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INTERNATIONAL COUNCIL OF
MARINE INDUSTRY ASSOCIATIONS

Selective Catalytic Reduction – technology overview and challenges in the marine environment

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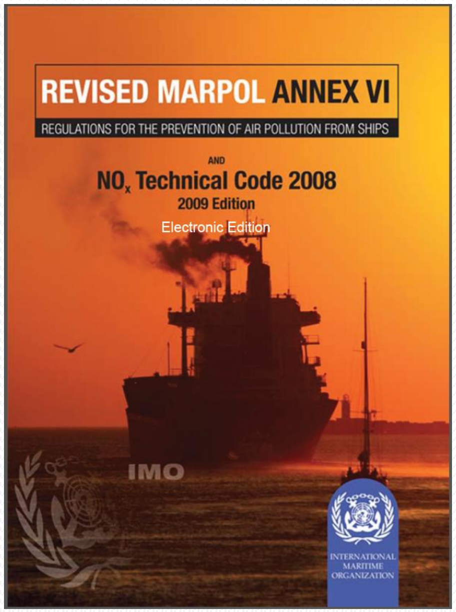
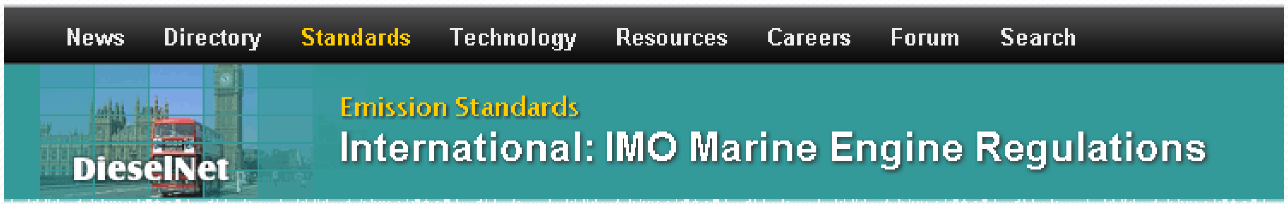
References:

NOx Technical Code, Dieselnet www.dieselnet.com/standards/inter/imo.php





For support and certification:

engine and aftertreatment system manufacturers, class societies, flag state authorities, associations

ICOMIA NOx Tier III WG 2011 activities

NOx WG comprises Tier III affected parties

- ⇔ Shipyards from Italy, Netherlands, UK, attending associations from Germany, Spain, SYBAss
- ⇔ Engine and aftertreatment manufacturers (Caterpillar, MTU, Johnson Matthey, Soottech, H+H)

⇔Tier III compliant system spec

Shipyard implementation studies

⇔IMO correspondence group input discussed

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Legal context – IMO MARPOL

International Maritime Organisation (IMO) UN agency

MARPOL, (International Convention on the Prevention of Pollution from Ships) originally settled in 1973 and 1978

Limits for emissions of sulphur in fuel (SOx) and nitrogen oxide (NOx) adopted in the 1997 protocol – annex VI

Revised annex VI (2008) allows for an emission control area to be designated for SOx/particulate matter, or NOx, or both types of emissions

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Legal context – IMO MARPOL

2008 Amendments (Tier II/III)—Annex VI adopted in October 2008 introducing

(1) new fuel quality requirements beginning from July 2010,

(2) Tier II (2011) and III (2016) NOx emission standards for new engines

Table 2. MARPOL Annex VI Fuel Sulfur Limits

Date	Sulfur Limit in Fuel (% m/m)	
	SOx ECA	Global
2000	1.5%	4.5%
2010.07	1.0%	
2012		3.5%
2015	0.1%	
2020[a]		0.5%

a – alternative date is 2025, to be decided by a review in 2018

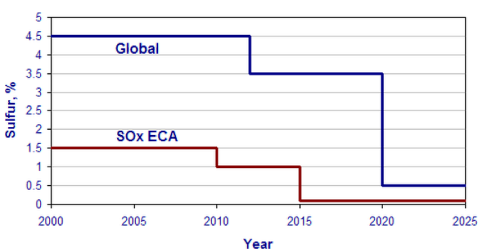


Figure 2. MARPOL Annex VI Fuel Sulfur Limits

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 outside ECAs).

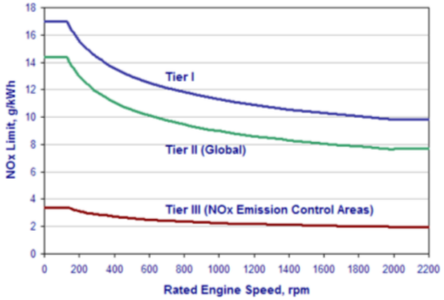
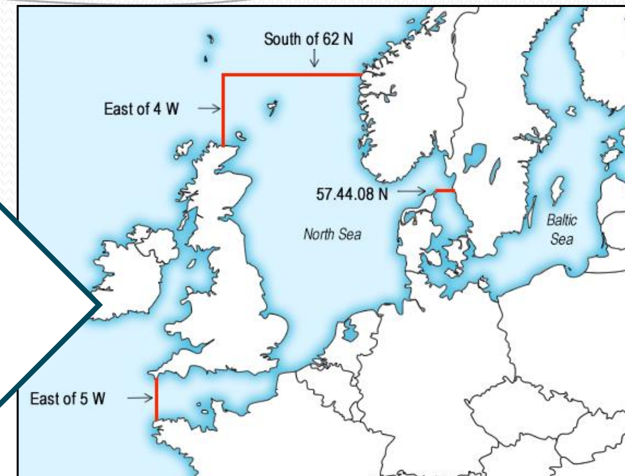
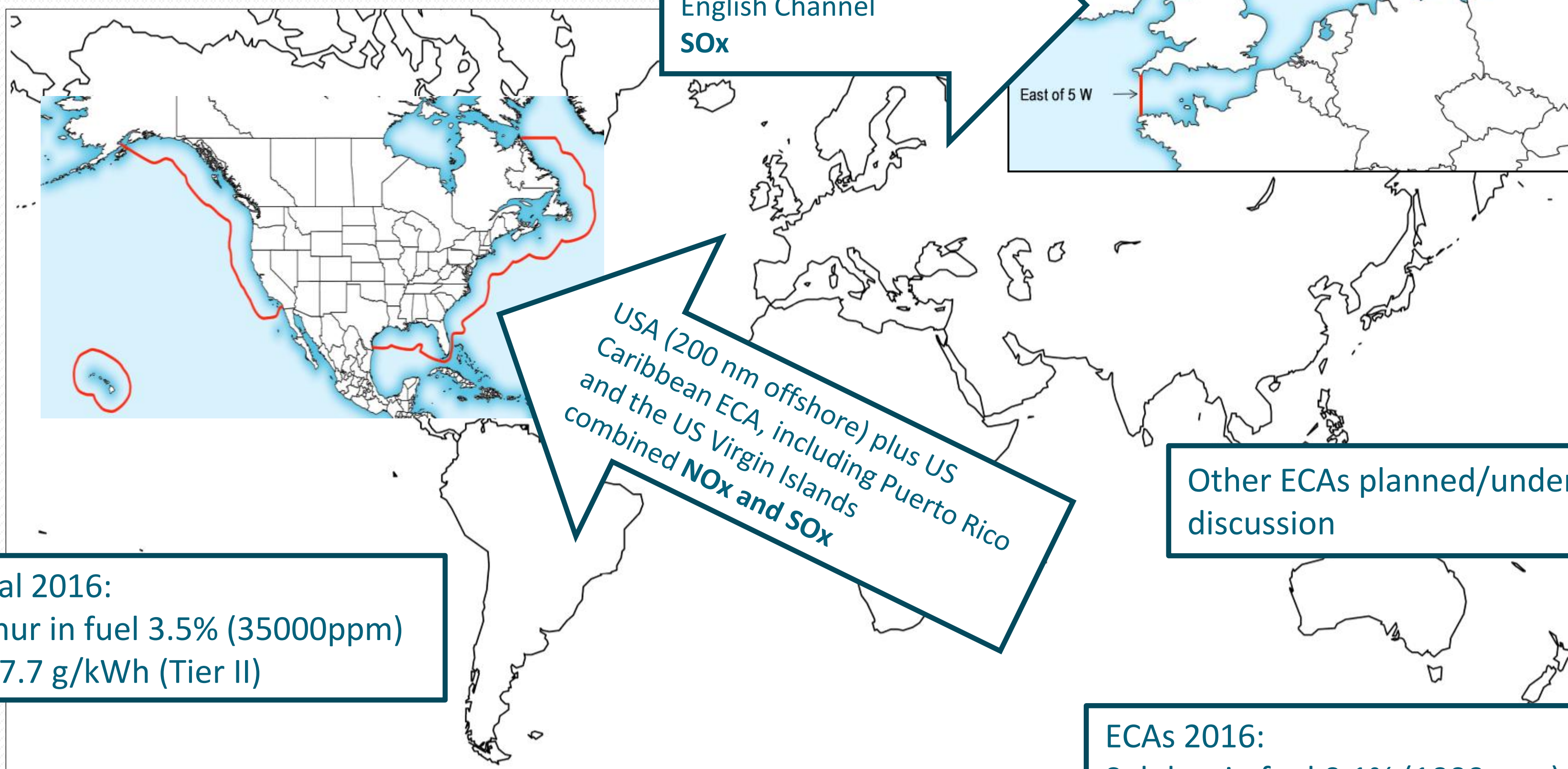


Figure 1. MARPOL Annex VI NOx Emission Limits

IMO MARPOL Emission Control Areas (ECAs) for NOx and SOx



Baltic, North Sea and English Channel
SOx



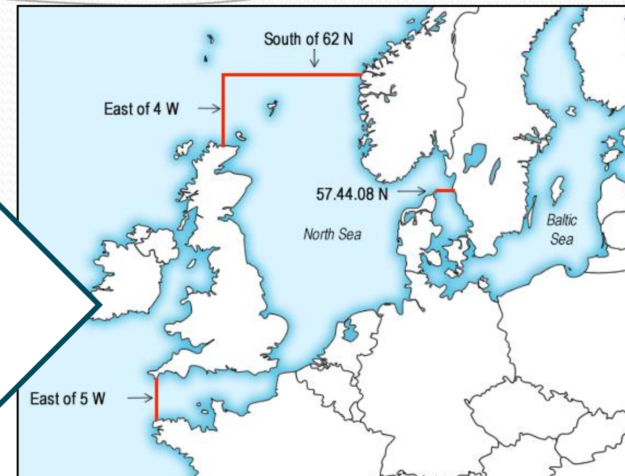
USA (200 nm offshore) plus US Caribbean ECA, including Puerto Rico and the US Virgin Islands combined **NOx and SOx**

Other ECAs planned/under discussion

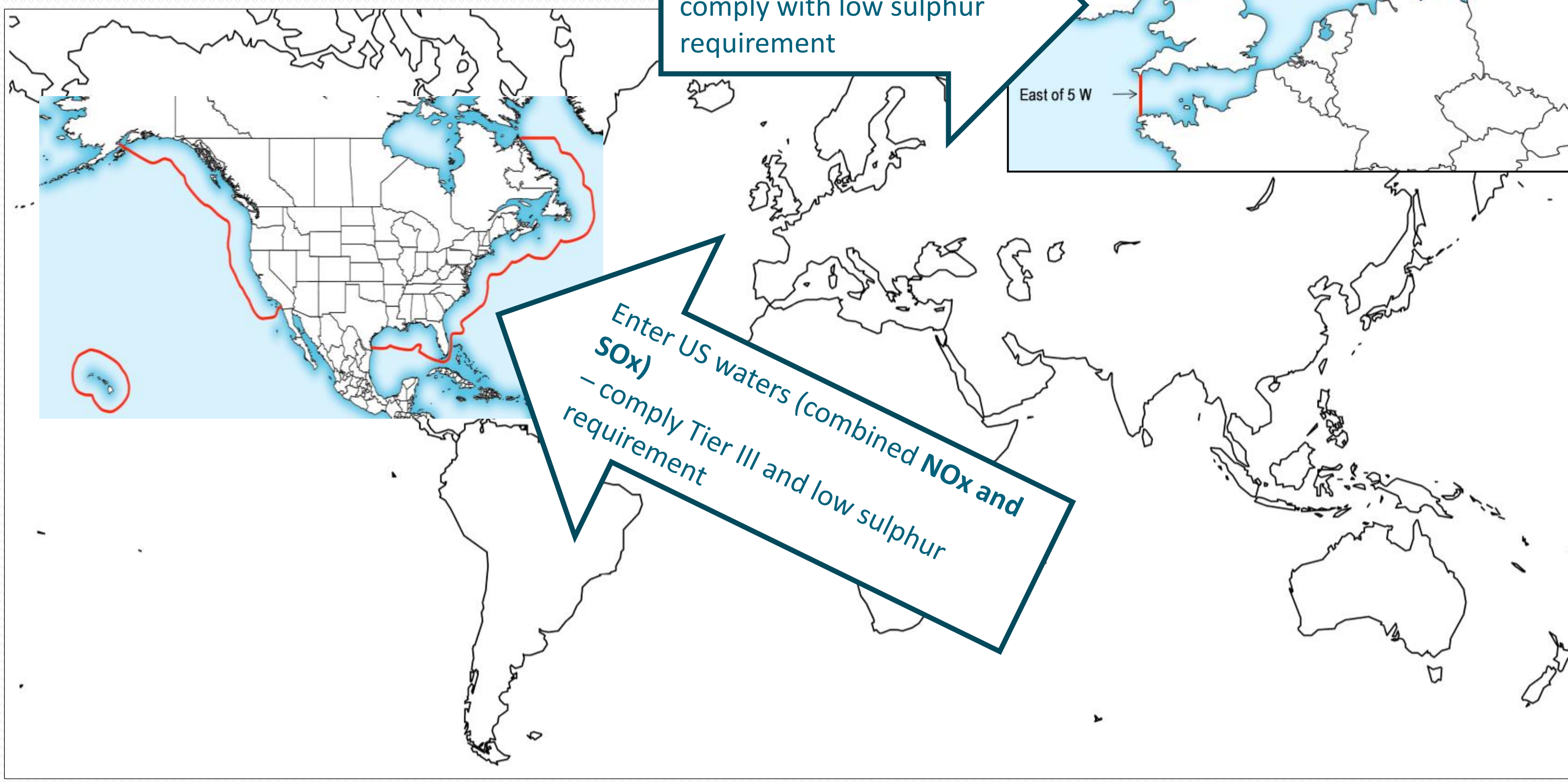
Global 2016:
Sulphur in fuel 3.5% (35000ppm)
NOx 7.7 g/kWh (Tier II)

ECAs 2016:
Sulphur in fuel 0.1% (1000ppm)
NOx 1.96 g/kWh (Tier III)

IMO MARPOL Emission Control Areas (ECAs) for NOx and SOx



Enter European SECA – comply with low sulphur requirement



Enter US waters (combined **NOx and SOx)** – comply Tier III and low sulphur requirement

IMO MARPOL design baseline scenario

(1) NOx Tier III limit ⇔ 1.98 g/kWh **in NOx ECAs** = Global compliance a must? Aftertreatment

(2) Outside ECA Tier II applies – law allows to switch off aftertreatment – down to system spec and aftertreatment has to cope with higher sulphur fuels

(3) Sulphur content for fuels used/available varies globally between 10 (EN 590) and > 15000ppm (DMA/DMB grades)

(4) Engines available might comply with **US EPA Tier 4** (NOx, HC and PM regulated = sulphur sensitive technology)

⇔ What is “marine environment”?

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Emission reduction technologies to meet IMO Tier III

In-engine optimization or Aftertreatment?

On-road aftertreatment systems:

- 3-way catalyst (petrol)
- Oxidation catalysts (diesel engines – no NOx reduction)

= sulphur sensitive and different oxygen ratio

⇔Selective Catalytic Reduction (SCR) currently most likely technology to meet Tier III

⇔In-engine solutions under discussion (feasibility, reliability)

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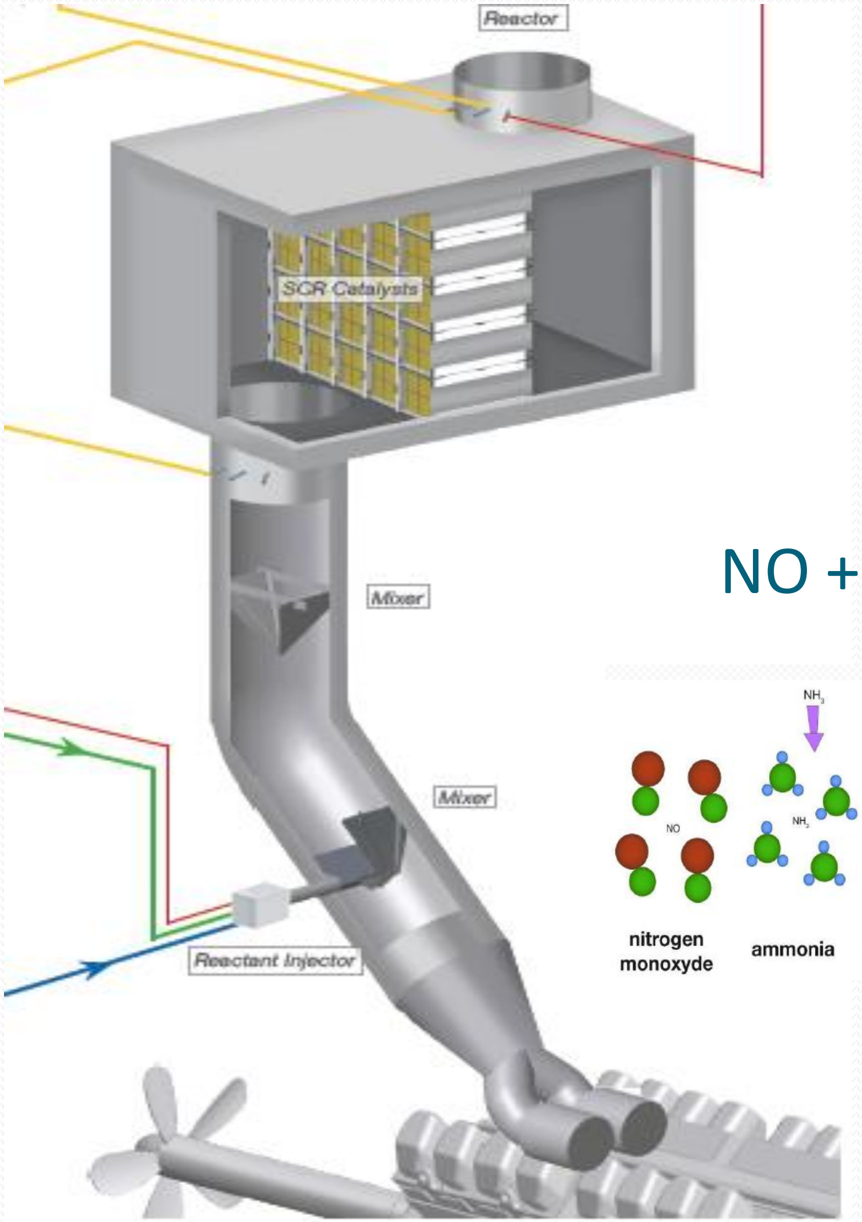
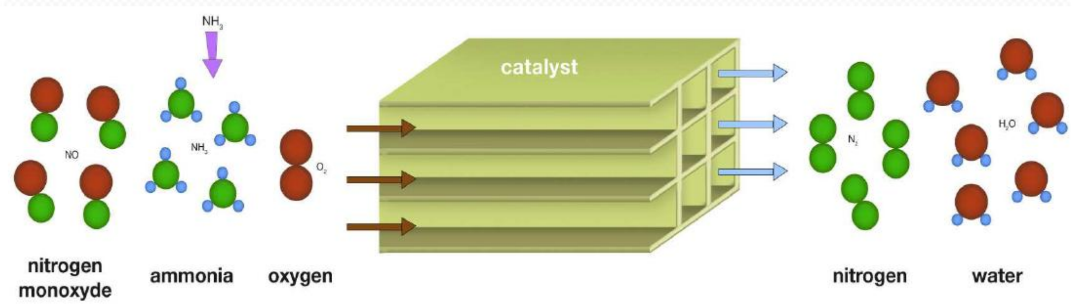


SCR – principle

$$NO + O_2 + \mathbf{NH_3} \rightarrow N_2 + H_2O$$



Known parameters in SCR design

– ICOMIA/BMF SCR outline information

SCR component of the exhaust system

Engine → Turbocharger → (Soot filter) → SCR → Silencer/Exhaust

Opportunities to combine? Catalyst performance?
*30 – 50% downsize expected with further technical development
Complex shape of exhaust piping

SCR reactor ~ 30 % of engine size, weight

Active volume of SCR ~ 0.7 m³/MW – sulphur dependent;
Reactor size ~ 1.3 m³/MW

Assembly? Cost?

- Higher engine backpressure < size
- Higher sulphur content in fuel > size

Basis – worst case scenario

Urea

Storage; length of mixing pipe nearly fixed

Accessories?

Urea tank/pump/dosing unit,, NOx analyser, Compressor, Control panel

IMO MARPOL design baseline scenario

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(3) **Sulphur** content for fuels used/available varies globally between 10 (EN 590) and > 20000ppm (DMA/DMB grades)

determining the size of the SCR system
– Yards/engine manufacturers to limit max sulphur content?
Beneficial only as long as low-sulphur fuel refuelled

(4) Engines available might comply with US EPA Tier 4 (NOx, HC and PM regulated = sulphur sensitive technology)

⇔ What is "marine environment"?

Design parameters – SIZE issue!!!

Technically feasible?
What type of vessel most affected?

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Known parameters in SCR design (contd.) – ICOMIA/BMF SCR outline information

Restriction to max allowable sulphur content?

Urea consumption

Temperature?

Operational parameters

SCR Outline Information

ICOMIA and BMF have met or corresponded with selected SCR manufacturers and the information obtained is summarised below for reference.

IMPORTANT: This information provides details on the current 'off-the-shelf' technology which has been applied to large commercial vessels and the strong message from the manufacturers is that this technology is developing at a rapid pace. The products available in 2016 may well bear little resemblance to those available today. The catalyst manufacturers need to understand in more detail the specific restrictions that yacht arrangements cause. There is potentially considerable flexibility in the design of these systems and there may be options to change catalyst shape, size, lengths etc. but there are many variables that influence this design.

Guidance on today's technology employed on commercial vessels:

The catalyst comprises of individual bricks each with approximate dimensions 450mm x 150mm x 150mm (lxbxh). Approximately 20-30 bricks are required per 1000kW, and the guidance varies as to whether one or two levels of bricks are required to achieve the NO_x reduction from IMO Tier II to Tier III. The manufacturers state that these bricks are not sensitive to the sulphur content of fuel used.

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Unknown parameters in SCR design

Technical development until 2016?

Vessels most affected?

Conclusions

- Vessels < 24m?
- Tier III preparation essential now for yards (tooling long-term RoI, …)

- Areas of concern (piping, sulphur, …)?
- Dialogue

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