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IMO Tier III NOx technology status for large two stroke engines

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Emission Technogy

R&D, BU-L, CPH

Agenda:

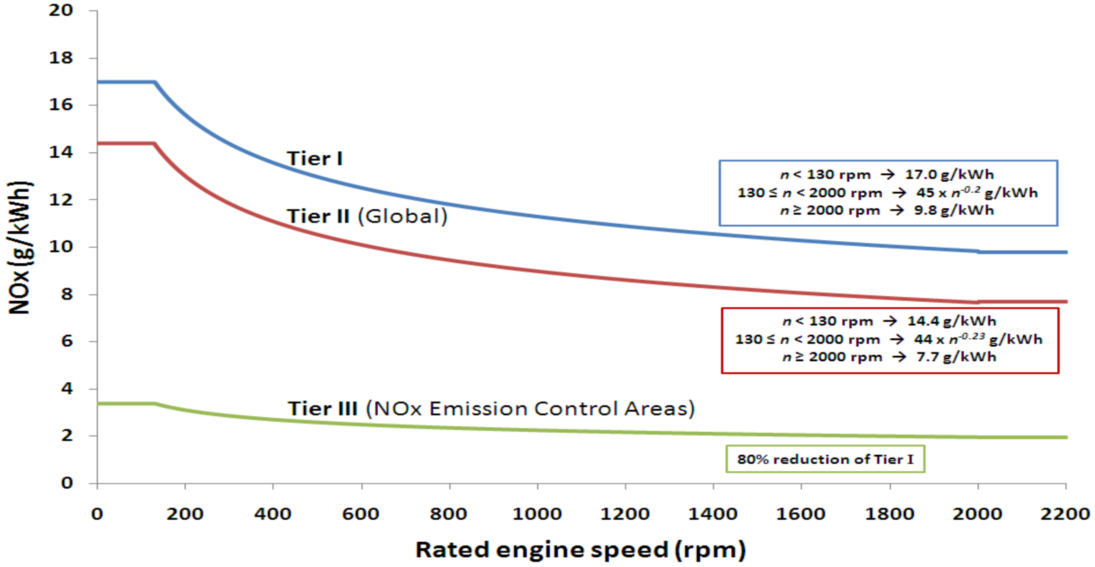
- The challenge: Emission regulation
- Expected demand for Tier III technology
- Economy
- SCR Installation
- EGR Installation

The challenge:

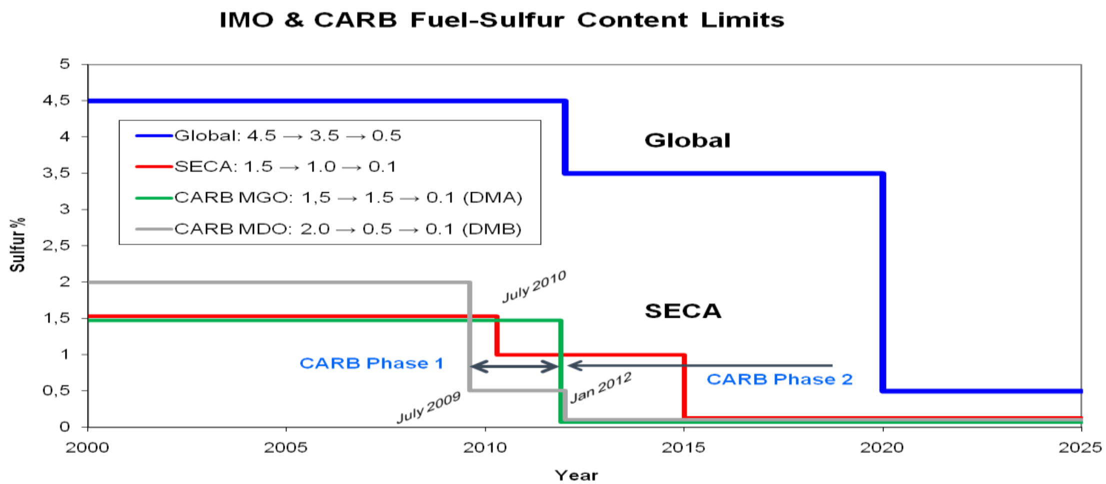
Emission regulation

IMO Regulations

NO_x:



SO_x:



Emission remedies to be in compliance with IMO NOx rules

Tier II (2011): Same basis design for Tier II as for Tier I engines!

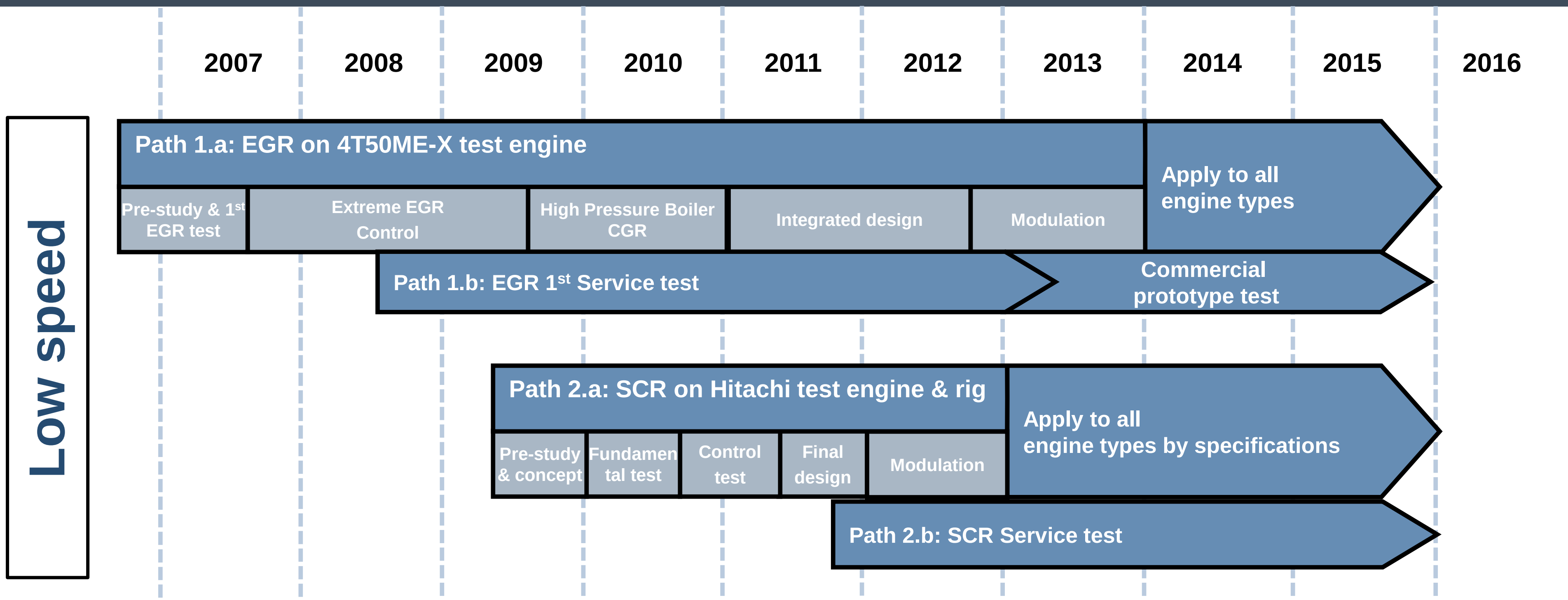
Tier III (2016): Two roads are followed for reduced NOx emission:

EGR (Exhaust Gas Recirculation)

SCR (Selective Catalytic Reactor)

Both equal applicable!

er III technology Schedules



Expected demand for Tier III technology

Emission areas

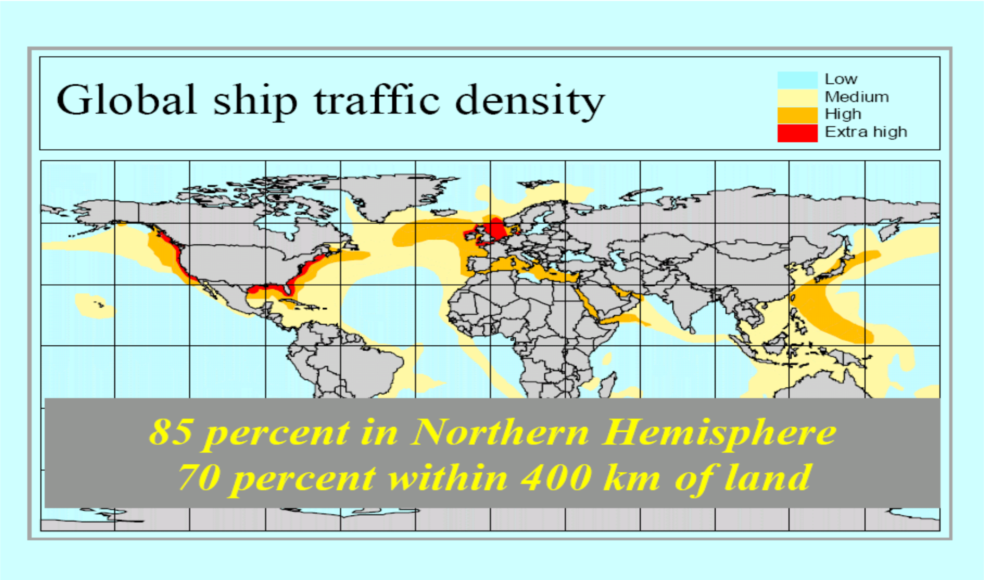
Emission restricted areas by IMO – ECAs in 2011

Operation analysis based on AIS data

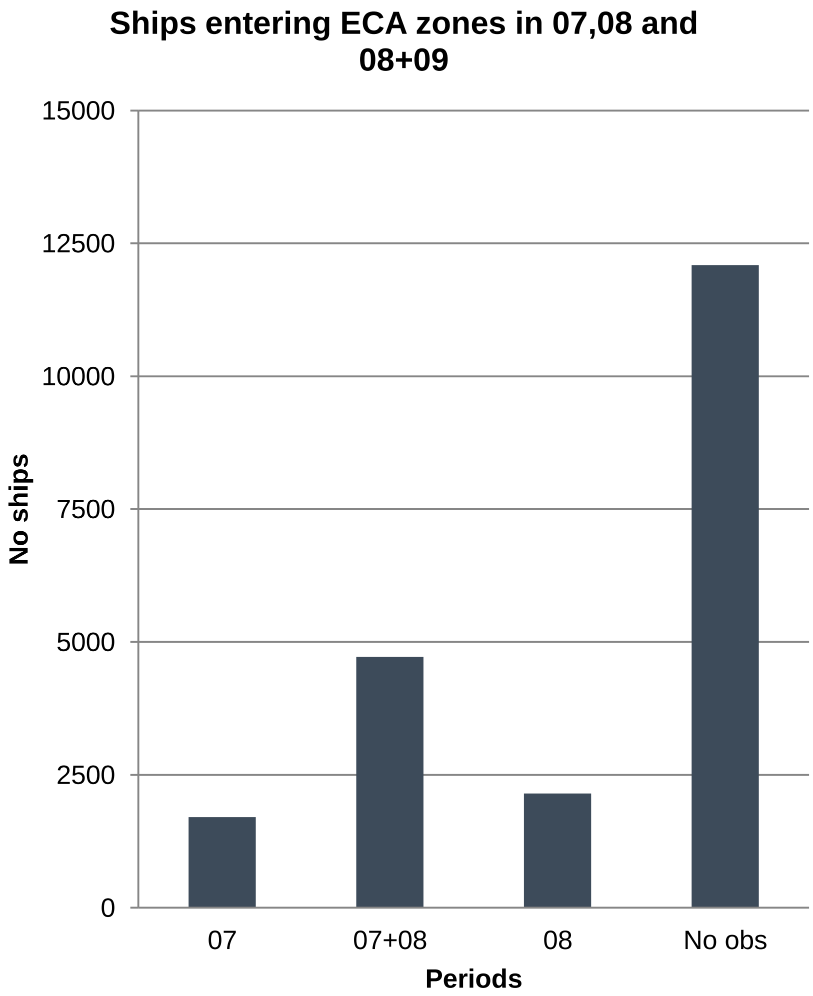
Total fleet with low speed engines is approximately 20000 ships

Distribution in ECA 2007-2008.→

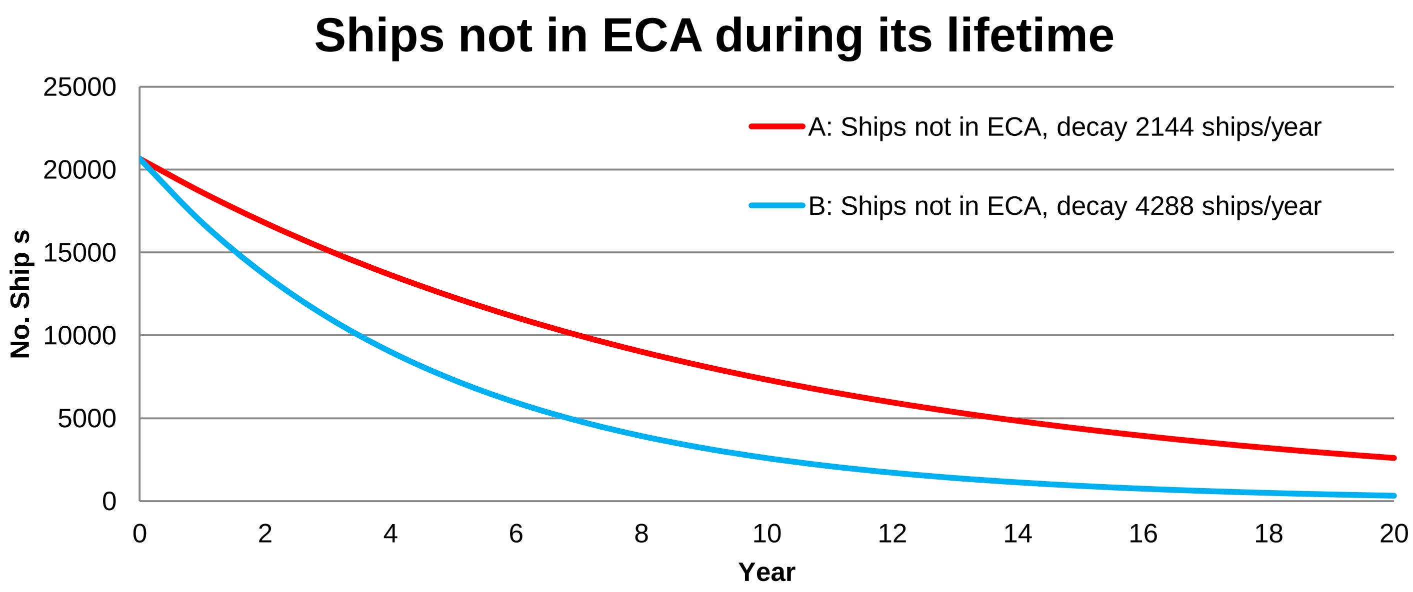
Net flux of new 2144 ships the first years



Source: IMO Study on Greenhouse Gas Emissions from Ships, MEPC 45(8), 2000.



Need for Tier III technology (estimate)



Estimated Ships mobility: Ship passing into the ECA area over a 20 year period.

Conclusion:

After 20 years at ~88% of the fleet has entered the present ECA zones

Investment in Tier III technology will ensure global mobility.

Economy

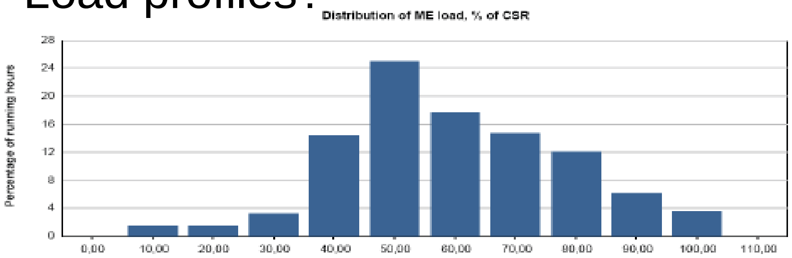
Cost parameters Tier III

Routing?

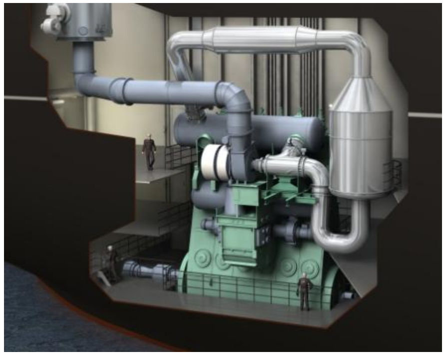
Operation?

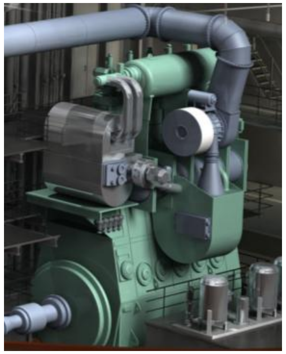
Common	EGR	SCR
HFO Price	NaOH price	Urea price
	NaOH bunker	Urea bunker
	Sludge handle	SCR element

Load profiles?



1st cost?

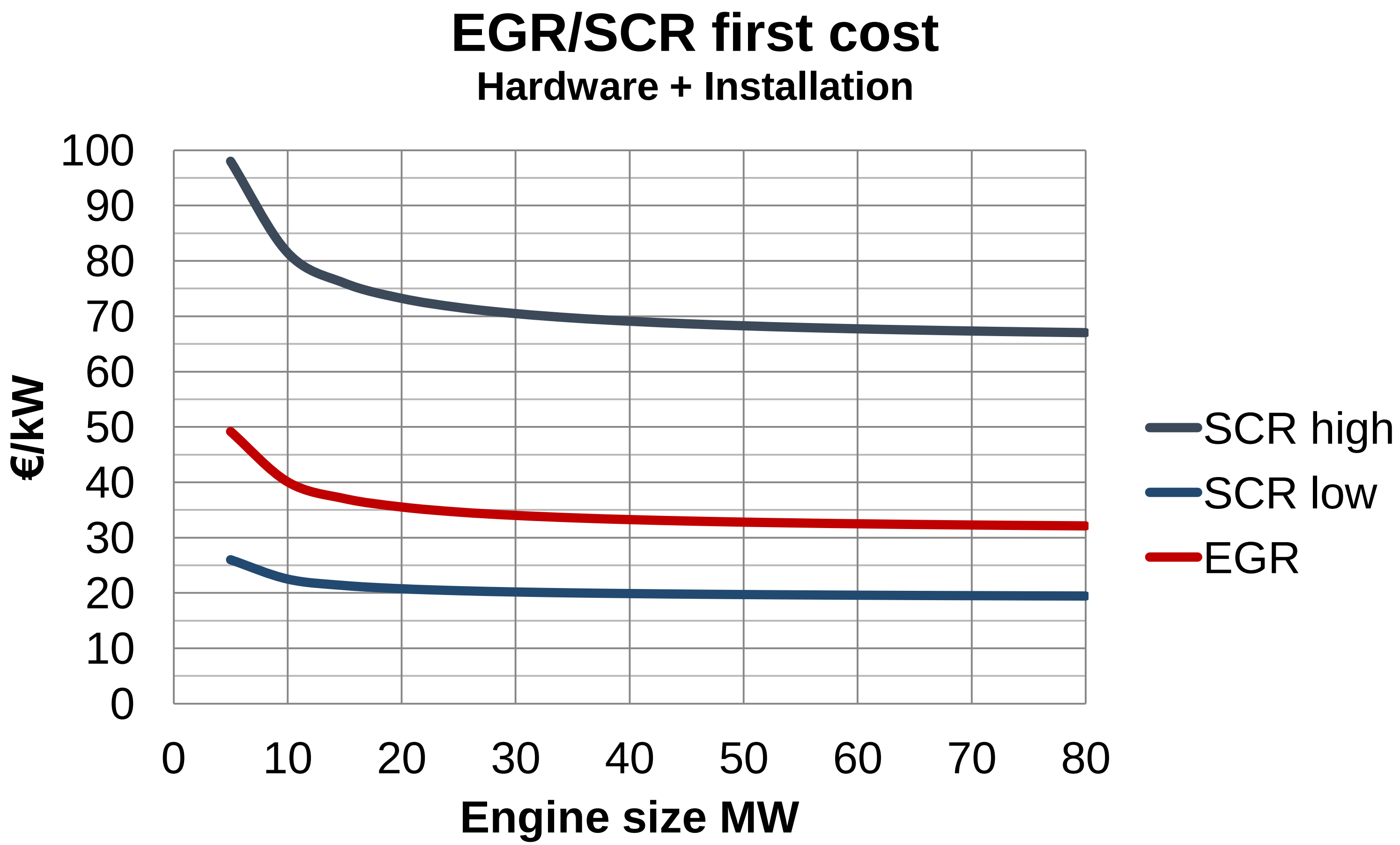




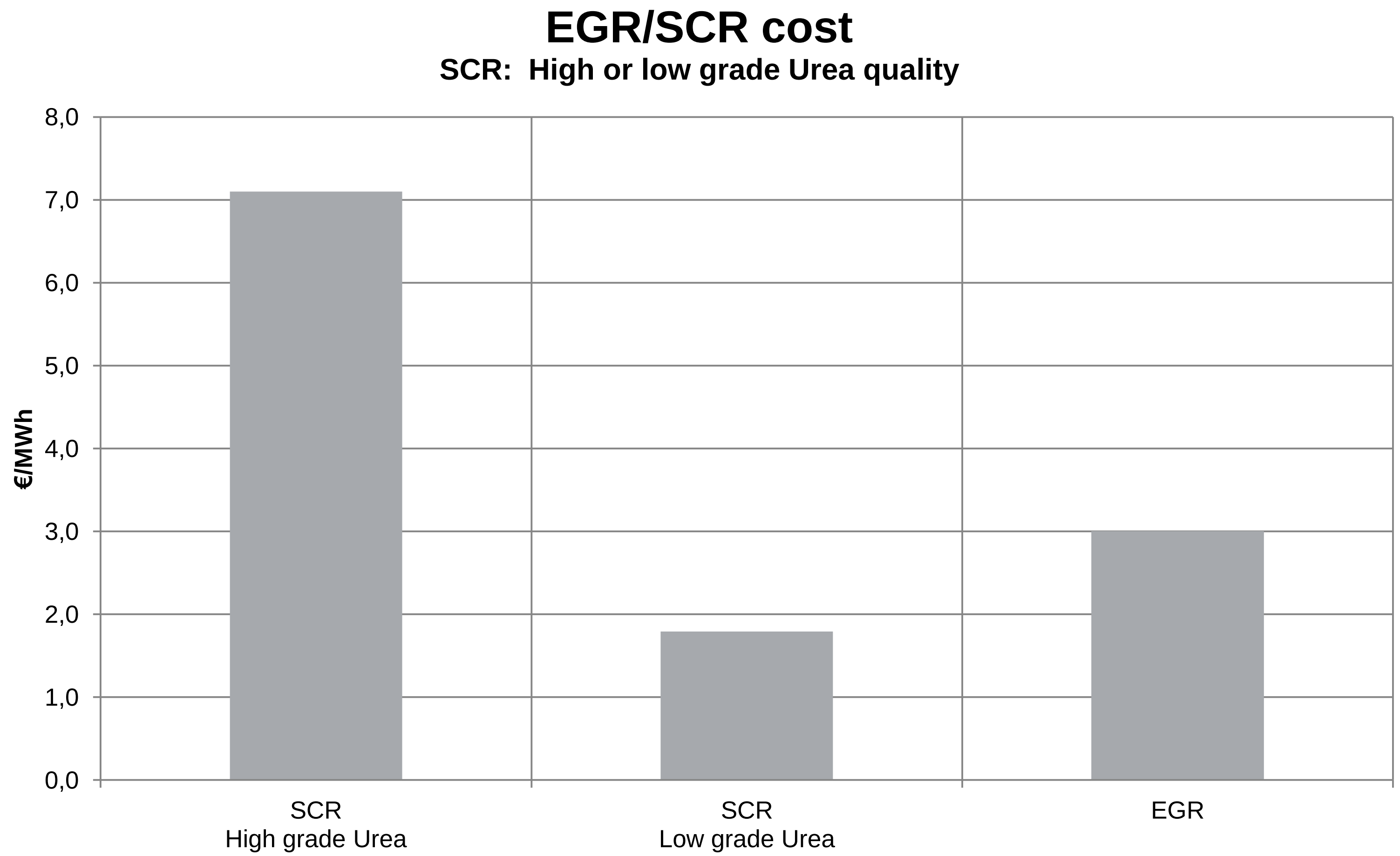
Bunkering?

Retrofit?

EGR and SCR comparison
First cost



EGR and SCR comparison
Operation cost

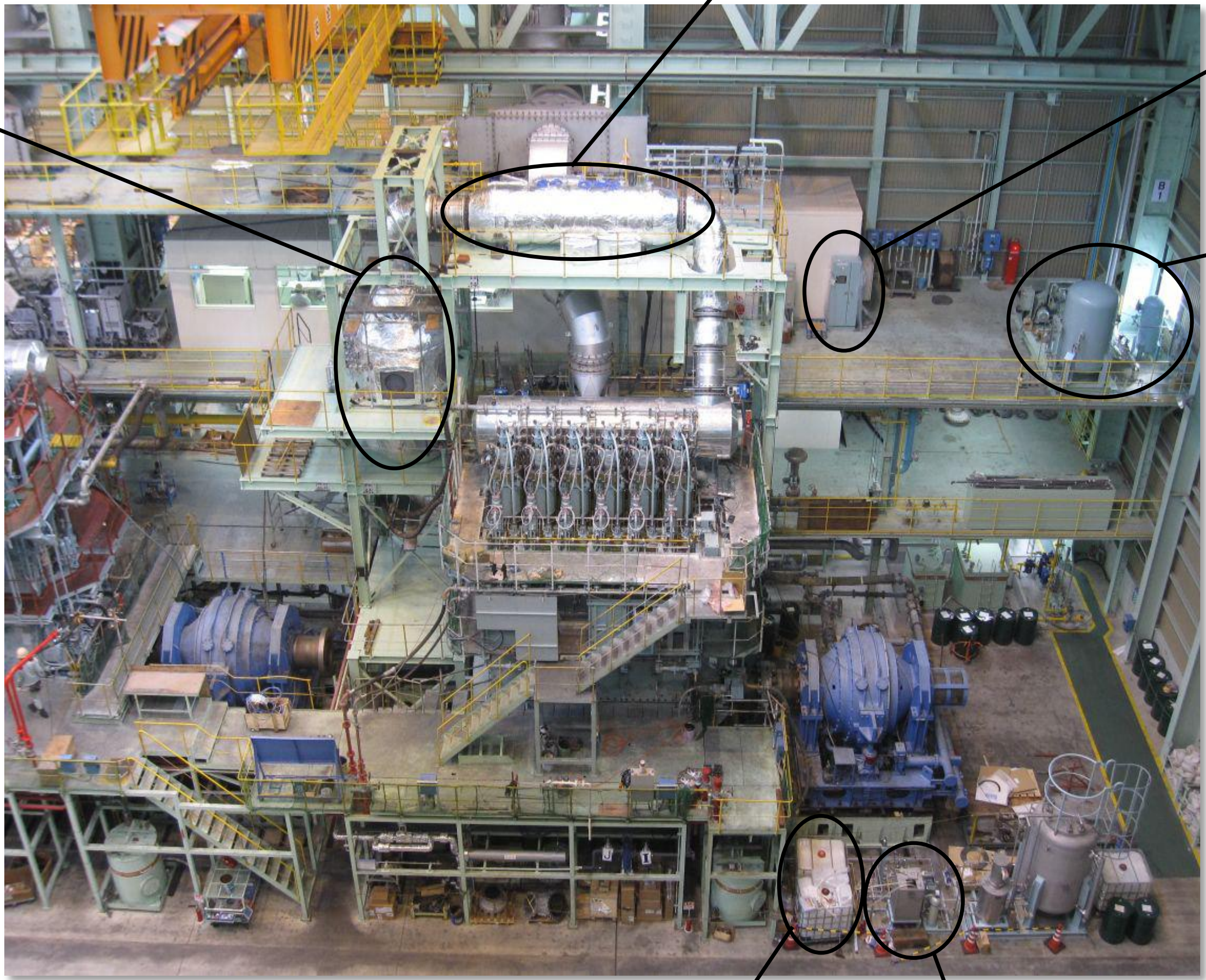


SCR Installation

SCR Tier III

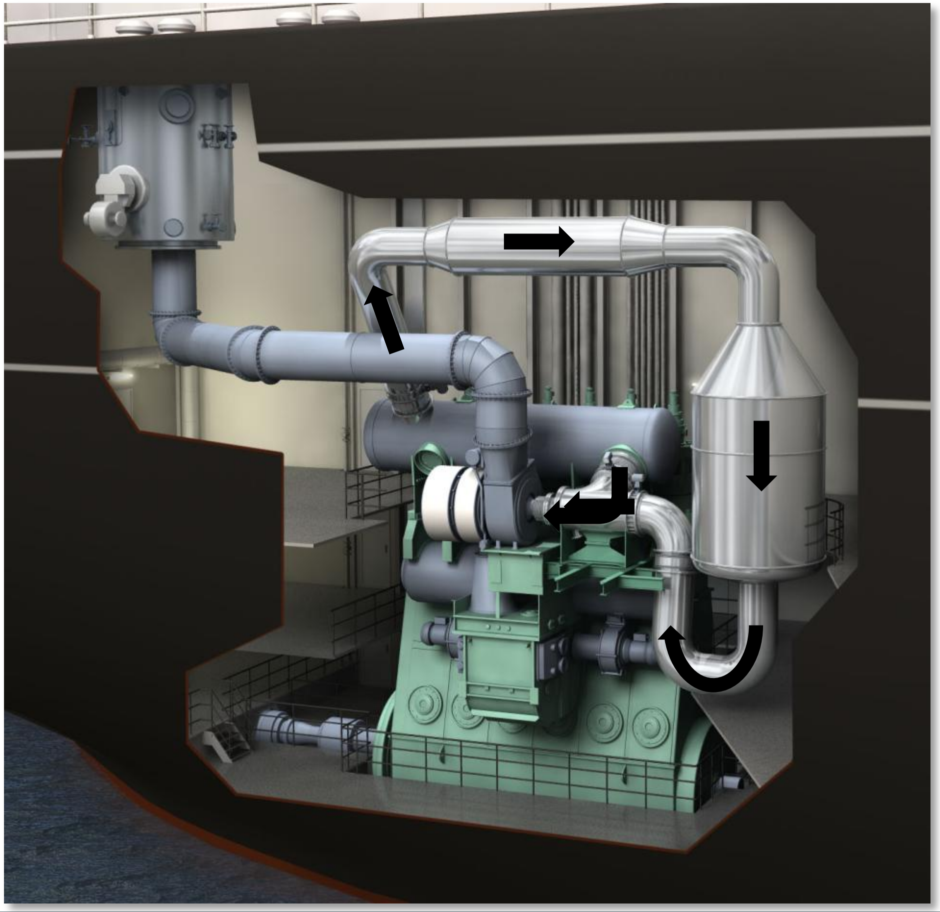
May 2011: First Tier III compliant two stroke engine!

Tier III achievement
6S46MC-C with SCR



The Tier III SCR system
High pressure SCR

- Challenge to ensure the right temperatures for SCR



Tier III achievement
Results

Tier III is achieved with high pressure SCR

- Sufficient temperature for HFO operation
- Also, at low load with Cylinder & SCR Bypass Valve support

6S46MC-C	25 % load	50 % load	75 % load	100 %load	Cycle
Tier I	18.1	17.2	14.7	12.4	15.8
Tier III	2.9	3.1	2.9	2.5	2.8

The high pressure Tier III SCR system ensures high fuel flexibility and low catalyst volume

'Rule of thumb' estimates of consumables for SCR.

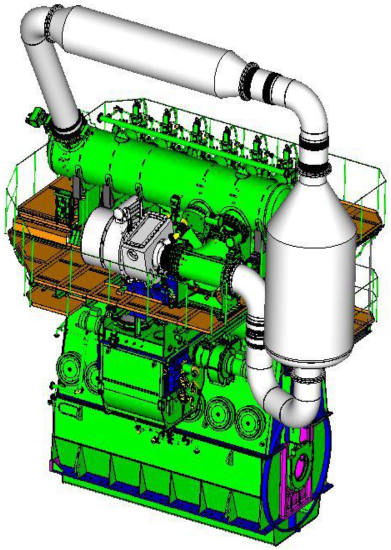
SFOC:

- **2-3 g/kWh** at low loads.
- **0 g/kwh** when the engine load is sufficient to ensure proper exhaust gas temperature.

Urea consumption (40% aqueous urea solution) depends on the engine setup:

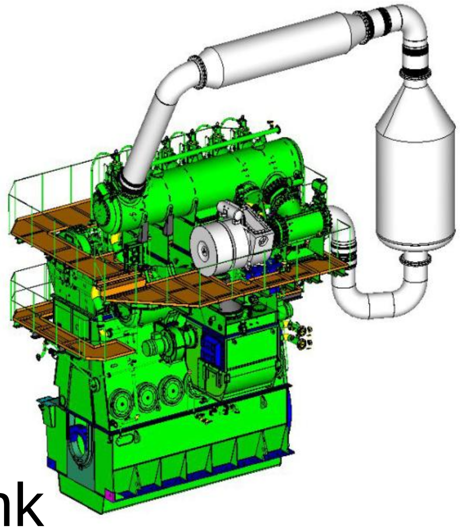
- Tier I engine: approximately **22 g urea/kWh**.
- Tier II engine: approximately **18 g urea/kWh**.

Electrical Power capacity: 6 kW/MW



‘Rule of thumb’ estimates of space & power requirements for SCR

Installations (+/-15%):



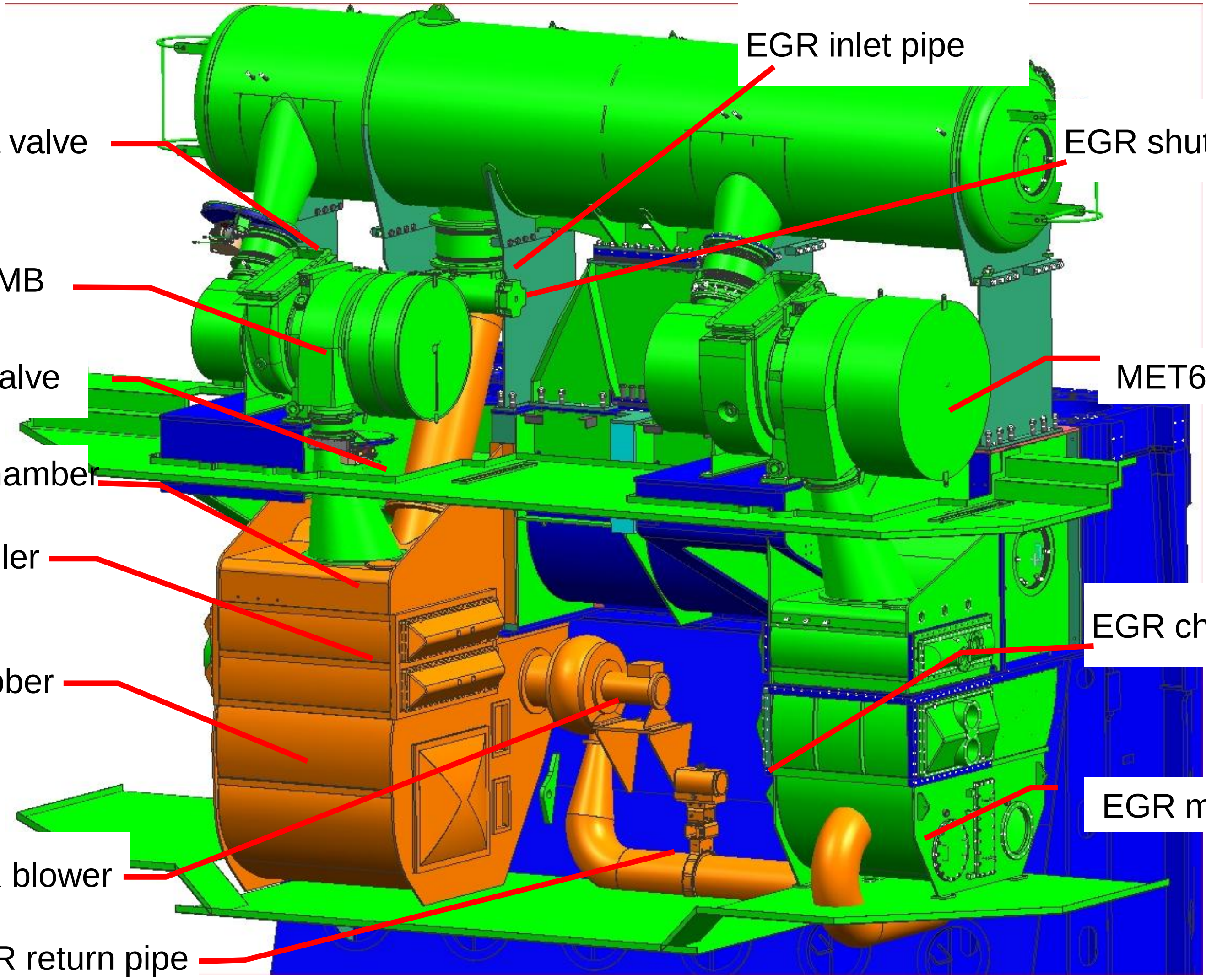
- **Catalyst housing**: 2 m^3/MW.
- **Urea/exhaust gas mixing unit**: 0.5 m^3/MW
- **Piping** interfaces from ME to Engine Room
- **Urea tank capacity**: about 10% of the fuel oil tank capacity, in case of 100% ECA operation and same bunker period for fuel and urea.

Example 7S50MC-C (10MW):

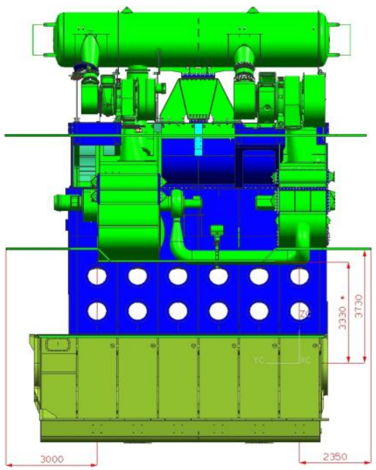
Catalyst house 20m3, urea mixer 5m3 + pipes, urea tank 100m3, power 60kW.

EGR Installation

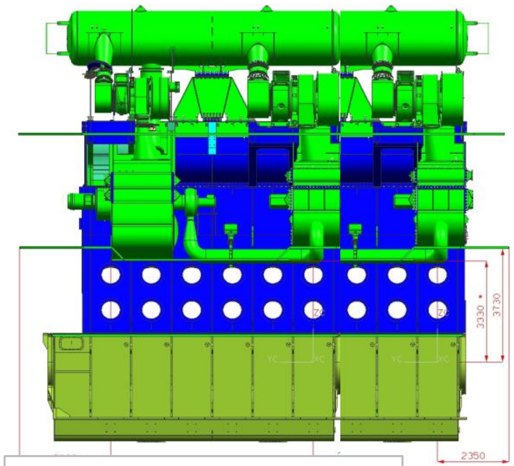
AFT mounted integrated EGR unit



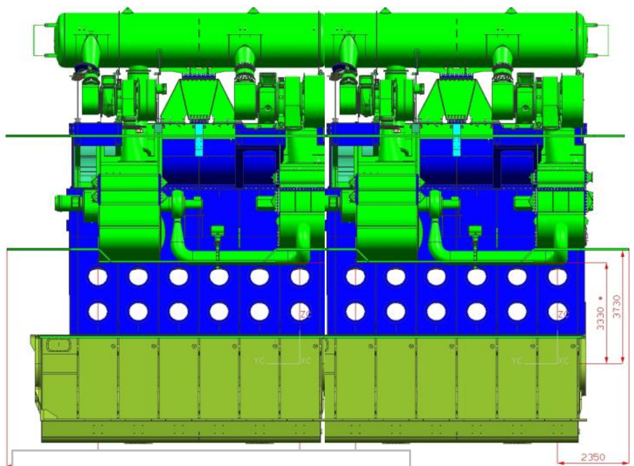
EGR variants to cover 4-90MW



1 by 1 configuration
4-46MW



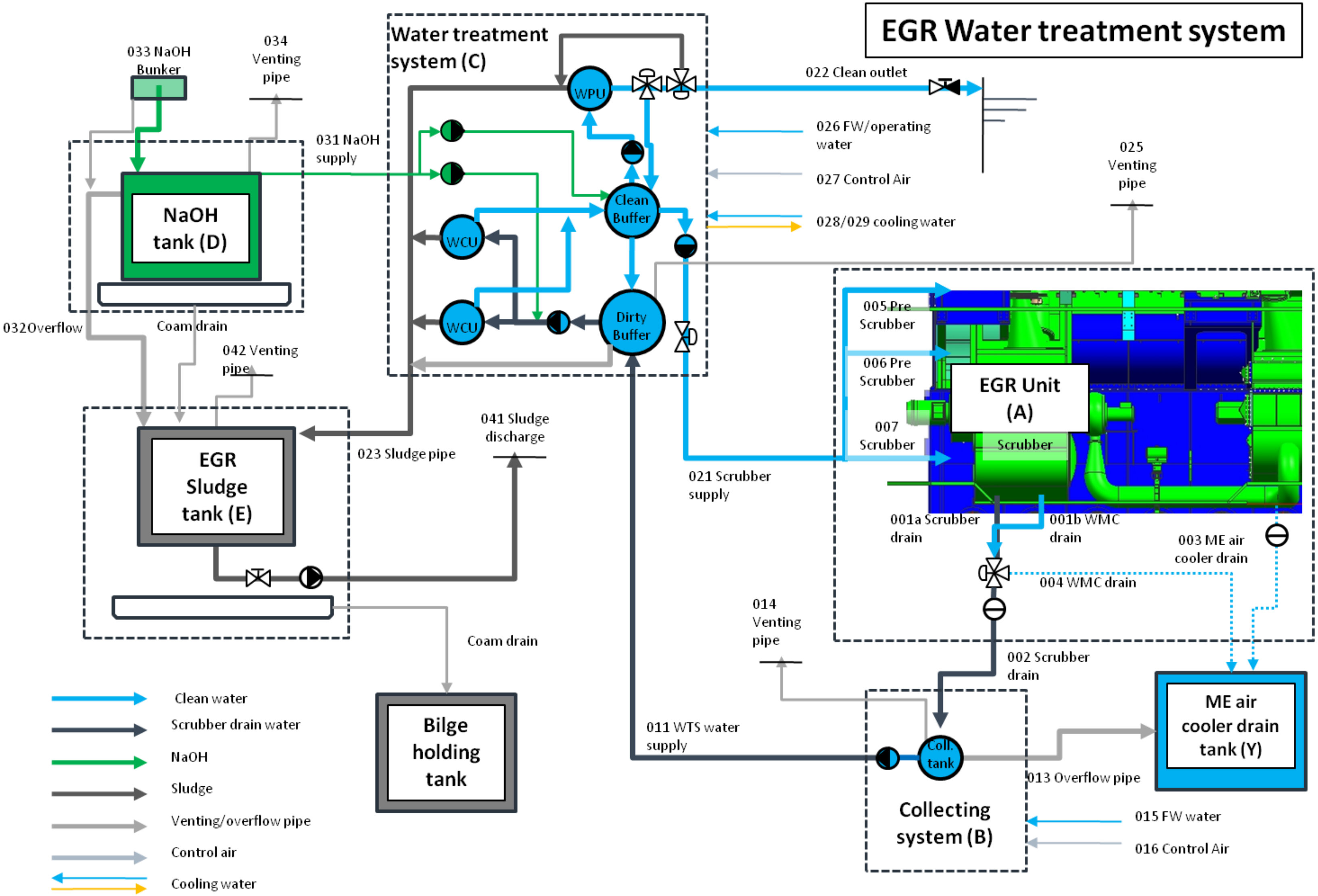
1 by 2 configuration
46-69MW



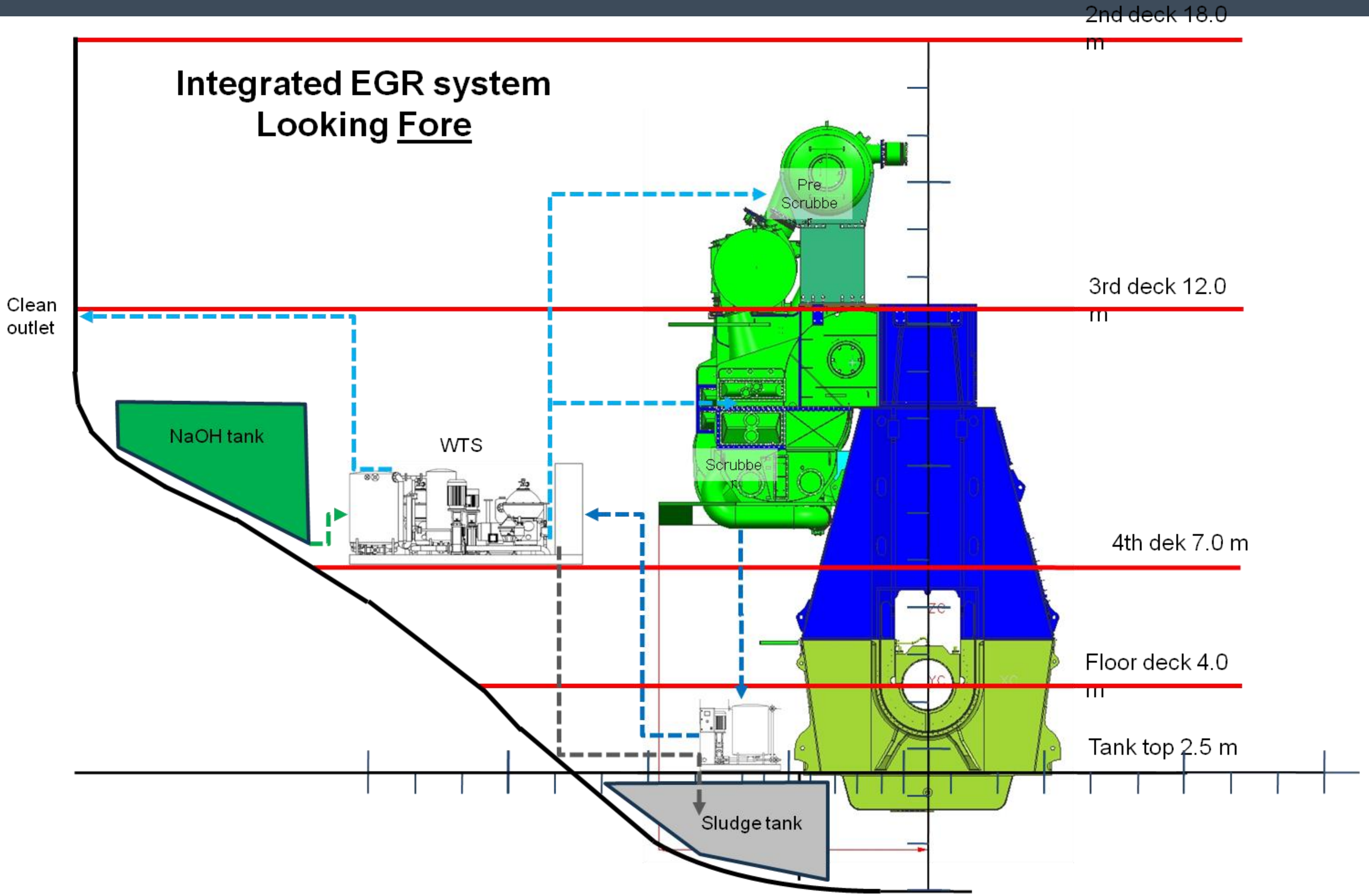
2 by 2 configuration
69-90MW

Single T/C EGR configuration???

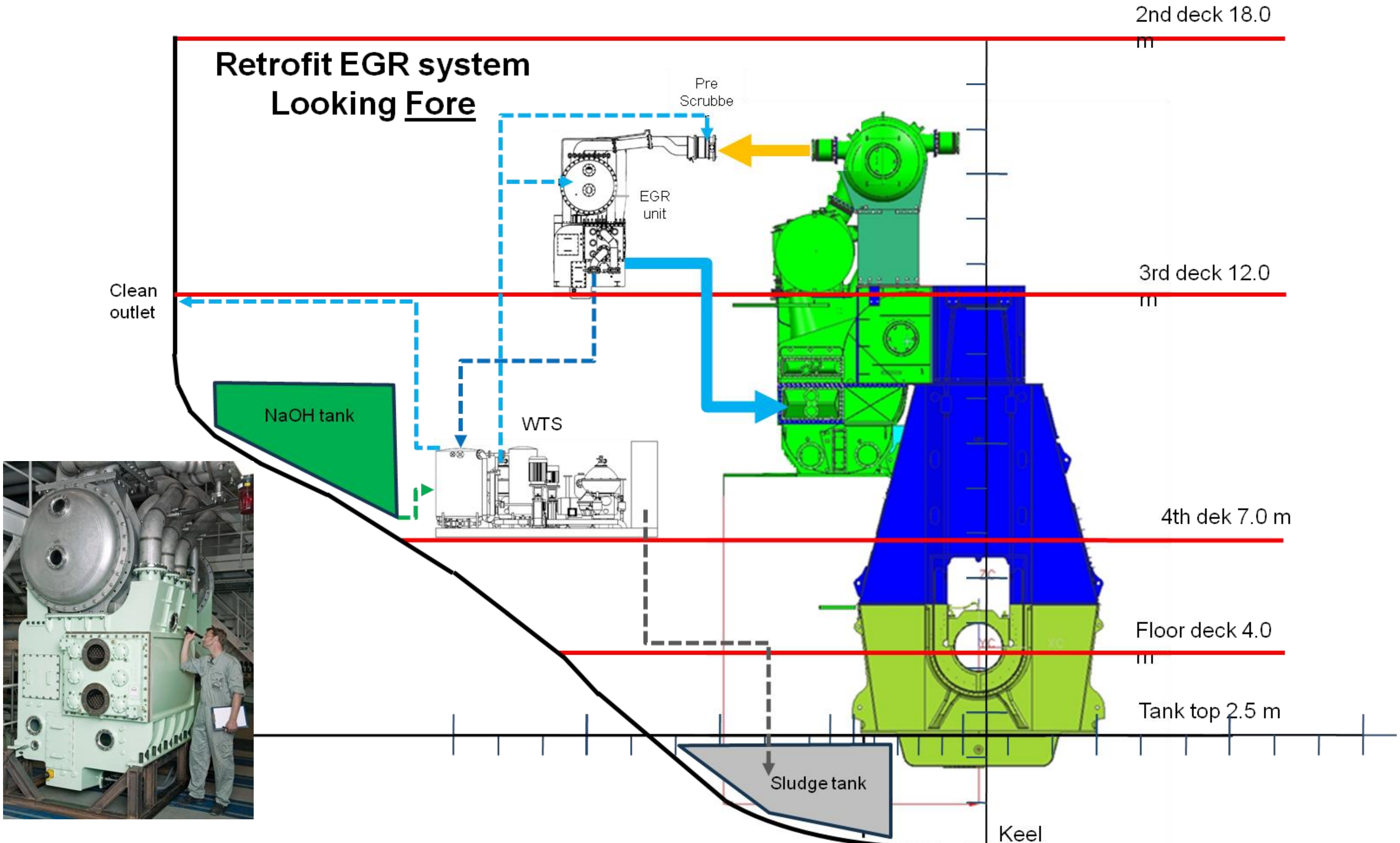
EGR water treatment system



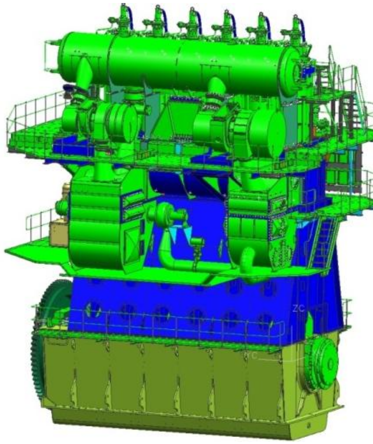
Integrated solution



Engine room installation



'Rule of thumb' estimates of consumables for EGR.



Specific SFOC:

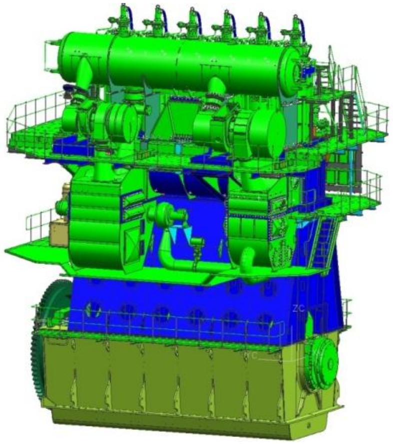
- 1-2g/kWh at all loads.

Specific NaOH consumption :

- Volume$_{[m^3/h]}$ = 2 $_{liter/MWh/\%S}$ *fuel-sulphur$_{[\%]}$*P$_{[MW]}$ *Pmean$_{[\%]}$

based on 50% aqueous sodium hydroxide solution

'Rule of thumb' estimates of consumables for EGR.



Engine EGR Outline:

- Integrated EGR: only minor change to outline
- Standalone EGR:

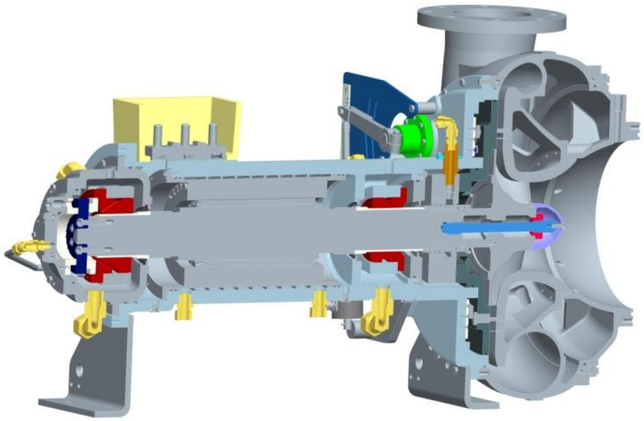
$Volume_{[m^3]} = P_{[MW]} * (1.8_{[m^3/MW]} + 61_{[m^3/(MW*S\%)]} * \text{fuel-sulphur}_{[\%]})$

$Area_{[m^2]} = Volume_{[m^3]} / 3.5_{[m]}$

‘Rule of thumb’ estimates of consumables for EGR.

EGR Power:

$Power_{[kW]} = 13_{[kW/MW]} * P_{[MW]}$



EGR cooling water:

$Volume_{[m^3/h]} = 5_{[m^3/h/MW]} * P[MW]$

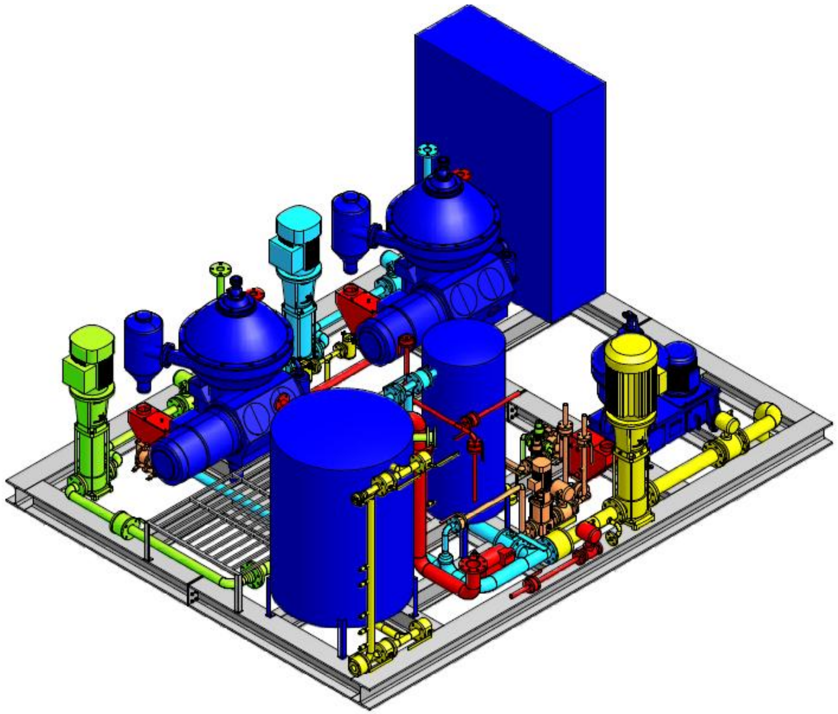
In addition to the normal cooling capacity

'Rule of thumb' estimates of space & power requirements for EGR

Water Treatment System outline:

$$\text{Area}_{[m^2]} = 32_{[m2/(MW*\%S)]} * \text{fuel-sulphur}_{[\%]} * P_{[MW]}$$

$$\text{Power}_{[kW]} = 290_{[kW/(MW*\%S)]} * \text{fuel-sulphur}_{[\%]} * P_{[MW]}$$



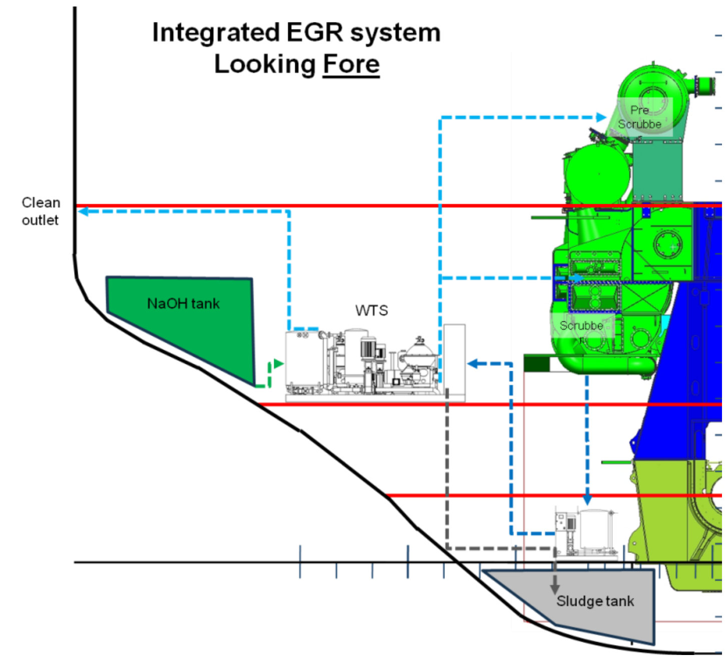
‘Rule of thumb’ estimates of space & power requirements for EGR

- **NaOH tank capacity**:

$$Volume_{[m^3]} = 282_{[m3/MW/\%/\ \%/\ S\%/mdr/\%]} \cdot {*}P_{[MW]} {*}Pmean_{[\%]} {*}OperationTimeYear_{[\%]} {*}fuel\text{-}sulphur_{[\%]} {*}BunkerPeriod_{[mdr]} {*}ECATime_{[\%]}$$

- **EGR sludge capacity:**

$$Volume_{[m^3]} = 329_{[m3/MW/\%/\%/S\%/mdr/\%]} \cdot {*}P_{[MW]} {*}Pmean_{[\%]} {*}OperationTimeYear_{[\%]} {*}fuel\text{-}sulphur_{[\%]} {*}BunkerPeriod_{[mdr]} {*}ECATime_{[\%]}$$



EGR Example

Input:

Engine Type	7S70ME-Cunit	
100% SMCR	23	MW
Operation Time per year	68	%
Average load of MCR	75	%
Sulfor %	3	%of HFO
NaOH bunker period	2,0	mdr
Period between EGR sludge disposal	1,5	mdr
Non ECA, Tier II EGR in %	80	% / year
ECA, Tier III in %	20	% / year

Output:

Scaled EGR unit dimensions for retrofit		
EGR unit volumen	84,5	m3
EGR unit area	24,2	m2

Other components in the engine room		
WTS area	22	m2
WTS power	200	kW
Blower power	300	kW
NaOH tank size (50%solution)	40	m3
EGR Sludge tank size	35	m3
Additional cooling water	123	m3/h

Thank You for Your Attention!

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