Tier 3 SCR solutions and system configurations

Solfic and H+H

HME seminar - April 19th, 2012

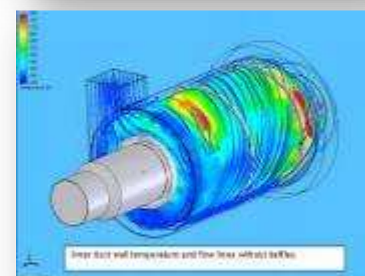
Presented by Alwin de Kock, Solfic

Solfic BV - introduction

- Solfic BV (founded 2000)
  - Engineering & consultancy
- Solfic Energy & Emission BV (founded 2011)
  - Engineering and manufacturing of energy and emission reduction systems:
    - Exhaust after treatment
    - Burners
    - Heat exchangers
    - Etc.

Solfic BV – competence and experience

- Thermo-dynamics
- Fluid dynamics
- Mechanics
- Process control
- Product development
- Project Management



Solfic BV – markets and applications

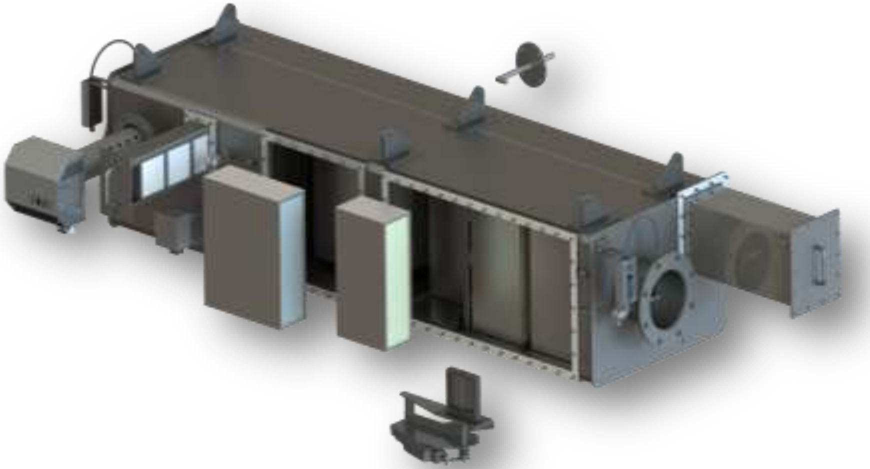
- Railroad
- Industrial thermo-processing
- High tech industry
- Agriculture
- Marine

Solfic Energy & Emission - Focus

- After-treatment (sub) systems and for mid-range applications 100 – 1500 kW
  - Marine, non-road, special off-road
  - Shared technology with H+H
- Represent H+H as leading supplier high end SCR systems
  - Marine, stationary

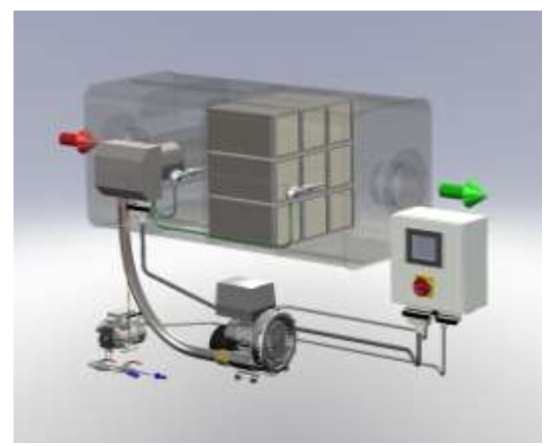
Solfic Energy & Emission – Price winning MPAT after treatment

- DPF+SCR (< 0,4 g/kWh NOx)
- By-pass
- Silencer
- Turn key

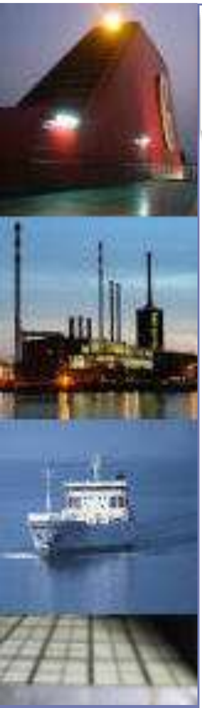


Solfic solutions for Sea going vessels and yachts

- Turn-key units 100 – 300 kW * incl. silencer function
  - DPF+ active regeneration
  - SCR (< 0.4 g/kWh)
  - DPF + SCR
- DPF -> Metal filters:
  - Much easier to clean as ceramic filters
  - Lower pressure drop increase with soot loading



* - 300 kW scheduled for Q4/2012
 - 1000 kW scheduled mid 2013



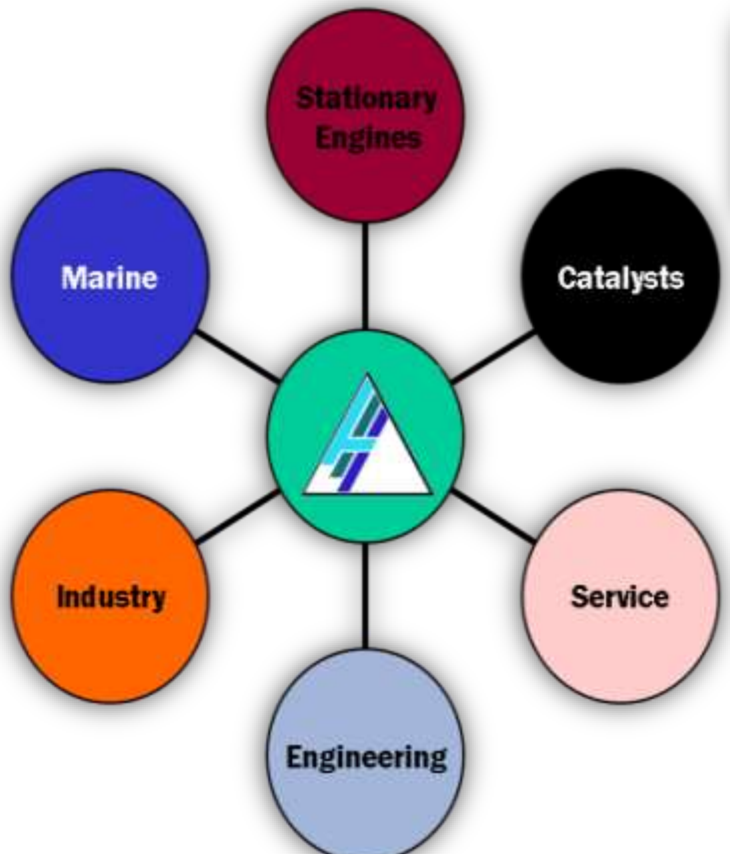
Typical Exhaust Gas Components of a Diesel Engine

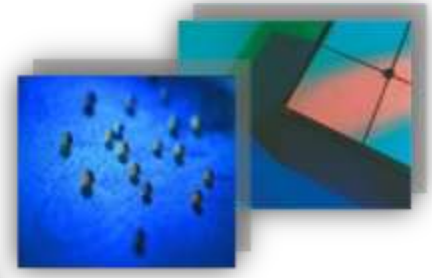
- Strategic cooperation with HAN automotive and other partners

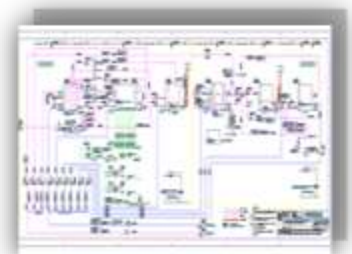
SCR-/DeNox-Anlagen im Schiffsbetrieb

Always a clear solution

Business Areas

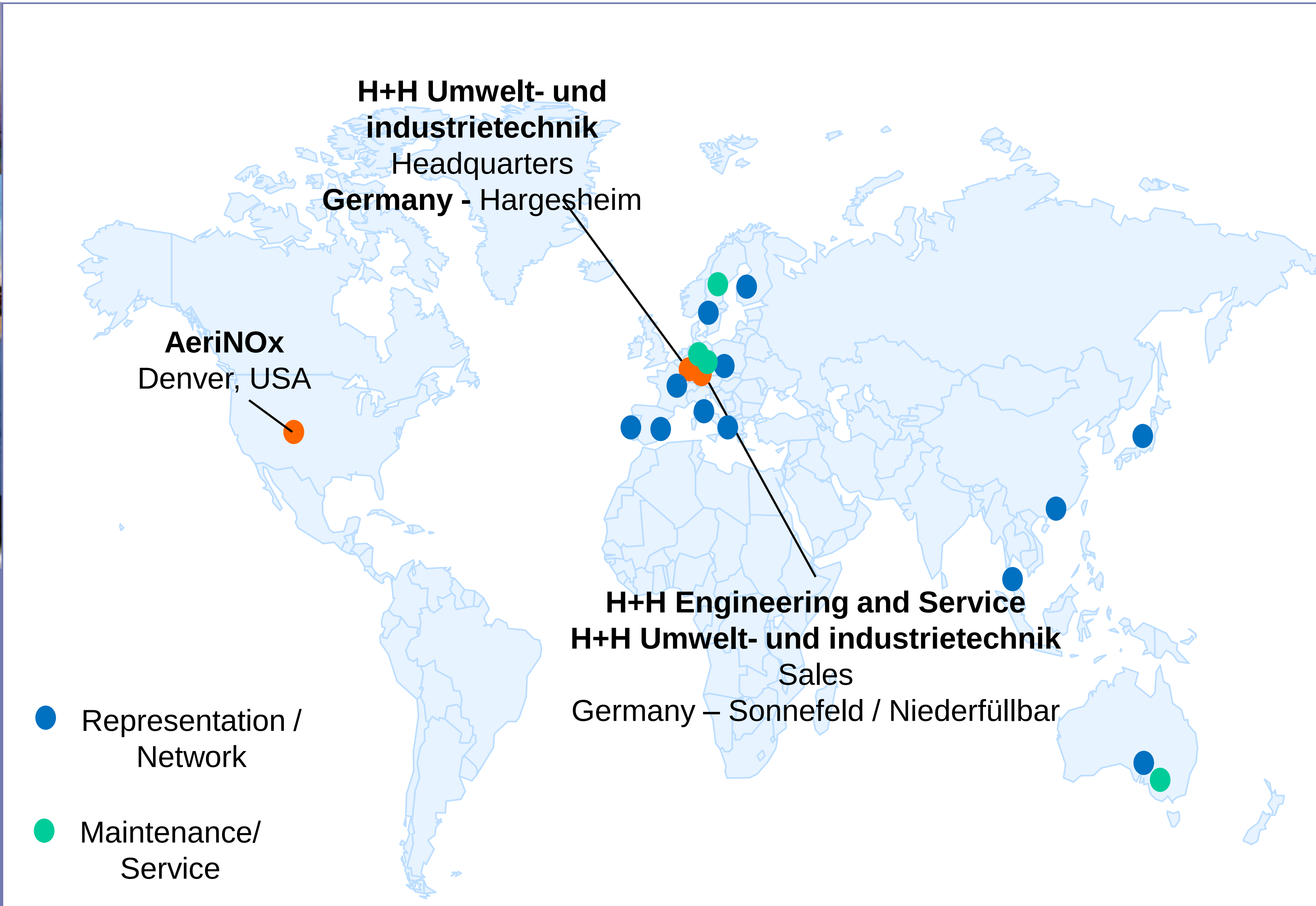






H+H Umwelt und
Industrietechnik GmbH

SOLFIC
Solutions in Heat, Flow and Force



Reference fields

Stationary applications
More than 160 SCR systems delivered
from 100 kW to 20 MW engines
Running with Diesel, HFO, gas, dual fuel, bio oil, animal fat

Marine applications
More than 500 SCR systems delivered
212 ships

Industrial applications
(incineration, chemical plants, glass furnace)
More than 23 references

About the company

- Foundation (former Didier Werk): 1998, 4 owners
- More than 30 people working for H+H
- Mostly Engineers with 5 to 20 years experience in SCR technologie
- Actually more than 700 SCR systems delivered
- Customers all around the world, in more than 20 countries
- Leading position in the SCR Marine Market

Typical Exhaust Gas Components of a Diesel Engine

Components	Typical range (Vol.)
Nitrogen oxides	1.000 - 1.500 ppm
Sulphur oxides	30 – 900 ppm
Carbon monoxide	20 – 150 ppm
Total hydrocarbons	20 – 100 ppm
Volatile organic compounds	20 – 100 ppm
Particles (PM)	20 – 100 mg/Nm³

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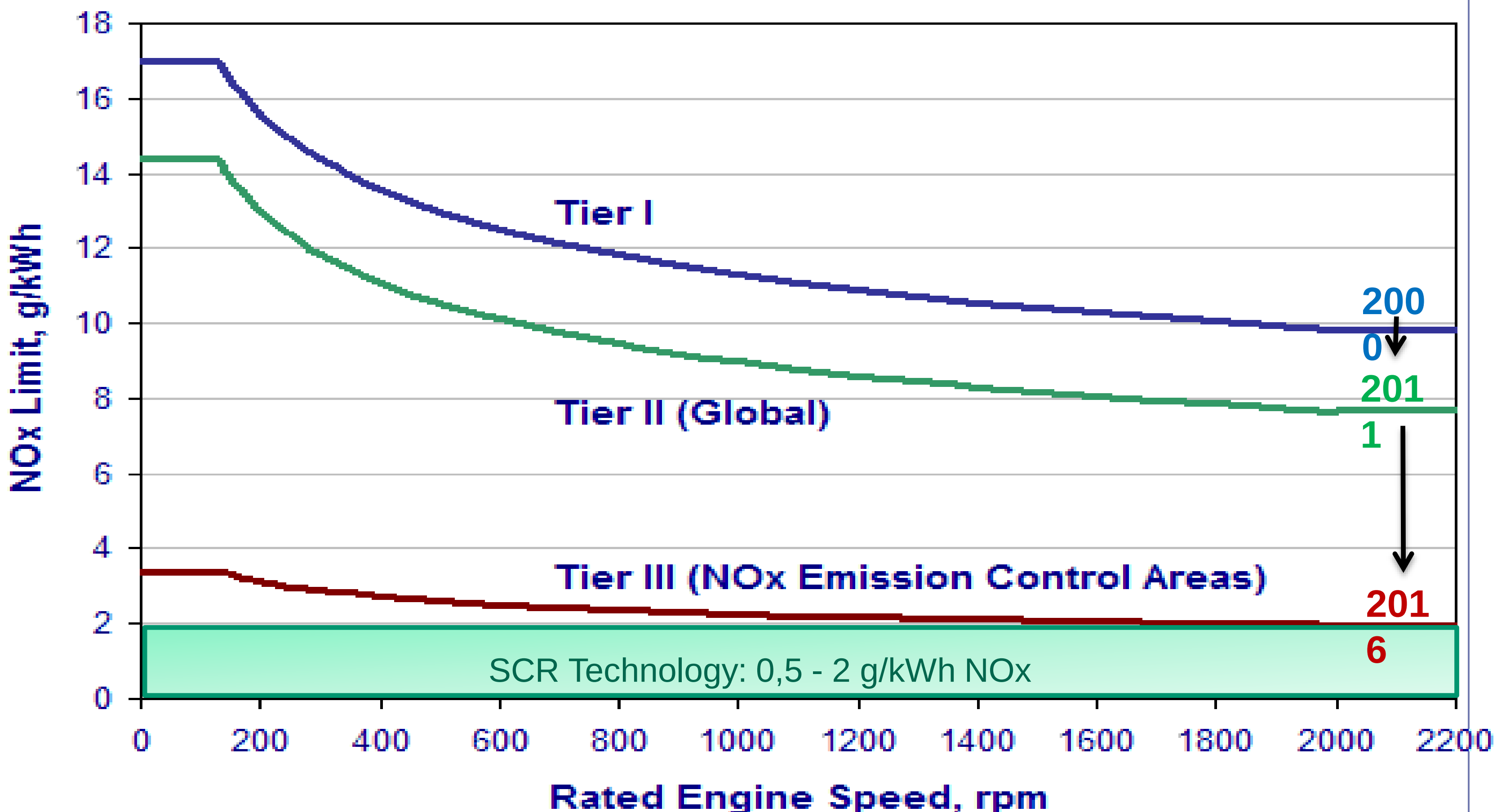
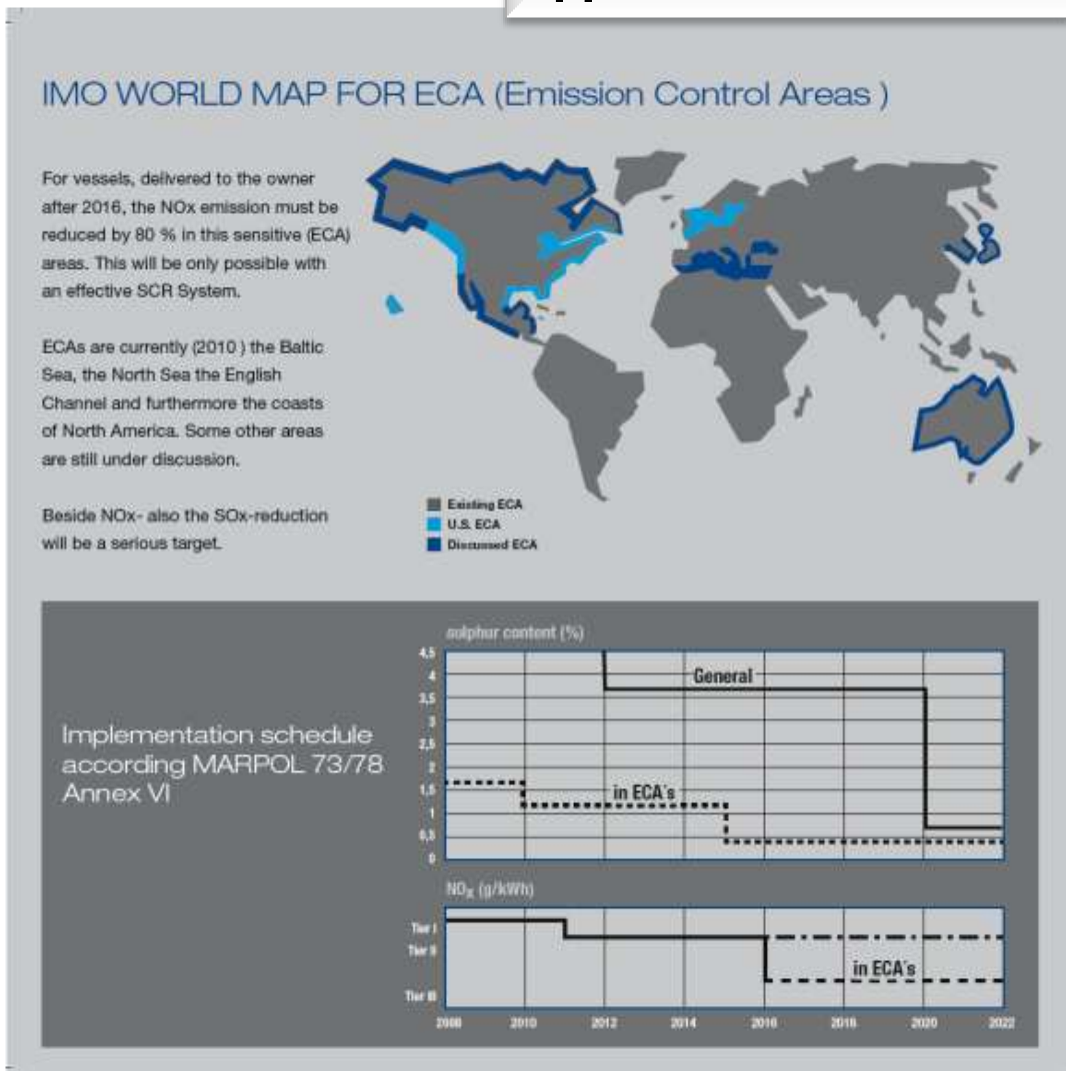
NOx Limits (IMO Regulation)



H+H Umwelt und Industrietechnik GmbH

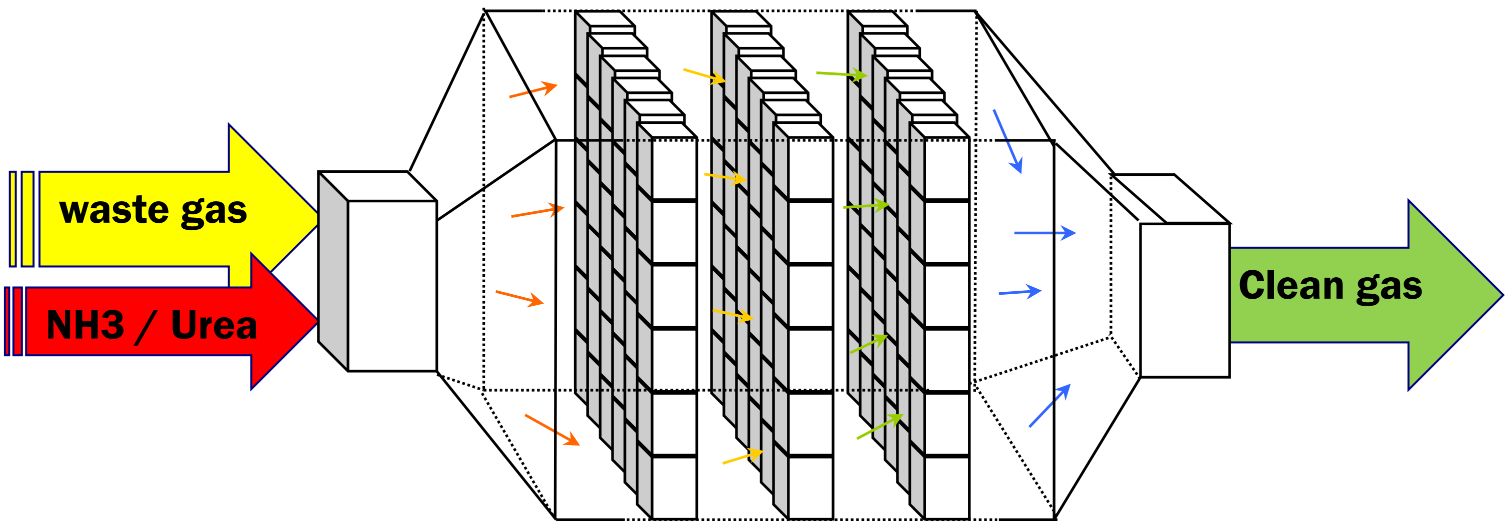
Latest Information on SCR Technology for marine application

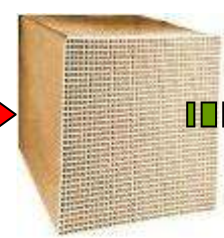


Different Ways and Technologies for NOx Reduction

Technology	Efficiency [% below IMO]
Basic internal engine modifications	- 20 %
Exhaust gas recirculation	- 35 %
Direct water injection	- 50 %
Humid air motor (HAM)	- 65 %
SCR	- 95 %

SCR Principle : Selective Catalytic Reduction

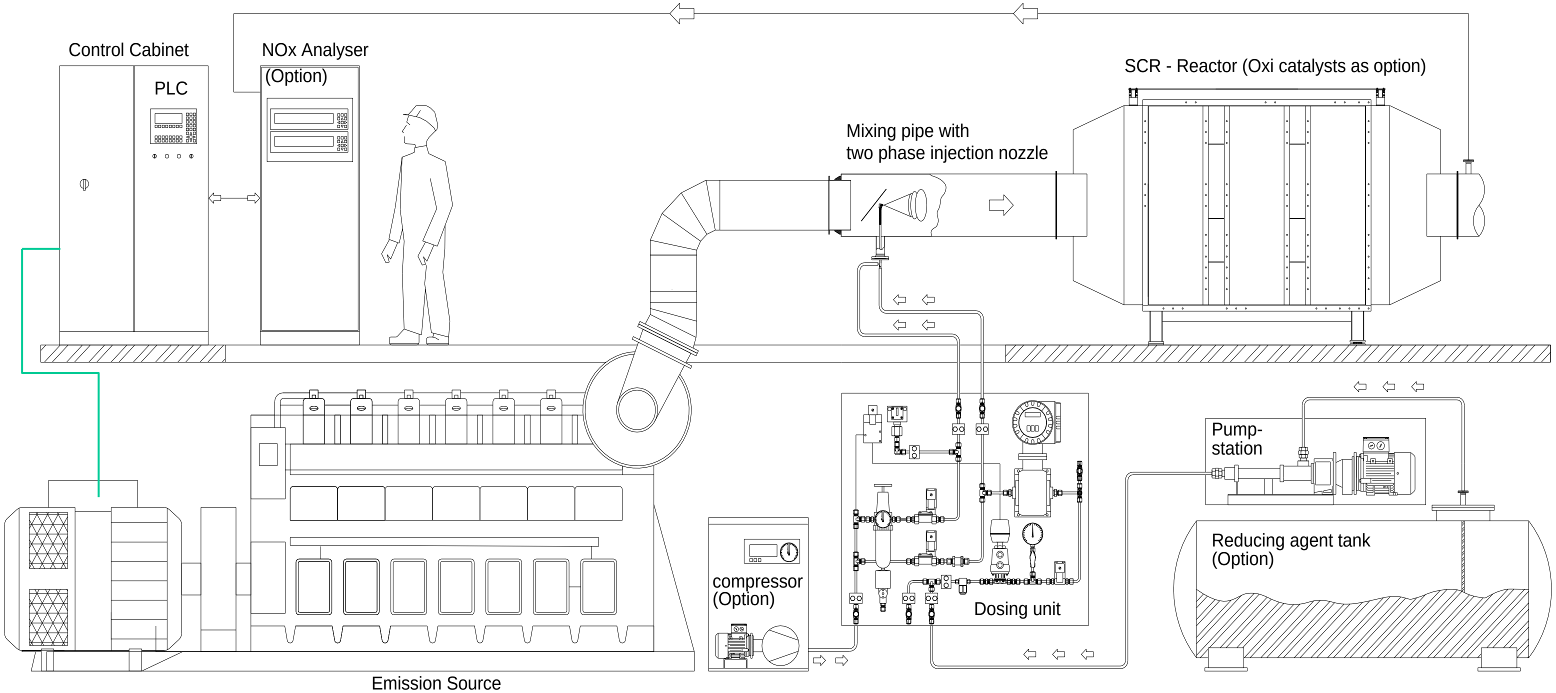




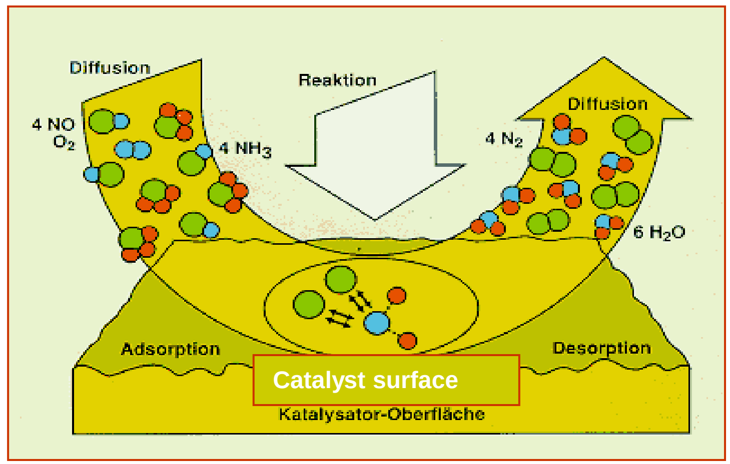
$$4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O$$

Nitrogen Oxides (NO and NO_2) — **Ammonia; formed by aqueous urea solution** → **Nitrogen** — **Water**

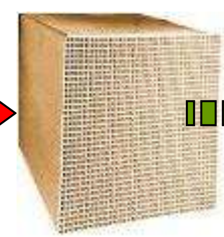
SCR Technology : General Arrangement (example)



SCR Principle (1): Selective Catalytic Reduction



$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$



Nitrogen Oxides (NO and NO_2)

Ammonia; generated by aqueous urea solution

Nitrogen

Water

SCR Principle (2): Selective Catalytic Reduction

1. Step : Injection of Urea Solution
$(CO(NH_2)_2 + H_2O)$

2. Step : Conversion of Urea to Ammonia
(NH_3)

3. Step : Reduction of NOx with Ammonia
$(NOx + NH_3 + O_2 \rightarrow N_2 + H_2O)$

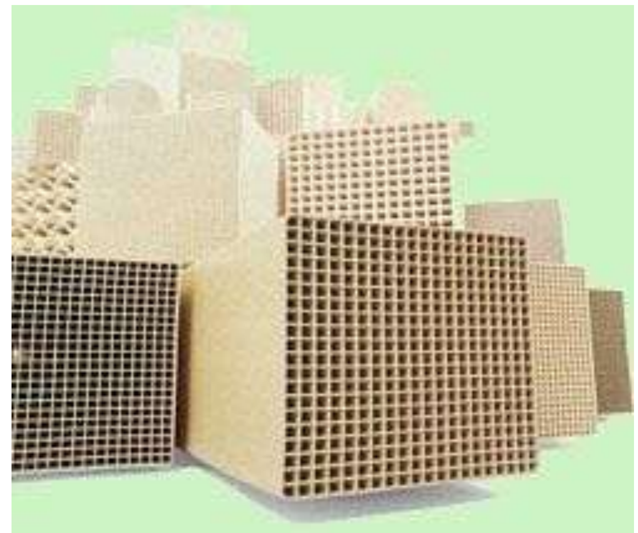
Result : NITROGEN and WATER

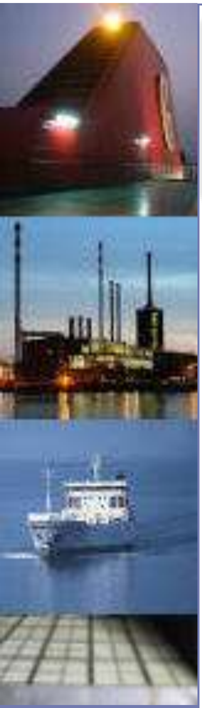
Main SCR Component: SCR Catalyst for the Reduction of NOx Emissions

- Honeycomb catalysts based on TiO_2
  - Full extrudate
  - Further components: WO_3, V_2O_5

- Choice of catalyst geometry depending on exhaust gas conditions

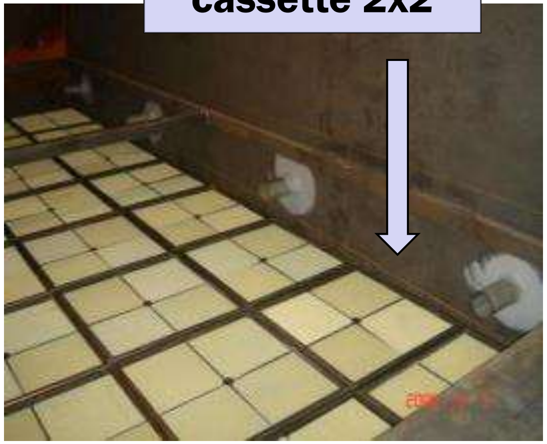
- High activity and mechanical stability as well as long operating times → low investment and operating costs

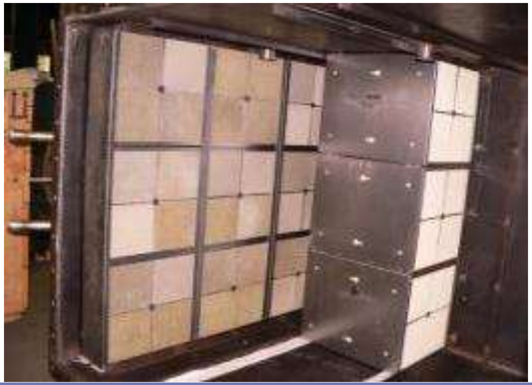


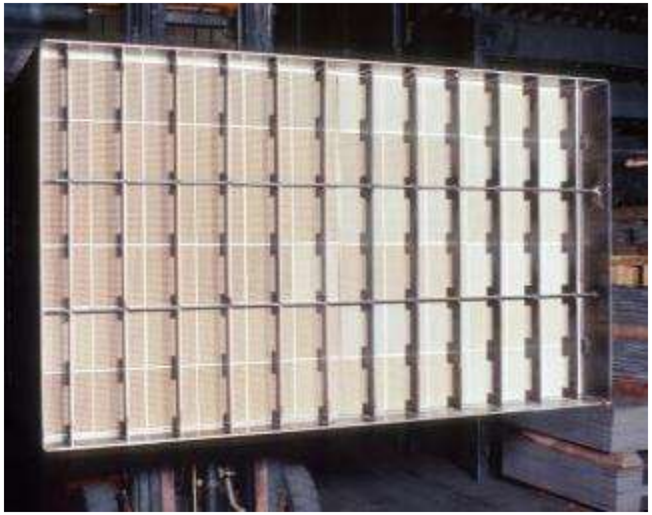


Main SCR Component: SCR Catalyst
Reduction of NOx Emissions

Element frames cassette 2x2







Catalyst in modules, premounted for industrial implantation

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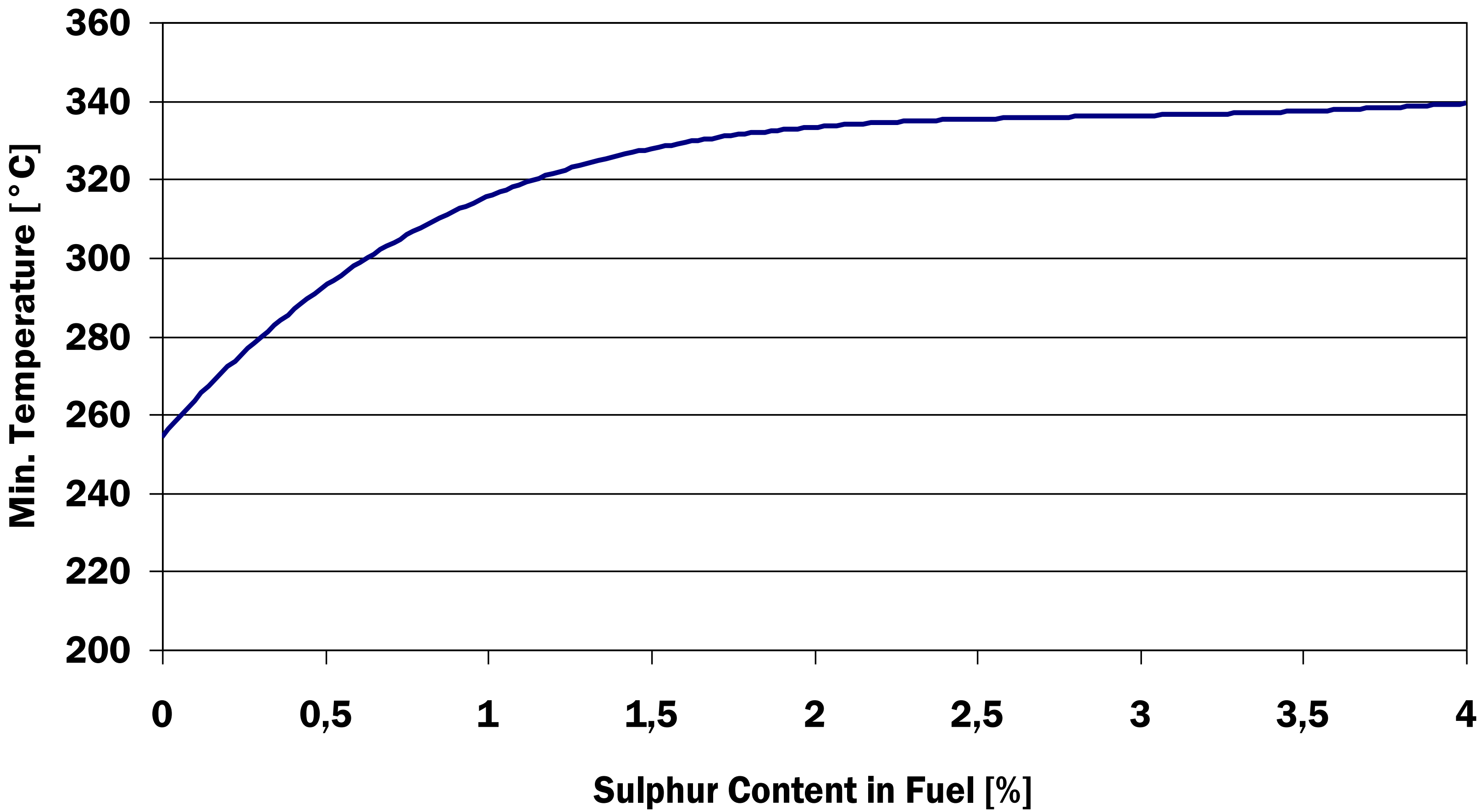
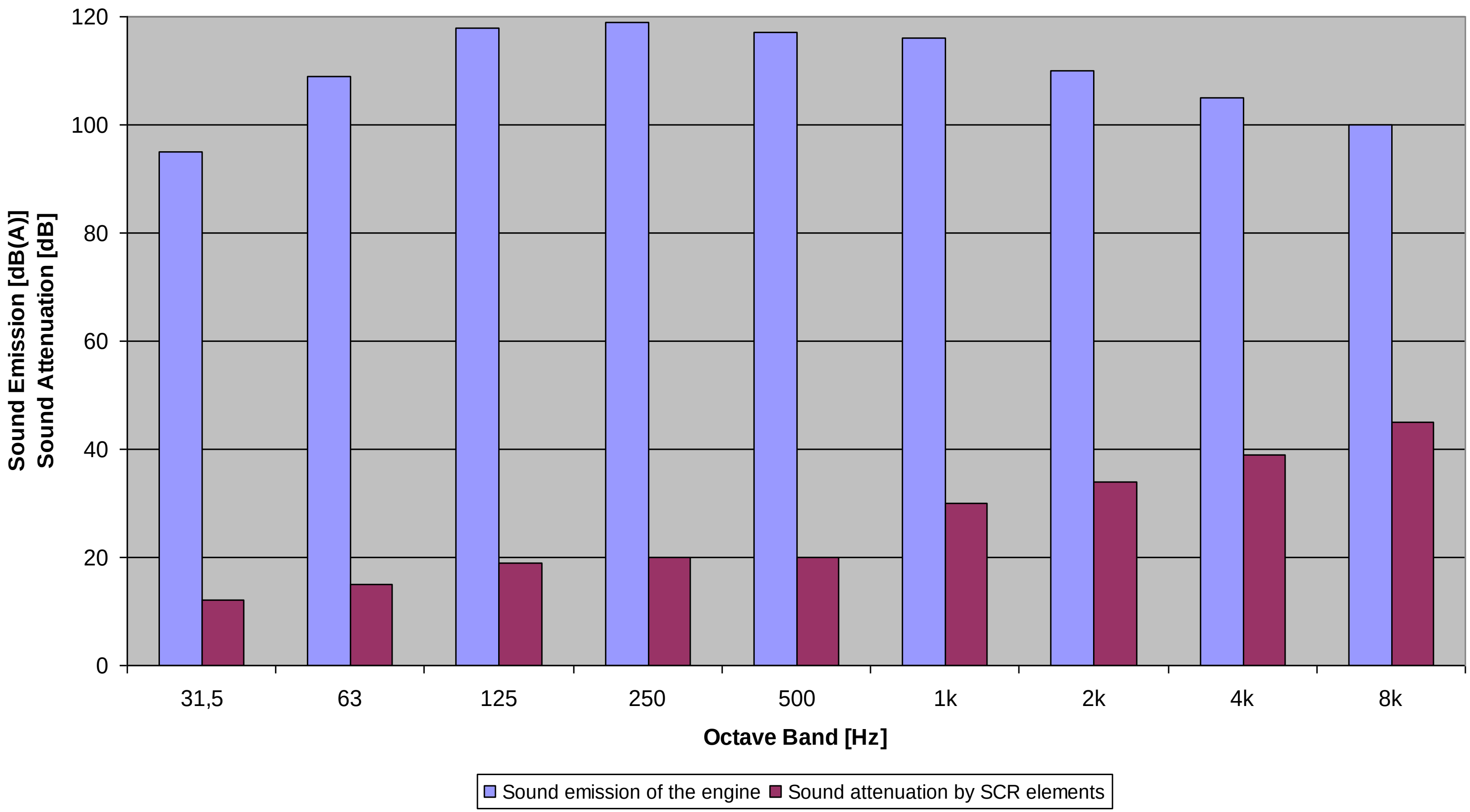
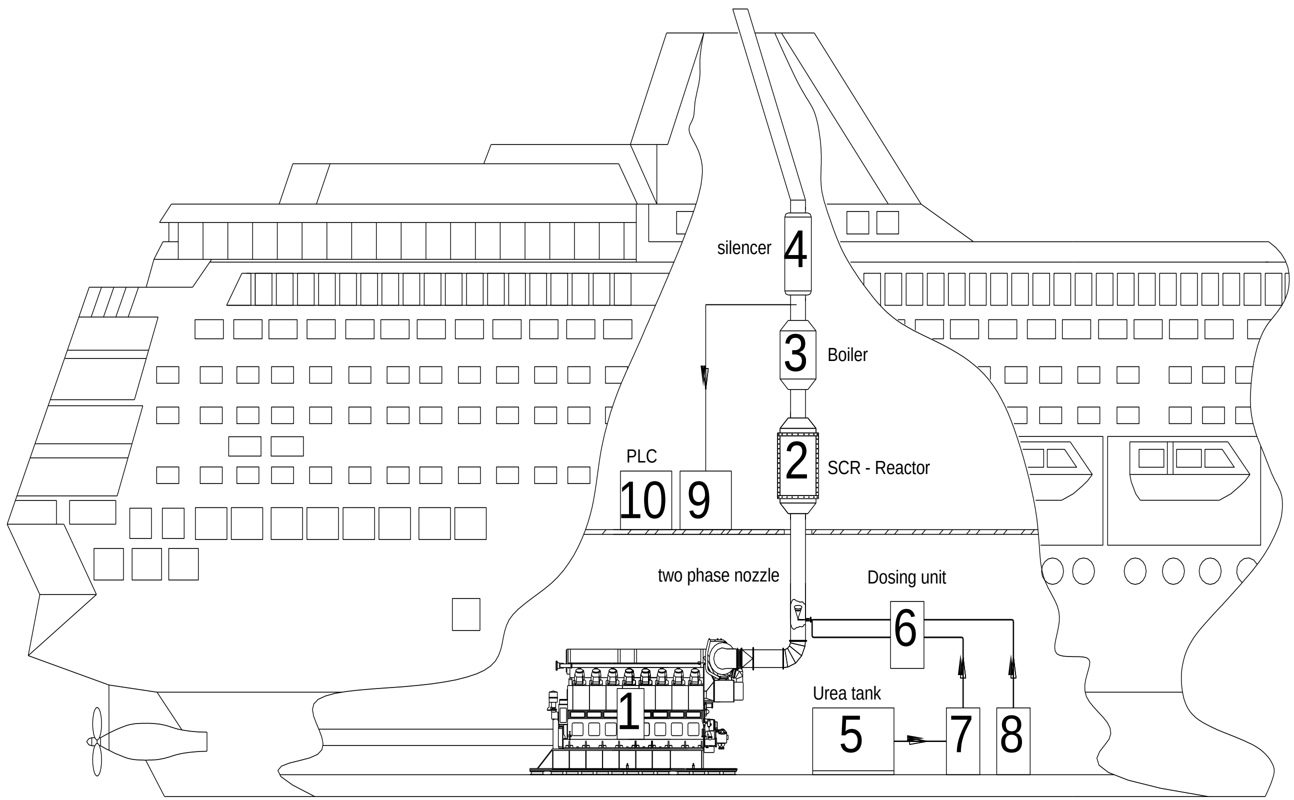
Minimum Temperature for SCR Long-term Operation



Sound Attenuation *(16 Cylinder Medium Speed Engine)*



General Arrangement



1. Diesel engine
2. SCR – reactor
3. Boiler
4. Silencer
5. Urea tank
6. Dosing unit
7. Urea pump skid
8. Compressor (working air)
9. NOx analyser (*optional*)
10. PLC Control cabinet

SCR - Main Figures

Performance :

- NOx Reduction 90 – 98 %
- HC Reduction 80 – 90 %
- Soot Reduction 20 – 30 %
- Sound Attenuation 10 – 35 dB(A)

Operation :

- Temperature Range 280- 510 °C
- Fuel MGO / MDO / HFO

Specific costs :

- Invest costs 30 – 50 € / kW
- Running costs 5 – 8 € / MWh

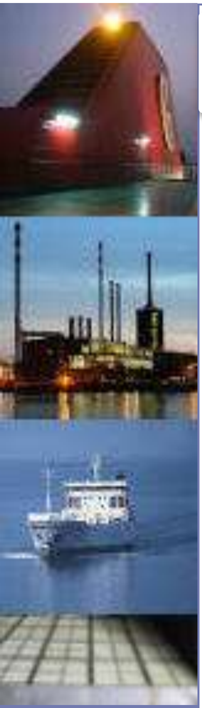
Thumbs Rules

Reduction :

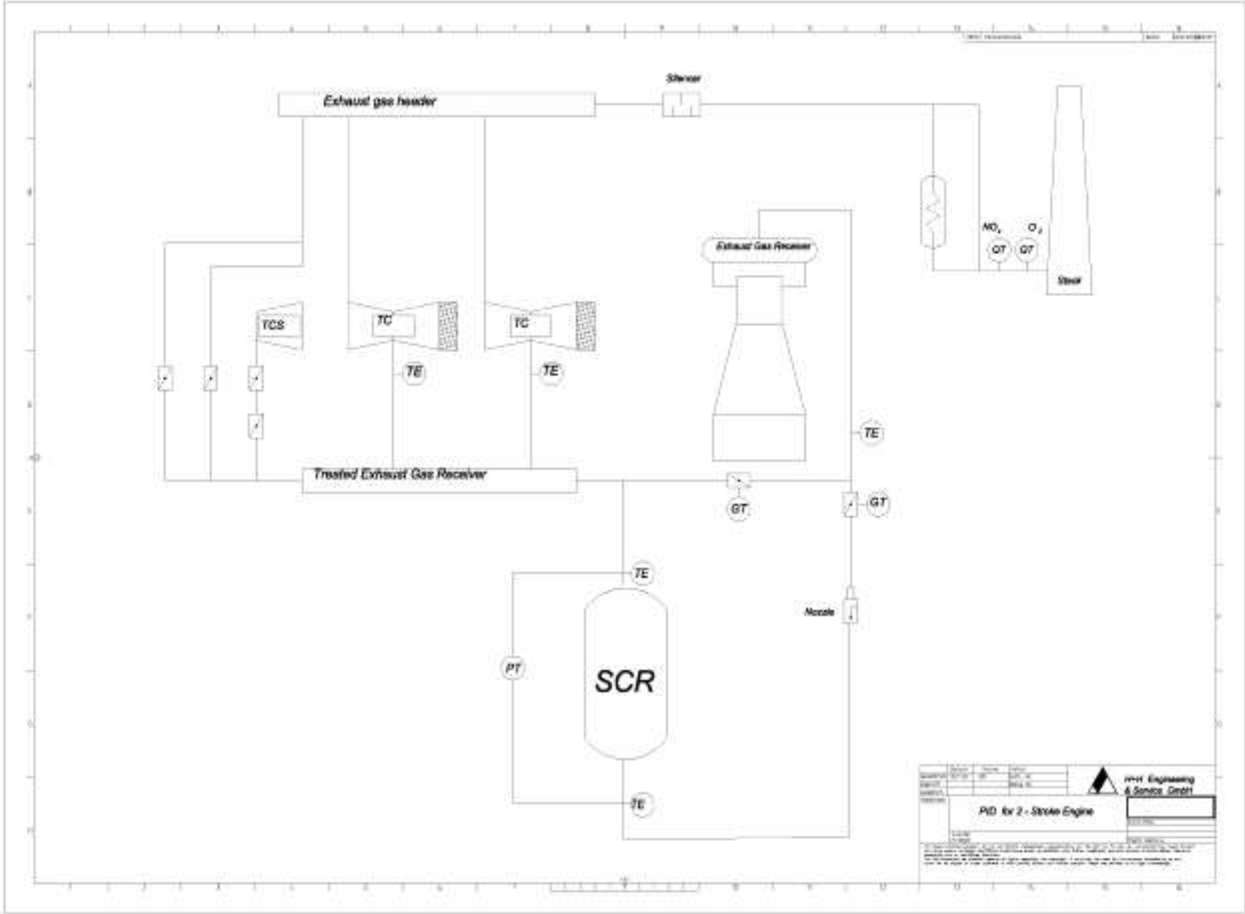
- 0,6815 kg NOx Reduction with 1 l urea
- 15 l/h urea / MW engine power
- for 90% NOx reduction

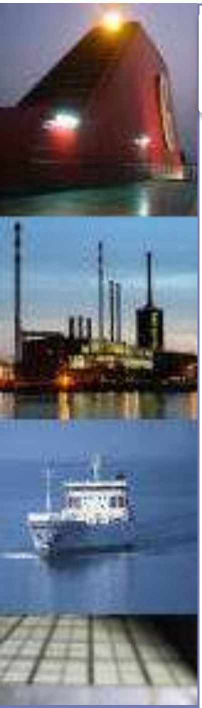
Consumption :

- per 100 l/h fuel oil ⇨ 7 l/h urea 40 %



Challenging solutions – pre-turbo SCR for 2 stroke engines

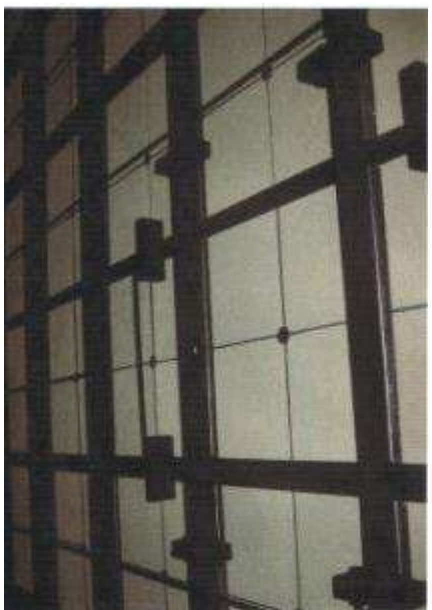




SCR Reference: M/F Pomerania

SCR Reference: M/F Pomerania

SCR Reference: Tallink Galaxy



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Seismic vessel

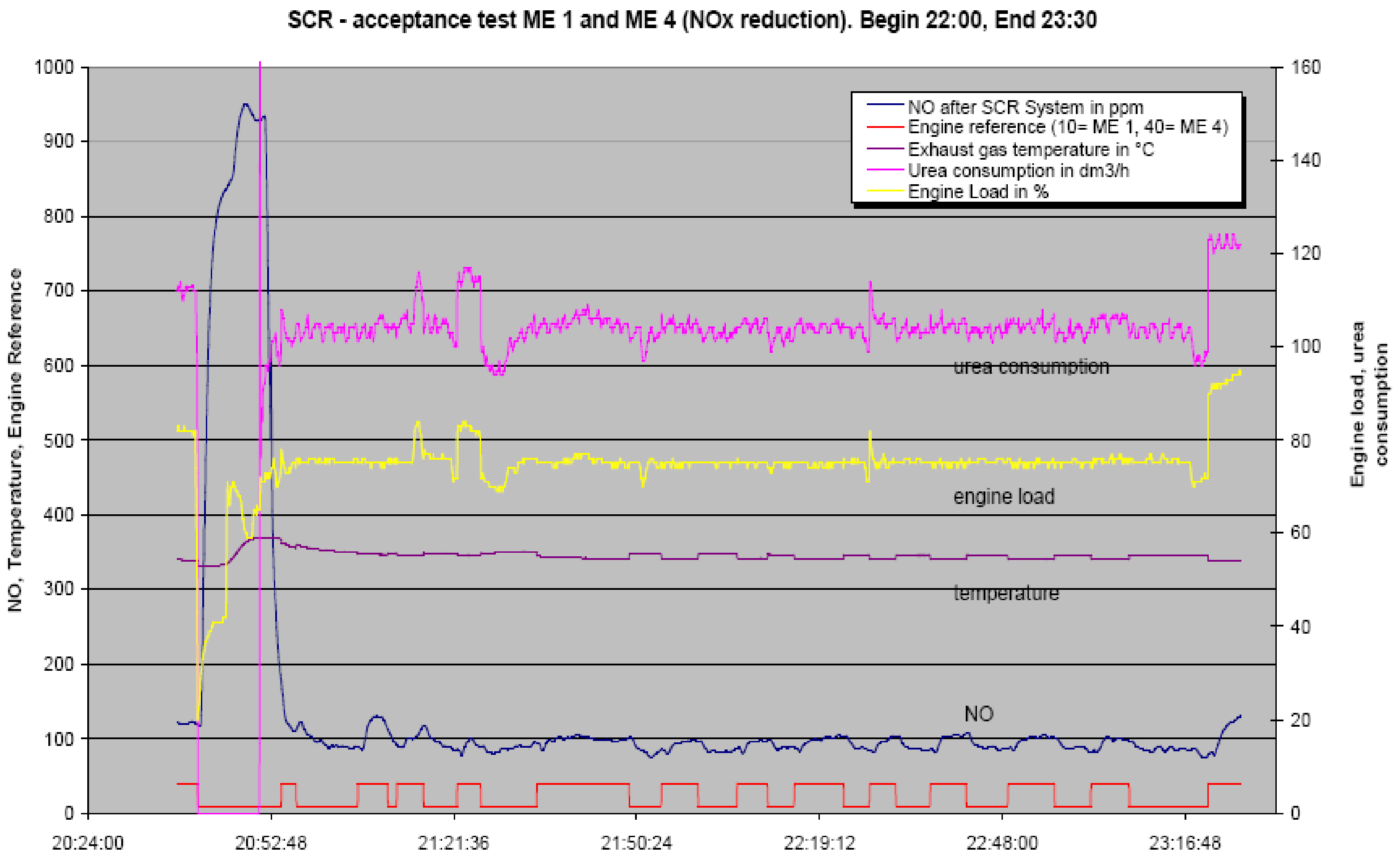
Customer: Mitsubishi Heavy Industries
Nagasaki Shipyard
2 vessels for PGS Norway

Engines : 6x 8L32 - 4.000 kW
Fuel : HFO
NOx reduction from 10 g/kWh to 1,5 g/kWh

Example Marine References : STENA / Wadan Yards

- Stena - ***Britannica***
- Stena - ***Hollandica***

Technical Data:	
Engine Types	2 x 8L48/60 - 9.600 kW 2 x 6L48/60 - 7.200 kW 1 x 7L21/31 - 1.540 kW 3 x 6L21/31 - 1.320 kW Länge : 240 m, Breite 32m Tiefgang 6,3 m
NOx out / engines	< 0,5 g/kWh
Hand over	2 x in 2010
Shipyard	Aker/Wadan Yards – Wismar


SCR - acceptance test ME 1 and ME 4 (NOx reduction). Begin 22:00, End 23:30
NO after SCR System in ppm
Engine reference (10= ME 1, 40= ME 4)
Exhaust gas temperature in °C
Urea consumption in dm3/h
Engine Load in %
urea consumption
engine load
temperature
NO
NO, Temperature, Engine Reference
Engine load, urea consumption
1000
900
800
700
600
500
400
300
200
100
0
160
140
120
100
80
60
40
20
0
20:24:00
20:52:48
21:21:36
21:50:24
22:19:12
22:48:00
23:16:48

Marine customers: (examples)

TALLINK

pon CAT

KLEVEN MARITIME

MAN Ferrostaal

SOLSTRAND AS

polferries
POLSKA ŻEGLUGA BAŁTYCKA SA

HAVYARD

WÄRTSILÄ

REDERI AB GOTLAND

Bergen Tankers as

EASTERN ECHO
Eastern Echo is now a member of Schlumberger
for more information please visit

Karmsund Maritime

SAMSUNG
SAMSUNG HEAVY INDUSTRIES

Mecmar AS
Mechanical and marine engineering

SILJA LINE

aker yards.

FJELLSTRAND

ULSTEIN

SUNDBUSSERNE
HELSINGØR-HELSINGBORG

VIKING LINE

REMONTOWA

LINDENAU GMBH
SCHIFFSWERFT & MASCHINENFABRIK

More than 200 vessels with SCR systems

About 700 SCR systems installed

Engine power from 1 MW to 10 MW

Summary :

- SCR is a reliable and proven technology for marine applications
- References: In total more than 200 vessels with about 700 engines worldwide!
- SCR means: combined with:
  - 90 - 95 % NOx reduction
  - HC Reduction
  - Soot Reduction
  - Sound Attenuation

ROYAL WAGENBORG

Royal Wagenborg

SCR Experience – Platform Scheepsemissies

Content

- Introduction Royal Wagenborg
- Upcoming regulations
- SCR Installation onboard
- Process, measurement, rebate
- Operations and costs

Royal Wagenborg

Our company...

- serves clients since 1898
- is 100% privately owned
- provides integrated logistic solutions
- works with state of the art equipment
- employs 3000 people

Our people…

- focus on solutions
- are dedicated and experienced
- have passion for the job
- don’t know the word impossible

Wagenborg Nedlift

- Crane rental (Benelux and Germany)
- Heavy transport and logistic management
- Turnkey heavy transport and lifting projects
- Factory-to-foundation projects with 100% Wagenborg resources
- Engineering and project management





Wagenborg Passenger Services

- Almost 10,000 departures a year
- 1.8 million passengers a year
- 5 ferries sailing to the Dutch isles, Ameland & Schiermonnikoog
- 3 High speed Water taxis operating in the Dutch Northern Coastal waters

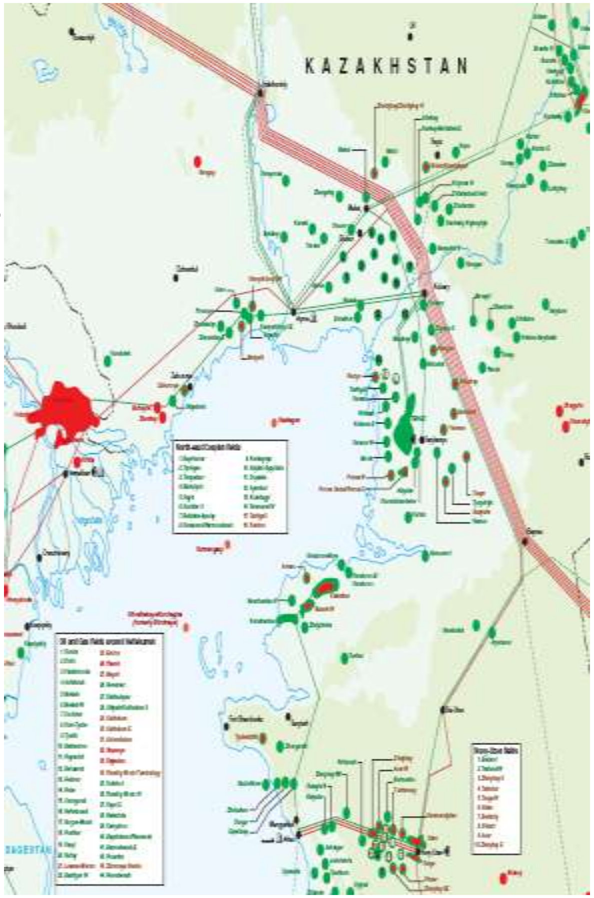
Reining

- Integrated solutions: transport, warehousing and distribution
- 320 vehicles
- Warehousing 100,000 m^2
- 4 European branche offices in the Netherlands and in Hungary
- Intermodal solutions
- Real-time information throughout supply chain

Wagenborg Offshore

Area of operations

- Worldwide
- Focus on activities in former CIS and Caspian Sea



Activities in the Oil- & Gas industry

- Operator and owner of vessels, rigging- and hydraulic
  piling equipment
- Rig move-, Inspection-, Management- and Consultant
  activities
- Commissioning of offshore structures and assembly of
  new drilling rigs

Wagenborg Shipping

Area of operations

- Worldwide
- Focus on activities in Europe, Middle East and Americas

Activities in the Multi Purpose Shipping Segment

- Operator and owner of vessels
- Commercial and technical operations
- Crewing
- Sale & purchase
- Insurance
- Projects and Newbuilding

Wagenborg Shipping

- 180 modern multi-purpose vessels ranging from 2.000 to 22.000 tons, mostly fully ice-classed, geared and gearless
- One of the largest ship owners in Europe by number of vessels
- Youngest fleet in Europe with an average age of 6.2 years due to continuous new building program
- Seamless access to the entire logistic chain through close cooperation with other Wagenborg companies
- More than 150,000 m2 of high quality storage facilities




Wagenborg Shipping

•Spaarne-/ Schie-/ Slingeborg

1. SCR on two stroke main diesel engine
2. Zero Dumping
3. Closed water lubricated propeller shaft
4. Low solvent paint system
5. 6 kV Shore connection
6. Waste management system

•In operation since 1999.

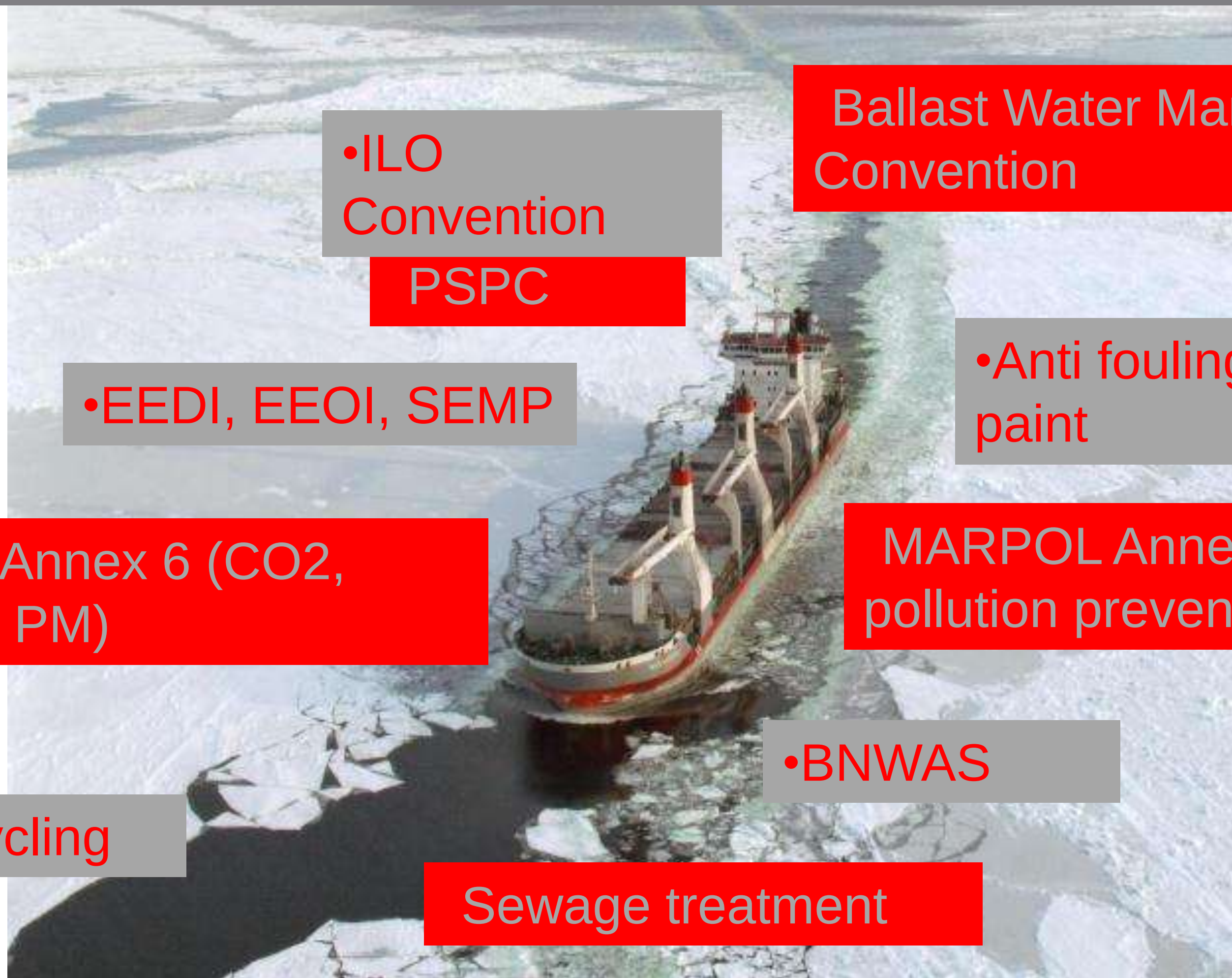
Wagenborg Shipping

• **Baltic-/ Bothniaborg**

1. 6 kV Shore connection
2. SCR
3. Environmental friendly propeller shaft seals
4. Zero Dumping
5. Ballast Water Treatment
6. Environmental Design Review

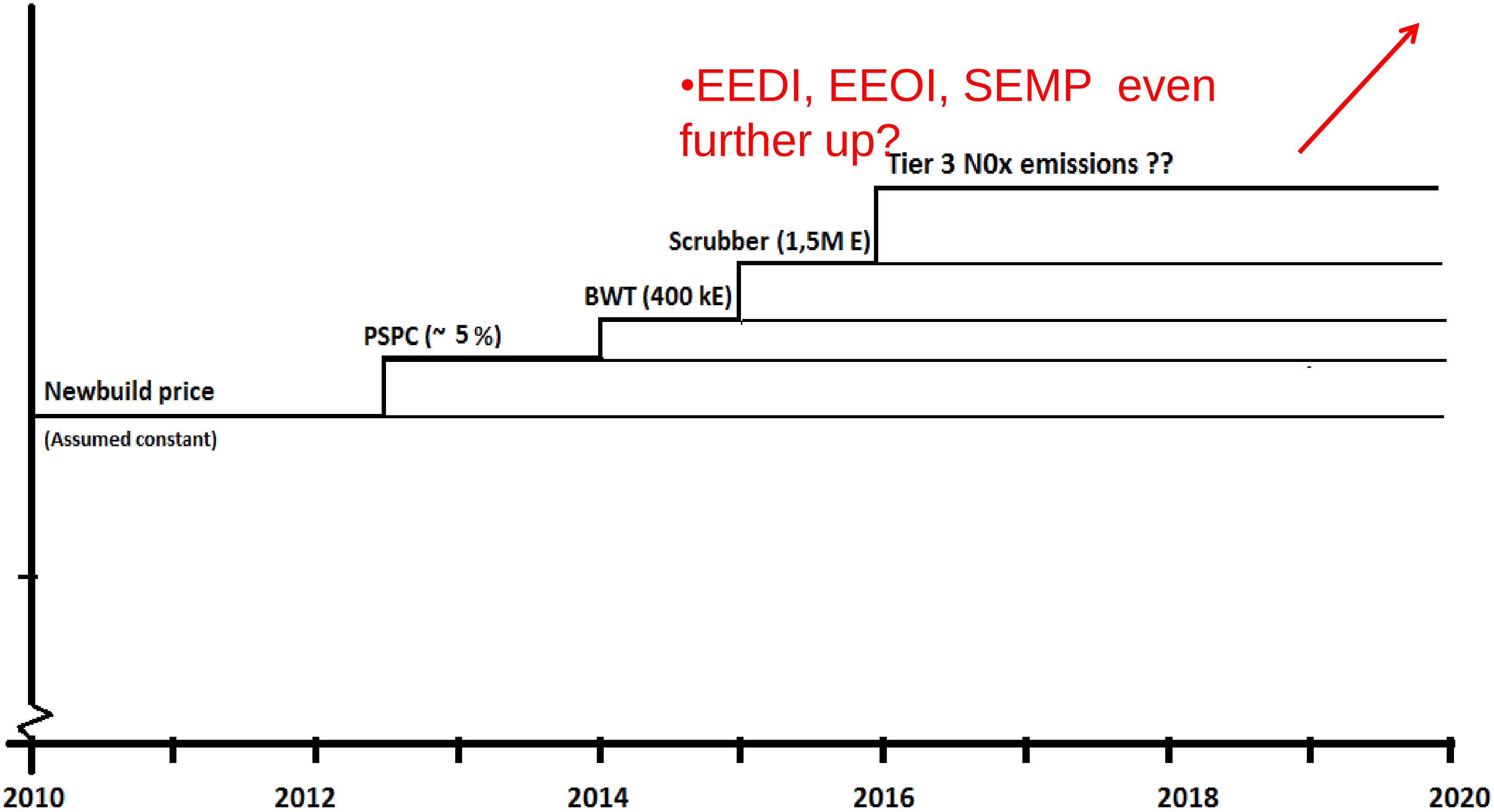
• In operation since 2004.

Upcoming Regulations



- Ballast Water Management Convention
- •ILO Convention
- PSPC
- •EEDI, EEOI, SEMP
- •Anti fouling paint
- MARPOL Annex 6 (CO2, NOx, SOx, PM)
- MARPOL Annex 1 (oil-pollution prevention)
- •BNWAS
- •Ship recycling
- Sewage treatment

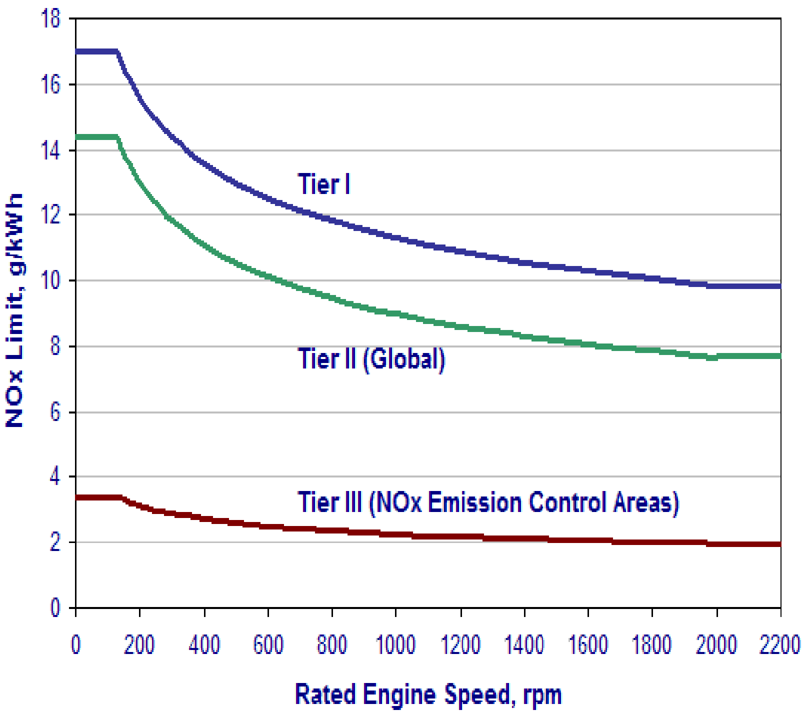
Effect of Upcoming Regulations



Marpol Annex VI NOX Emission limits

Table 1. MARPOL Annex VI NOx Emission Limits				
Tier	Date	NOx Limit, g/kWh		
		n < 130	130 ≤ n < 2000	n ≥ 2000
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96
† In NOx Emission Control Areas (Tier II standards apply				

•**Table 1.** MARPOL Annex VI NOx Emission Limits

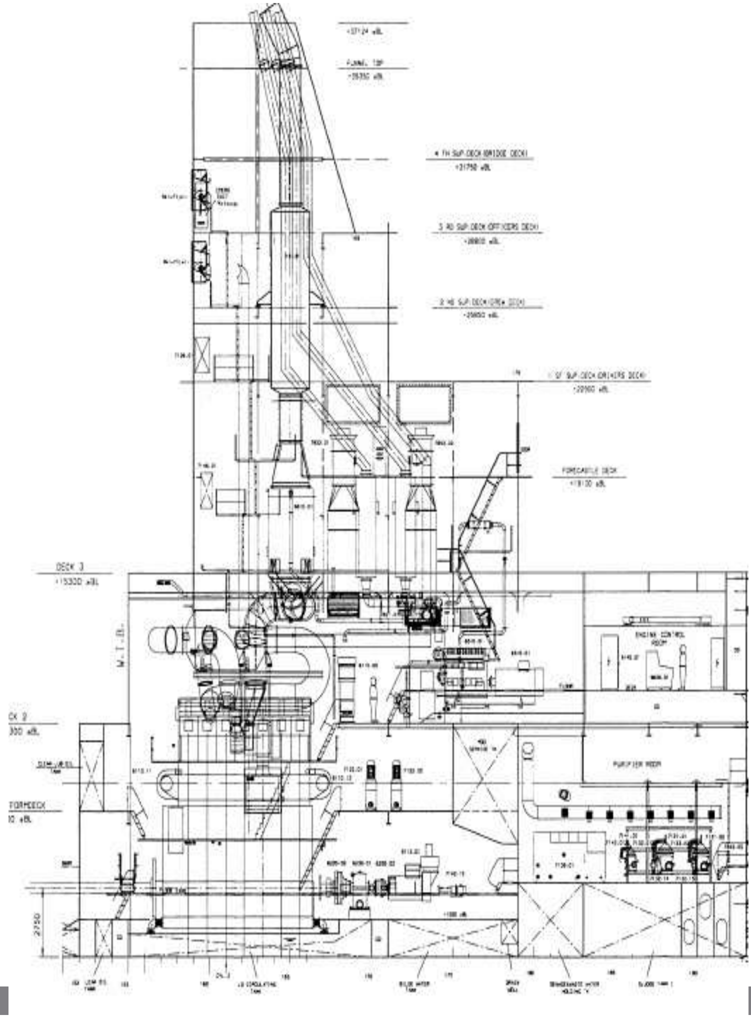


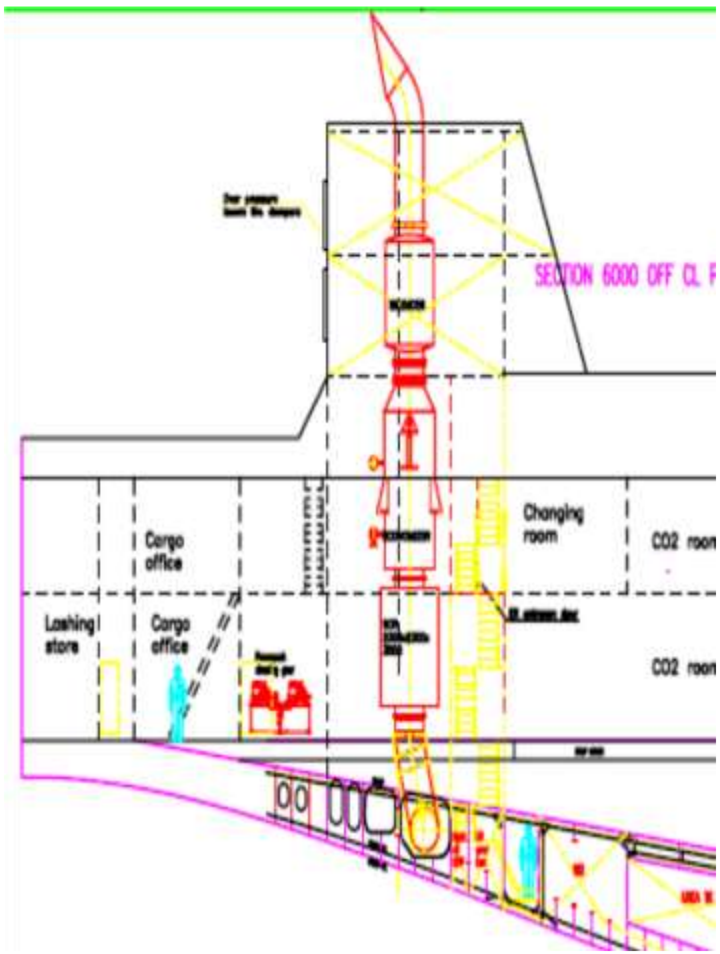
•**Figure 1.** MARPOL Annex VI NOx Emission Limits

Technical specifications

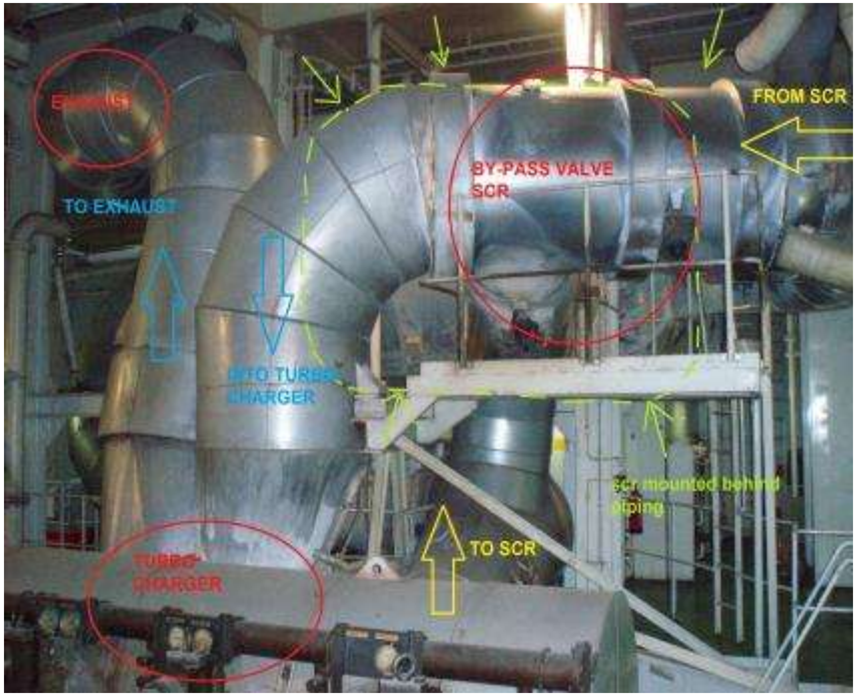
Engine / SCR data	B-Series	S-Series
Engine Make/type	Wartsila 7RTA52U	Wartsila 9L46C
Power at MCR	10.920kW	9.450kW
Exhaust gas flow	89.544kg/h	59.400kg/h
Exhaust gas press.	3,2bar	1,0bar
Exhaust gas temp.	430°C (385°C at 75%MCR)	365°C (330°C at 75%MCR)
SCR Make/type	ABB 147H/PT	Munters 196V
Size (lxwd)/weight		4.000x2.400x2.400mm. (9.500kg)
NOx baseline at 75%MCR	17,0g/kWh	13,0g/kWh
NOx performance at 75%MCR	2,0g/kWh	2,0g/kWh
Urea consumption	191 l/h	120 l/h

Schematic installation onboard





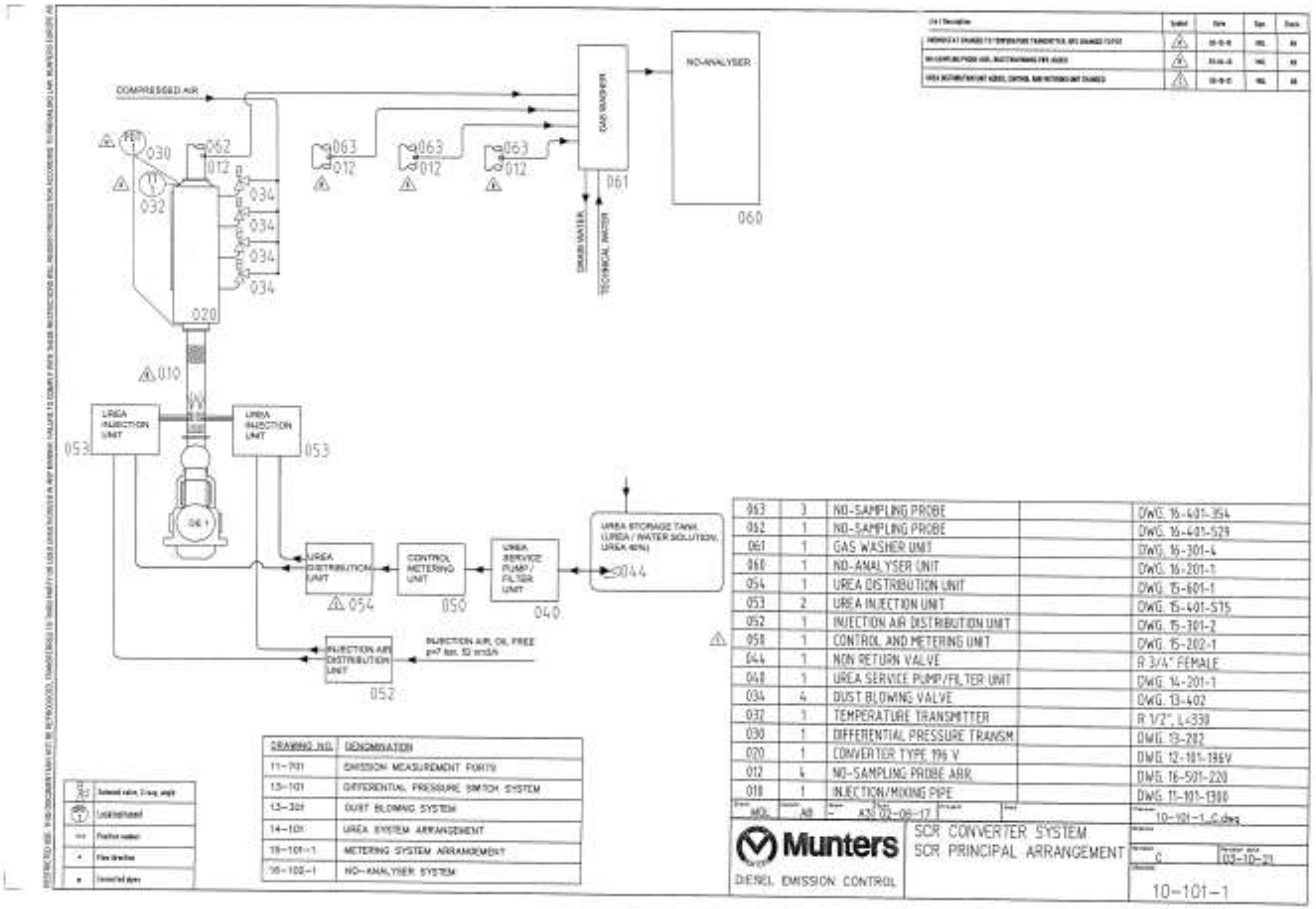
SCR



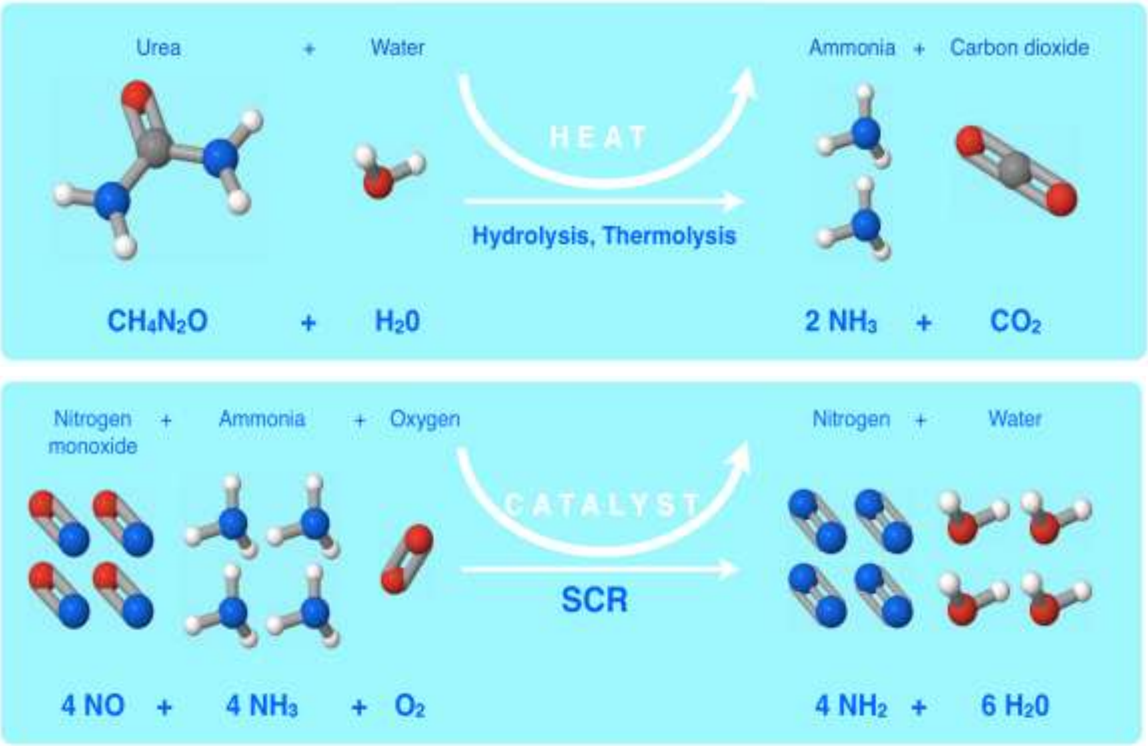
Exhaust gas system S-series

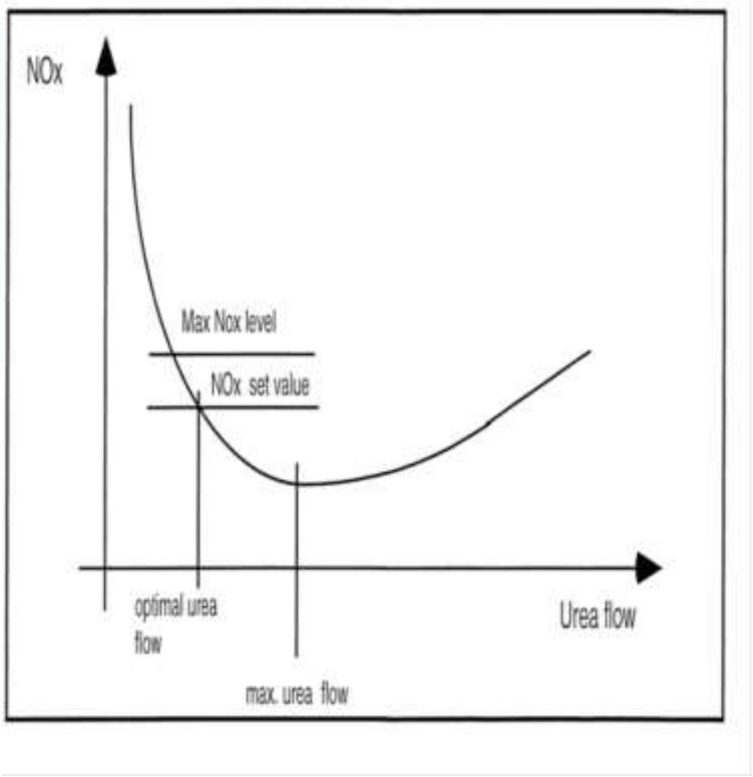
Internals SCR B-series

SCR Schematic



SCR Process


Urea + Water
HEAT
Hydrolysis, Thermolysis
Ammonia + Carbon dioxide
CH_4N_2O + H_20
2 NH_3 + CO_2
Nitrogen monoxide + Ammonia + Oxygen
CATALYST
SCR
Nitrogen + Water
4 NO + 4 NH_3 + O_2
4 NH_2 + 6 H_20


NOx
Max Nox level
NOx set value
optimal urea flow
max. urea flow
Urea flow

Urea product specification

DEC Marine	**SPECIFICATION SHEET** For 40% Urea Solution		Doc.No: DEC 920 Date: 2007-10-09 Sheet no: 1 (1)
Chemical name: **Urea Solution**			
Molecular Formula: $(H_2N)_2CO + H_2O$			
Physical Properties: Absolutely Clear (Visual Inspection) Odourless			
Analytic Specification:			
Urea Concentration		Percent by Weight	40 ± 1
Biuret		Percent by Weight	< 0.3
Aldehyde		mg / kg	< 5
Insoluble		mg / kg	< 20
Phosphate	PO_4	mg / kg	< 0.5
Calcium	Ca	mg / kg	< 0.5
Iron	Fe	mg / kg	< 0.5
Copper	Cu	mg / kg	< 0.2
Zinc	Zn	mg / kg	< 0.2
Chromium	Cr	mg / kg	< 0.2
Nickel	Ni	mg / kg	< 0.2
Aluminium	Al	mg / kg	< 0.5
Magnesium	Mg	mg / kg	< 0.5
Sodium	Na	mg / kg	< 0.5
Potassium	K	mg / kg	< 0.5

UREA for use in DEC's SCR Converter System must follow the above specifications. The Urea tank approval according to requirements specified in doc DEC921 shall also be fulfilled before filling of the tank

Accreditated measurements

EMK

The REPORT is done by an accredited laboratory No 1879

REPORT
Edition 1
11/12/2009/EF/HSn

Page 4 (5)
PNo 9049

Engine		Main engine	Auxiliary engine 1	Auxiliary engine 2	Auxiliary engine 3
Day of test	date	16/10/09	15/10/09	15/10/09	15/10/09
Power	%	78 %	48%	50%	52 %
Test started	time	11:26	17:06	15:54	14:42
Effective test duration	h	0.50	0:40	0:43	0,41
Air temperature outside	°C	5	7	7	7
Air temperature on board	°C	22,8	25,2	22,2	20,8
Atmosphere pressure	kPa	103,0	102,2	102,2	102,3
Air humidity on board	%	33,5	28,6	29,6	31,8
O_2- content	vol % dg	12,4	13,4	13,3	13,3
CO_2- content	vol % dg	6,58	5,71	5,81	5,77
CO- content	vol ppm dg	87,0	54,3	47,2	48,0
Equivalent CO- content	g/kWh	0,49	0,41	0,33	0,33
NO_x-content	vol ppm dg	82,9	606	671	641
Equivalent NO_x -content	g/kWh	0,70	7,23	7,42	6,72
TOC content as metan	vol ppm wg	0,03	0,08	0,04	0,03
Equivalent TOC content	g/kWh	0,0001	0,001	0,0002	0,0001
Ammonium-nitrogen at 15 % O2	ppm	4,0	-	-	-
Gas temperature	°C	374	229	243	241
Exhaust flow	m^3wg/h	71339	3184	3127	3141
Exhaust flow	m^3(n)wg/h	34796	1553	1525	1532

NO_x-emission

Weighted average value	g/kWh	--------------------1,32------------------------
Expanded uncertainty*	g/kWh	----------------1,16 - 1,48-------------------

Remarks: m^3(n) = gas volume at 1 bar (abs) and 0°C
dg = dry gas
wg = wet gas
* = Expanded uncertainty at 95 % confidence level with a coverage factor of 2.

Swedish Fairway dues

SWEDISH MARITIME ADMINISTRATION

Nox Rebate on GT based portion of the fairway dues:

Emission level, Nox g/kWH	Passenger vessels. SEK	Cruising vessels, SEK	Other vessels, SEK
0 – 0,50	0	0	0
0,51 – 1,00	0,15	0,03	0,25
1,01 -2,00	0,40	0,08	0,61
2,01 – 3,00	0,63	0,16	0,77
3,01 – 4,00	0,77	0,24	0,93
Etc.			
10,01 -	1,80	0,80	2,05

Operational issues

- Increase of delta P (alarm setting 3kPa);
- Clogging of stones; Calcium from luboil (TBN), impurities from HFO and Urea.
- Reduction of reactivity; increase of ammonium slip.
- Failing of stones
- Operational above 300°C exhaust gas temp
- Bunkering of Urea and availability

Problems with catalyst stones

Broken stones
B- series: 50% of total 576

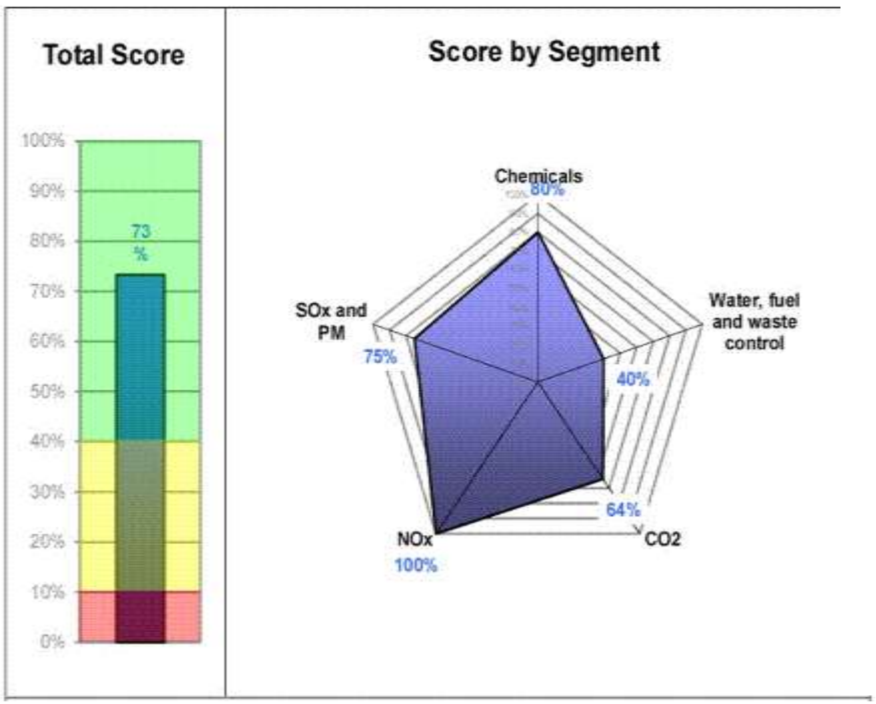
Clogged stones

Operating costs

- Costs of Urea; +/- €160-200/ton
- Consumption of Urea; approx. 10% of HFO consumption
- Costs of measurements for Swedish Fairway reduction;
  +/- €10.000 every 3 years
- Calibration, check up costs
- Urea analyzing costs
- General maintenance costs; i.e. dust blowers, injectors etc.
- Exchange of catalyst stones, when needed; €60.000 - €100.000.

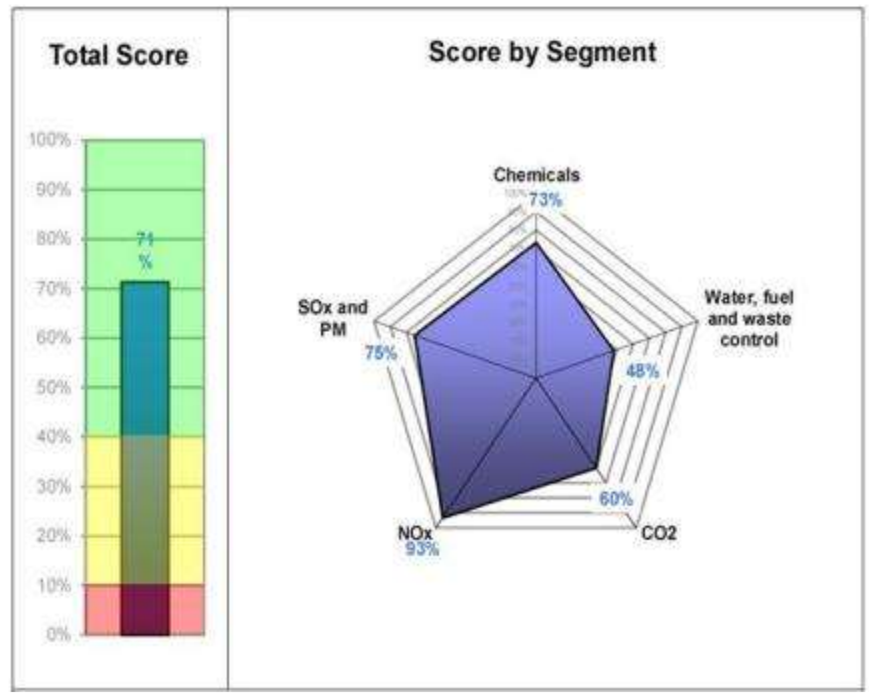
Clean Shipping Index

Clean Shipping Index - Summary
Shipping Line:
Number of vessels: 3



S-Series

Clean Shipping Index - Summary
Shipping Line:
Number of vessels: 2



B-Series

ROYAL WAGENBORG

Royal Wagenborg

Duurzame binnenvaart

LNG als oplossing voor lage NOx emissies in de binnenvaart

Raymond Gense

mei 2012

Ontwikkelingen tot 2030

Verbranding fossiel → **Elektrisch/ Non fossiel**

- Benzine
- Diesel
- Gas

- Batterij
- Waterstof
- Groengas/Biodiesel

Drijvende krachten

Lokale luchtkwaliteit

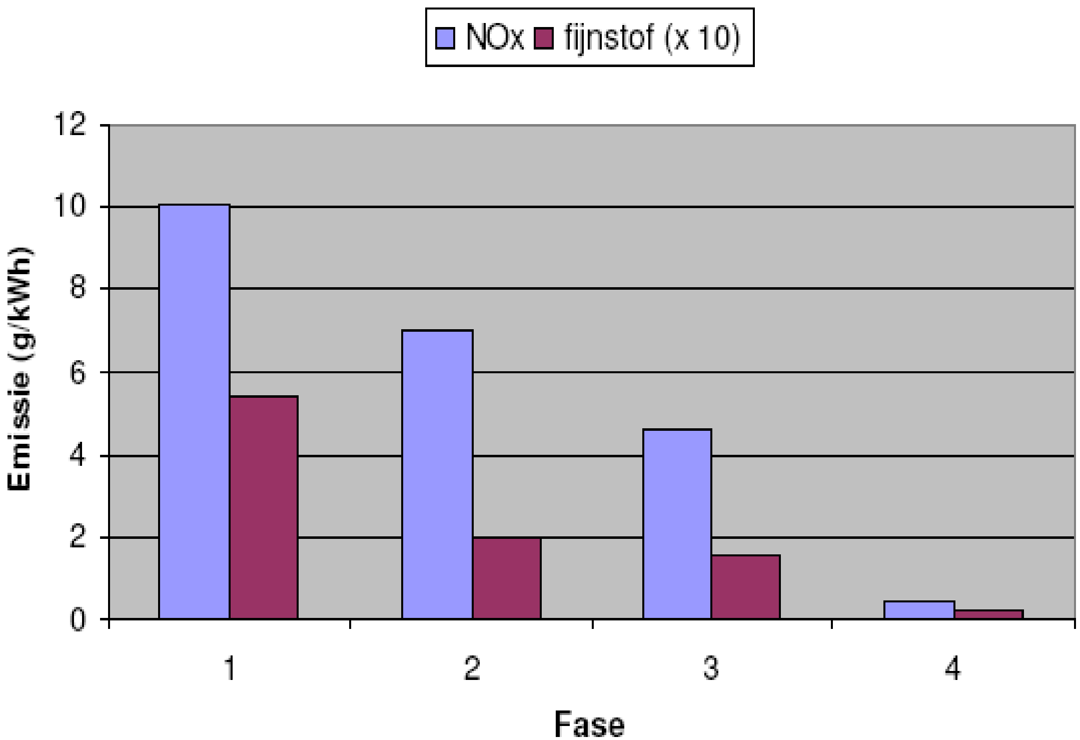
Brandstofschaarste

Klimaatverandering

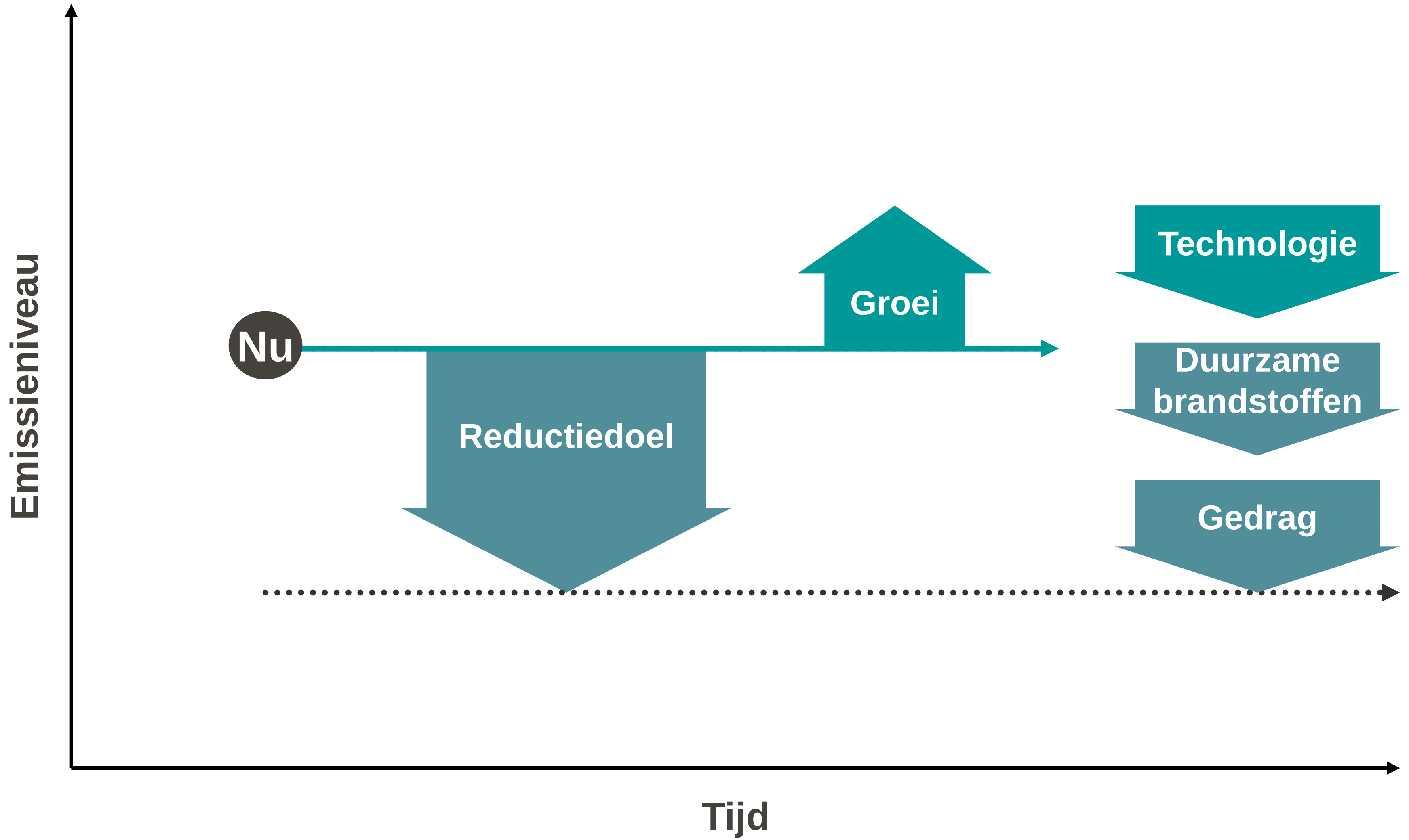
Wetgeving ter stimulering voor duurzaam varen

CCR (Centrale Commissie Rijnvaart):

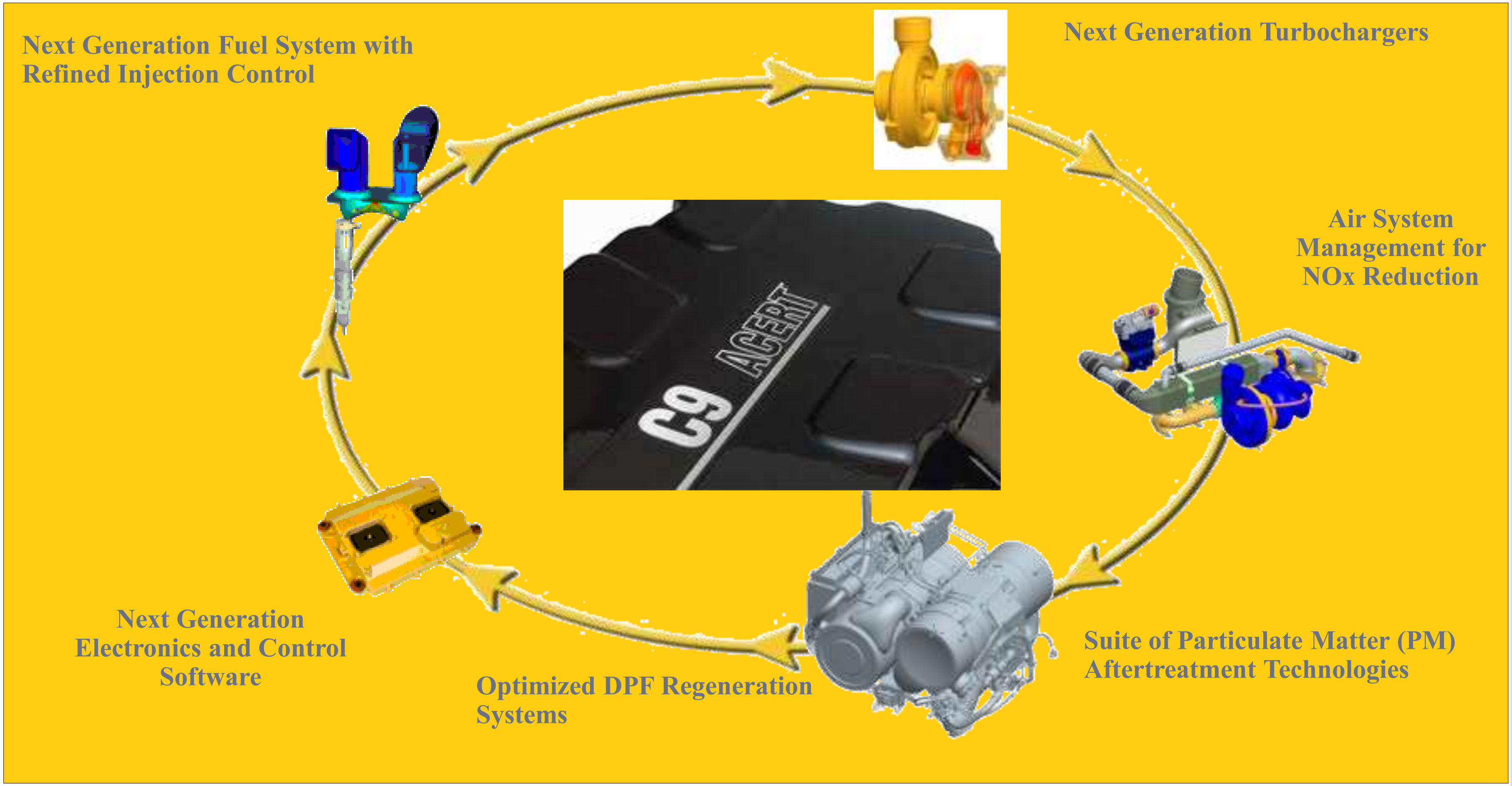
- **Eisen aan zwavelgehalte brandstof**
- **Eisen aan uitstoot NOx en Fijnstof uitstoot**



Oplossingen

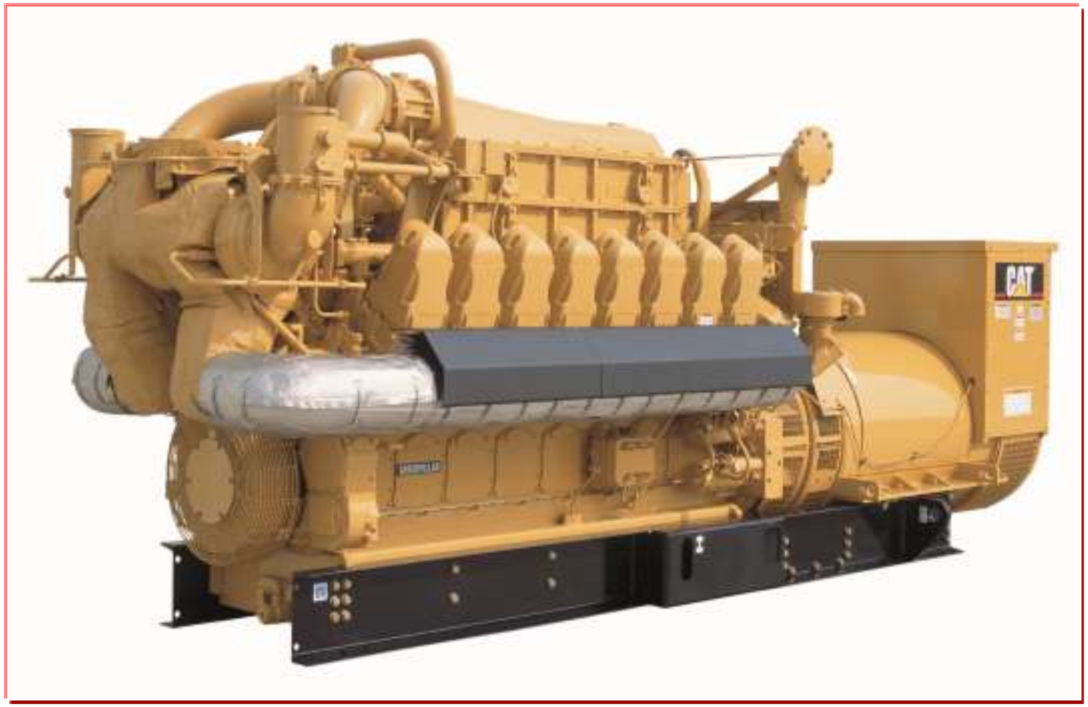


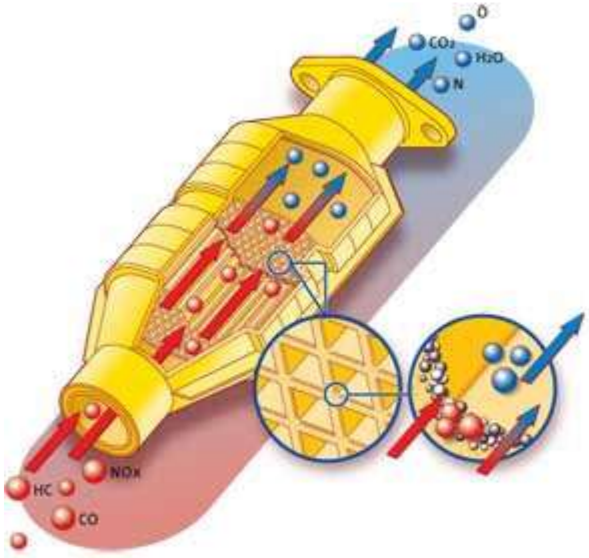
Geoptimaliseerde diesel motor + uitlaatgasnabehandeling



Schoon, maar tegen extra kosten en nauwelijks CO_2 reductie potentie

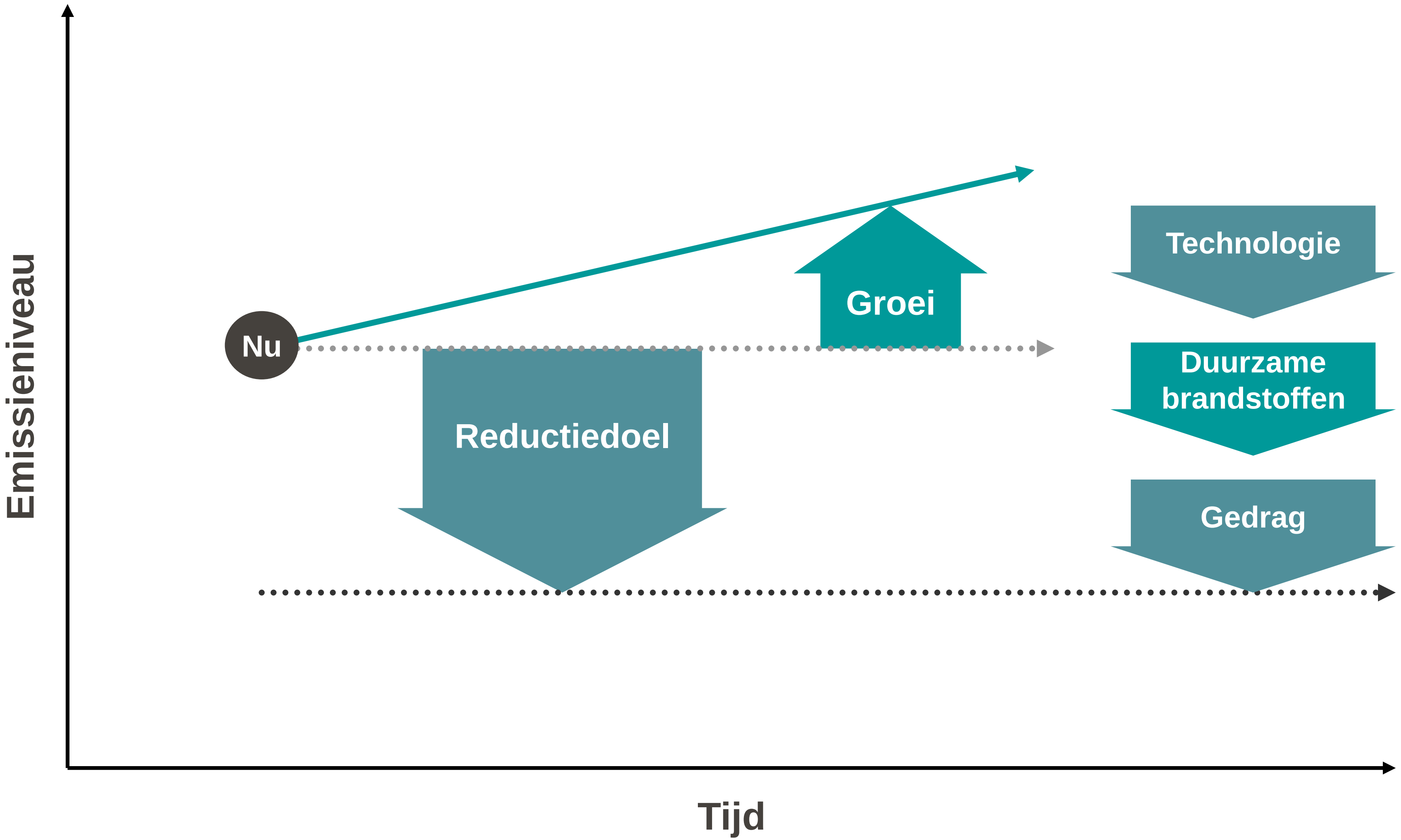
Gasmotor + uitlaatgasnabehandeling (3-weg katalysator)



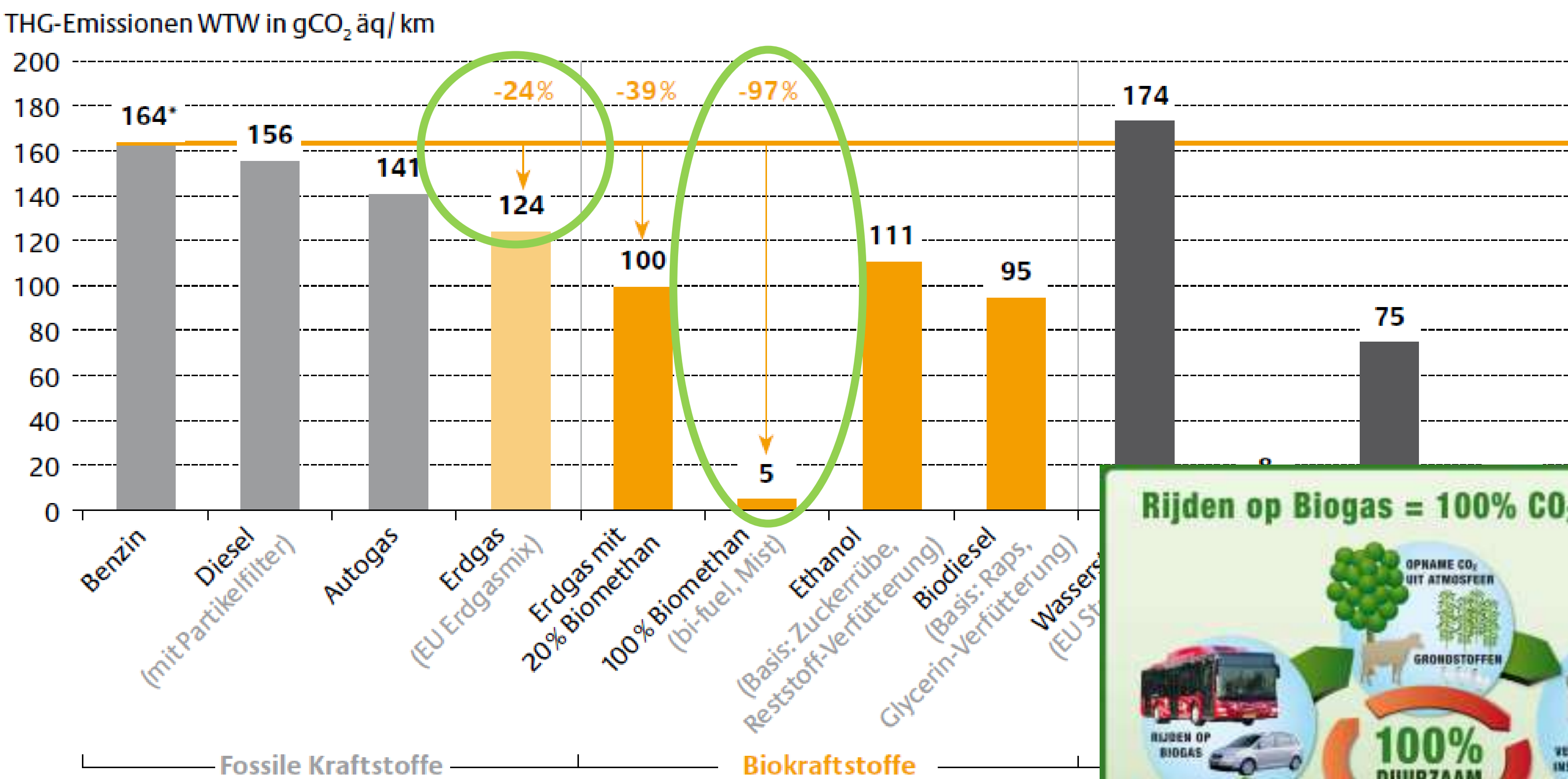


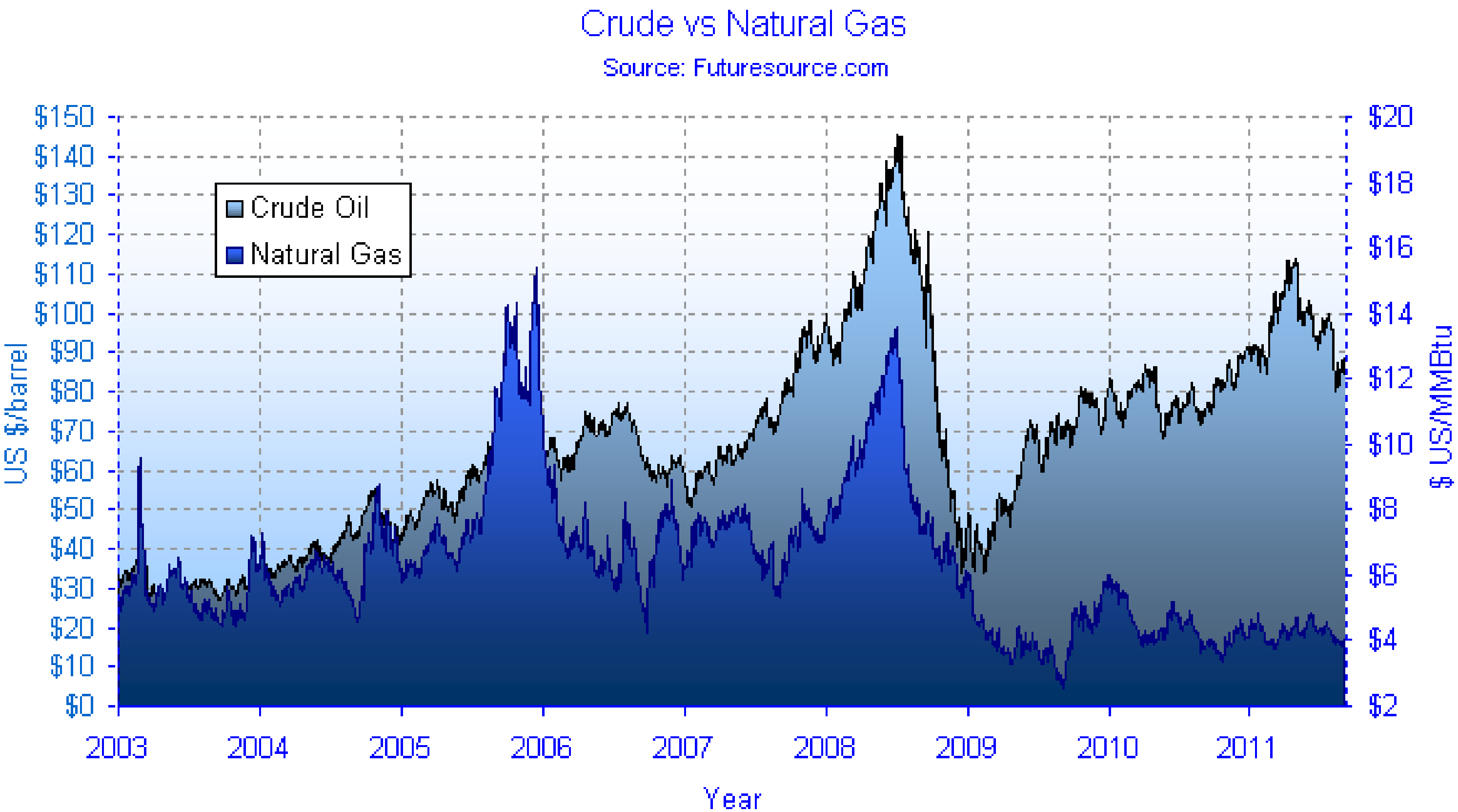
Zeer schoon, matig dynamisch gedrag en hoge CO_2 reductie potentie

Oplossingen



De stap naar Liquid Bio Methane (LBM)





En lage brandstofkosten door grote gasvoorraden wereldwijd

Voor en nadelen van varen op diesel en methaan

- **Diesel SCR/PM filter**
  - Voordelen:
    - Bewezen betrouwbare diesel technologie
    - Bewezen Fijnstof en NOX filter technologie (automotive, power plants)
  - Nadelen:
    - Dure technologie zonder terugverdientijd
    - Grote installatie omvang
    - CO_2 reductie enkel als 2e generatie biodiesel betaalbaar beschikbaar (>2020)

- **Methaan (CNG/LNG)**
  - Voordelen
    - Bewezen schone technologie (gensets en automotive)
    - Hoog CO_2 reductie potentieel: 20% op aardgas, >80 % op biogas
    - Hoog terugverdienpotentieel via goedkope stabiele brandstofprijs
  - Nadelen
    - Geen binnenvaart scheepmotoren beschikbaar (wel zeevaart)
    - Nog geen tankinfrastuctuur beschikbaar (moeilijke overgangsfase)
    - Klasse goedkeuring noodzakelijk via nieuw protocol

Dual Fuel

Dual Fuel LNG : Het beste van 2 werelden

- Betrouwbare dieseltechniek als basis
- Eenvoudige bewezen gastechnologie als toevoeging
- Toepassing van brandstof met stabiele lage prijs (LNG)
- Upgrade naar CO_2 arme biobrandstof mogelijk (LBM)
- Varen op 100% diesel nog steeds mogelijk
- Retrofit van bestaande machinekamers eenvoudig mogelijk

Maar, bij initieel idee (2009):

- Varen op 2 brandstoffen niet voorzien in Europese wetgeving
- Klasse moest nog worden opgelijnd
- Brandstofbunkering nog niet geregeld
- Transient gedrag en maximale bijmenging niet bewezen

EFRO subsidieproject "Argonon"

Dual Fuel :

Hoog efficient Dieselproces met (bio)methaan als hoofdbrandstof

Introduction
Dual-Fuel Explanation
System Operation
Maintenance
Possible Applications

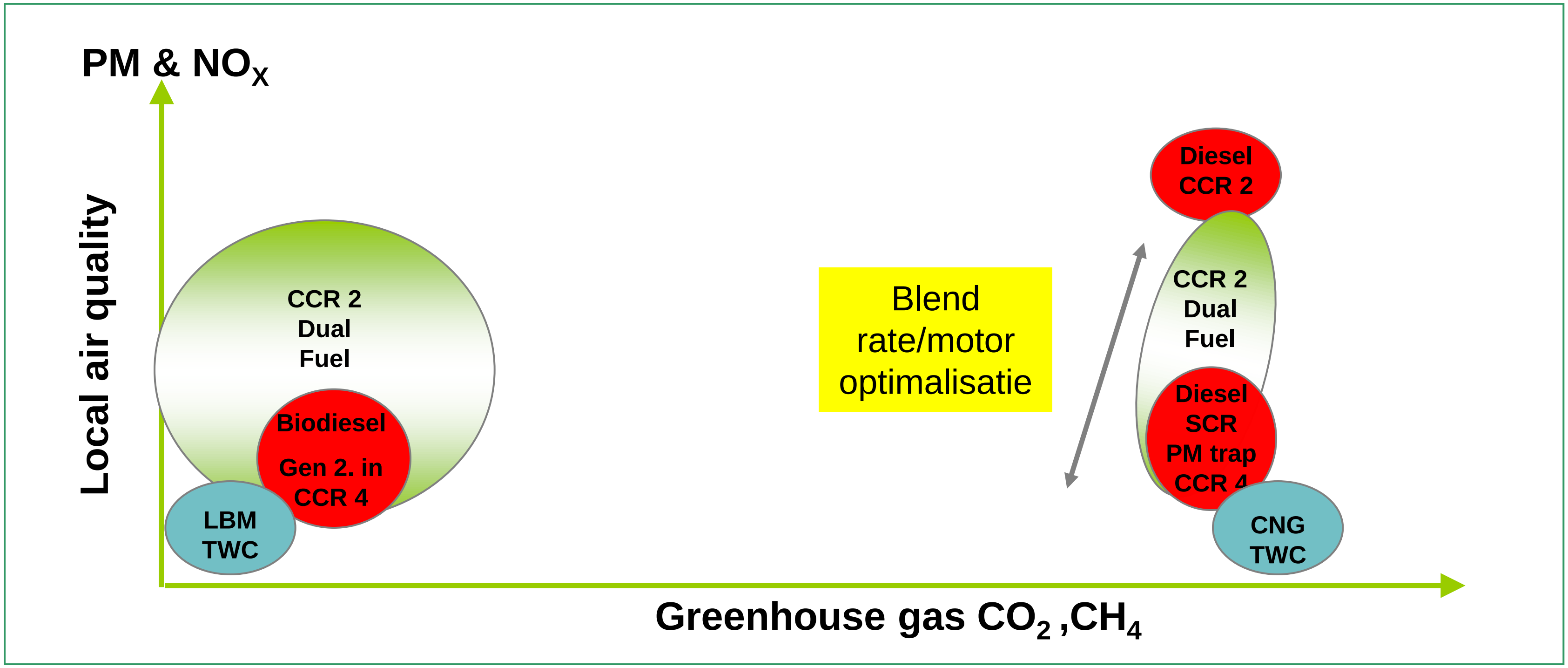
Resultaten Argonon project

- Argonon sinds januari 2012 in de vaart
- Klasse, CCR en ADR goedkeuring verkregen voor geheel Europa
- Bijmenging is constant tijdens alle vaaromstandigheden
- Schip vaart geheel stabiel bij 80% gasbijmenging,
- Geen verschil met Dieselaandrijving in vermogen en responstijd
- Geen methaanslip door toepassing van katalysator
- Bunkering via vrachtwagens geregeld
- Motorrendement op dieselniveau (CO_2 reductie op fossiel LNG 25%!)
- CO_2 reductie Argonon op LNG : 300 ton/jaar (= uitstoot 350 vrachtwagens)
- CO_2 reductie Argonon op LBM: 1190 ton/jaar
- Brandstofkosten besparing: 30% = € 110.000/j

Volgende stappen:

- **NOx reductie optimalisatie**
- **Retrofit Dual Fuel op bestaande schepen**

NOx reductie optimalisatie



Retrofit Dual Fuel op bestaande schepen

Waarom?

- Directe kostenbesparing
- Directe CO_2 uitstoot reductie (25% op LNG)
- Direct beperkte NOx-en fijnstof uitstoot reductie
- Stimuleren opstart “varen op LNG/LBM” (bunkeren/LBM productie)

Hoe?

- Pon Power verzorgd gehele retrofit
  - Technische installatie inclusief cryogene LNG tank
  - Ombouw + oplevering
  - Begeleiding bij Klasse (veiligheidsstudie)

- Resultaat:
  - Emissies beter dan CCR 2 motor
  - Terugverdientijd bij 350 ton gasolie verbruik per jaar : 5 jaar

Conclusie

- Het varen op LNG/LBM biedt grote kansen voor de binnenvaart
- De eerste stappen in de richting van schone, CO_2 neutrale en betaalbare binnenvaart zijn nu gezet met de Argonon
- Nu moet de “keten” snel op gang komen
- Pon zet de eerste stap met het aanbieden van Dual Fuel Retrofit

Dank voor uw aandacht!

Operating in Emission Control Areas

After treatment and Natural Gas powered ships

Platform Scheepsemissies NOx seminar

April 19th 2012, Benny Mestemaker

The technology innovator.

IHC MERWEDE

IHC MERWEDE

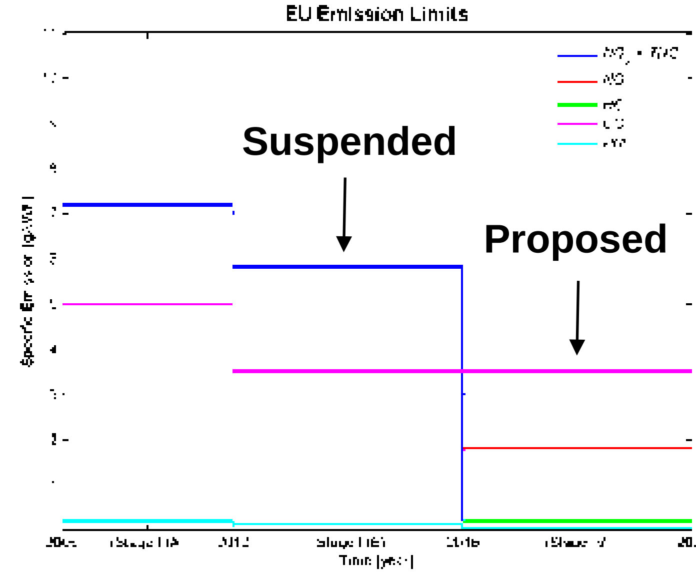
Content

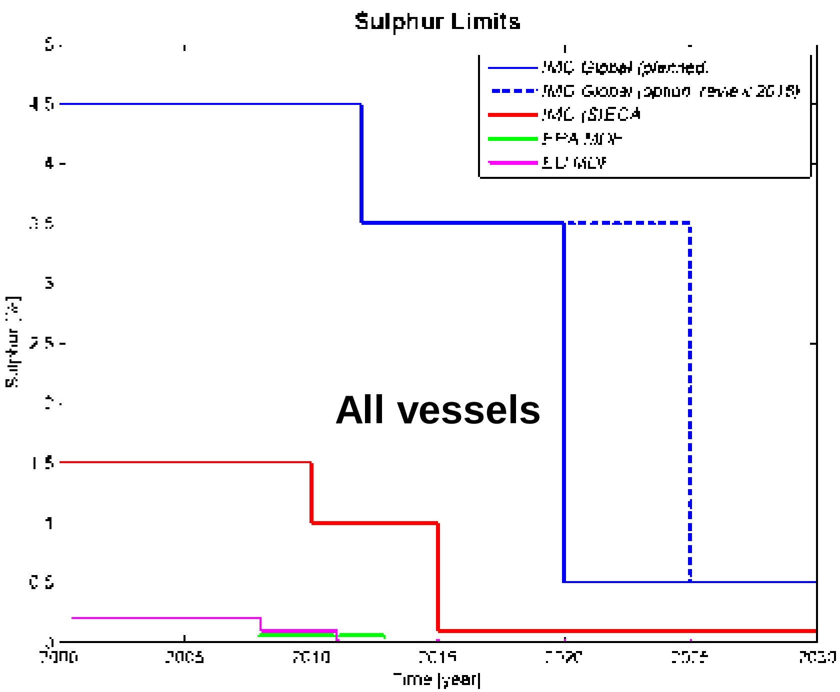
- Emission regulations
- Fuel price developments
- Offshore & dredging activities
- Possible solutions
  - After treatment
  - Natural Gas
- The road ahead
- Conclusions

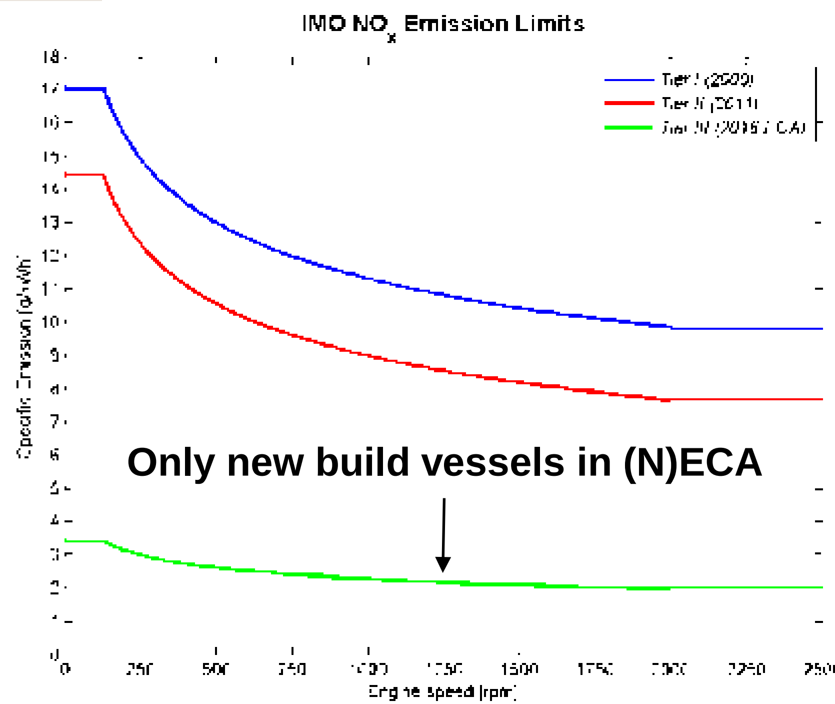
Emission regulations

Legislation

- Emission legislation IMO/EPA/EU/CCNR
- Legislation Trend:
  - Shipping follows road transport/ inland power generation
  - Decrease emission limits







Emission regulations

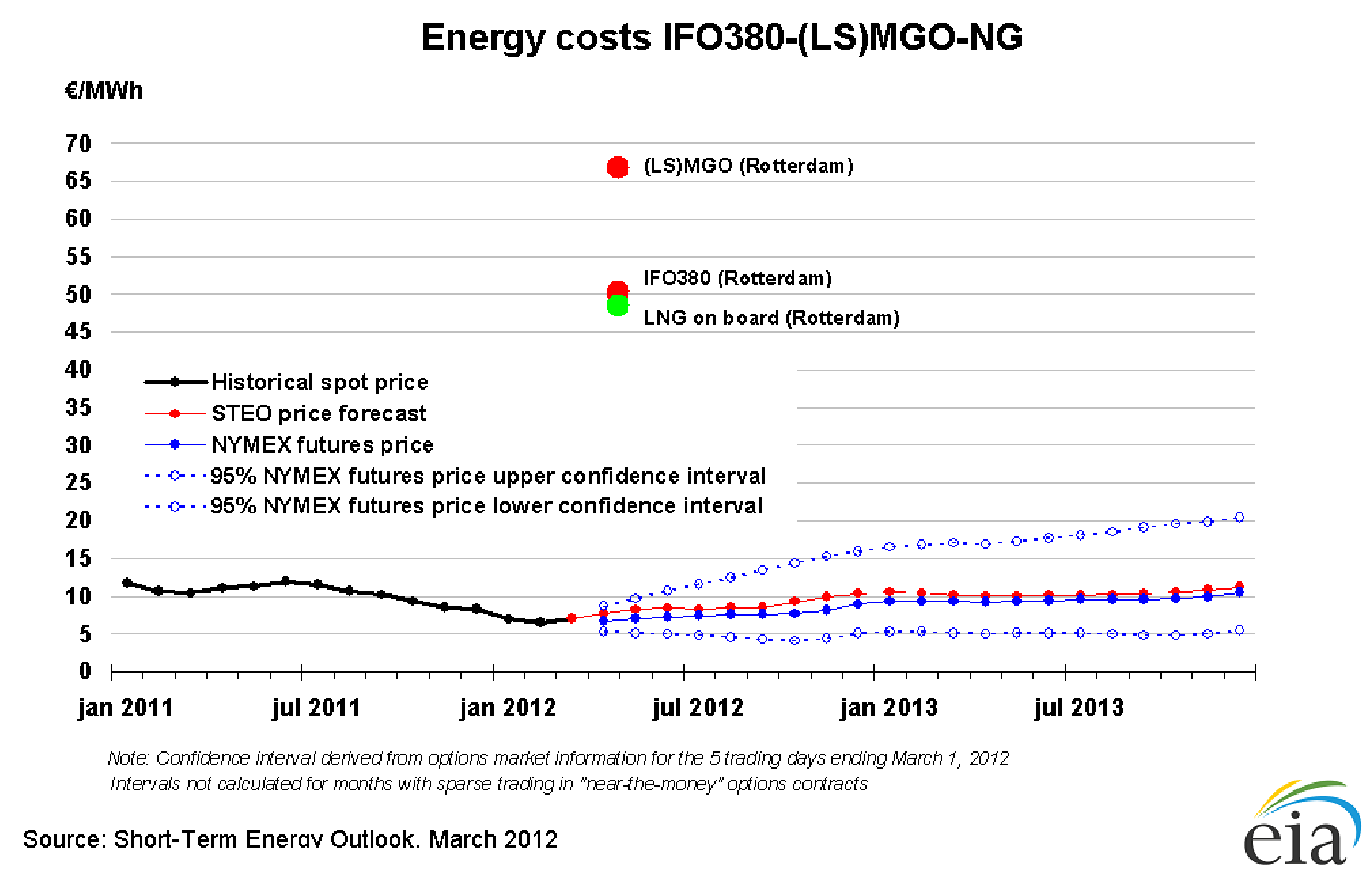
ECA’s (Emission Control Areas)

- ECA: NOx + SOx (USA (incl. Hawaii) & Canada)
- SECA: SOx (North sea & Baltic Sea)

Fuel price developments

Natural Gas versus fuel oil

- LNG on board same price as HFO
- Large availability NG: (±200yrs)



Payback time?

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Offshore and dredging activities

State of technology for offshore

Areas

- Activity in ECA’s is high (Norway)

Technical

- Low engine loads
- Large part of fleet diesel-electric
- High redundancy

Current status

- First gas fuelled ships already in service

Offshore and dredging activities

State of technology for dredging

Areas

- Worldwide applications; small part of fleet, temporary in ECA

Technical

- Highly transient behaviour of engine loads
- Almost always diesel-direct propulsion
- Sometimes diesel-electric pump drive

Current status

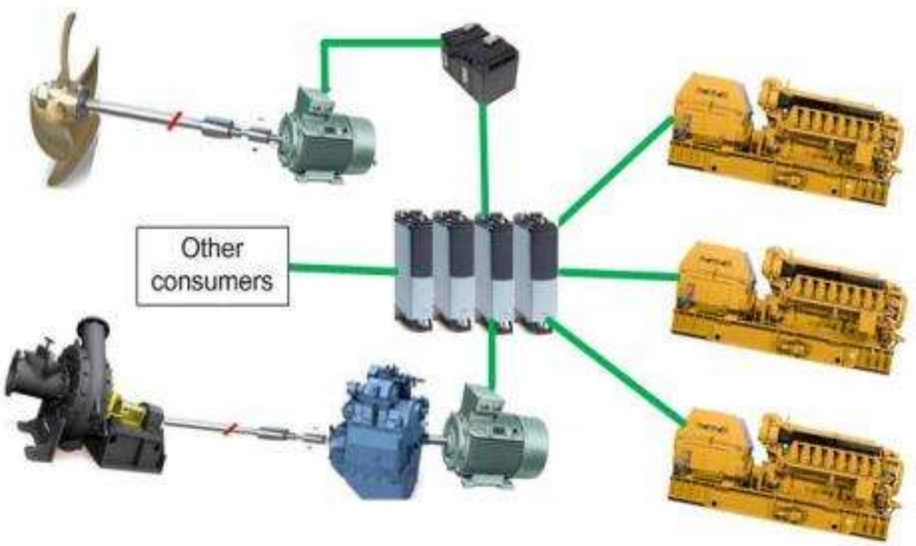
- Principal class approval by IHC Merwede

Offshore and dredging activities

IHC Merwede knowledge development on:

- Energy management
- Drive system design and integration
- After treatment system design and specification
- Natural gas powered dredger design and specification
- (Emission) field measurements (validation)

Total drive system solutions



Offshore and dredging activities

IHC Merwede knowledge development for:

- Innovative product development for offshore and dredging activities

- Optimal drive system design for ships (new build & retrofit)

  Advising client for most optimal solution/system

  Enabling system trade-offs (from risk, cost, etc. perspective)

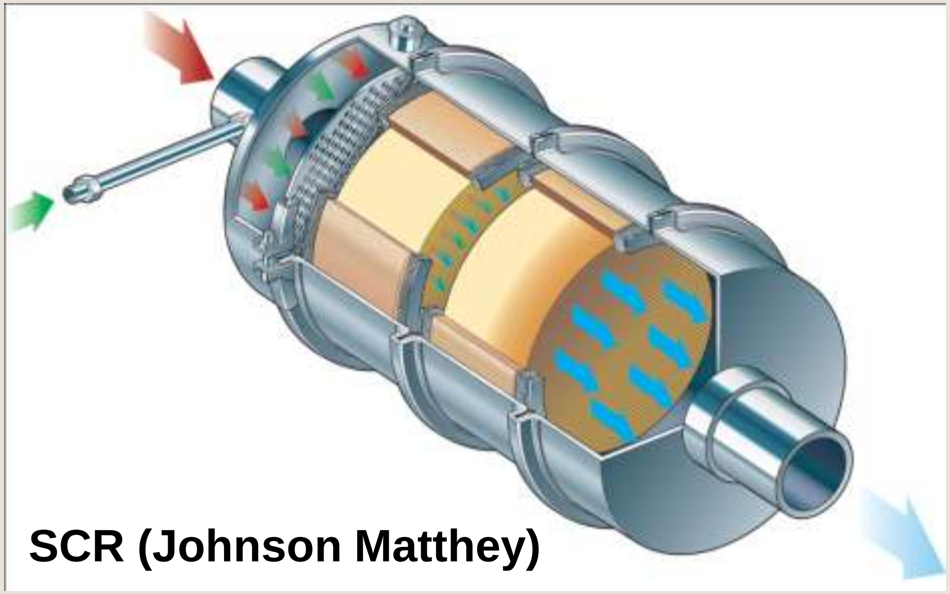
- Development of simulators for new concepts

  For integration of all drive system components

Possible solutions

Options to comply to the emission regulations of SO_x & NO_x

- New diesel engine developments
- Gas turbines & fuel cells
- **After treatment exhaust gasses (SCR & scrubber)**
- **Natural gas engines**
    - Dual fuel
    - Lean burn



SCR (Johnson Matthey)

Possible solutions

Options to comply to the emission regulations of SO_x & NO_x

- New diesel engine developments
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- **Natural gas engines**
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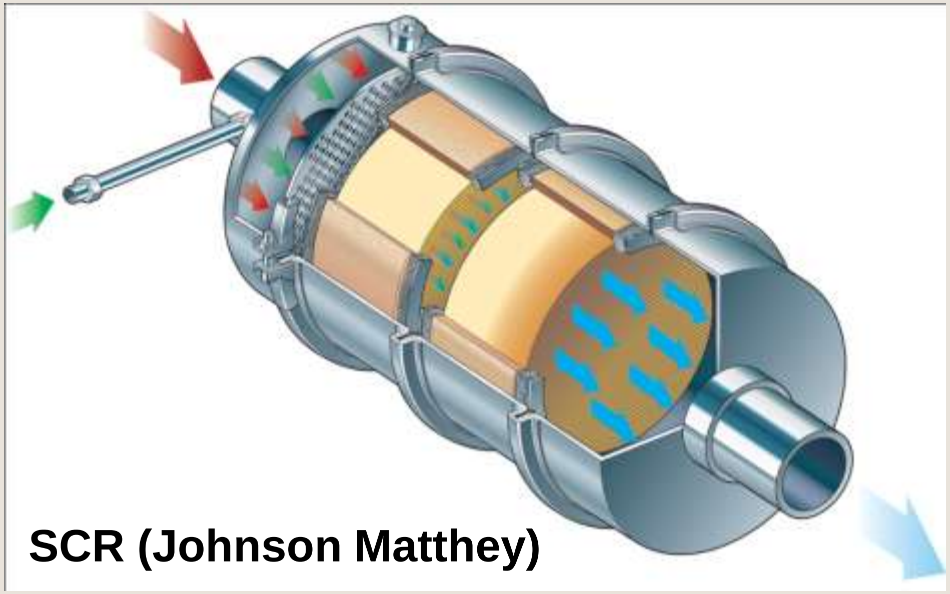


SCR (Johnson Matthey)

Possible solutions

After treatment: SO_x reduction

- Location:
  - (S)ECA: → 0.1% Sulphur (2015)
  - World: → 0.5% Sulphur (2020/2025)
- Possible systems:
  - **Wet scrubber**
  - Dry scrubber
  - CSNOx (Ecospec)
  - *Clean fuel (low sulphur <0.1%S)*
    - *(LS)MGO*
    - *Natural Gas*

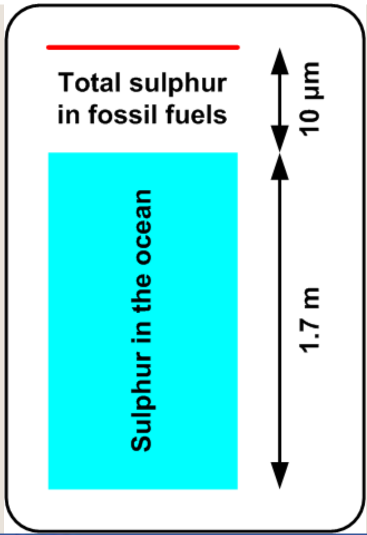
Scrubber (Alfa Laval Aalborg)

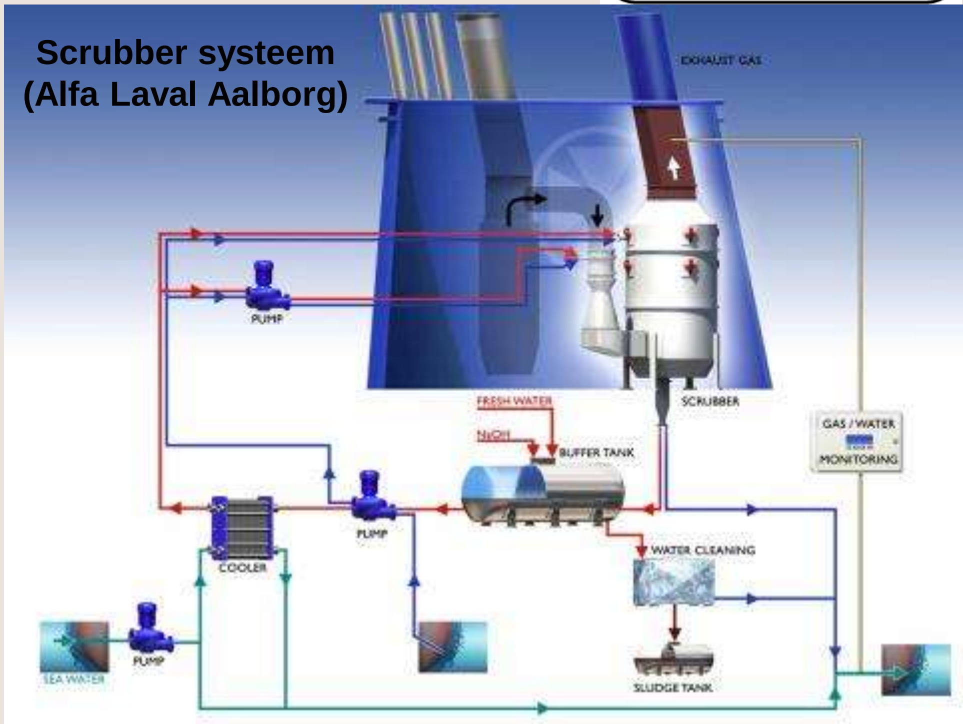
IHC MERWEDE

Possible solutions

After treatment: Wet scrubber

- Emission reduction
  - SO_x: 97-99% (continuous monitoring required)
  - PM: 70-80% (coarse particulates)
  - NO_x: 5-10% (only NO_2)
- 3 wash water systems:
  - Seawater (1300 umol/L)
  - Fresh water (caustic soda)
  - Hybrid system
- Installation end pipe
- *Response to dynamics*





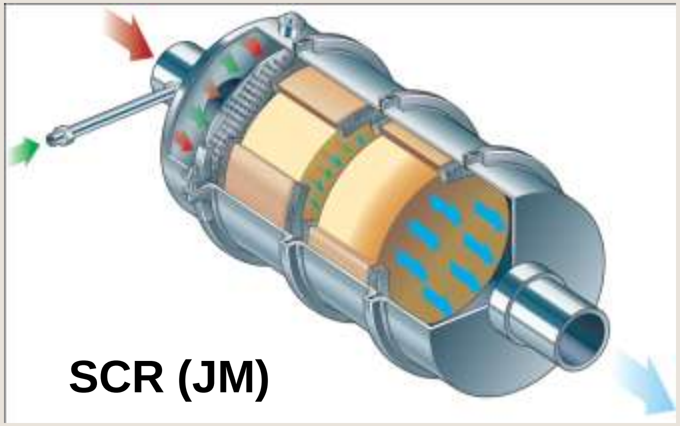
Scrubber systeem (Alfa Laval Aalborg)

Possible solutions

After treatment: NO_x reduction

- Area’s:
  - ECA: New builds (2016), all vessels
  - IWW: New builds (2016), ocean going exempted

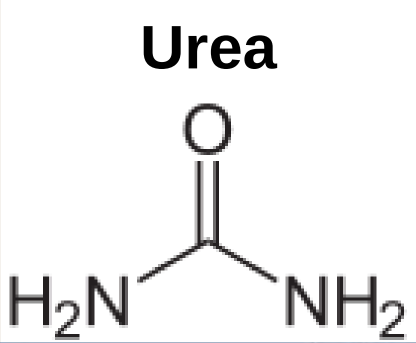
- Possible systems
  - **Selective Catalyst Reduction (SCR)**
  - Selective Non Catalyst Reduction (SNCR)
  - NO_x absorber
  - CSNOx (Ecospec)
  - *Natural Gas*



Possible solutions

After treatment: Selective Catalyst Reduction (SCR)

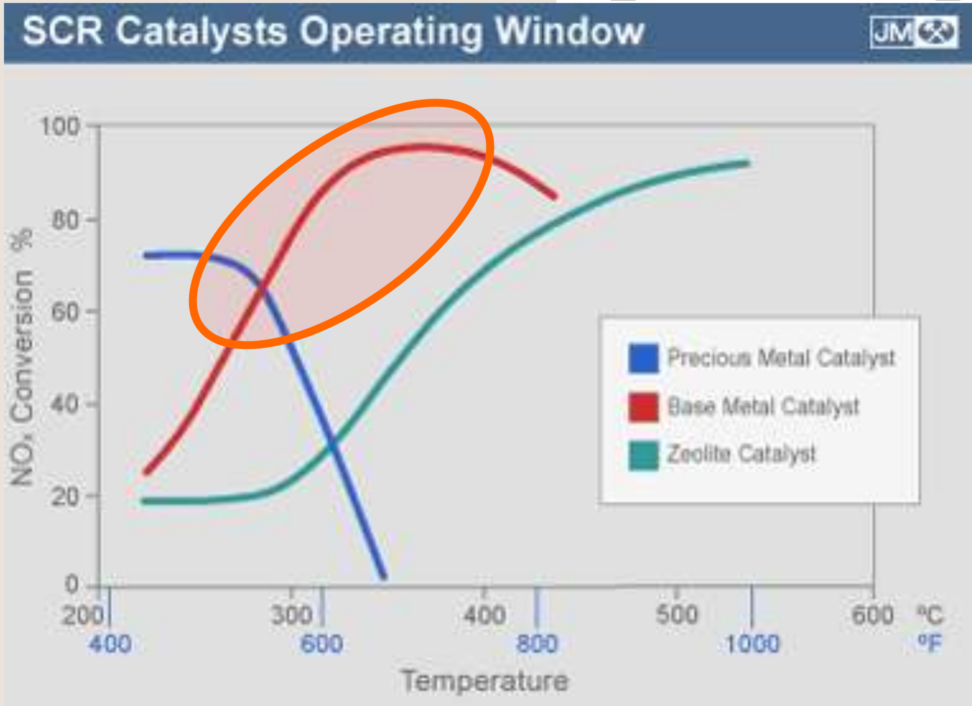
- Low sulphur fuels:
  - Urea consumption: 5-10% (fuel)
  - Ammonia slip catalyst (AMOX)
  - Temperature requirement in range diesel engine



- Emission reduction:
  - NOx: 80-90%
  - CO: 98% (AMOX)
  - HC: 95% (AMOX)
  - PM: 30% (AMOX)

- Installation directly behind engine

- *Response to dynamics*



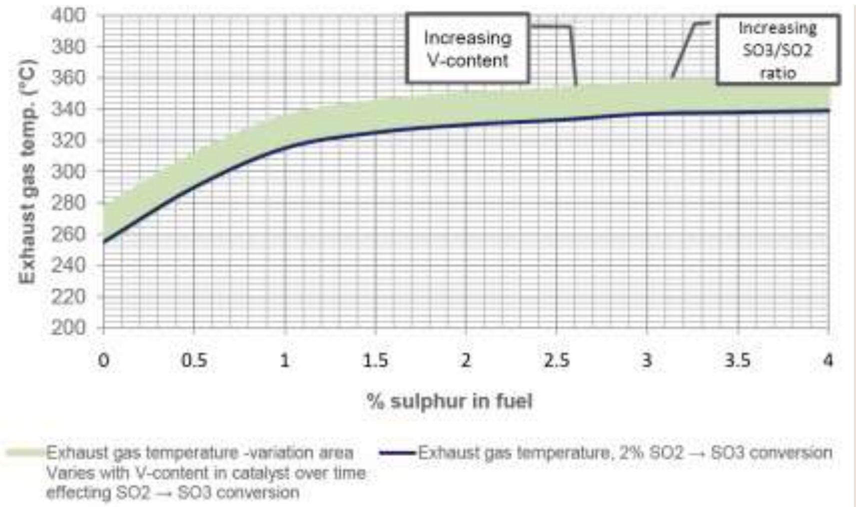
Possible solutions

After treatment: SCR HFO

- High sulphur also possible
  - Bigger SCR (more catalyst)
  - Temperature requirement
  - Increased urea consumption
- NOx reduction: 70-80%
- Installation directly behind engine
- *Response to dynamics: ammonia slip*
- *Ammonium (bi) sulphate formation at low temperatures*
- *Catalyst poisoning heavy metals HFO*

Ammonium bisulphate (Lehigh)

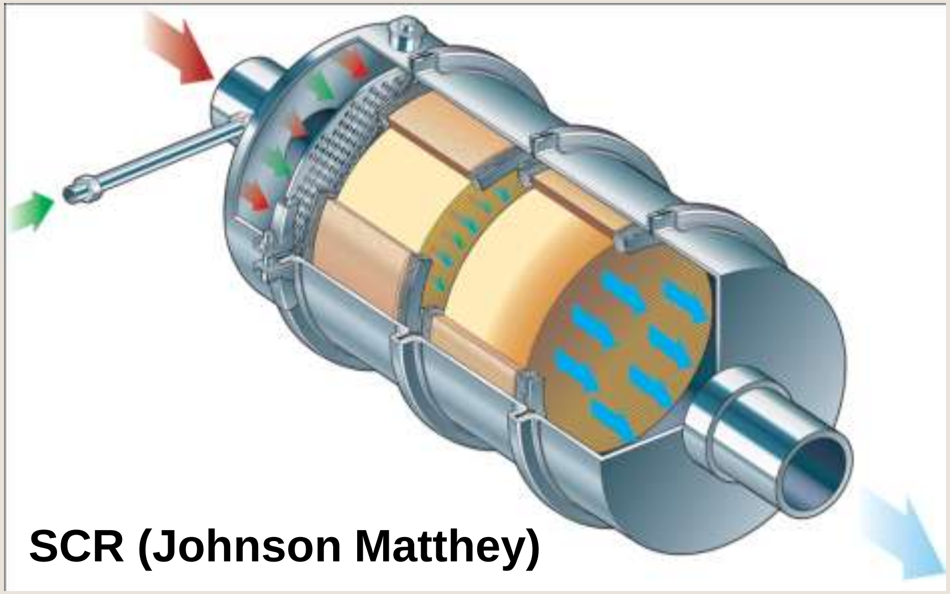
Minimum temperature SCR (Yarwil)



Possible solutions

Options to comply to the emission regulations of SO_x & NO_x

- New diesel engine developments
- Gas turbines & fuel cells
- **After treatment exhaust gasses (SCR & scrubber)**
- **Natural gas engines**
  - Dual fuel
  - Lean burn



SCR (Johnson Matthey)

Possible solutions

Natural Gas powered ships

Pros/profits

- Low emissions
- Fuel price
- Future availability

Challenges

- Transient behaviour
- Energy storage density
- Methane slip

Possible solutions

Natural Gas powered ships: Prime mover transient capability

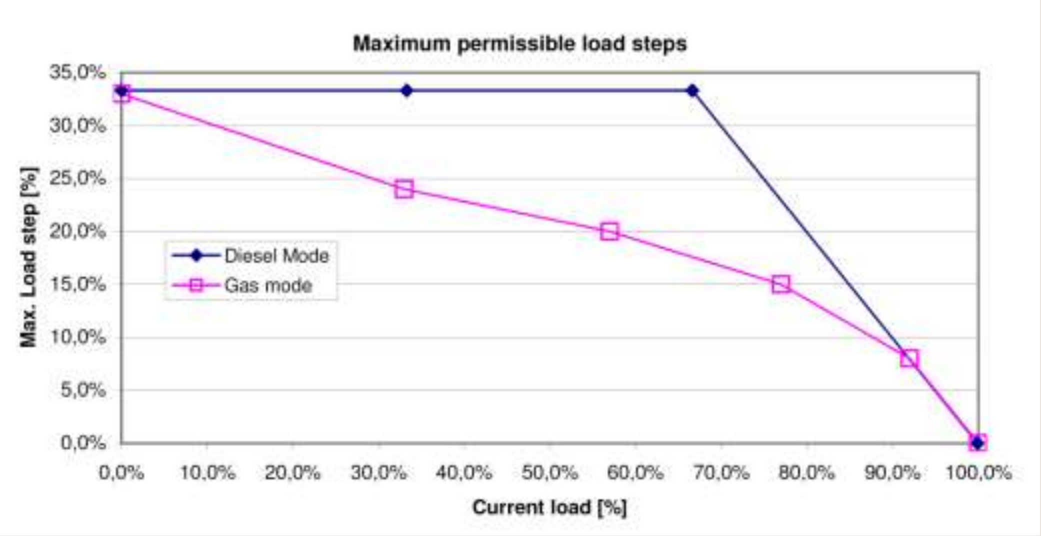
- Dual fuel engine: preliminary data MAK M46DF
- Gas mode: half of diesel mode

  (at 60-100% load)
- Recovery time from step:

  5-10s (warmed up)
- Above gas mode limit switch to diesel mode

  (instant NG → Diesel)

  (gradual Diesel → NG)



The road ahead

Required after treatment system: overview

	2015 SECA (Sulphur → 0.1%)	**2016 ECA** (NOx + Sulphur)	**2020/2025 Global** (Sulphur → 0.5%)
HFO (3.5% S)	Scrubber (now also required)	Scrubber + SCR	Scrubber
LSHFO (<1% S)	Scrubber (now not required)	Scrubber + SCR	Scrubber
MDO/MGO (<0.1% S)	*NA*	SCR	*NA*
LNG (dual fuel)	*NA*	SCR (diesel mode)	*NA*
LNG (single fuel)	*NA*	*NA*	*NA*

IHC MERWEDE

The road ahead

Technological risk

Required after treatment system: risks

	2015 SECA (Sulphur → 0.1%)	2016 ECA (NOx + Sulphur)	2020/2025 Global (Sulphur → 0.5%)
HFO (3.5% S)	Scrubber (now also required)	Scrubber + SCR	Scrubber
LSHFO (<1% S)	Scrubber (now not required)	Scrubber + SCR	Scrubber
MDO/MGO (<0.1% S)	*NA*	SCR	*NA*
LNG (dual fuel)	*NA*	SCR (diesel mode)	*NA*
LNG (single fuel)	*NA*	*NA*	*NA*

Legislation risk

Bunkering/fuel risk

The road ahead

Investment & operational costs: overview

	2015 SECA (Sulphur → 0.1%)	2016 ECA (NOx + Sulphur)	2020/2025 Global (Sulphur → 0.5%)
HFO (3.5% S)	CAPEX: +- OPEX: ++	CAPEX: -- OPEX: +	CAPEX: +- OPEX: ++
LSHFO (<1% S)	CAPEX: +- OPEX: +-	CAPEX: -- OPEX: -	CAPEX: +- OPEX: +-
MDO/MGO (<0.1% S)	CAPEX: ++ OPEX: -	CAPEX: + OPEX: --	CAPEX: ++ OPEX: -
LNG (dual fuel)	CAPEX: --? OPEX: ++?	CAPEX: --? OPEX: +?	CAPEX: --? OPEX: ++?
LNG (single fuel)	CAPEX: -? OPEX: +++?	CAPEX: -? OPEX: +++?	CAPEX: -? OPEX: +++?

The road ahead

Investment & operational costs: remarks

	2015 SECA (Sulphur → 0.1%)	**2016 ECA** (NOx + Sulphur)	**2020/2025 Global** (Sulphur → 0.5%)
HFO (3.5% S)	CAPEX: +- OPEX: ++	CAPEX: -- OPEX: +	CAPEX: +- OPEX: ++
LSHFO (<1% S)	CAPEX: +- OPEX: +-	CAPEX: -- OPEX: -	CAPEX: +- OPEX: +-
MDO/MGO (<0.1% S)	CAPEX: ++ OPEX: -	CAPEX: + OPEX: --	CAPEX: ++ OPEX: -
LNG (dual fuel)	CAPEX: --? OPEX: ++?	CAPEX: --? OPEX: +?	CAPEX: --? OPEX: ++?
LNG (single fuel)	CAPEX: -? OPEX: +++?	CAPEX: -? OPEX: +++?	CAPEX: -? OPEX: +++?

LSHFO: Practically unavailable

LNG (dual fuel): Temporary solution

LNG (single fuel): Worldwide bunker network

Conclusions

- IHC Merwede recognizes that compliance to future legislation can come from different **technologies and fuels**.
- Our R&D focuses on **knowledge development** on the application of the new technologies in all the ships drive systems in order to create customer value
- In doing so IHC Merwede enables her customers to make **trade-offs** in the different ways to comply to the future legislation

IHC MERWEDE

Operating in Emission Control Areas

After treatment and Natural Gas powered ships

Platform Scheepsemissies NOx seminar

April 19th 2012, Benny Mestemaker

The technology innovator.

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Discussion

1

We will have ships which will not be allowed into ECA’s, the so called “no ECA ships”.

2

The requirements for new ships will have a negative effect on newbuilding orders.

3

The Nox techniques are not widely available and the investments are too high.

- "Availability of Technology" - clause Marpol Annex 6 should be used-

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4

New and more strict requirements are positive because it will boost innovations in the maritime world.

5

The phased in approach in Marpol Annex 6, regulation 13 (NOx) should be an example for all environmental legislation.

6

The maritime sector is not ready to combine all measures to fulfill all ECA requirements.

7

Engine manufactures will not be able to supply enough spare parts.

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8
Maintenance costs will rise.

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9

In a few years IMO should increase the requirements on NOx (and PM and Black Carbon).

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The presentations can be found on the website by next week

www.scheepsemissies.nl

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