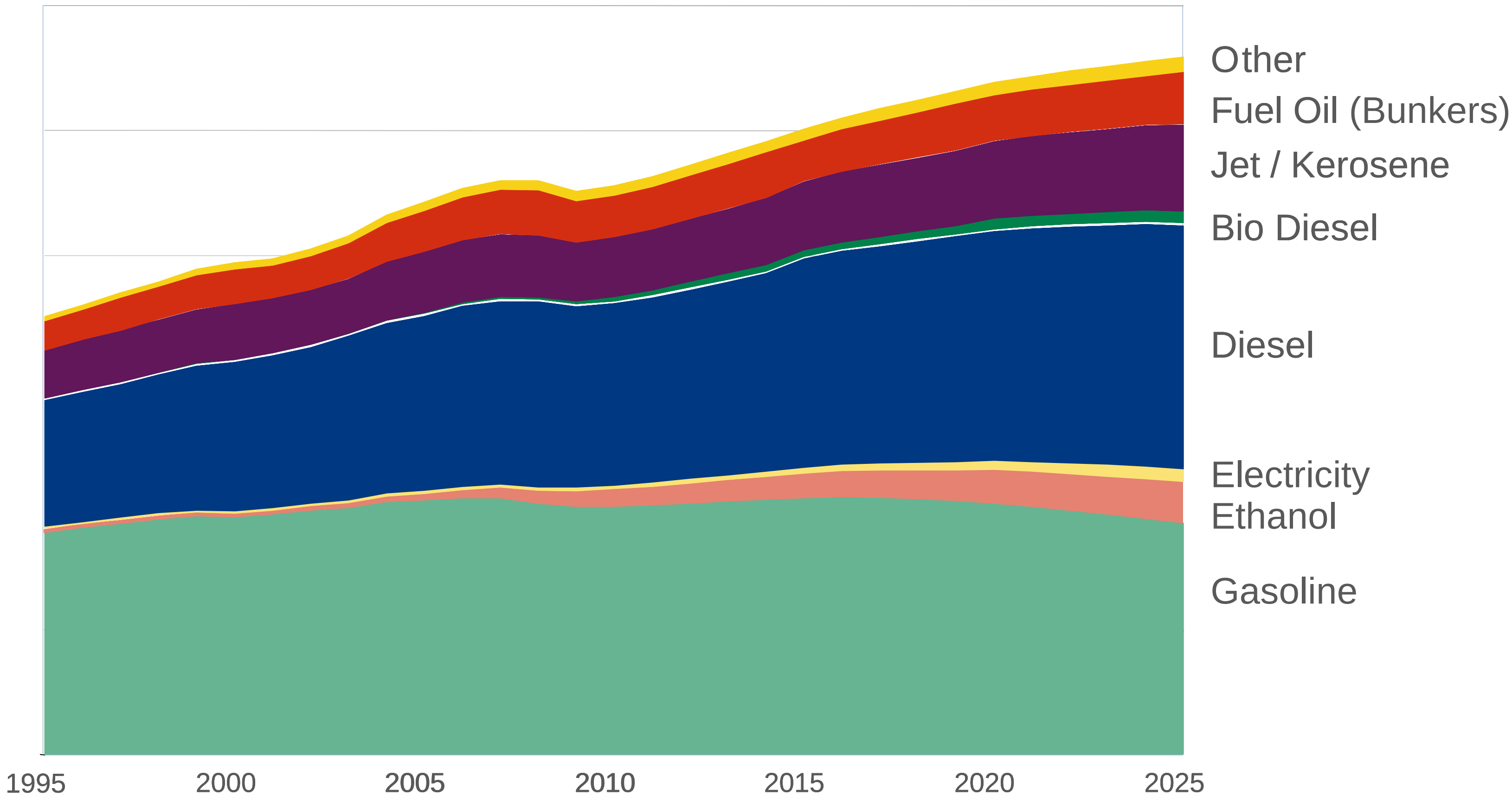
- Is a better than Blueprints pathway possible?
- Or is the world going as slow as Scramble?

SOURCE: IEA, SHELL

SOURCE: SHELL, MIT, IPCC, IEA, HANSEN., MEINSHAUSEN ET.AL.

Demand Growth continues, led by Diesel and Jet

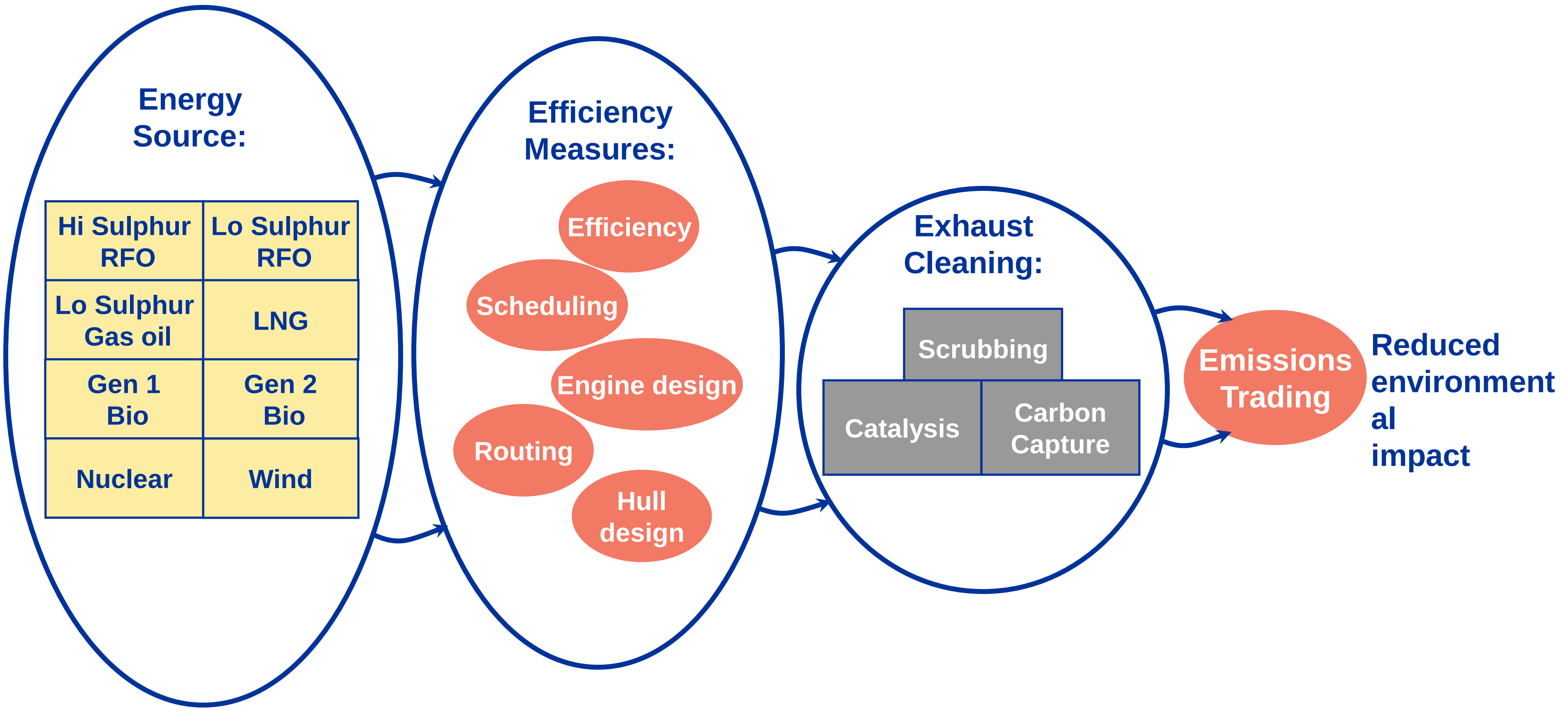
Global Oil Products Demand in Transportation by Fuel Grade



- ***Bunker HFO demand is a relatively small cut of the barrel, but if shipping wants a full switch to Gasoil, this would be a game changer for refiners***

Source: Shell Analysis, historic demand from PIRA

Shipping Emissions to Air: Step changes for SOx, NOx, CO_2
The Path to the Future is not Straightforward

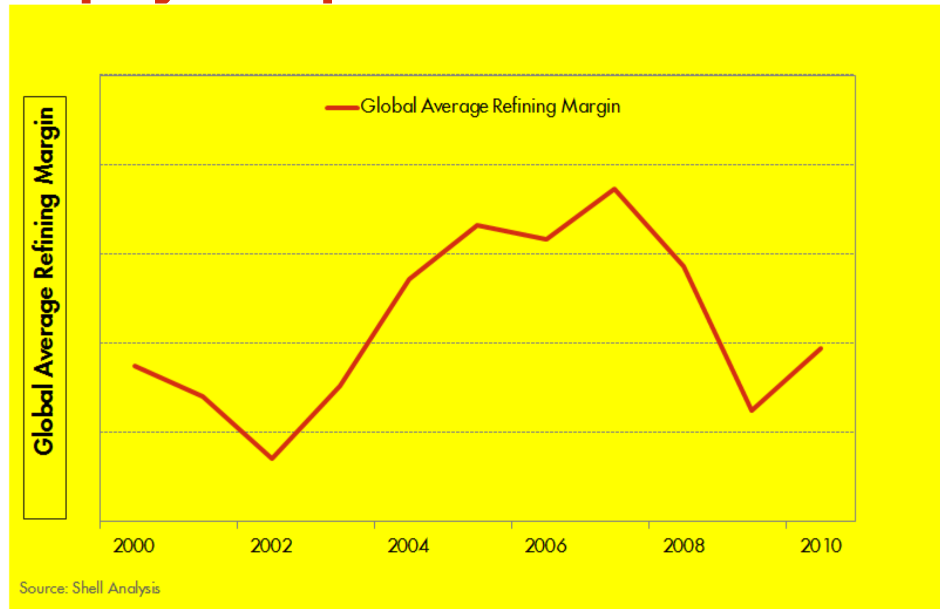


- *There are no easy answers and there is no silver bullet!*

Refinery Solution: 0.1-0.5% sulphur fuel basically means Gasoil

Are bunker consumers ready to pay the price?

- It is uneconomic to desulphurise HSFO and very little 0.5% LSFO available
- Refiners have various options to destroy or upgrade residual fueloil
- Refining industry highly fragmented: Different refiners make decisions basis their own economics / drivers



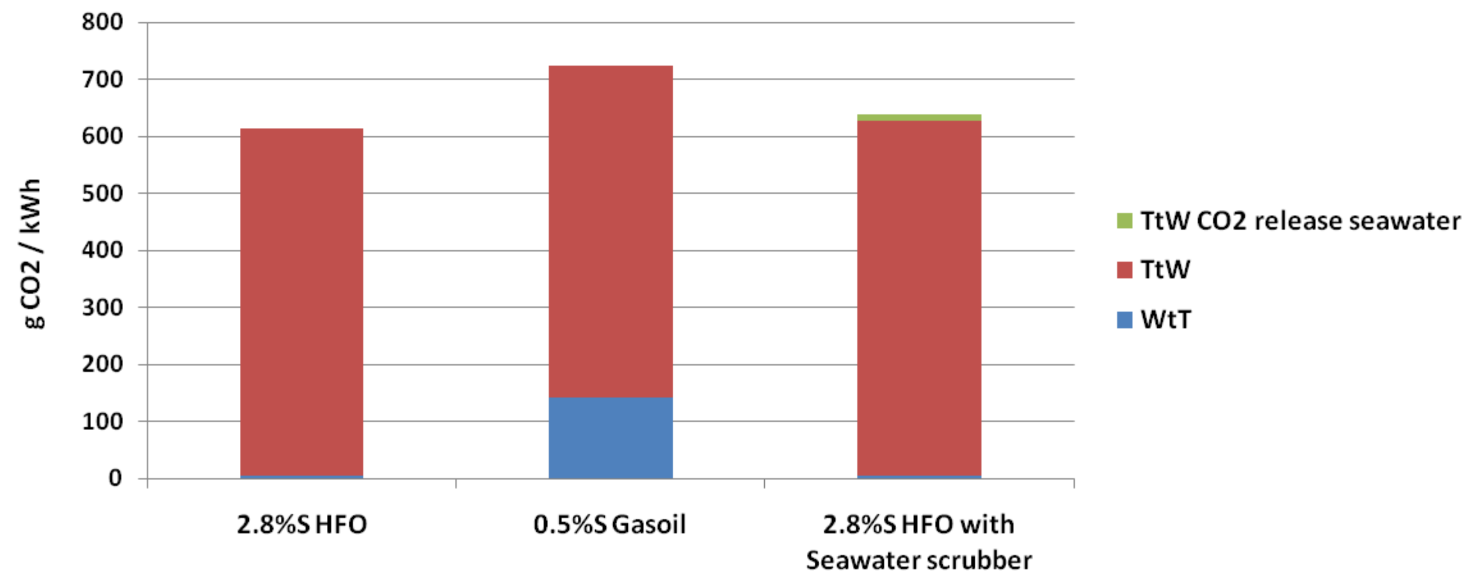
- Investments are substantial but refinery cashflows at lower end of range
- Sense of urgency: ~10 year elapsed time required... ***need to start now!***

If shipping wants low sulphur fuel, refiners will respond but fuel cost will increase significantly and transition unlikely to be smooth...

Scrubbers allow low-cost HFO and lower CO_2 vs Gasoil

- Key advantage: continue to burn low-cost fuel
- Well-to-Wake (WtW) CO_2 lower for Scrubbers/HFO than Gasoil

Car carrier example vessel



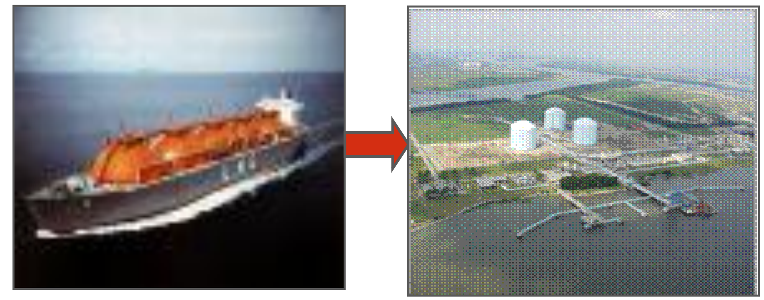
Source: Shell Analysis

- 50-65% of bunkers consumed by ‘only’ 5000-10000 ships
- Scrubbers have own challenges: retrofit, unclear wash water regulations

LNG is attractive for emissions, but would require significant investments to have a material impact on bunker demand

<u>Key Benefits:</u>

- Reduced emissions: Zero SOx ,minimal particulates, significant NOx reduction, 0-20% lower WtW CO_2 emissions



<u>Critical Enablers:</u>

- Clear interest and investments by ship owners: retrofits feasible?
- Development of LNG infrastructure for bunkering
- Continued innovation in engine design and onboard storage
- (Inter)national rules and guidelines for LNG fuelled ships and bunkering

- ***LNG could well play a significant role in ECAs, and could in the longer term offer opportunities for ocean-going demand...***

Bunkers to 2020 and Beyond – What Next?

- 2015 ECAs and 2020 emissions requirements are real discontinuities: will not be 'business-as-usual'!
- No easy answers and combination of responses is likely: efficiency measures, different fuels, abatement, ...
- Well-to-Wake CO_2 will matter, and have a cost
- Refining industry has no clear steer, is not coordinated, and has long investment lead times...

 It's time for urgent engagement between shipping and refining to chart the course together!

KONINKLIJKE VERENIGING VAN NEDERLANDSE REDERS

SOx - Modal Back Shift

Platform Scheepsemissies
8 September 2011

Paul Altena
Stafmedewerker Milieuzaken KVNR

Koninklijke Vereniging van Nederlandse Reders

(S)ECAs

- 2011
  - * Noordzee
  - * Het Kanaal
  - * Oostzee
- Augustus 2012
  - * VS, Canada
- 2014
  - * VS Caribisch gebied
- >2012
  - * Japan? Singapore? Middellandse Zee?

Brandstoffen

- Zwaveleisen

	Wereldwijd	ECA	ECA reductie
2011	4,50%	1,00%	78%
2015	3,50%	0,10%	97%
2020/2025	0,50%	0,10%	80%

- Huidige prijzen (Rotterdam 7/9/2011)

  * IFO380 643 $/ton
  * MDO 933 $/ton (+45%)
  * MGO 955 $/ton (+49%)

Modal Back Shift

Impact studies van de EU, lidstaten, instituten en belanghebbenden

- ISL (Duitsland)
  - * 46% verlies aan lading SSS
  - * 604.000 trailers naar wegvervoer
  - * 820.000 containers naar wegvervoer
  - * 187 milj. extra truckkilometers op de Duitse wegen

Modal Back Shift

- Compass Studie EU

- EC voorstel EU Sulphur Directive
  - * Bevestiging

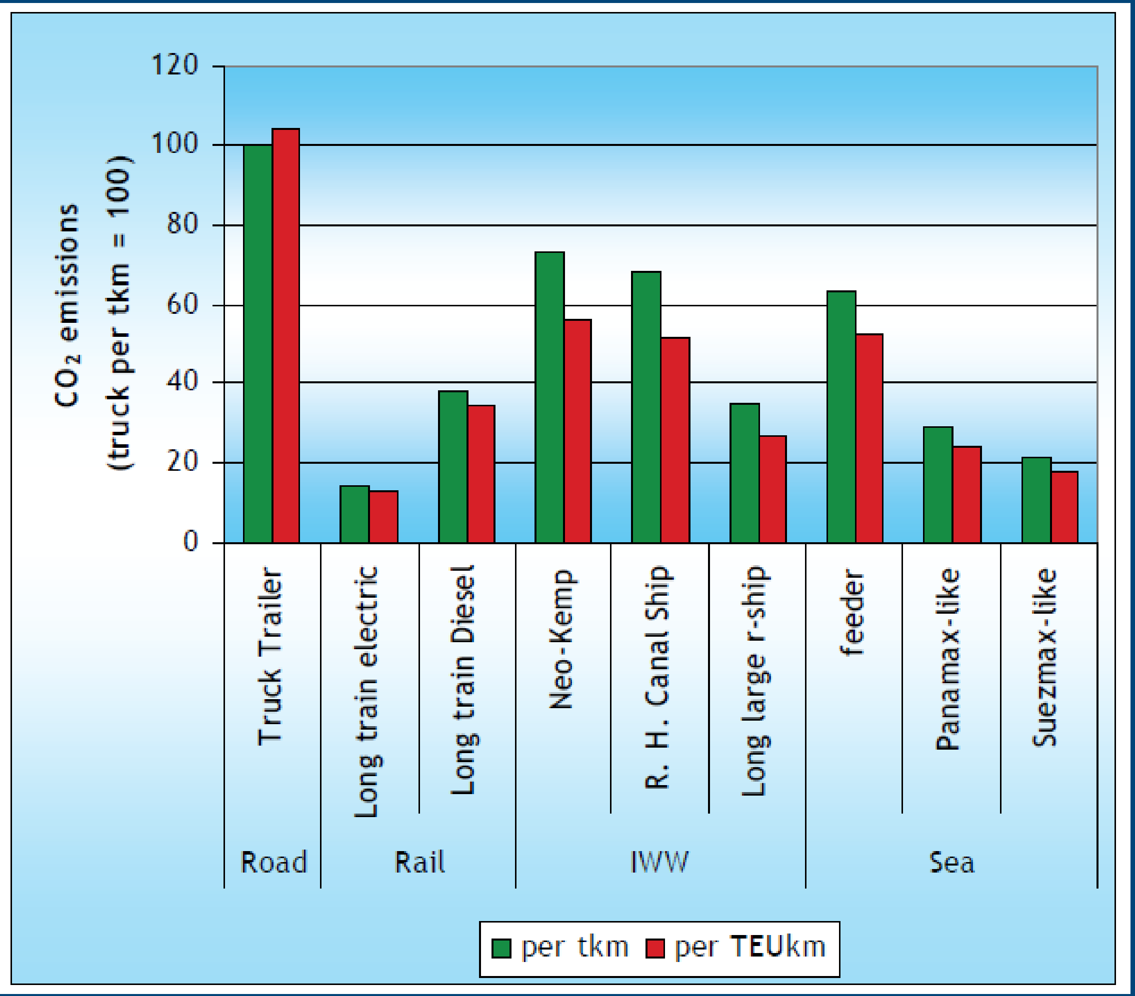
Modal Back Shift

- Meer locale emissies van:
  - * NOx
  - * PM
  - * Congestie
  - * Ongevallen
  - * Geluid
  - * Etc.

- EU 2050 Transport beleid
  - * Stimulering van SSS

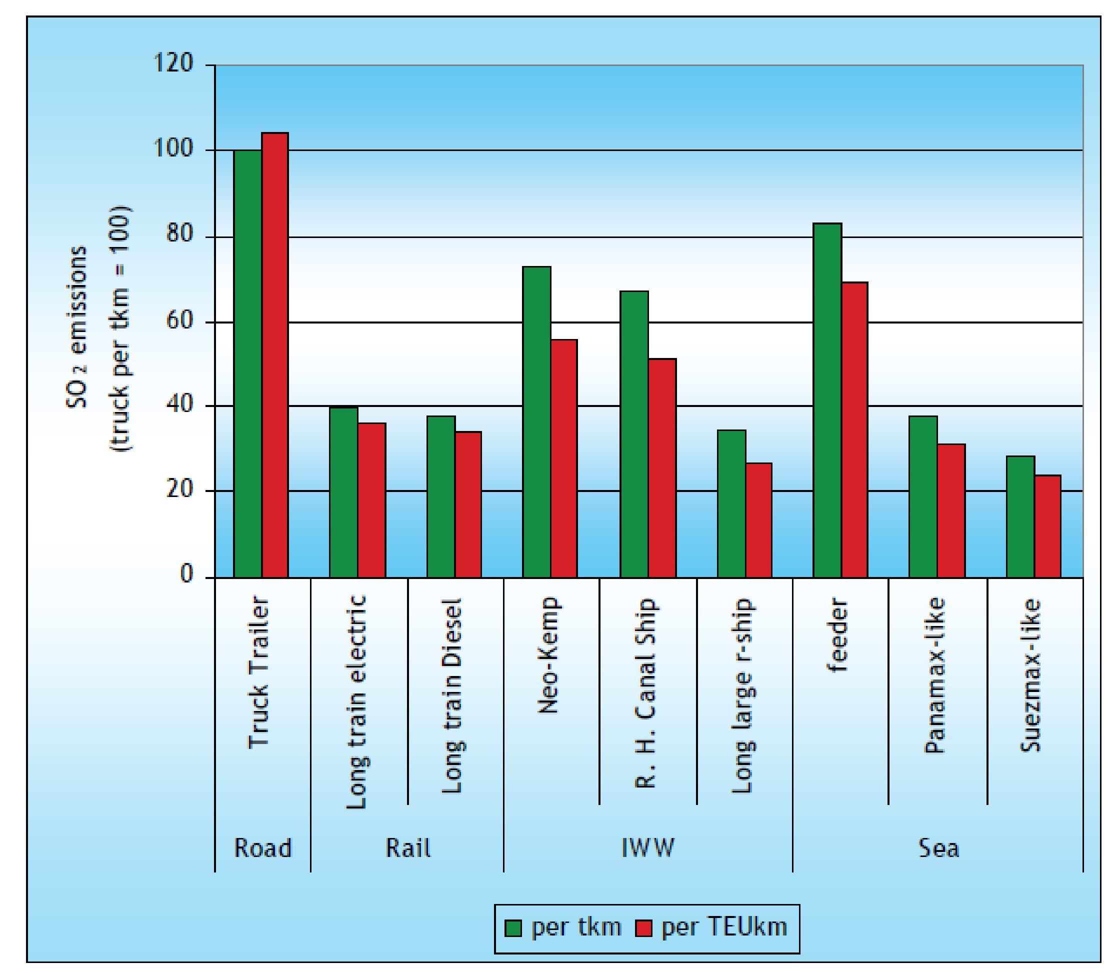
Modal Back Shift

- CO2



Modal Back Shift

- SO2



Mitigating options

- Laagzwavelige brandstof
  - MGO
  - LNG
- Scrubbers
  - Dry
  - Sea water
  - Fresh water
- Equivalente maatregelen
  - Marpol Annex 6 vs EC-Directive 2005/33/EC

Mitigating options

Beschikbaarheid en feasibility

- MGO
- LNG
  - * Financieel / Technisch / Operationeel
- Scrubbers
  - * +/-10 verschillende systemen
  - * Voornamelijk getest op kleinere (hulp)motoren
  - * Weinig ervaring continue operatie
  - * Financieel / Technisch / Operationeel

Relevante ontwikkelingen

- NECA VS/Canada
  - * Tier III – 2016
  - * Motor efficiency
  - * Baltic?
  - * Noordzee?
- Ballastwater
  - * 2014 – D1
  - * 2016 – D2
- CO2 reductie
  - * EEDI / SEEMP
  - * MBM's (EU; IMO; Wereld)?

-> Opstapeling investeringen

Openstaande vragen

- Laagzwavelige brandstoffen
  - * Beschikbaarheid - Investeringen raffinage capaciteit
  - * Prijs
    - CO2 prijs
    - Invoer EU
    - Vraag
- Equivalente maatregelen
  - * Interpretatie
  - * Administratieve kosten

Openstaande vragen - Scrubbers

- Technische zekerheid
  * Belastingswisselingen
- Operationele zekerheid
  * Continue operatie, gewicht, volume
- Juridische zekerheid
  * Waswater criteria, wat als system niet werkt
- Subsidies, lease constructies, extra CO2 emissies

Openstaande vragen - LNG

- Prijs
  * Opdrijvend effect grotere vraag
- Beschikbaarheid (Kip-ei)
  * Bunkerstations, NIMBY
  * Stimulering EU / NL
- Bemanningseisen
- Ruimte / gewicht
- Technische aanpassingen
- Bunkeringproces
  * Mogelijkheden laden en lossen (passagiers)

Voorstel KVNR

Uitstel ≠ afstel

- Wereldnorm vs eca norm
- IMO Marpol Annex 6 vs EU Richtlijn
  - * Relevantie EU Richtlijn
  - * Passagiersschepen
  - * Equivalente Methoden
  - * Non-availability clausule

Voorstel KVNR

0.1% S in 2020

- IMO Fuel Availability studie uitvoeren op korte termijn, inclusief 0.1% ECA
- Testprojecten Scrubbers
  - * Meerdere typen schepen, operationele profielen, zwaardere motoren, EU-breed
  - * Waswater criteria
  - * EGCSA : afronding 2014
- Financieringsmogelijkheden uitbreiden
- Garanderen bedrijfszekerheid gebruikers en leveranciers

Bedankt voor uw aandacht

www.kvnr.nl
altena@kvnr.nl

KONINKLIJKE VERENIGING VAN NEDERLANDSE REDERS

IMO GHG Study 2009

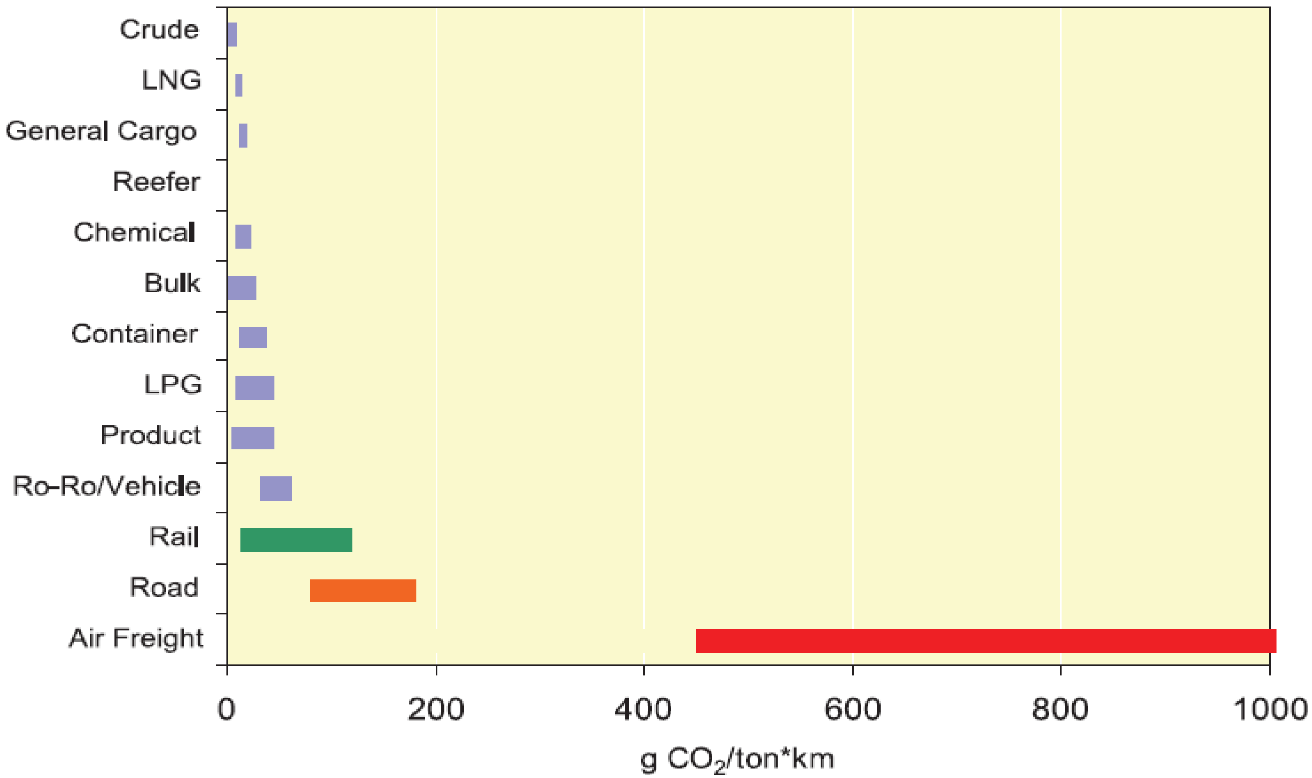


Figure 9.3 *Typical range of ship CO_2 efficiencies compared to rail, road and air freight*

IMO GHG Study 2009

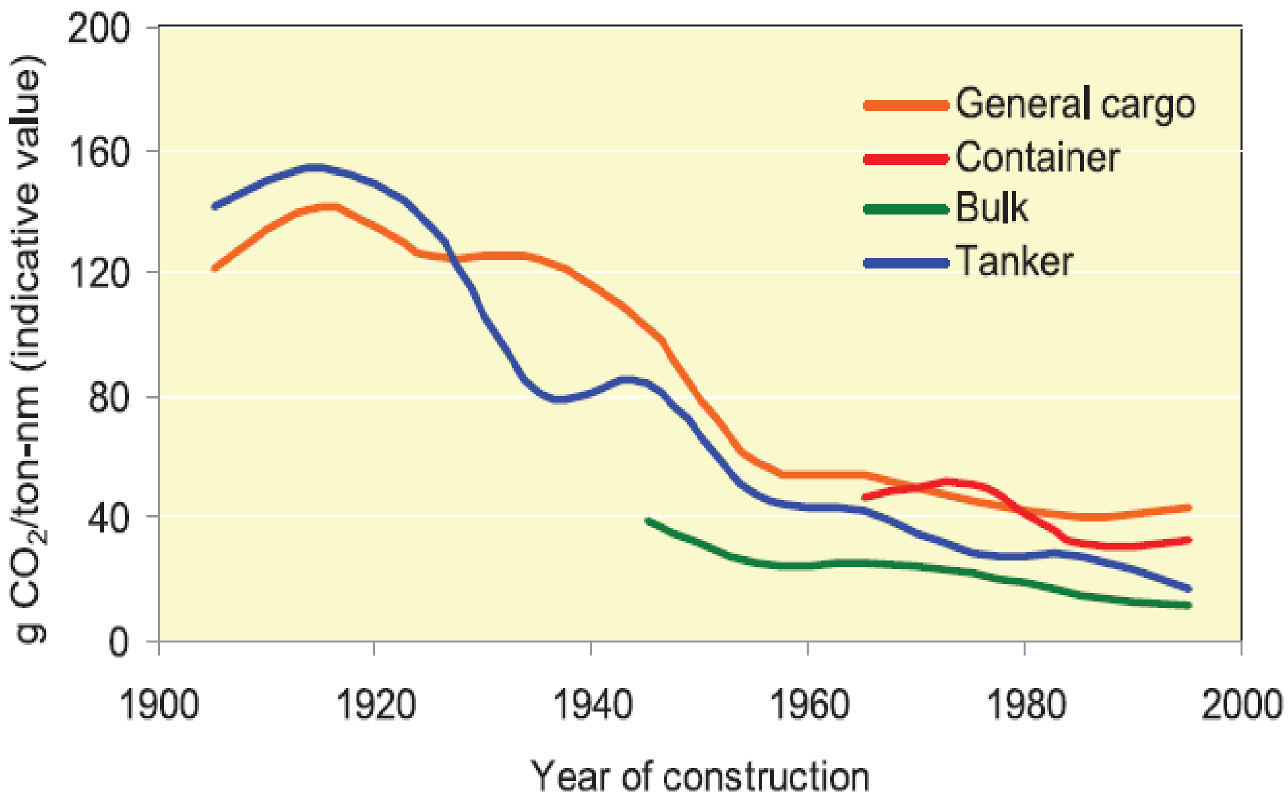
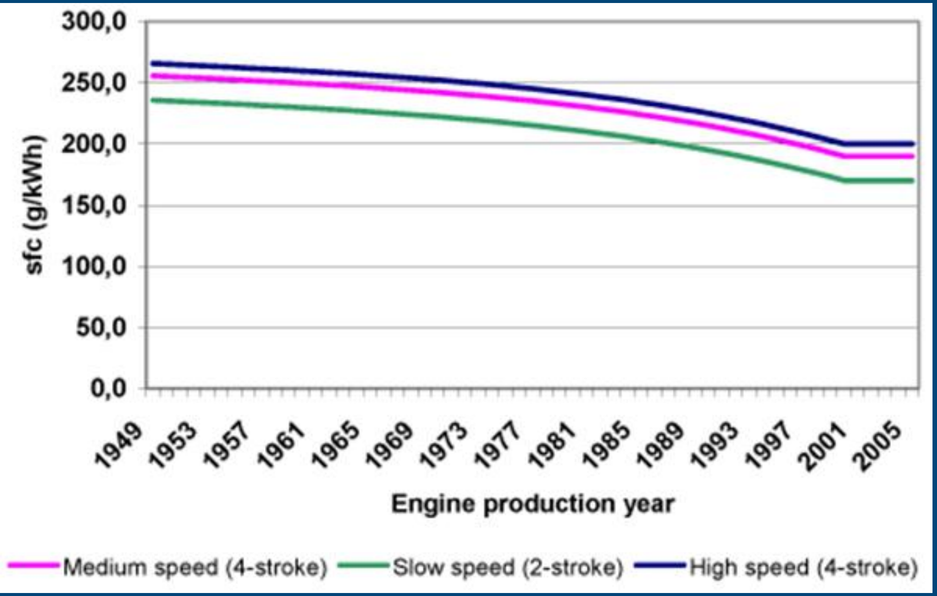
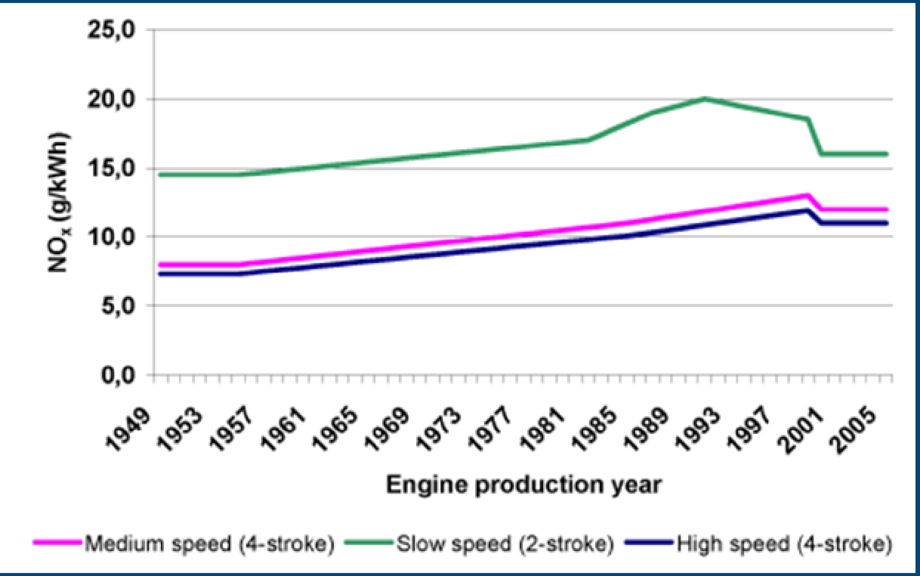


Figure 9.4 *Indicative development in average ship design transport efficiency*



Danish Ministry of Environment 2009



www.alfalaval.com

AALBORG INDUSTRIES - PART OF THE ALFA LAVAL GROUP

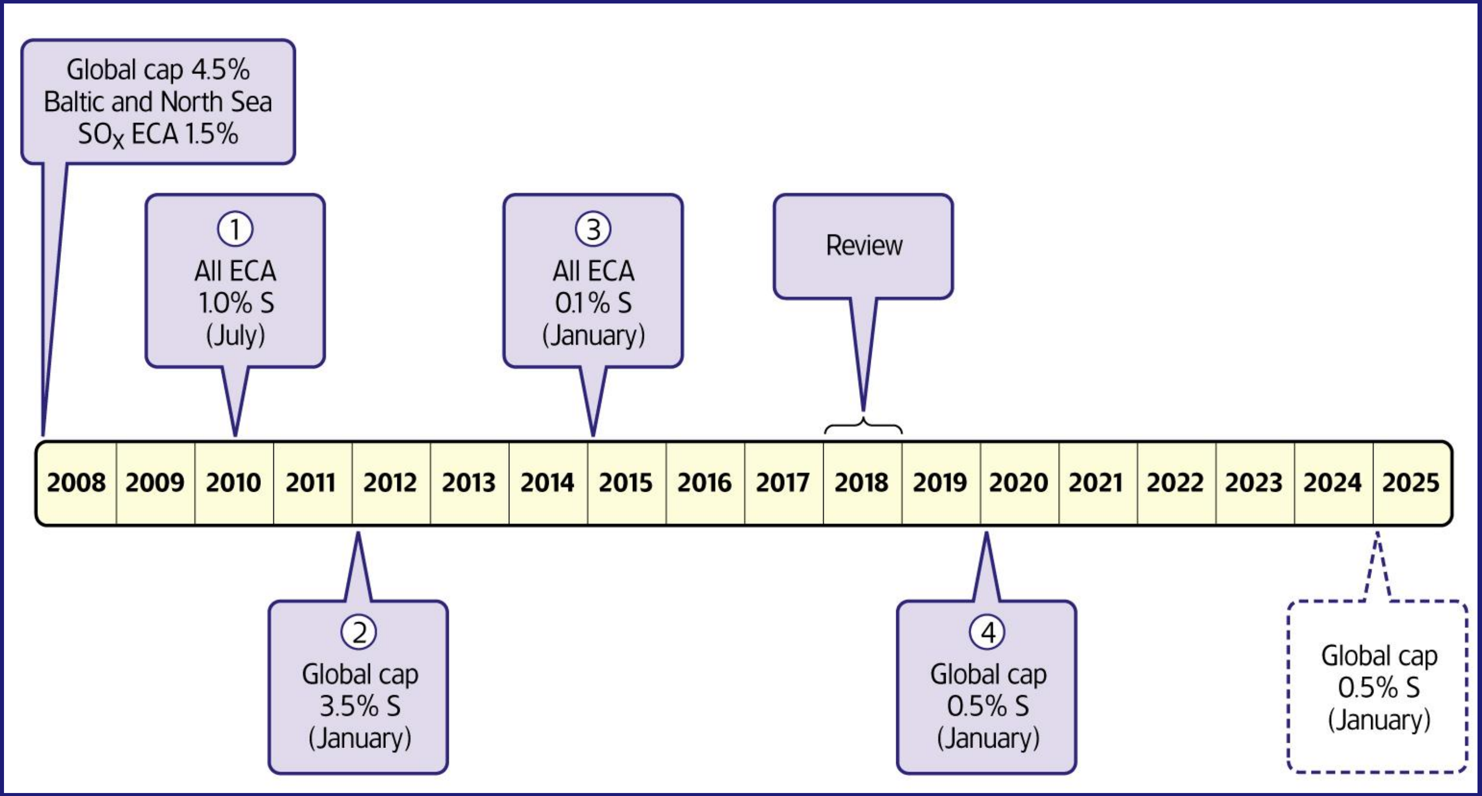
Seminar SO_x Richtlijnen

September 8th 2011

Exhaust gas cleaning

Legislation

SO_2 reduction schedule



Source: IPIECA

Expanding Emission Control Areas

ECA 1 – North Europe
ECA 2 – U.S + Canada – Aug 2012
ECA 3 – U.S Carribean - 2012
ECA 4 – Japan
ECA ? – Singapore ? Australia ? Med .?

Source: www.imo.org

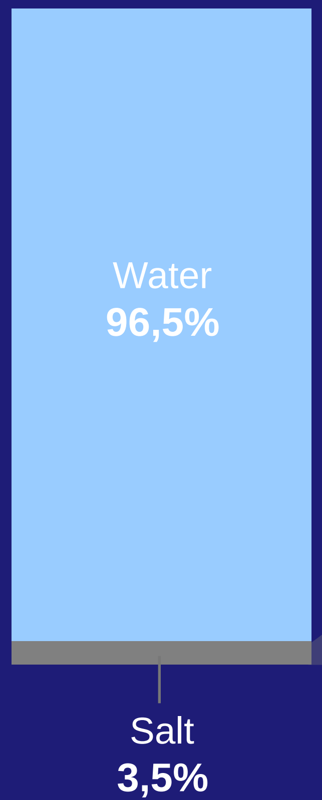
Discharge water criteria

- pH ≥ 6.5 for the overboard discharge (dilution okay)
- Limit on dissolved oil (PAH)
- Nitrate: Max. 12 % of NO_x in exhaust gas or max. 60 mg/liter
- Limit on soot particles (turbidity)
- No maximum sulfate level

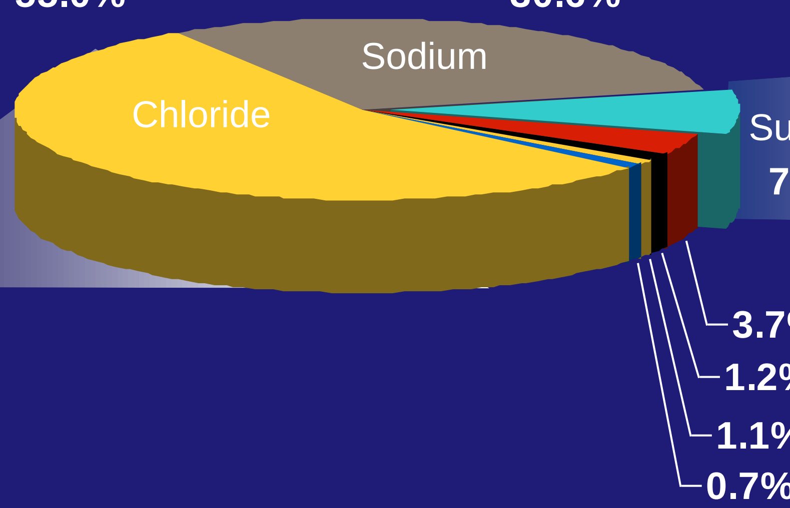
Environmental impact

Impact on Sea Water emissions

Sea water



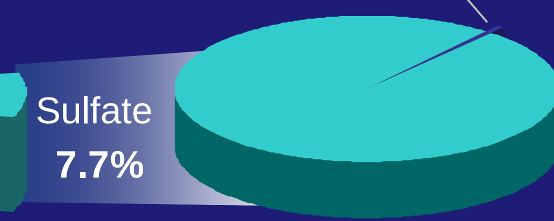
Sea salts



Sulfates

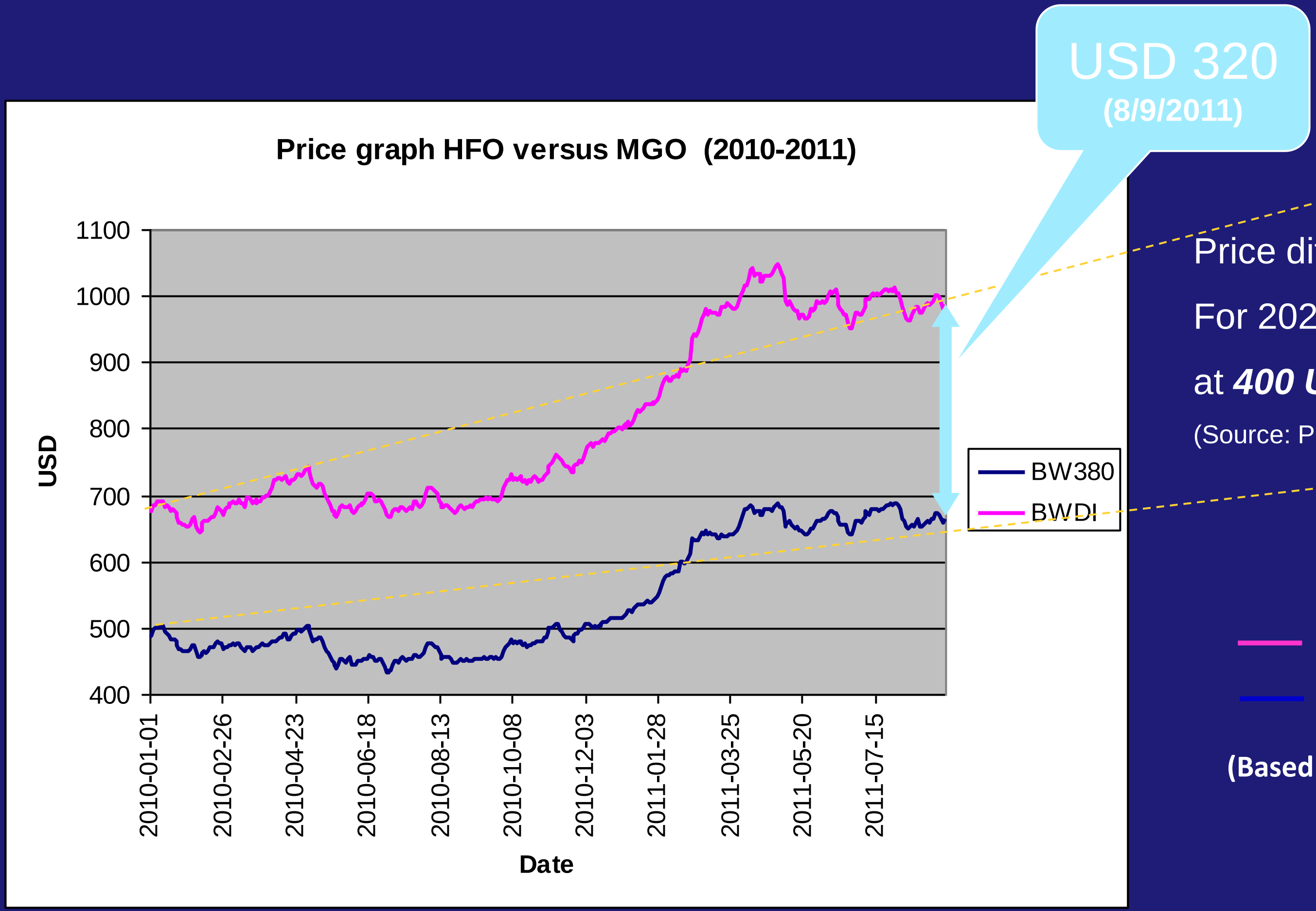
Sulfates are harmless to the environment and a natural constituent in seawater and organisms.

Burning all known oil reserves in the world the sulphate increase would be difficult to measure.



Fuel price development

Fuel price development



Price difference HFO-MGO

For 2020 estimated

at ***400 USD/mt***

(Source: POTEN & PARTNERS 2010)

MGO

HFO

(Based on average value 20 ports)

Distillates will significantly increase in price

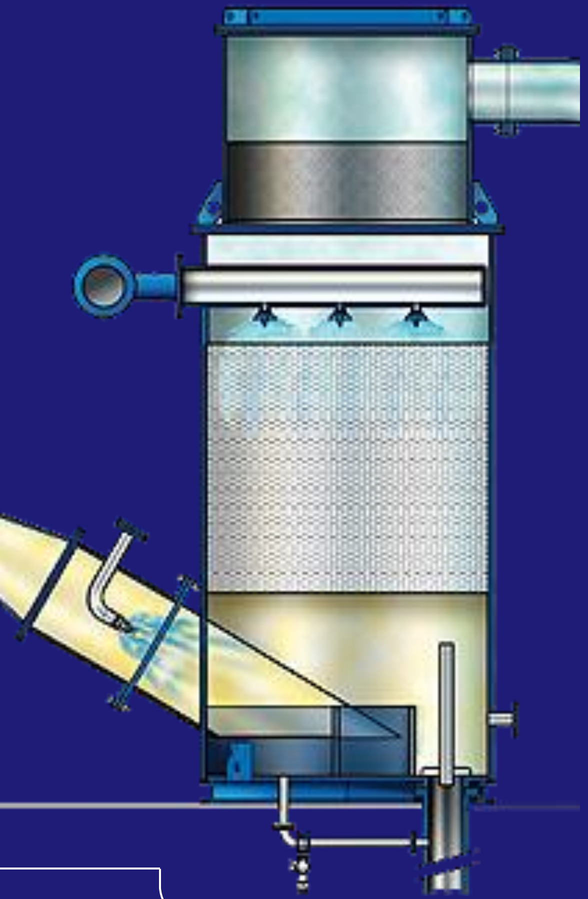
Reasons to believe………

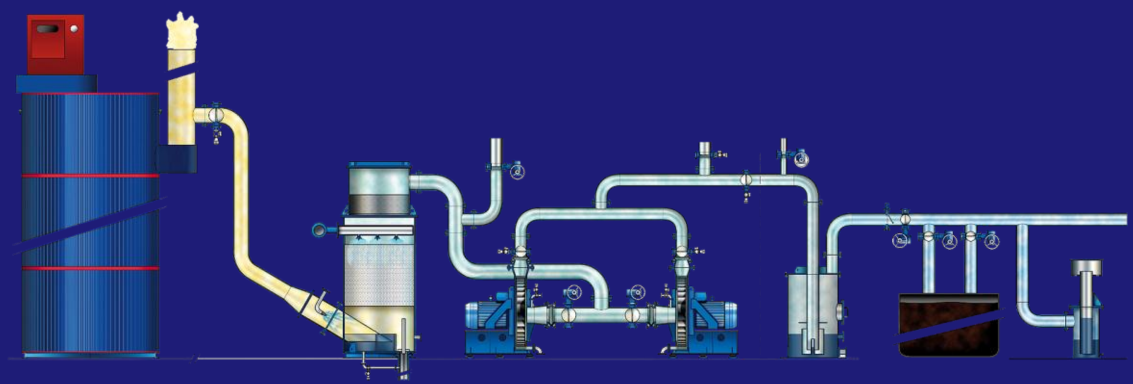
- Shortage of distillates is foreseen, already in Europe we import 30 million tonnes a year (we would need another 50 million)
- Distillate fuels will have to compete with road transportation fuels
- Refinery investments are uncertain and will take > 2020
- Refinery industrie is very fragmented (Shell ~4% market share)
- Distillates will increase worldwide CO_2 levels (well to hull)

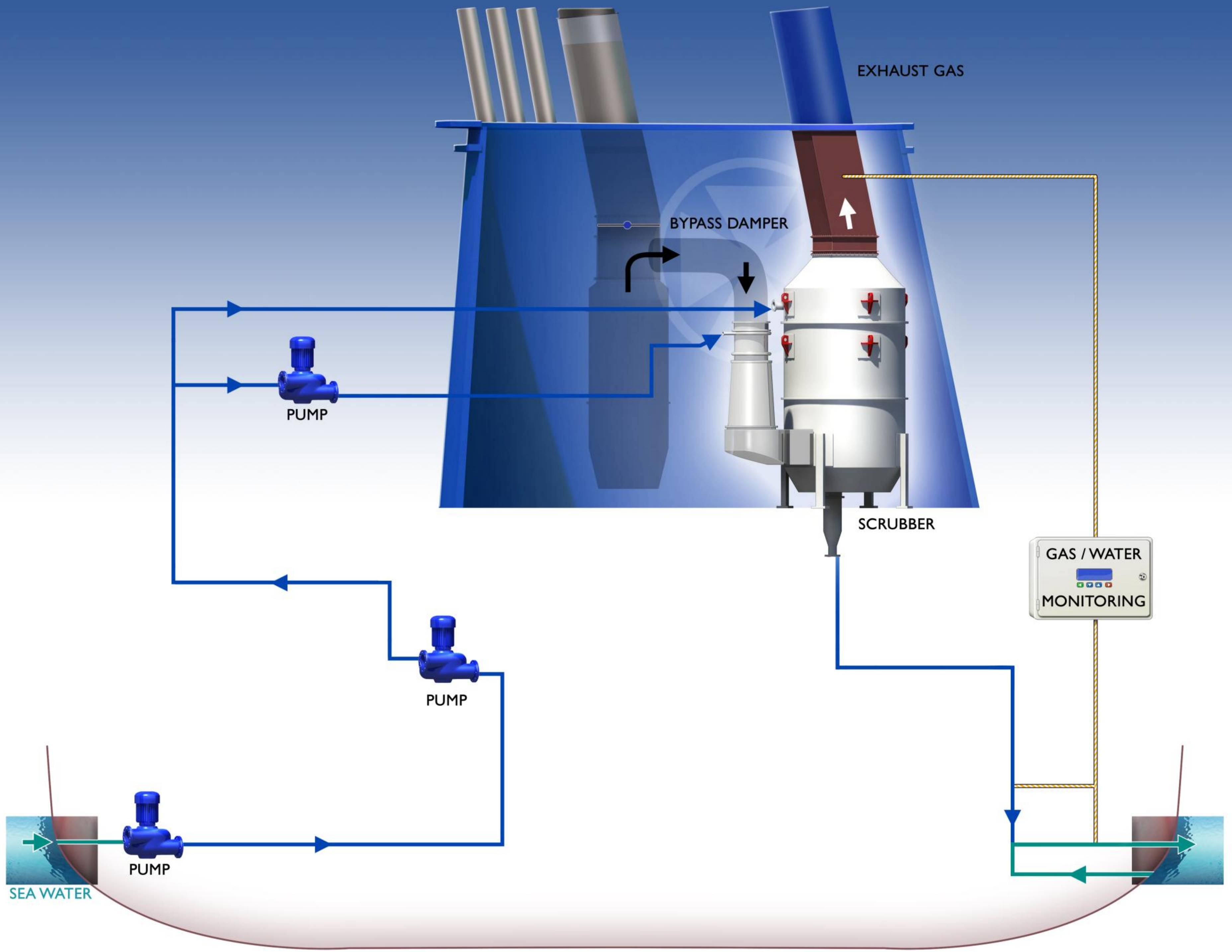
EGC, How does it work?

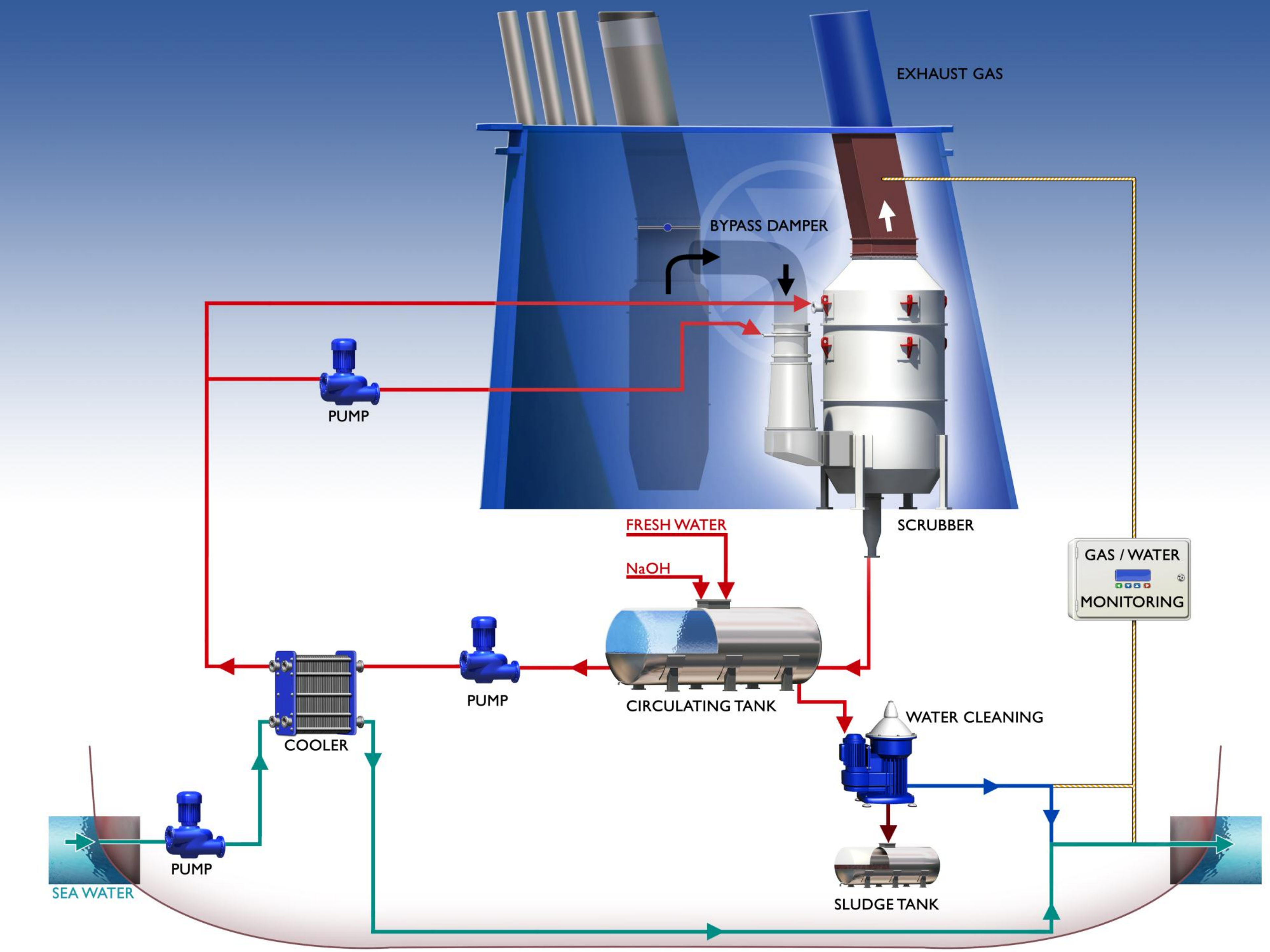
Technology history

- ~1000 Flue gas systems sold since 1972
- ~3000 Combustion systems sold with scrubber section

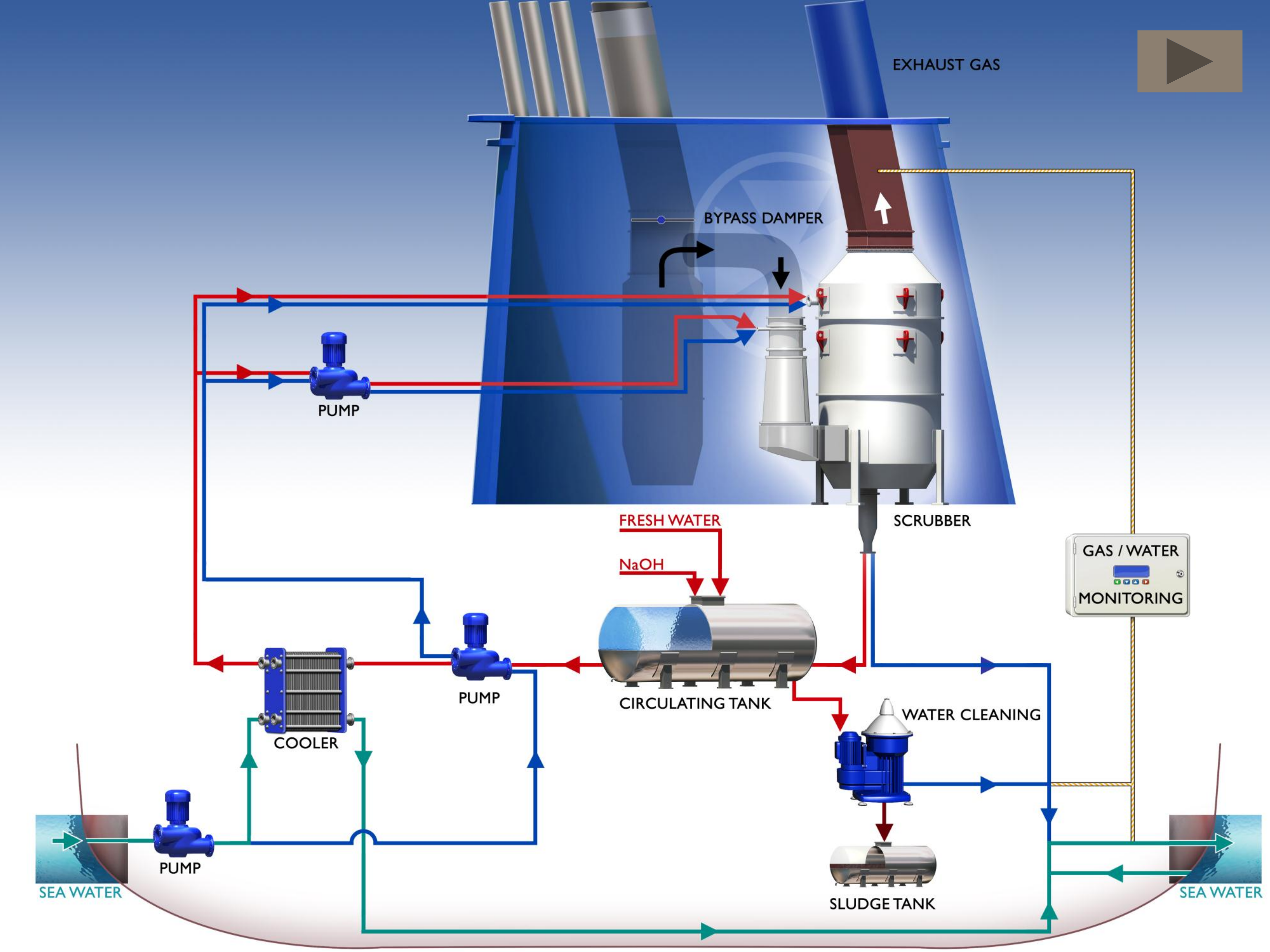





EXHAUST GAS
BYPASS DAMPER
PUMP
SCRUBBER
GAS / WATER
MONITORING
PUMP
PUMP
SEA WATER



EXHAUST GAS
BYPASS DAMPER
PUMP
FRESH WATER
NaOH
SCRUBBER
GAS / WATER
MONITORING
PUMP
CIRCULATING TANK
WATER CLEANING
COOLER
PUMP
SEA WATER
SLUDGE TANK

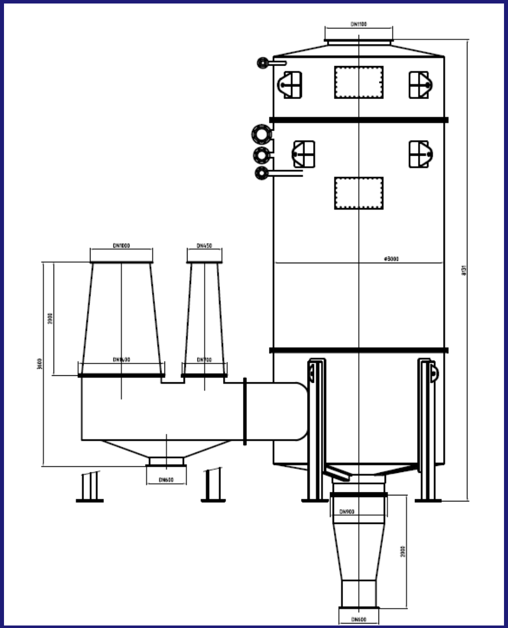


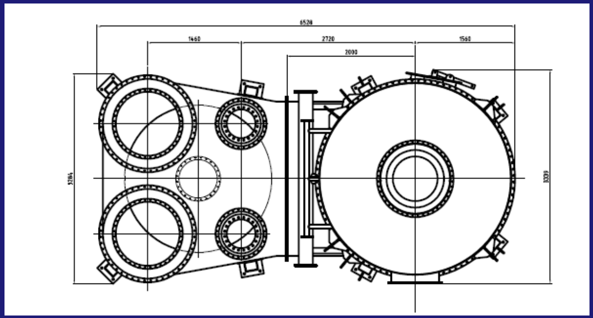
EXHAUST GAS
BYPASS DAMPER
PUMP
SCRUBBER
FRESH WATER
NaOH
GAS / WATER
MONITORING
PUMP
CIRCULATING TANK
WATER CLEANING
COOLER
PUMP
SEA WATER
SLUDGE TANK
SEA WATER

Advantages hybrid system

- Running on SW at open sea whenever possible (lowest costs, ease of operation)
- Zero discharge whenever required (ports, estuaries, sensitive area's)
- Ability to cope with low alkalinity waters (Baltic, estuaries, rivers)
- No switching between MGO/HFO -> maximum fuel savings
- Maximum flexibibility

Multiple inlet systems





- Combinations of ME + AUX
- Less space required
- Less investement costs
- Other configurations possible

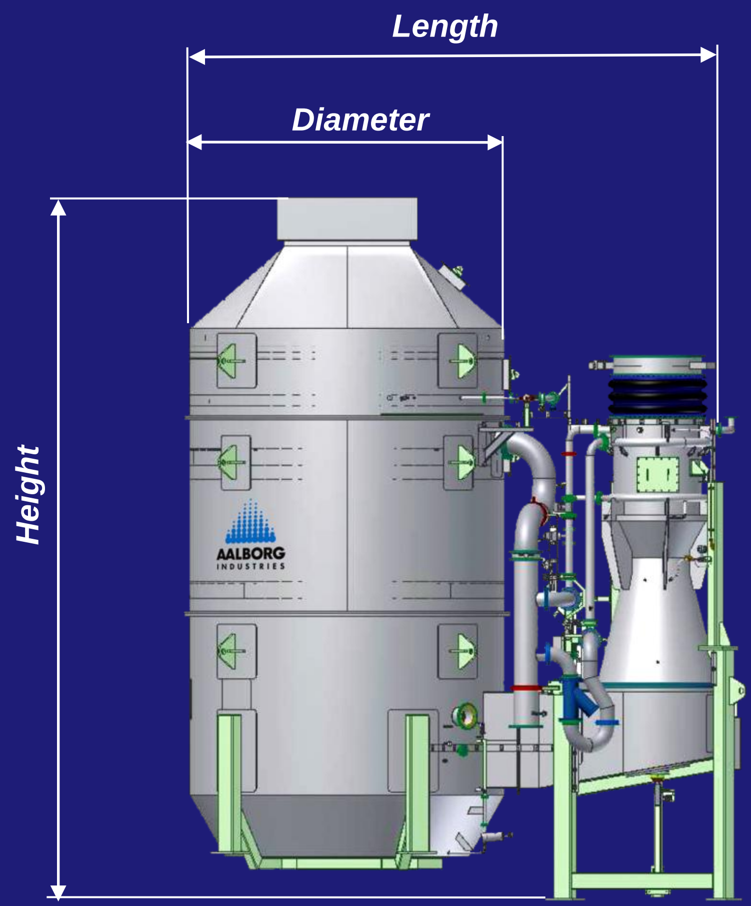
Retrofit on DFDS Tor Ficaria

Technical data Tor Ficaria

Technical data

- Year built 2006
- Length 199,8 meters
- Width 26,50 meters
- Speed 22,5 knots
- Cargo capacity 3,831 lane meters
- MAN B&W type 9L60 MC-C (21MW)
- Classification LRS

EGC installed on Tor Ficaria



Technical data:

• In operation since	May 2010
• Height	10.5 Meters
• Length	8.2 Meters
• Diameter	4.6 Meters
• Weight empty	24T
• Weight with water	32T
• Exhaust gas	192,000 Kg/h
• Material	SS alloys
• PM Scrubbing	Jet + venturi
• Sea water pump	200KW/1000m^3/h

DFDS Tor Ficaria
Funnel - modification

Before	During	After


A Day in the life of a Scrubber

Nr.	Fuel Spec.	Mode	NaOH kg/h 50 % solution
1.	1200l/h (2.2%)	FW	115kg/h
2.	2500l/h (2.2%)	SW	---
3.	1800l/h (2.2%)	FW	172kg/h
4.	3900l/h (2.2%)	SW	---
5.	2400l/h (2.2%)	FW	229kg/h

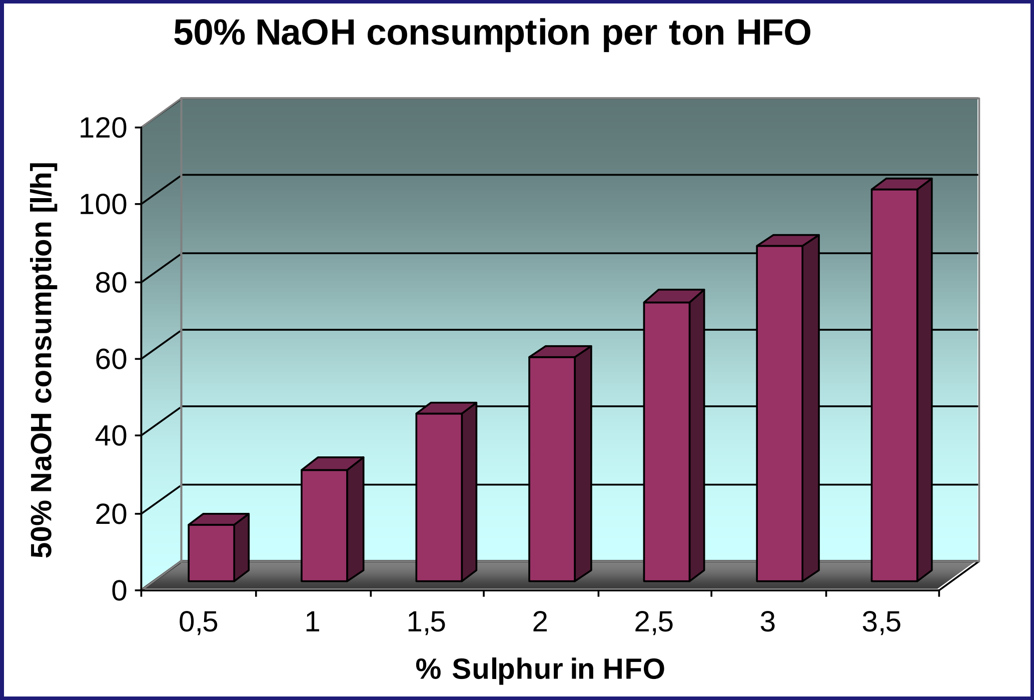
Operational Performance

June 2010 - June 2011

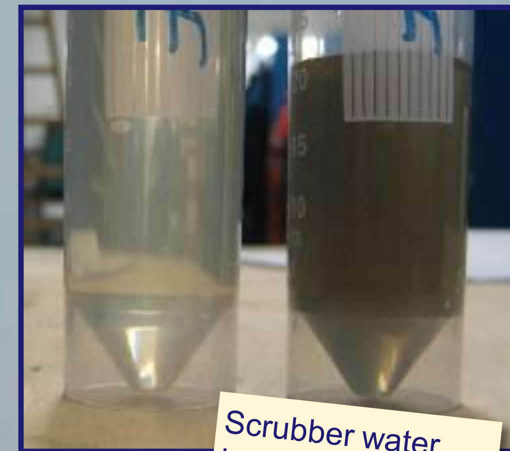
- 3018 hours of operation
- The exhaust from combustion of 7711 ton of HFO has been cleaned
- 170 ton of SO_2 has been removed
- The scrubber plant is handed over to the crew
- Actual monthly saving (1%S - 2,2%S): USD 45,000

NaOH consumption

- **NaOH**
  - Concentration: 50%
  - Density 1.48 kg/l
- **HFO**
  - Sulphur: 2.2%
  - Density: 0.98kg/l
- Molar Reaction rate [NaOH/S]: 1.75



Alfa Laval separator used onboard for SO_X treatment



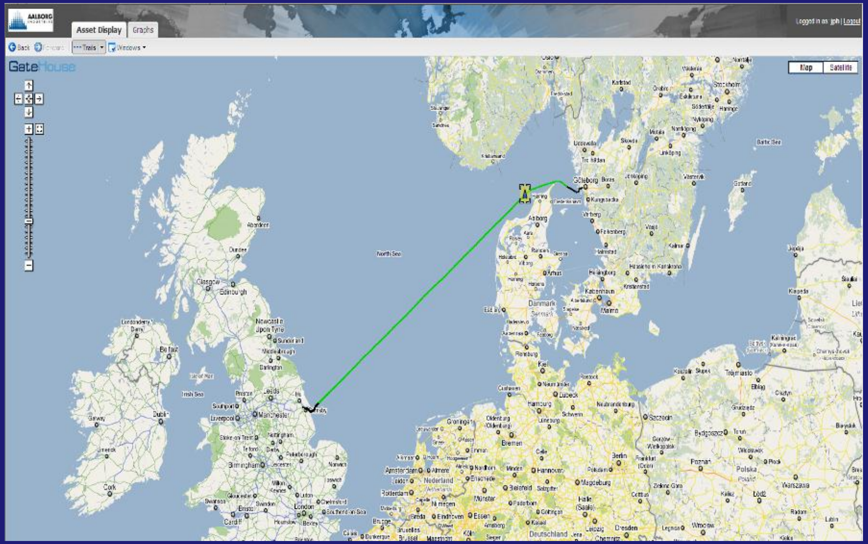
Scrubber water before and after treatment

"Sludge" from the Alfa Laval water treatment

Water treatment with separators used on scrubber field test vessel

Data Logging/Recording

- Surveillance System via internet since 2010
- Logging every 30 seconds
- Target
  - Ship Owners
  - Authorities (EPA, Classification)
  - Aalborg (trouble shooting, optimizing)
- Measured data:
  - Gas
    - SO_2
    - CO_2
  - Water
    - PH
    - Turbidity
    - PAH



Operational issues

Soot stains on deck

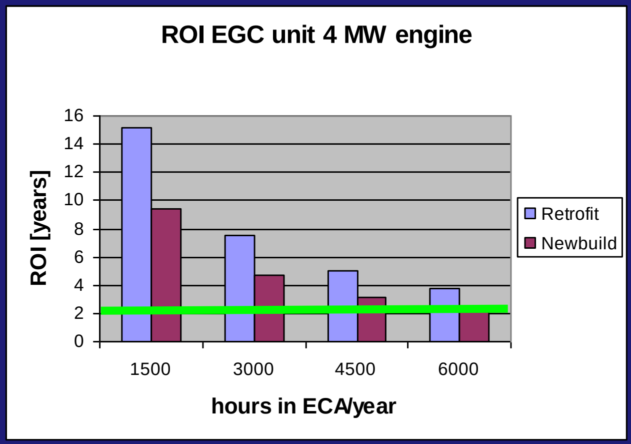
- Cleaning of demister
- Increase discharge velocity from chimney

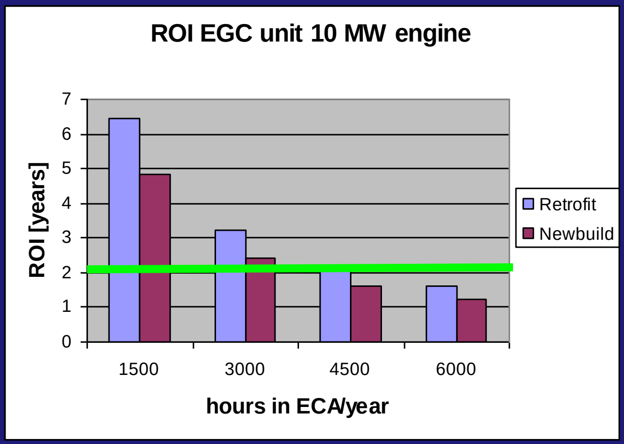
Corroded pipes:

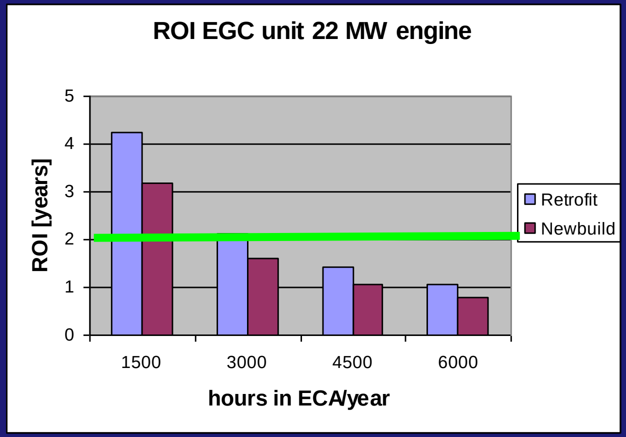
- Exchange corroded pipes.
- Use resistant pipes

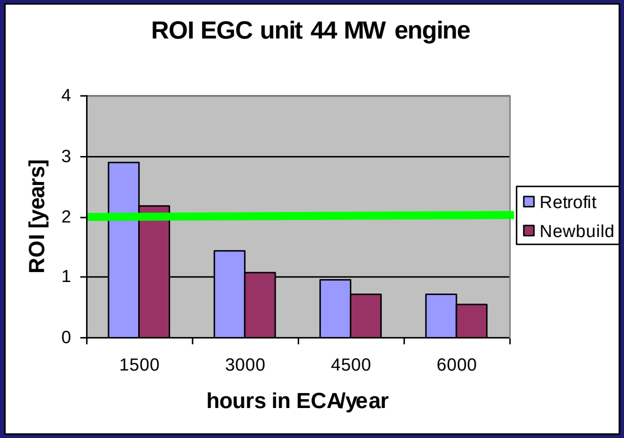
Economics

ROI for several engine sizes









Based on price difference of USD 335,= between MGO and HFO

Conclusions

- 40 years of scrubbing experience from flue gas installations
- Maximum cost savings (100% running on HFO)
- Maximum flexibility (hybrid system)
- Largest EGC system installed on Tor Ficaria (21 MW MAN B&W)
- Short pay back time 1-2 years
- Global sales & service network

What About Gas?

Dan Veen
Sales Development Manager – North Europe

HME Seminar
Putten, 8 September 2011

Why?

How?

What?

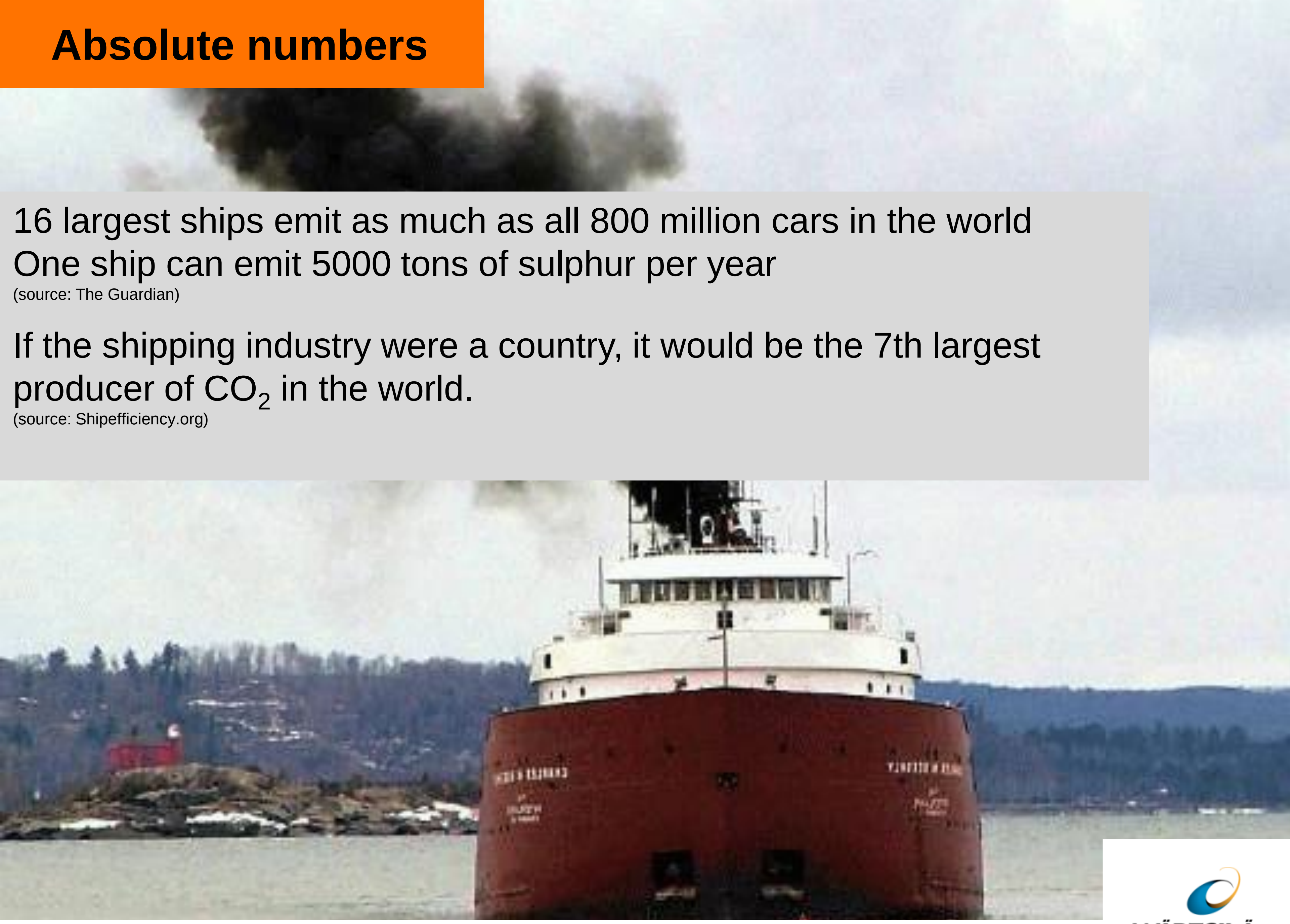
References

Business Cases

Absolute numbers

16 largest ships emit as much as all 800 million cars in the world
One ship can emit 5000 tons of sulphur per year
(source: The Guardian)

If the shipping industry were a country, it would be the 7th largest producer of CO_2 in the world.
(source: Shipefficiency.org)



Why natural gas?

It is Safe:

- Narrow ignition area.
- High ignition temperature (> 500 °C).
- Slow flame rate in atmospheric pressure.
- LNG does not burn, it has to evaporate first
- Lighter than air

It is Clean:

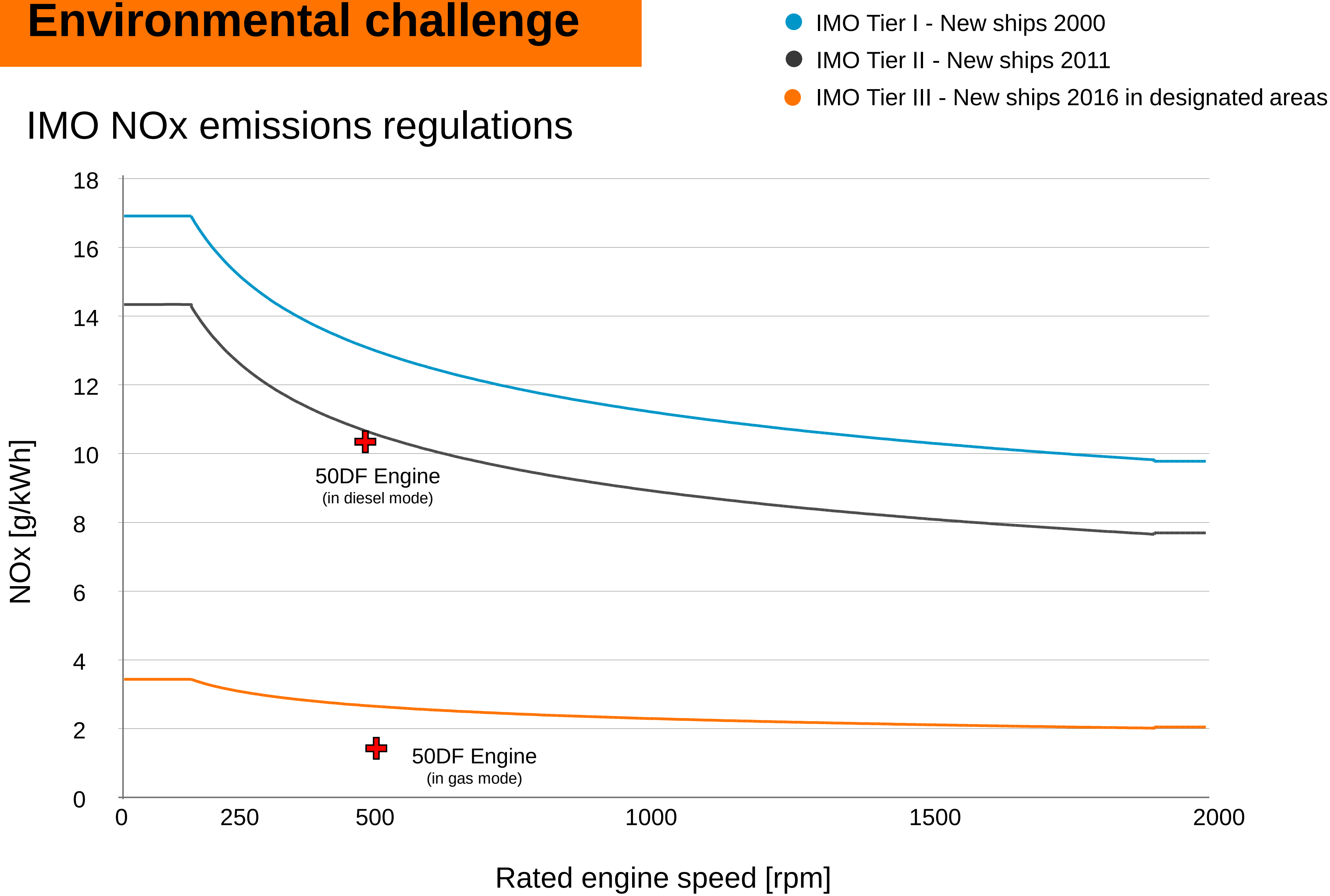
- No Particulates.
- 85% lower NOx, 20-30% lower CO_2, no SOx
- Meets the future Tier3 /CCR4 requirements without aftertreatment

It is Available:

- +150 years outlook with current gas reserves.

Environmental challenge

IMO NOx emissions regulations



WÄRTSILÄ

Dual-fuel engine characteristics

- High efficiency
- Low gas pressure
- Low emissions
  - High efficiency
  - Clean fuel
  - Lean-burn combustion
- Fuel flexibility
  - Gas mode: Natural gas + MDO pilot
  - Diesel mode: MDO + MDO pilot / HFO + MDO pilot
  - Transfer between modes without loss of power and speed.
- Extensive output range
  - Wärtsilä 20DF: 1.0 to 1.6 MW
  - Wärtsilä 34DF: 2.7 to 9.0 MW
  - Wärtsilä 50DF: 5.7 to 17.55 MW

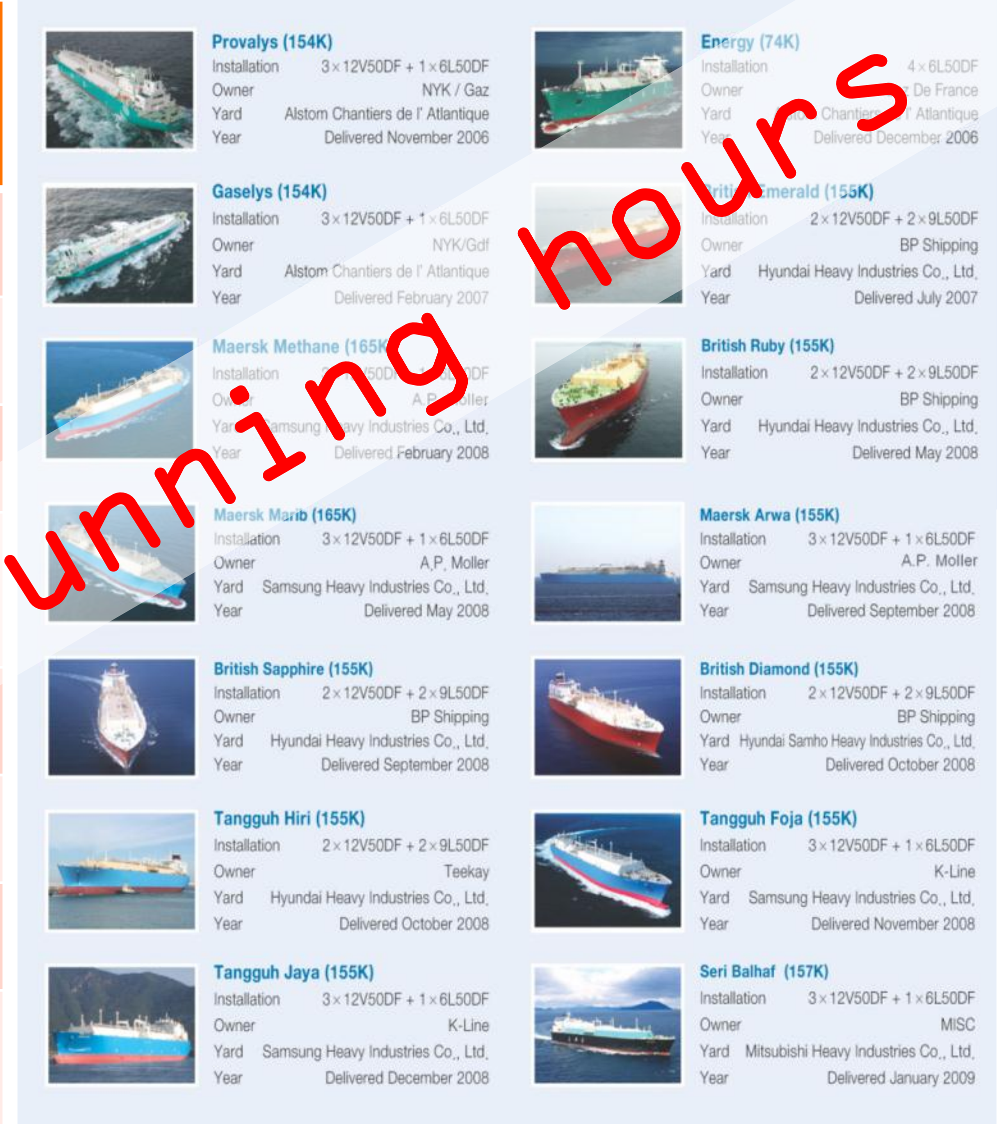
WÄRTSILÄ

Dual-Fuel engines in LNG carriers - Overview

Wärtsilä DF Engines represent the leading technology in LNGC propulsion systems.

Total vessels ordered	62
Total vessels delivered	36
Total 50DF delivered	128
Total 50DF delivered from WHEC	59
Total cylinders on order	2'328
Total kW on order	2‘167‘320
Total BHP on order	2‘946‘796
Total vessels ordered with HFO capability	25

1'500'000 running hours



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Dual-fuel engines in LNG carriers (1/3)

Installation	Name	Owner	Yard	Year	Hrs
4x 6L50DF	Gaz de France Energy	Gaz de France	Atlantique	2006	62’000
3x 12V50DF + 1x 6L50DF	Provalys	Gaz de France	Atlantique	2006	54’000
3x 12V50DF + 1x 6L50DF	Gaselys	Gaz de France	Atlantique	2007	51’000
2x 12V50DF + 2x 9L50DF	British Emerald	BP Shipping	Hyundai	2007	68’000
3x 12V50DF + 1x 6L50DF	Maersk Methane	AP Møller	Samsung	2008	47’000
2x 12V50DF + 2x 9L50DF	British Ruby	BP Shipping	Hyundai	2008	49’000
1x 12V32DF	Explorer	Exmar	Daewoo	2008	1’500
2x 12V50DF + 2x 9L50DF	British Sapphire	BP Shipping	Hyundai	2008	38’000
3x 12V50DF + 1x 6L50DF	Maersk Marib	AP Møller	Samsung	2008	23’000
3x 12V50DF + 1x 6L50DF	Maersk Arwa	AP Møller	Samsung	2008	20’000
2x 12V50DF + 2x 9L50DF	Tangguh Hiri	Teekay	Hyundai	2008	19’000
2x 12V50DF + 2x 9L50DF	British Diamond	BP Shipping	Hyundai Samho	2008	40’000
3x 12V50DF + 1x 6L50DF	Maersk Magellan	AP Møller	Samsung	2009	20’200
3x 12V50DF + 1x 6L50DF	Tangguh Foja	“K” Line	Samsung	2008	18’000
2x 12V50DF + 2x 9L50DF	Abdel Kader	MOL	Hyundai	2009	9’000
3x 12V50DF + 1x 6L50DF	Tangguh Jaya	“K” Line	Samsung	2008	15’000
3x 12V50DF + 1x 6L50DF	Tangguh Palung	“K” Line	Samsung	2009	14’000
2x 12V50DF + 2x 9L50DF	Tangguh Sago	Teekay	Hyundai Samho	2009	17’000
2x 12V50DF + 2x 6L50DF	BW GdF Suez Brussels	Bergesen	Daewoo	2009	13’000
1x 12V32DF	Express	Exmar	Daewoo	2009	Delivered
2x 12V50DF + 2x 6L50DF	BW GdF Suez Paris	Bergesen	Daewoo	2009	14’000
3x 12V50DF + 1x 6L50DF	Seri Balhaf	MISC	Mitsubishi	2009	18’000
3x 12V50DF + 1x 6L50DF	Seri Balqis	MISC	Mitsubishi	2009	17’000

Dual-fuel engines in LNG carriers (2/3)

Installation	Name	Owner	Yard	Year	Hrs
3x 12V50DF + 1x 6L50DF	GdF Suez Neptune	Høegh	Samsung	2009	Delivered
3x 12V50DF + 1x 6L50DF	Gaslog Savannah	Chevron	Samsung	2010	Delivered
3x 12V50DF + 1x 6L50DF	Woodside Donaldson	AP Møller	Samsung	2009	12'000
2x 12V50DF + 2x 9L50DF	Ben Badis	MOL	Hyundai Samho	2009	Delivered
1x 12V32DF	Exquisite	Exmar	Daewoo	2009	Delivered
3x 12V50DF + 1x 6L50DF	STX Frontier	STX Pan Ocean	Hanjin	2010	Delivered
3x 12V50DF + 1x 6L50DF	Maersk Meridian	AP Møller	Samsung	2009	4'000
1x 12V32DF	Expedient	Exmar	Daewoo	2009	11'000
2x 12V50DF + 2x 6L50DF	ASEEM	MOL	Samsung	2009	Delivered
3x 12V50DF + 1x 6L50DF	Hull 1689	Høegh	Samsung	2010	3'000
3x 12V50DF + 1x 6L50DF	Methane Julia Louise	BG	SHI	2010	Delivered
3x 12V50DF + 1x 9L50DF	Hull 2269	Knutsen	DSME	2010	Delivered
2x 12V50DF + 2x 6L50DF	Hull 2273	Brunei Gas	DSME	2010	Delivered
3x 12V50DF + 1x 9L46D	Hull 2268	TMT	DSME	2010	
3x 12V50DF + 1x 6L50DF	Hull 1642	Chevron	Samsung	2010	
3x 12V50DF + 1x 9L50DF	Hull 2267	Knutsen	DSME	2010	
3x 12V50DF + 1x 6L50DF	Hull 1810	Angola	SHI	2011	
3x 12V50DF + 1x 6L50DF	Hull 1746	BG	SHI	2010	
3x 12V50DF + 1x 6L50DF	Hull 1811	Angola	SHI	2011	
3x 12V50DF + 1x 6L50DF	Hull 1812	Angola	SHI	2011	
3x 12V50DF + 1x 6L50DF	Hull 1813	Angola	SHI	2011	
3x 12V50DF + 1x 6L50DF	Hull 1858	BG	SHI	2010	
3x 12V50DF + 1x 6L50DF	Hull 1859	BG	SHI	2010	

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Dual-fuel engines in LNG carriers (3/3)

Installation	Name	Owner	Yard	Year
3x 12V50DF + 1x 9L46D	Hull 2278	TMT	DSME	2010
3x 12V50DF + 1x 9L50DF	Hull 2274	Knutsen	DSME	2010
3x 12V50DF + 1x 9L50DF	Hull 2275	Knutsen	DSME	2011
3x 12V50DF + 1x 6L50DF	“LH#3”	Undisclosed	SHI	2012
2x 12V50DF + 2x 6L50DF	UL2L	Undisclosed	DSME	2012
2x 12V50DF + 2x 6L50DF	UL2K	Undisclosed	DSME	2012
2x 12V50DF + 2x 6L50DF	Hull 2277	Brunei Gas	DSME	2010
2x 12V50DF + 2x 6L50DF	UL2P	Undisclosed	DSME	2012
2x 12V50DF + 2x 6L50DF	UL1R	Undisclosed	DSME	2012
2x 12V50DF + 2x 6L50DF	ULCS	Undisclosed	DSME	2012
4x 12V50DF	Hull 1761	Flex LNG	SHI	2012
4x 12V50DF	Hull 1762	Flex LNG	SHI	2012
4x 12V50DF	Hull 1839	Flex LNG	SHI	2013
4x 12V50DF	Hull 1850	Flex LNG	SHI	2013
1x 12V32DF	Hull 2272	Exmar	Daewoo	2010
1x 12V32DF	Hull 2287	Exmar	Daewoo	2011

62 installations / 230 engines / > 1’500’000 running hours*

* Last updated 2010/5

WÄRTSILÄ

Dual-fuel engine references – 32DF / 34DF

Petrojarl 1
FPSO
Petrojarl
2x 18V32DF
2x 32’000 running hours

Sendje Ceiba
FPSO
Bergesen
1x 18V32DF
18’000 running hours

Viking Energy
DF-electric offshore supply vessel
Eidesvik
Kleven Verft
4x 6R32DF
4x 19’500 running hours

Stril Pioner
DF-electric offshore supply vessel
Simon Møkster
Kleven Verft
4x 6R32DF
4x 16’500 running hours

Viking tbn (Gass Avant) hull 29
DF-electric offshore supply vessel
Eidesvik
West Contractors
4x 6R32DF
Ship delivery 2007

Viking tbn (Gass Avant) hull 30
DF-electric offshore supply vessel
Eidesvik
West Contractors
4x 6R32DF
Ship delivery 2008

6 x DF-electric LNG Carrier
Exmar
12V32DF
Auxiliary generating sets

DF-electric offshore supply vessel
Aker yards
3x W6L34DF
Engines delivery 2010

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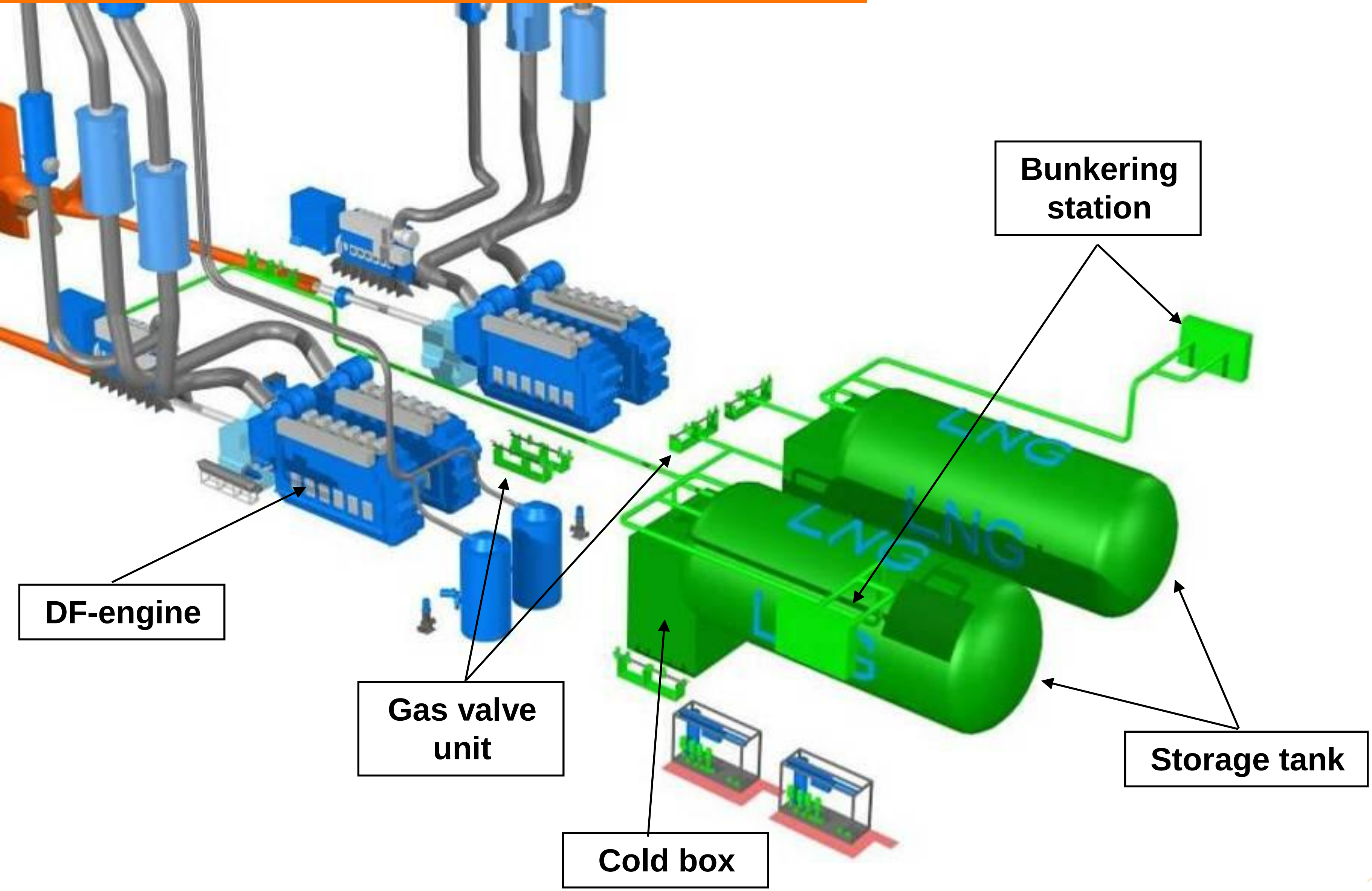
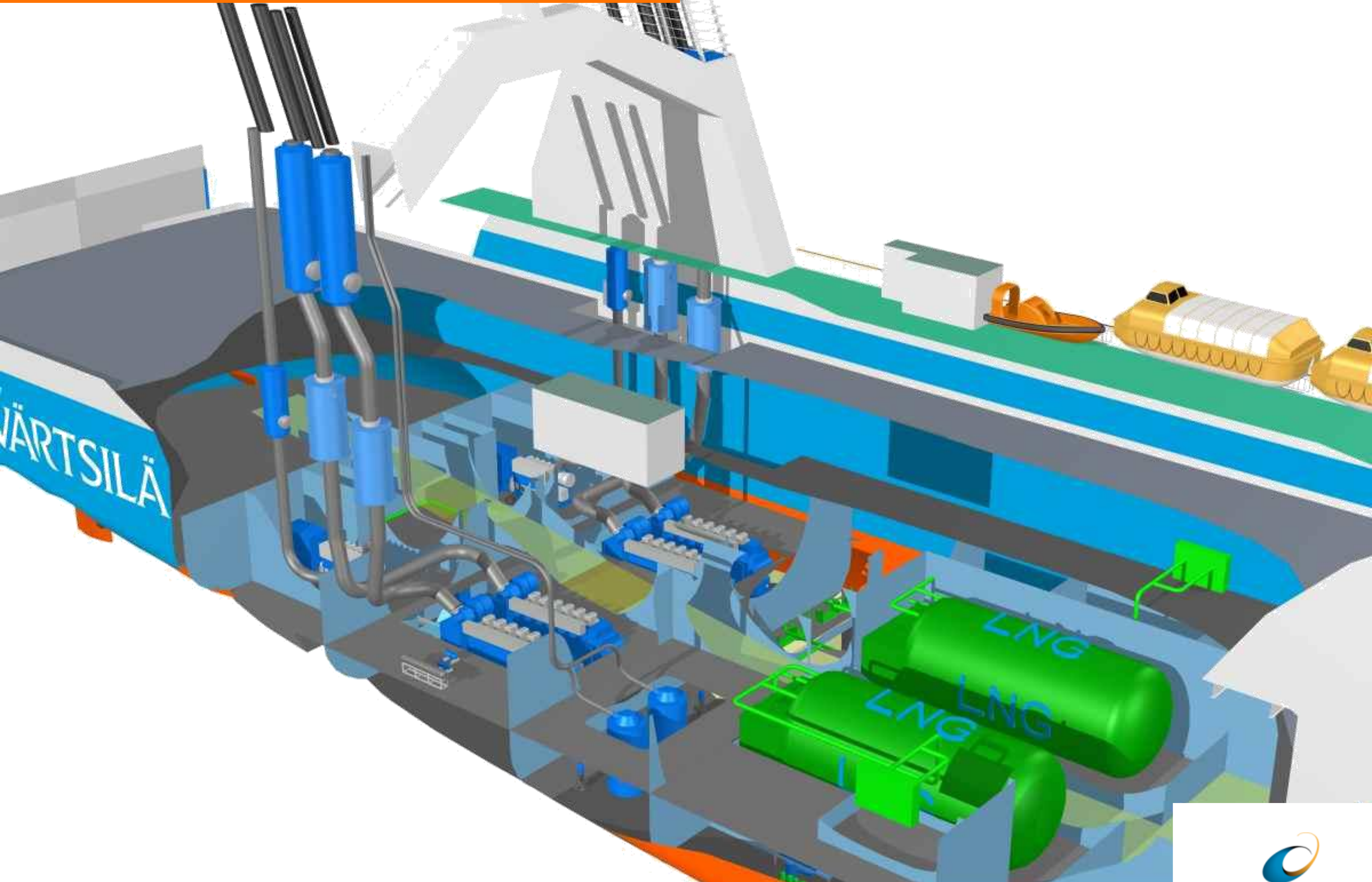
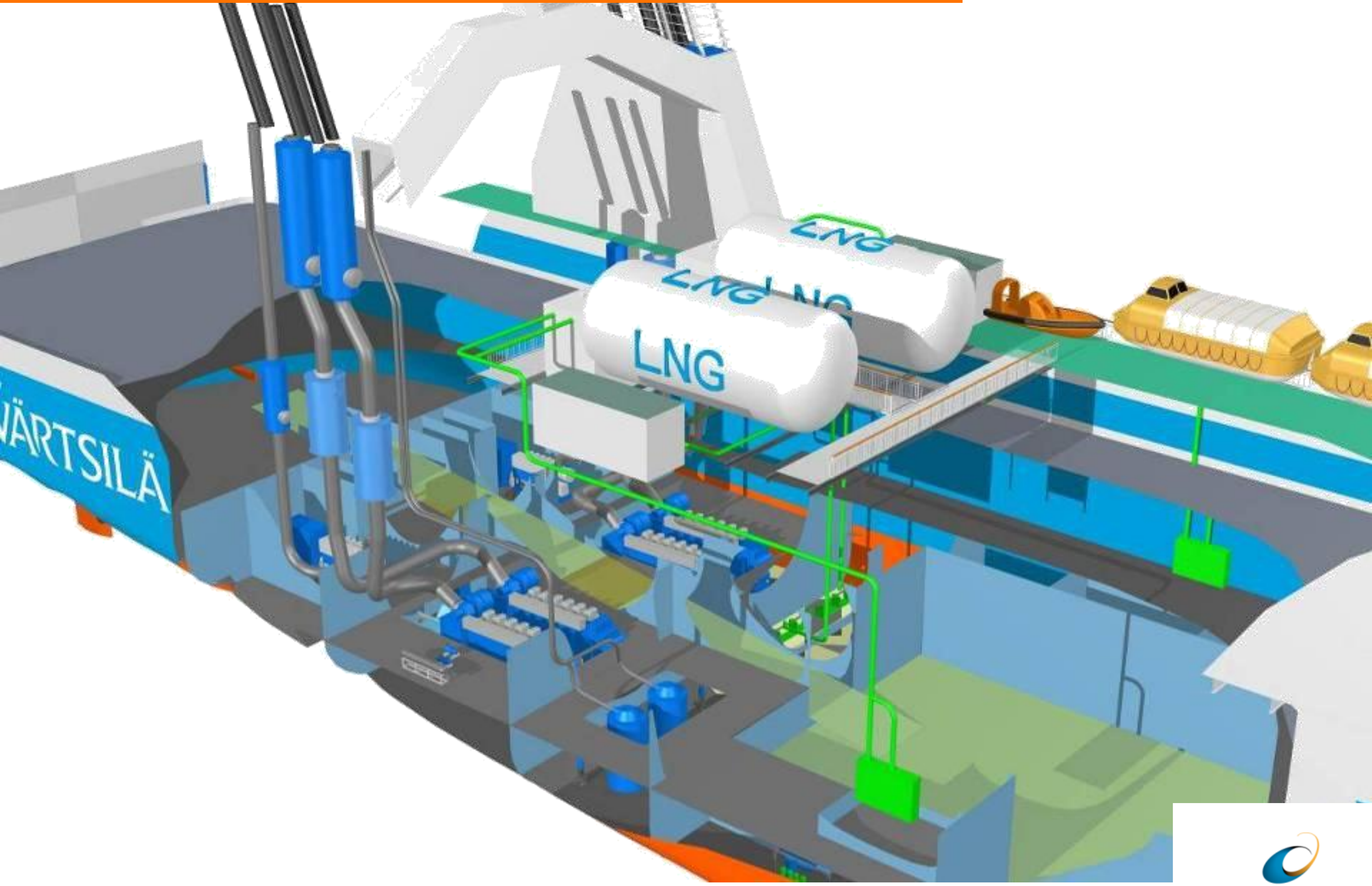
Main Components (C-type tanks)



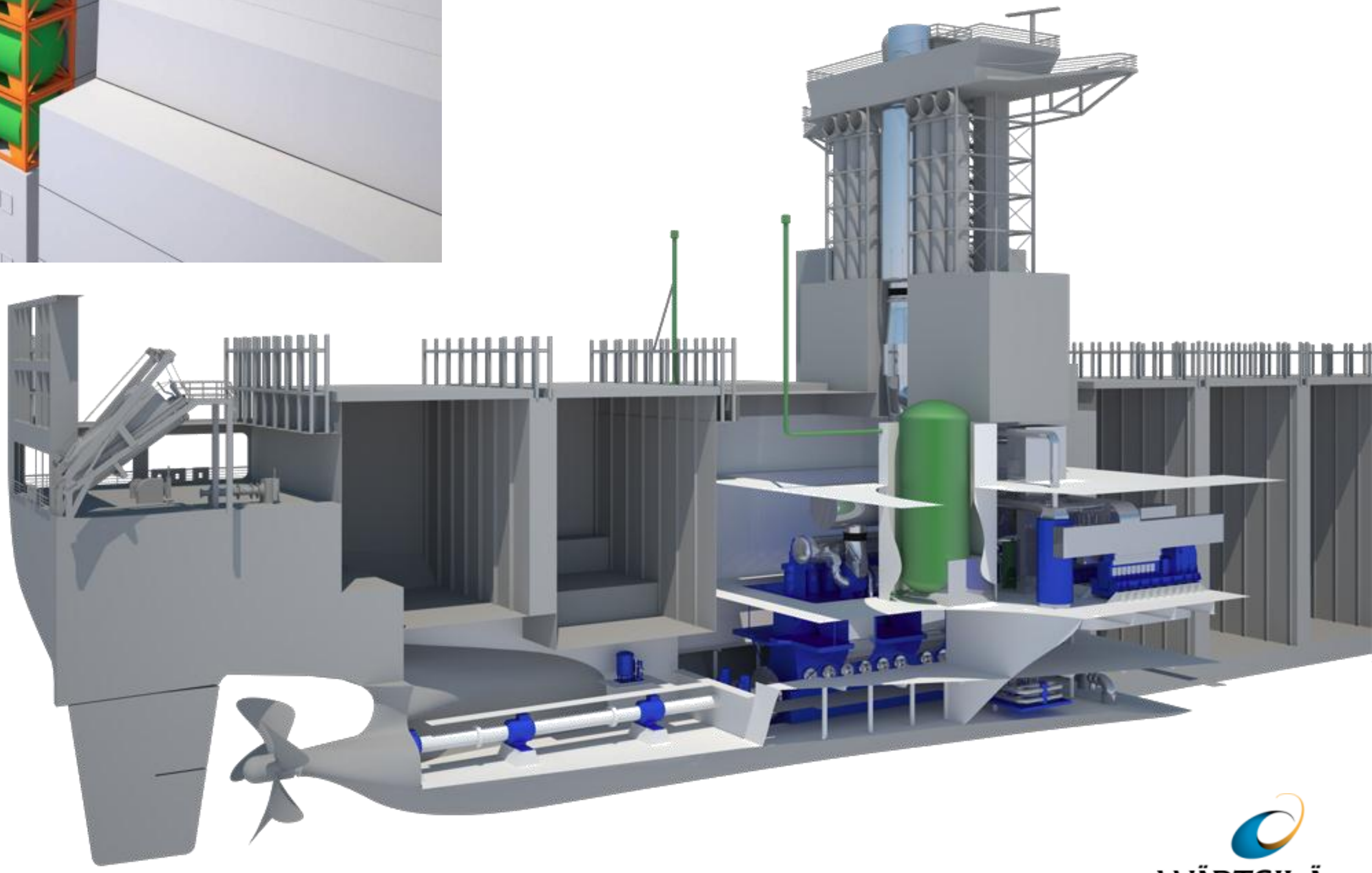
C-type tanks – below deck



C-type tanks - Alternative arrangement



LNG storage alternatives



LNG tank location

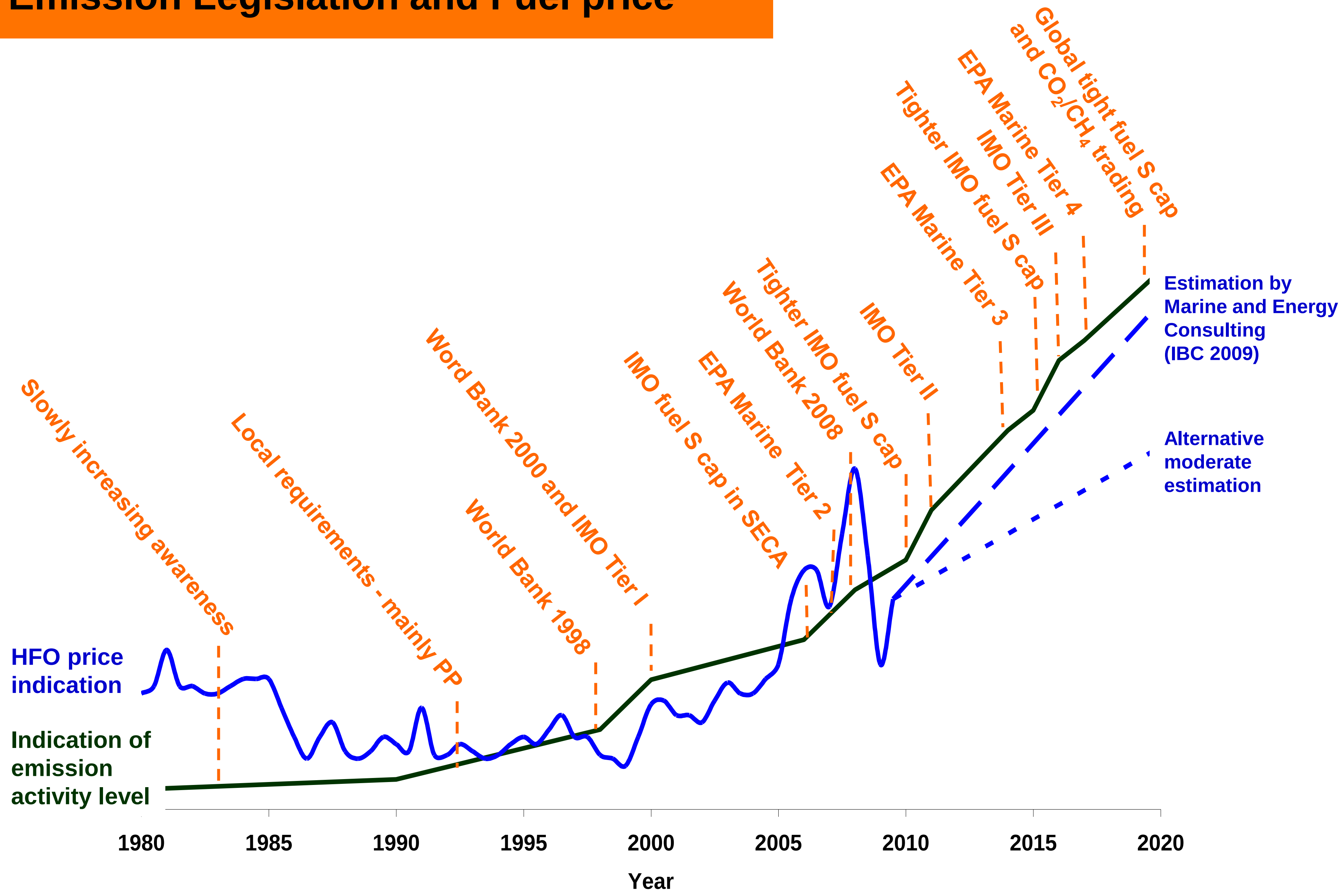
The LNG tanks are located on the upper deck behind the superstructure

- Located outside
  - Good ventilation
- No ventilation casing needed trough accommodation
- Vent pipe for tanks still needed
- Visible location for good PR

LNG BuSINESS CASEs

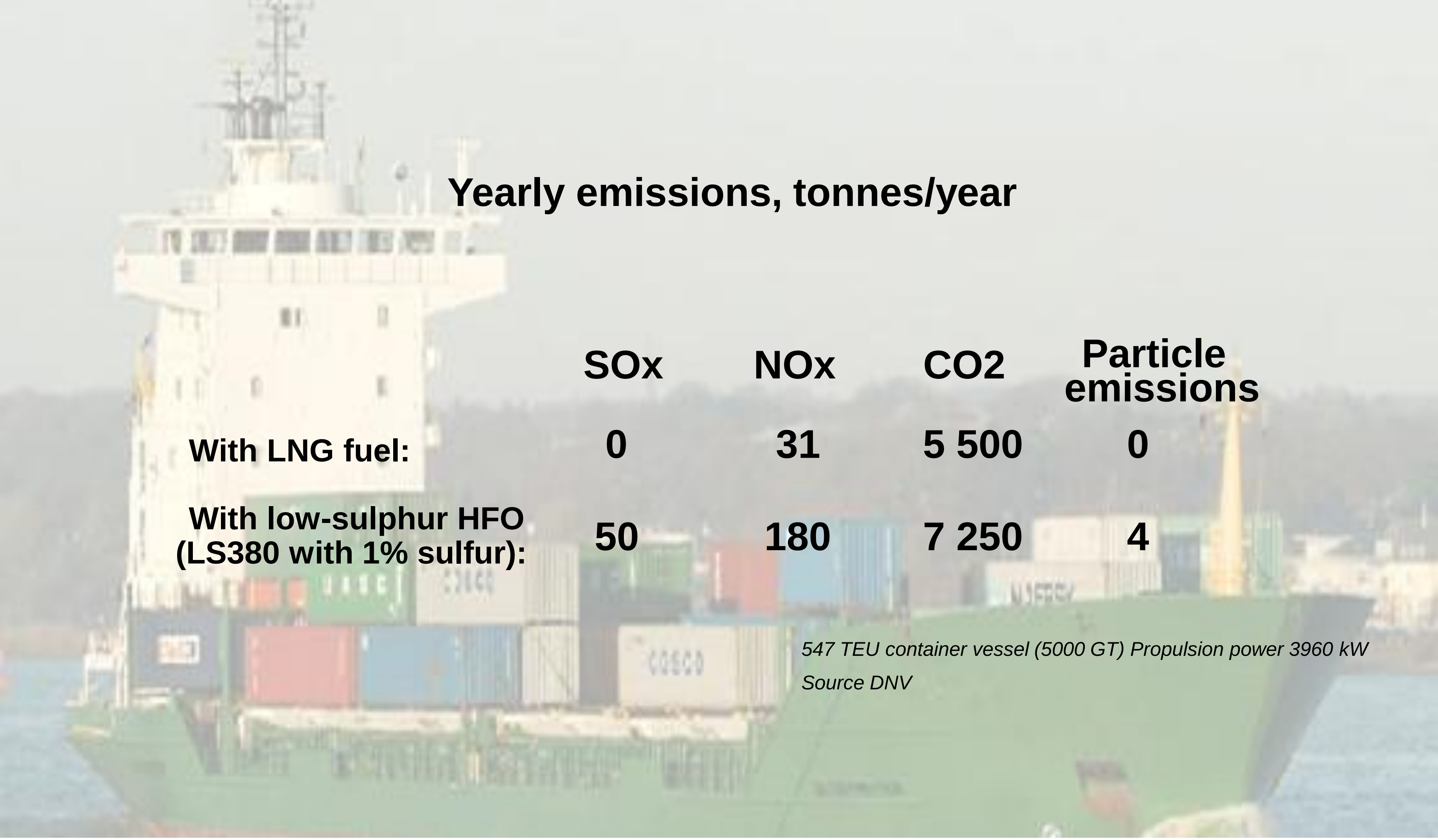
WÄRTSILÄ

Emission Legislation and Fuel price



WÄRTSILÄ

A typical Baltic Sea cargo ship



Yearly emissions, tonnes/year

	SOx	NOx	CO2	Particle emissions
With LNG fuel:	0	31	5 500	0
With low-sulphur HFO (LS380 with 1% sulfur):	50	180	7 250	4

547 TEU container vessel (5000 GT) Propulsion power 3960 kW

Source DNV

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A typical Baltic Sea cargo ship

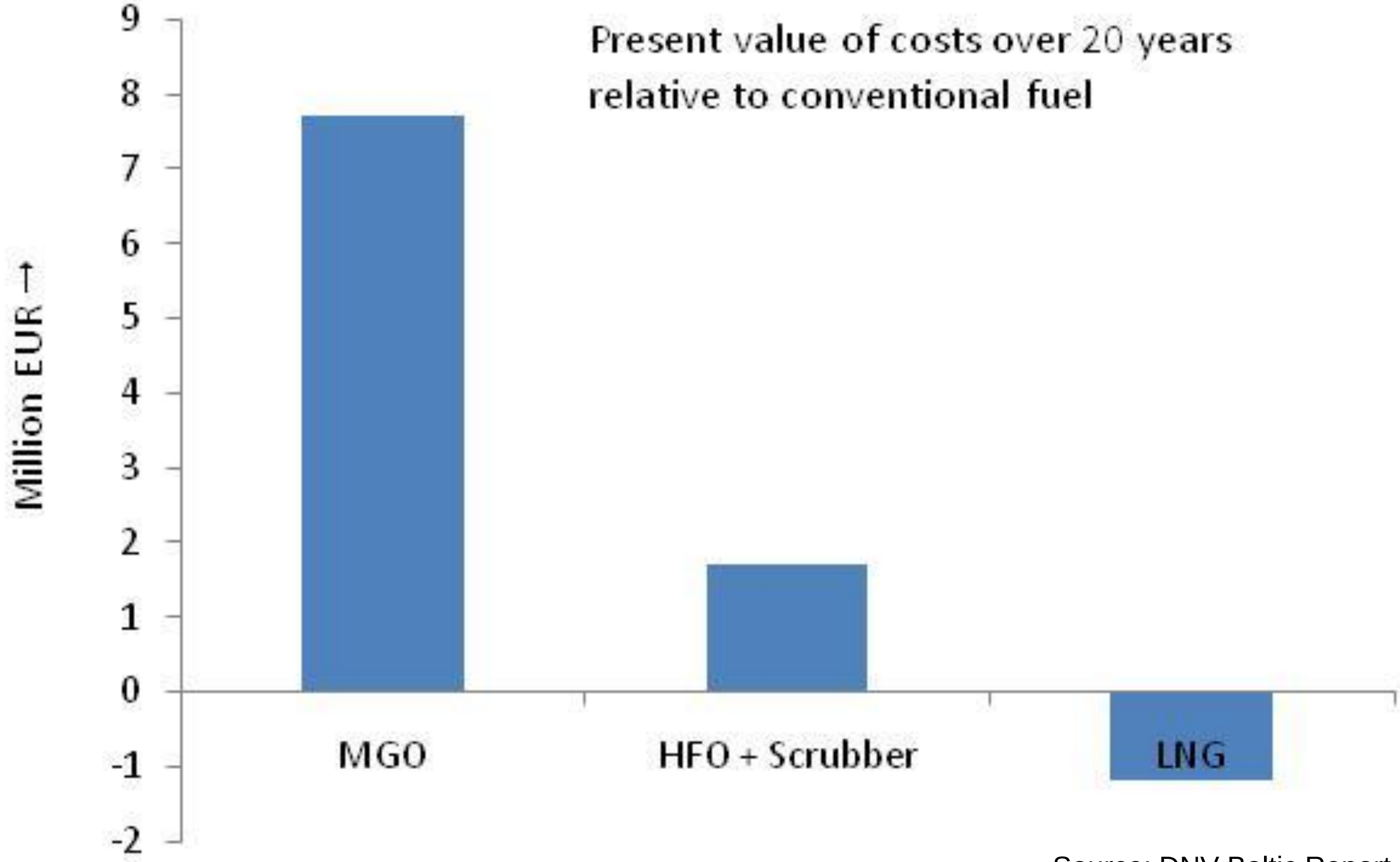
	LNG	MGO	HFO
CAPEX	LNG Cryogenic Tank / 2 tanks when mono fuel Gas Valve Units Double Walled Piping Automation	SCR (as of 2016)	Heater Units Booster Units Scrubbers (as of 2015) SCR (as of 2016)
OPEX	Lower fuel costs Lower cargo capacity (?)	Higher Fuel Costs	Lower fuel costs

Typical Baltic Sea cargo ship of approximately 2,700 gross tonnes, 3,300 kW main engine and 5,250 yearly sailing hours.

LNG Capex +2,5 Million EUR compared to MGO
Scrubber Costs 1 Million EUR

Source DNV

In the end it all adds up….



Source: DNV Baltic Report

WÄRTSILÄ

Experience in maintenance

Component	Time between inspection or overhaul (h)		Expected life time (h)	
	Gas / MDO	100% HFO	Gas / MDO	100% HFO
Piston, crown	18,000 [1)]	12,000 [1)]	72,000	36,000
Piston, skirt	18,000 [1)]	12,000 [1)]	72,000	60,000
Piston rings	18,000	12,000	18,000	12,000
Cylinder liner	18,000	12,000	96,000	72,000
Cylinder head	18,000	12,000	72,000	60,000
Inlet valve	18,000	12,000	36,000	24,000
Inlet valve seat	18,000	12,000	36,000	24,000
Exhaust valve	18,000	12,000	36,000	24,000
Exhaust valve seat	18,000	12,000	36,000	24,000
Inj.valve nozzle	6,000	6,000	6,000	6,000
Inj. valve complete	6,000	6,000	18,000	18,000
Injection pump element	12,000	12,000	24,000	24,000
Main bearing	18,000 [1)]	18,000 [1)]	36,000	36,000
Big end bearing	18,000 [1)]	18,000 [1)]	36,000	36,000
Camshaft bearing	36,000 [1)]	36,000 [1)]	72,000	72,000
Turbocharger bearing	12,000	12,000	36,000	36,000
Main gas admission valve	18,000	18,000	18,000	18,000

[1)] Inspection of one


Questions ?

LNG: Chain analysis

Maritiem Milieu Seminar ‘SOx Innovatie en slim ondernemen

8 september 2011

Ruud Verbeek, Filipe Fraga
Pim van Mensch, Gerrit Kadijk, Sebastiaan Bleuanus, Bas van den Beemt

TNO innovation for life

Joint Industry Project: **LNG Fuel for Shipping**

Environmental chain analysis study for LNG as fuel for shipping





Rolls-Royce
Anthony Veder
Port of Rotterdam
DAMEN
SMIT
Argos Oil
TNO innovation for life
gasunie
pon CAT
Vopak
COFELY GDF SUEZ
WÄRTSILÄ

Chain analysis basics

Objective

- Comparison of LNG with diesel as fuels for shipping
- Focus on environmental aspects, (PM, NO_x, SO_x, CO_2, CH_4) some economics included

Considered short sea, port and inland shipping

Overview of “the chain”

greenhouse gas emissions, complete chain: Well-to-Propeller

Production + conditioning at source → Trans-formation at source → Transpor-tation to market → Transfor-mation in market → Conditioning and distribution → Use in engine

air quality emissions

from ship only: Tank-to-Propeller

Method and assumptions GHG

Well To Tank	Tank To Propeller
Feedstock Production method Transport distance and method	H/C ratio fuel engine / driveline-efficiency

Component	CO_2 equivalent
CO_2	x 1
CH_4	x 25
N_2O	x 298

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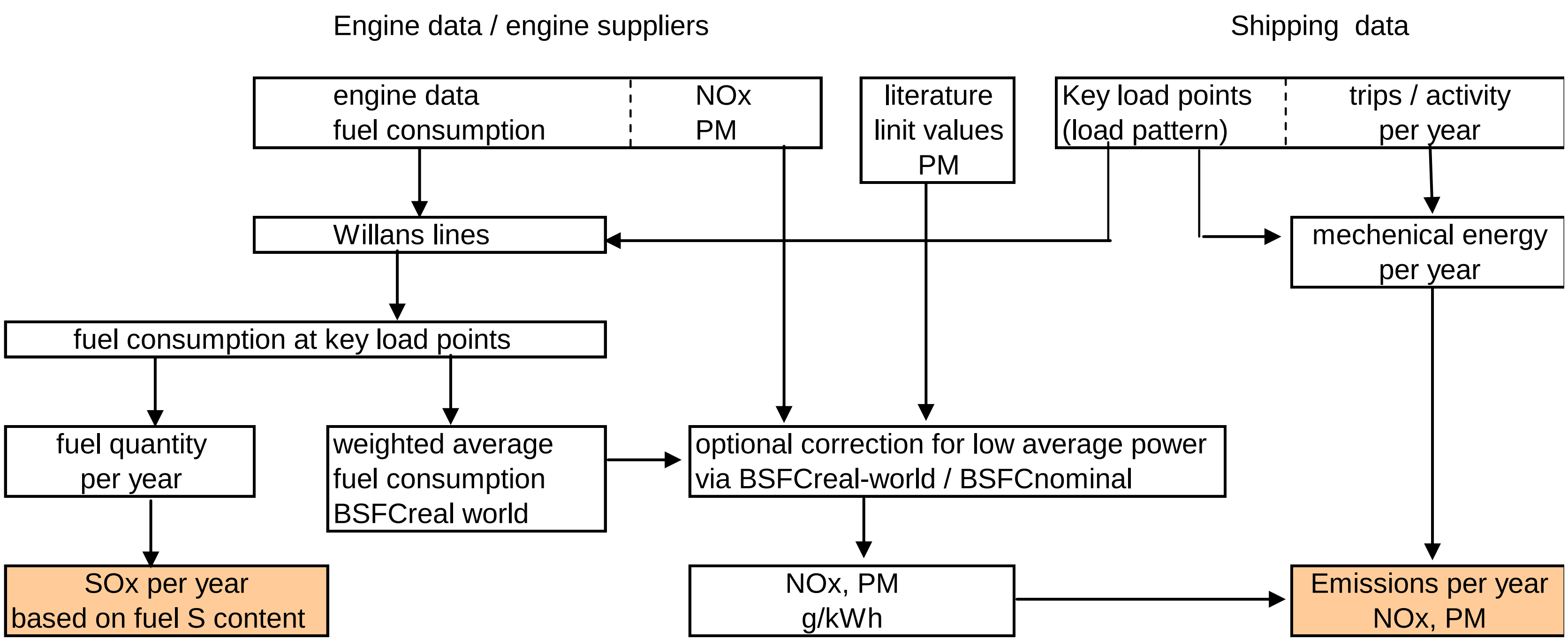
Applications (cases)

Application	Specification of ship and engine	Specification for refuelling	Diesel fuel 2011 - 2015	Diesel fuel 2015/2016 □
Short sea	Container f. 800 TEU	Several places - 15-20 day autonomy required (50% of autonomy with diesel)	MDO S < 1.00 %	MGO S < 0.10 %
	8400 kW @ 500rpm			
Port ship	tug 80 ton	Rotterdam	EN590 S < 10 ppm	EN590 S < 10 ppm
	2 x 2500 kW @ 1000rpm			
Inland ship	110 m 11,45m	Rotterdam bunkering	EN590 S < 10 ppm	EN590 S < 10 ppm
	1125 kW @ 1300rpm	Ludwigshafen return trip on 1 tank: 575km		

Engines used for assessment

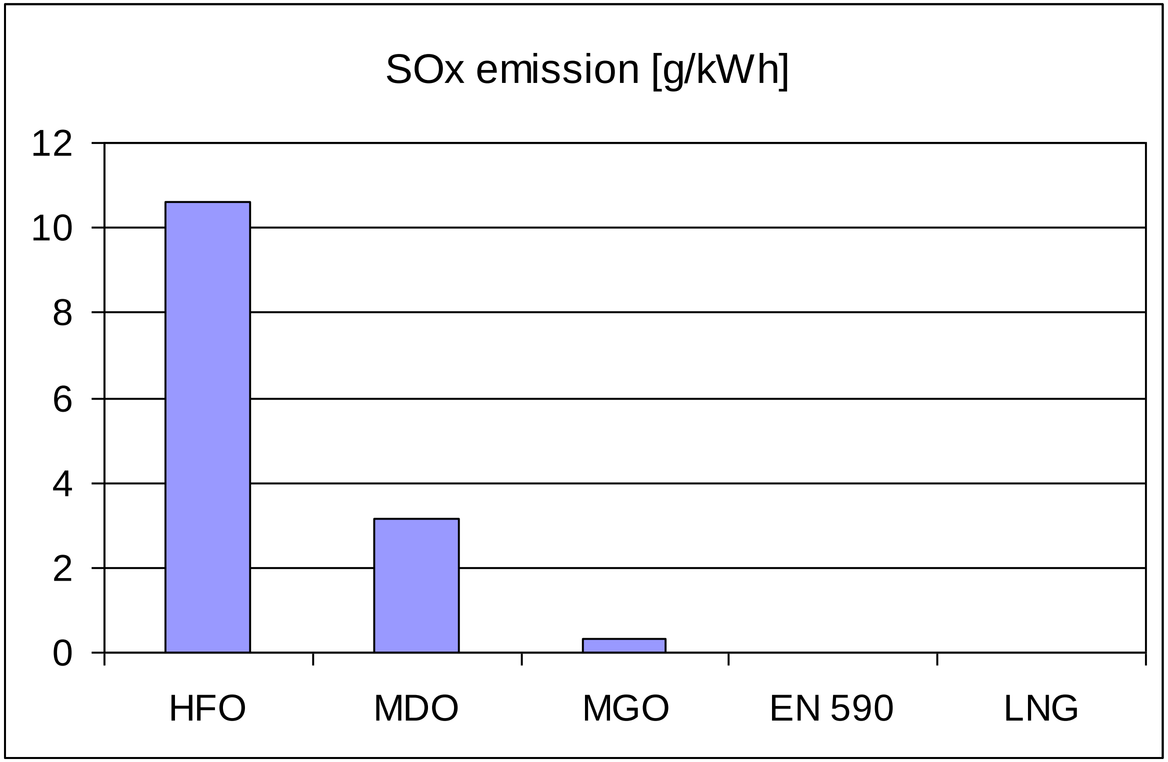
Case	Fuel	Brand	Type	Fuel system	Pmax [kW]
Short sea	Diesel	Wartsila	8L46 (DE)	Compress. Ignition	8,400
	LNG	Rolls Royce	B35:40V16AG	Lean burn	7,000
		Wartsila	Wartsila 8L50 DF (DE)	Micropilot/dual fuel	7,600
		Wartsila	Wartsila 9L50 DF (DE)	Micropilot/dual fuel	8,550
Port ship	Diesel	Wartsila	8LW26 (AE/DE)	Compress. Ignition	2,600
	LNG	Rolls Royce	C26:33L9AG	Lean burn	2,430
		Jenbacher	J616 GS	Lean burn	2,745
Inland ship	Diesel	Caterpillar	DM8467	Compress. Ignition	1,118
	LNG	Jenbacher	J416 GS	Lean burn	1,161
		Caterpillar	3512 dual fuel	Dual Fuel	1,118

Calculation method



SOx only dependent on fuel sulphur content

Fuel	average S content [m/m] %
HFO	2.7
MDO	0.8
MGO	0.08
EN 590	0.0008
LNG	0.0005



based on 43% engine efficiency / no SOx scrubber

Energy per year:
engine efficiency with LNG 0-2% lower than with diesel

Case	Fuel type	Mechanical energy (work)	Energy input (fuel)	Average Efficiency
		[kWh/y]	[MJ/y]	[%]
Short sea	Diesel	23,905,000	187,794,700	46%
	LNG	23,905,000	197,534,983	44%
Port ship	Diesel	1,459,600	14,708,526	36%
	LNG	1,459,600	14,697,724	36%
Inland ship	Diesel	5,437,500	45,507,525	43%
	LNG	5,437,500	46,172,531	42%

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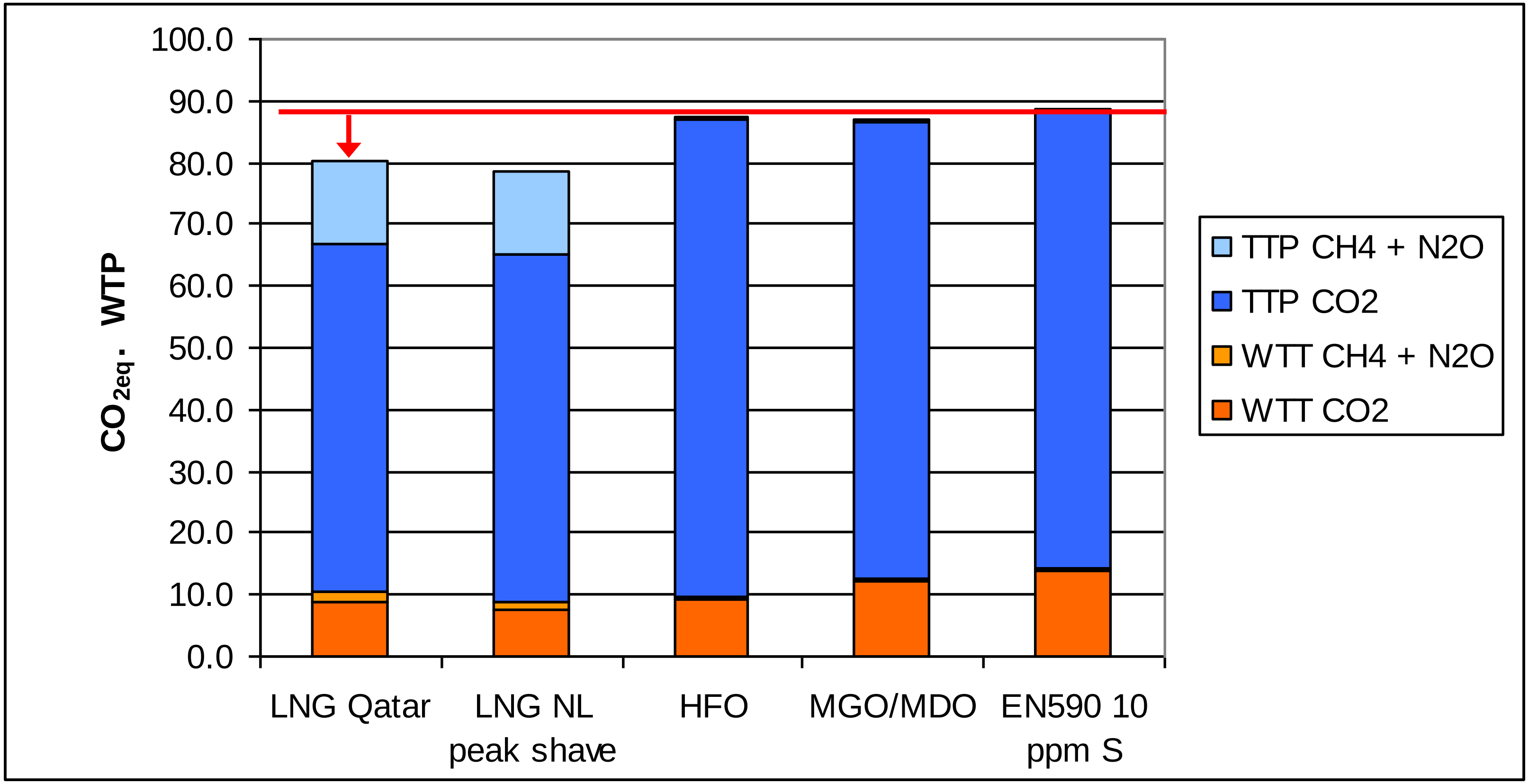
GHG emissions with LNG around 10% lower

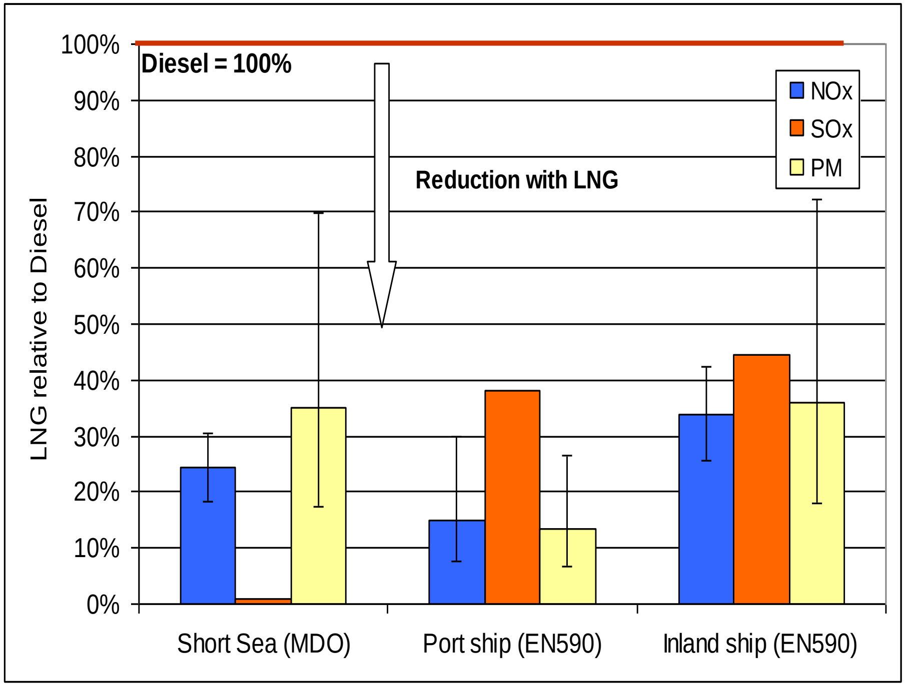
$CO_{2eq.}$ in g/MJ fuel energy



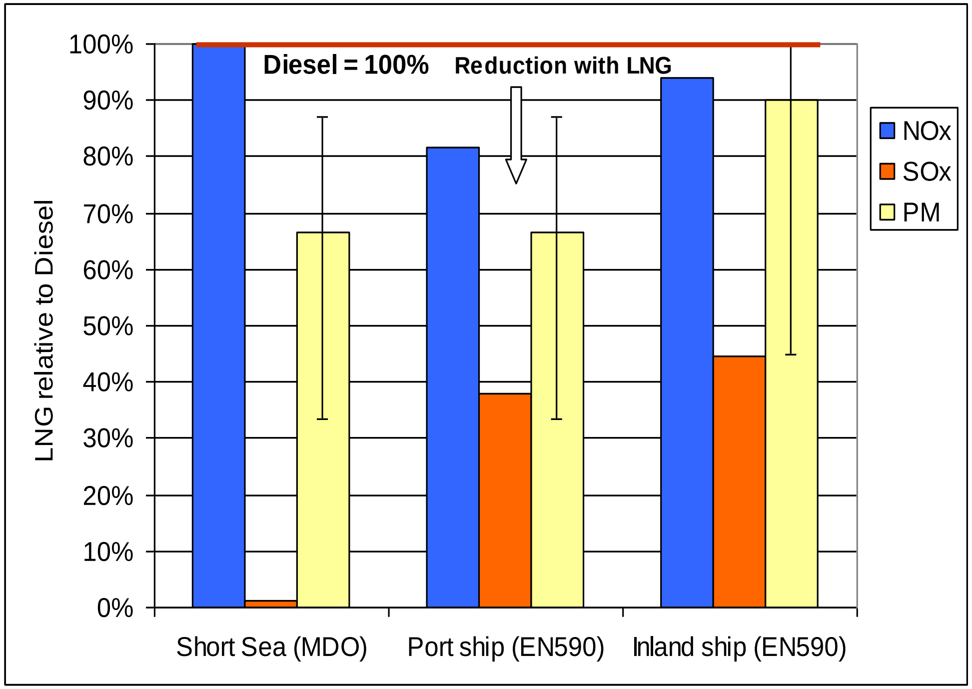
…. ….. And another ~10% improvement potential

Air pollutant emissions: 60% - 85% improvement vs diesel (2011-2015)

2011 – 2015



2016 □

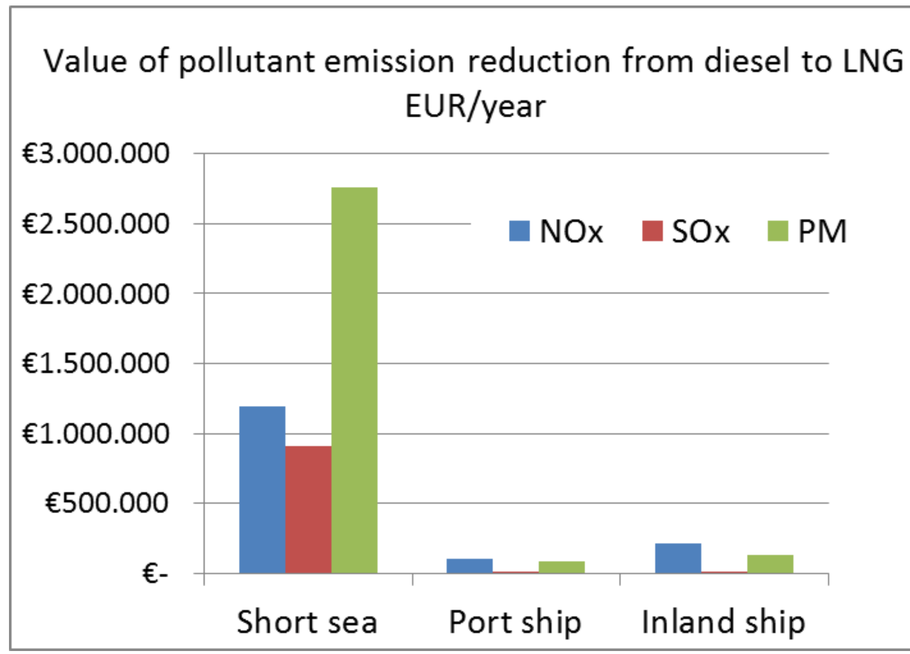


Assumptions for 2016 scenario:
NOx drops for diesel (NECA & CCNR IV)
Short sea: S level drops to 0.1% (2015)
Limited change in LNG engine technology

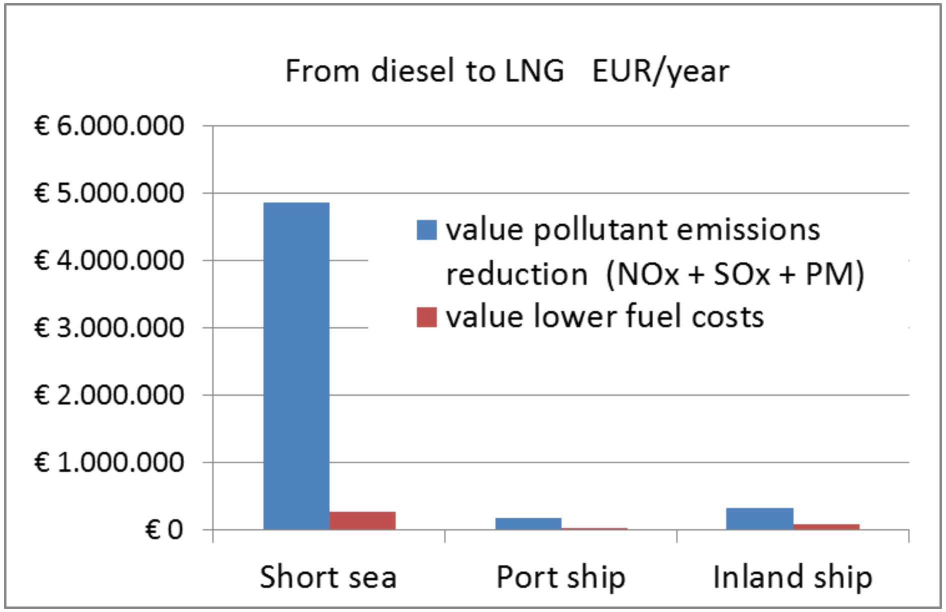
Air pollutant costs and fuel costs

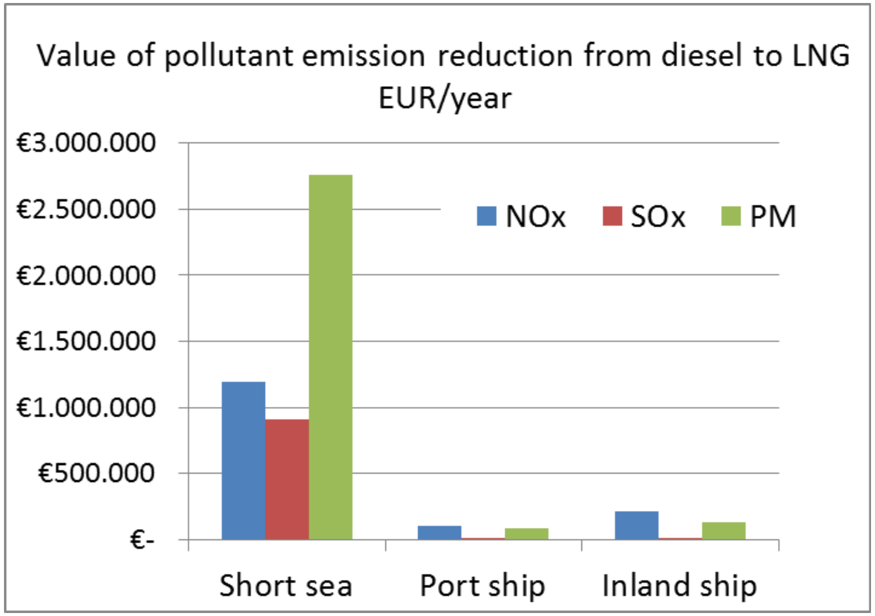
Air pollutant costs [Maibach 2008]

	NOx	SOx	PM
EUR/ton	6600	13000	422500



Air pollutant costs and fuel costs






Key insights

Environment / emissions:

- 10% GHG reduction and 60-85% reduction of other emissions until 2016

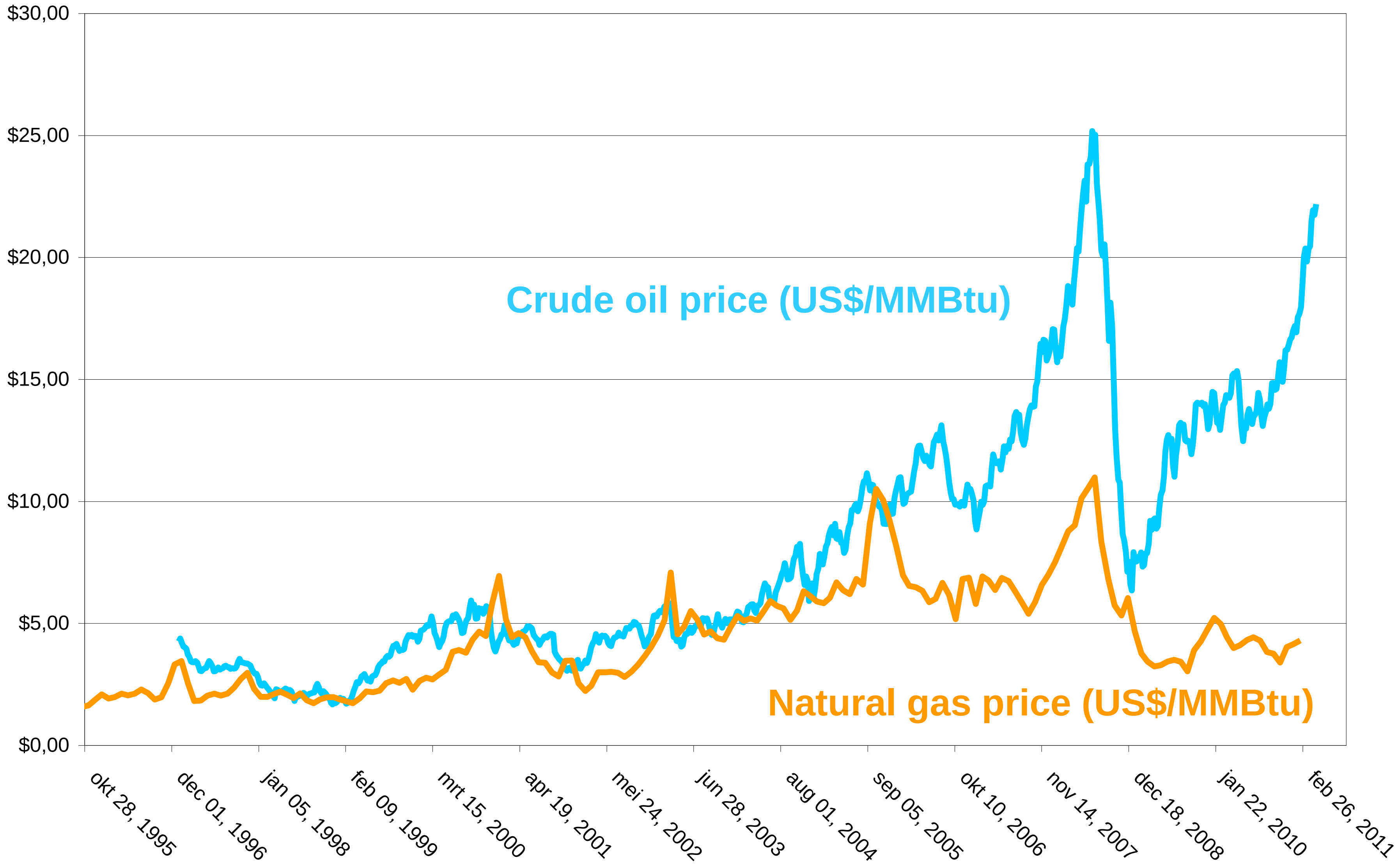
Economics positive, but advantage is not immediate

- Cost of LNG engine plus fuel tank is ~2x cost diesel engine plus fuel tank
- Fuel price of LNG is in most cases lower (not for MDO though)

LNG is economically attractive if:

- Fuel price of LNG is low enough to cover additional cost of LNG storage system
- The application in question shows a high fuel consumption per year

Promising outlook for long term LNG prices


$30,00
$25,00
$20,00
$15,00
$10,00
$5,00
$0,00
Crude oil price (US$/MMBtu)
Natural gas price (US$/MMBtu)
okt 28, 1995
dec 01, 1996
jan 05, 1998
feb 09, 1999
mrt 15, 2000
apr 19, 2001
mei 24, 2002
jun 28, 2003
aug 01, 2004
sep 05, 2005
okt 10, 2006
nov 14, 2007
dec 18, 2008
jan 22, 2010
feb 26, 2011

Report chain analysis:

www.tno.nl/LNG, click: “LNG as fuel for shipping”

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Engine load profiles for 3 cases

#	name	time / year hrs / year	ship speed [kn]	engine speed rpm	engine power kW
Short Sea: cont. 800 TEU, 8400 kW					
1	Maximum speed	800	18+	500	6200
2	Normal speed	4000	15-18	500	3900
3	Slow speed	1200	12-15	500	2500
4	Manoeuvring	300	< 4	500	1150
5	Port mode - ME stopped	2460	0 kn	1500	300
TUG, 80 ton, 2x 2500 kW					
1	Standby; no load	680	0	450	30
2	Standby	1040	1.5	500	60
3	Transit	1200	9	825	563
4	Low bollard pull	1040	0	780	530
5	Full bollard pull	60	0	1000	2500
Inland ship 110x11.45m, 1250 kW					
1	Upstream	4500	11	1300	1125
2	Downstream	1500	20	782	250
3					