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Nowe regulacje w żegludze morskiej w zakresie ochrony środowiska – wyzwania, technologie, możliwości

5 INTERNATIONAL MARITIME CONGRESS

8-9 June 2017 Szczecin

New environmental regulations in maritime shipping - challenges, technologies, opportunities

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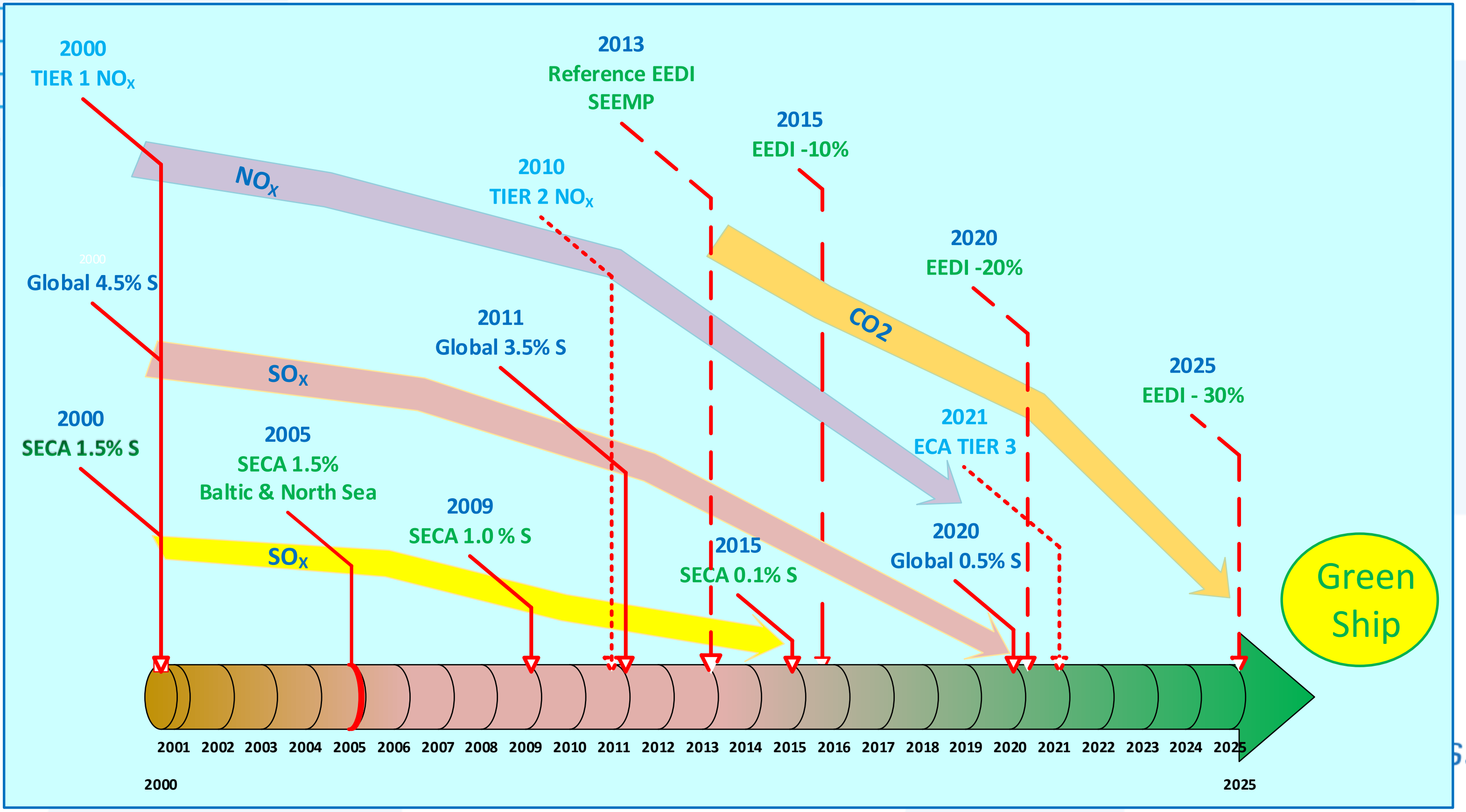
Environmental legislation programs

1. International Maritime Organization adopted **MARPOL 73/78 Annex IV**:

- Regulation 13 - **Nitrogen Oxides - NO_X**
- Regulation 14 – **Sulphur Oxides - SO_X** and **Particulate Matter - PM**
- RESOLUTION MEPC.203(62): **Energy efficiency for ships – CO_2**

2. EU Directive - **EU 2005/33/EC**, 2005 for ships moored in EU ports - **SO_X**



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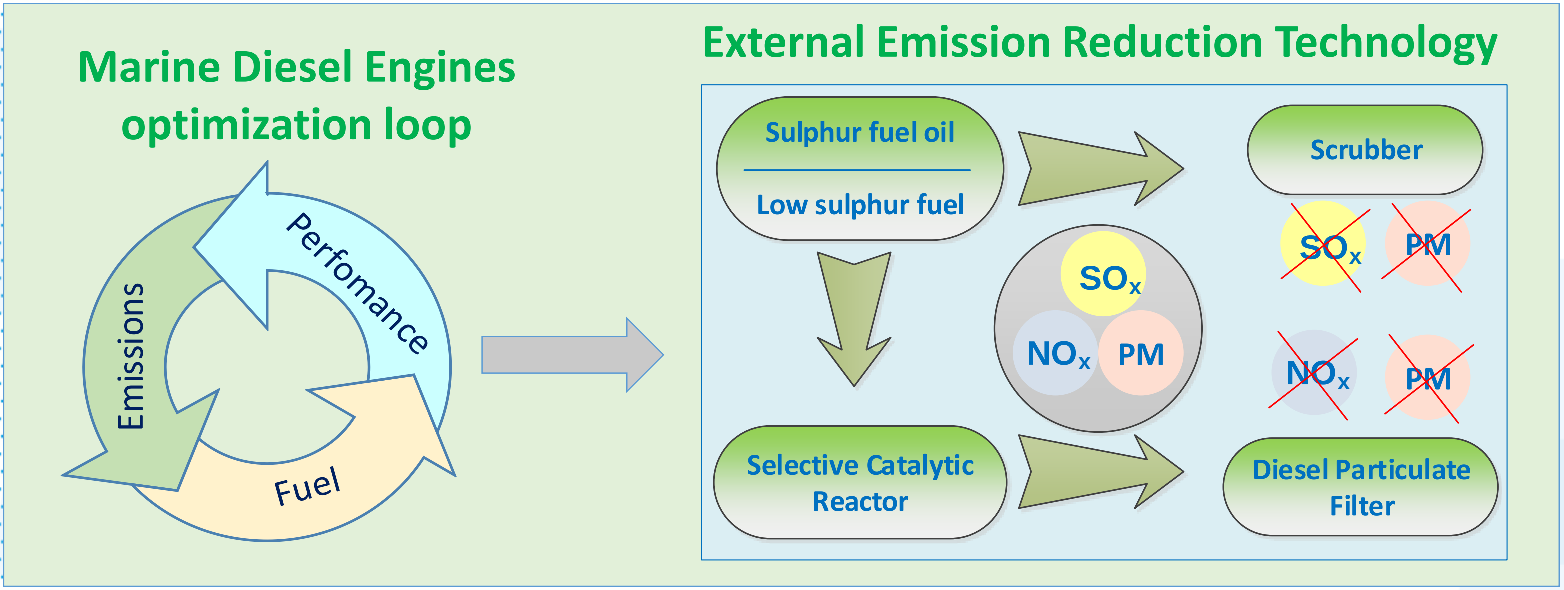

SO_x emission control means may be divided into methods termed:

- **Primary** - formation of the pollutant is avoided (ultra-low sulphur or alternative fuels)
- **Secondary -** pollutant is formed but removed, prior to discharge to the atmosphere (scrubbers).

NO_x reduction technologies can be divided into three basic categories:

- **pre-treatment** - lowering the combustion temperatures by external treatment or use of alternative fuels,
- **internal measures -** altering the engine configuration to modify the combustion process (EGR),
- **after-treatment** - systems fitted externally to the engine and are applied directly to the exhaust gases (SCR, EGR).

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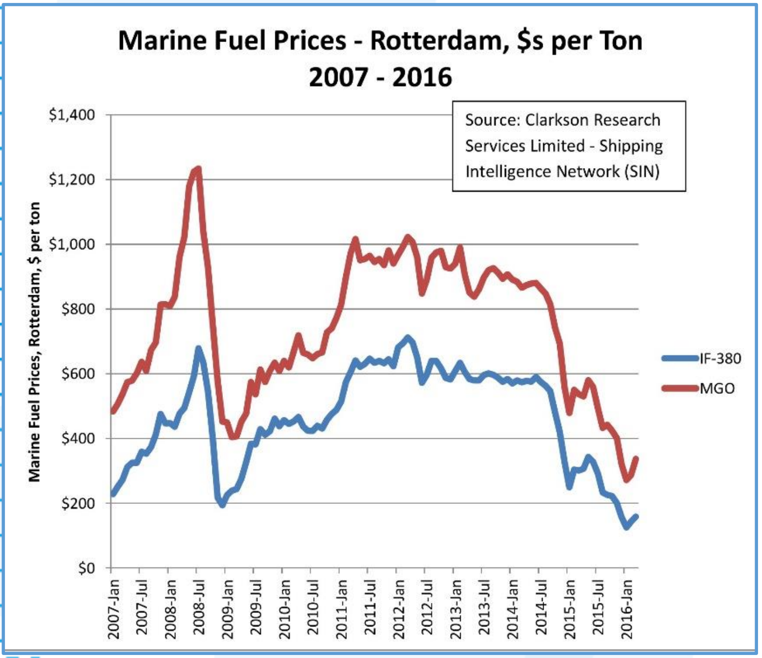
Ships' speed changes influenced by fuel oil prices and freight rates



Ship Type	Size, lower	Size, upper	Units	Design Speed	2007 Speed	2012 Speed	2016 Speed
Bulk Carrier	60,000	99,999	dwt	15.3	13.0	11.9	11.7
Bulk Carrier	100,000	199,999	dwt	15.3	12.8	11.7	11.6
Bulk Carrier	200,000		dwt	15.7	11.5	12.2	11.9
Container	3,000	4,999	TEU	24.1	18.6	16.1	16.4
Container	5,000	7,999	TEU	25.1	20.6	16.3	17.5
Container	8,000	11,999	TEU	25.5	21.3	16.3	17.7
Container	12,000	14,499	TEU	28.9	20.6	16.1	18.5
Container	14,500		TEU	25.0		14.8	19.7
Oil Tanker	80,000	119,999	dwt	15.3	13.3	11.6	12.7
Oil Tanker	120,000	199,999	dwt	16.0	13.7	11.7	12.9
Oil Tanker	200,000		dwt	16.0	14.6	12.5	12.8

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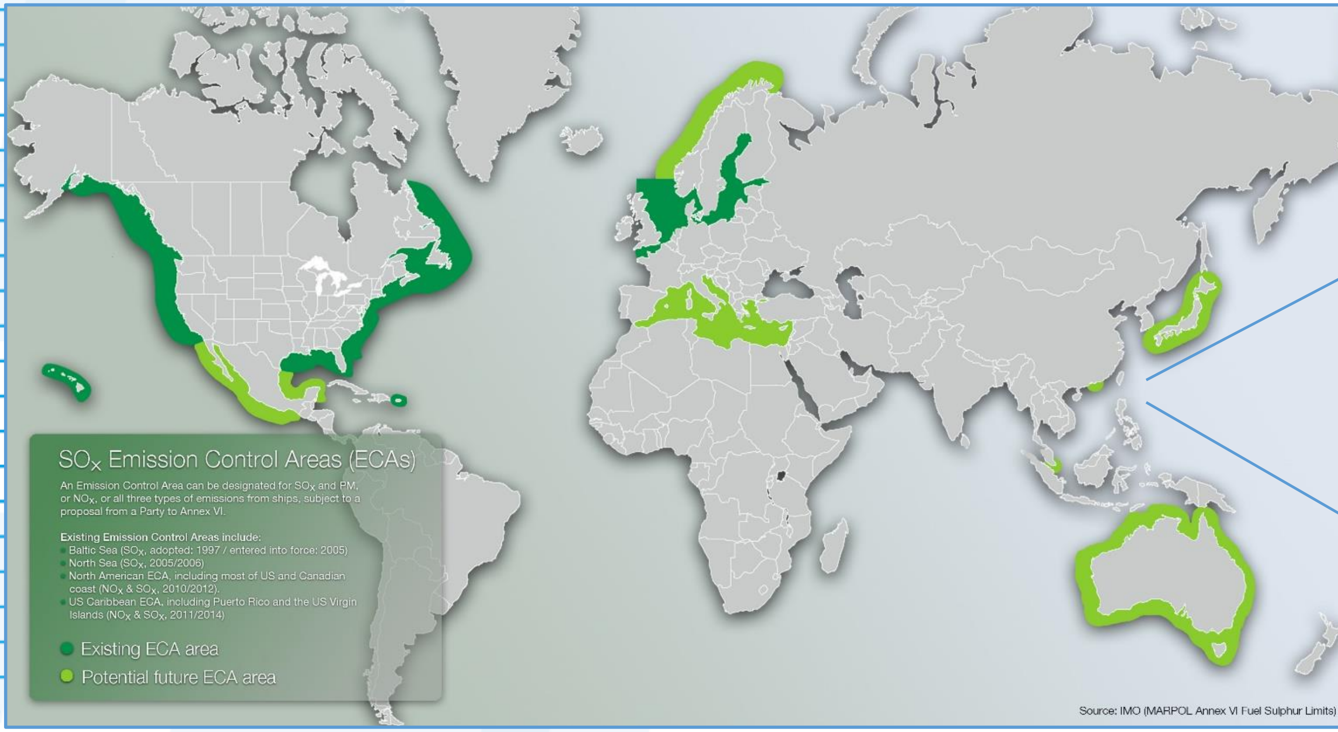
Emission Control Areas existing and potential in future



Global 0.50% m/m on and after 1 January 2020 or 2025, depending the outcome of a review to be completed by 2018 to determine availability of fuel oil to comply with the fuel oil standard.

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Marine common fuels facing current and future requirements

Marine Typical Fuel Grades

WORLD Model Grade	ISO8217 Grade	Key Specifications Employed							
		density @ 15C - max	wt % sulphur - max	flash point degC - min	viscosity @ 40C (mm2/s) - max	viscosity @ 50C (mm2/s) - max	pour point Summer / Winter average (degC) - max	cetane index - min	micro carbon residue (%m/m) - max
Marine Distillate Fuels									
'Traditional' MGO	DMA	890	1.5/0.5	60	6		0/-6 = -3	40	
ECA MGO	DMA	890	0.1	60	6		0/-6 = -3	40	
Global MDO	DMB	900	0.5	60	11		6/0 = 3	35	0.3
IFO Fuels									
HS IFO180	RMG	0.991	3.5	60		180	30		18
HS IFO380	RMG	0.991	3.5	60		380	30		18
Global IFO 80 / 'Hybrid'	RMD	0.975	0.5	60		80	30		14
Global IFO 380	RMG	0.991	0.5	60		380	30		18

New fuel arrival

New „**hybrid**” fuel products containing a maximum of 0.10% m/m sulphur as an alternative to using distillates in order to meet the MARPOL Annex VI requirements

Characteristics	Unit	Limit	HDME 50 (EXXONMOBIL)	Fuel Oil (Chemoil)	DMB (Chemoil)	Fuel Oil (Chemoil)2	ULSFO (Shell)	SK ULSFO (SK Energy)	BP 0.1 RMD (BP)	Eco Marine Fuel (Lukoil)
Kinematic viscosity at 50 °C	mm2/s	min/max	25 to 45	16.84	10.5	26.3	10-60	30~40	6-13	65
Density at 15 °C	kg/m3	max	895 to 915	0.8589	0.885	0.896	790-910	0.928	850-890	0.91
Cetane index	—	min			40				—	
CCAI	—		795 to 810			795	800	790~800	760-820	860
Sulphur	mass %	max	0.1	0.084	0.085	<0.1	<0.1	<0.1	0.10	0.095
Flash point	°C	min	70	>60	70	>60	>60	70	60	60
Hydrogen sulfide	mg/kg	max	1		0.1		<2		2	2
Acid number	mg KOH/g	max	0.1		0.1	2.35	<0.5		2.5	2.5
Total sediment existent	mass %	max	0.01	0.01	0.05	0	0.01-0.05	0.02	—	
Total sediment aged	mass %	max	0.01	0.01		0.01	0.01-0.05	0.02	0.07	0.1
Oxidation stability	g/m3	max	0.01						—	
Carbon residue: micro method	mass %	max	0.3	<0.10	0.1	3.8	2	6	4	14
Cloud point	°C	max	—							
Pour point (upper) W	°C	max	9 to 15	-20	-4	-6	18	20~25	+27	20
S	°C	max	9 to 15							
Appearance	—	—	brown/ green - opaque	Not Clear and bright	ot Clear and brig	Not Clear and bright		Black	—	
Water	volume %	max	0.05		0.05		0.05	0.2	0.3	0.1
Ash	mass %	max	0.01	0.003	0.005	0.06	0.01	0.05	0.04	0.07
Lubricity, (wsd 1,4) at 60 °C	µm	max	320		310				—	
Vanadium	mg/kg	max	1			<1	2	0.7	50	2
Sodium	mg/kg	max	1	4		1	10	2	50	2
Al & Si	mg/kg	max	3	<3		<10	12-20	10~20	25	17
Calcium	mg/kg	max	1	13		175	free of ULO	5		free of ULO
Phosphorus				7		<1	free of ULO			free of ULO
Zinc	mg/kg	max	1	2		<1	free of ULO	1		free of ULO
Calc. Gross Specific Energy	mg/kg								45.2	

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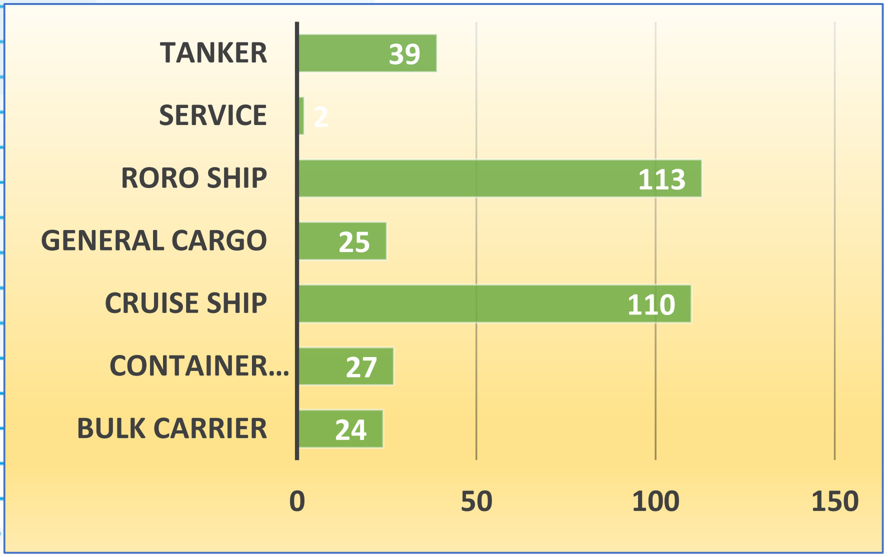
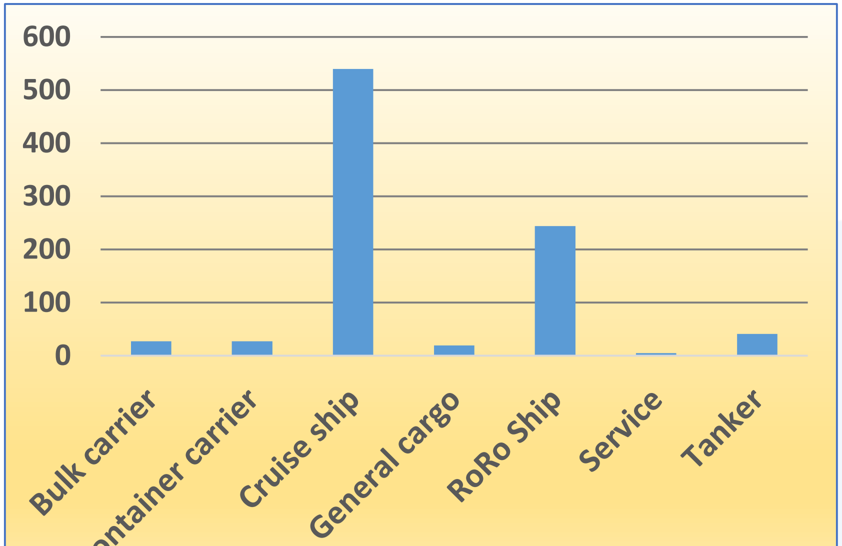
Actual EGCS installations

Ships equipped with EGCS



Scrubber units in service



Estimated number of scrubber units onboard	
In Service	843
Keel laid	13
Launched	16
On order and not commenced	21
Under construction	2
Total	895

List of EGCS manufacturers

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- WÄRTSILÄ MOSS
- AEC MARITIME
- ANDRITZ AIR POLLUT. CONTROL
- CHINA ENVIRONMENTAL PROJECT
- ECOSPRAY TECHNOLOGIES
- LANGH TECH
- PURETEQ
- ALFA-LAVAL
- CLEAN MARINE
- FUJI ELECTRIC
- MAN DIESEL
- SAACKE MARINE SYSTEMS
- BABCOCK NOELL
- CR OCEAN ENGINEERING
- LAB
- MARINE EXHAUST SOLUTIONS
- TRITON EMISSION SOLUTIONS INC.
- BLUESOUL
- DUPONT BELCO CLEAN AIR
- IONADA™
- MUNTERS
- YARA MARINE

Wet and Dry Scrubbing – current approach

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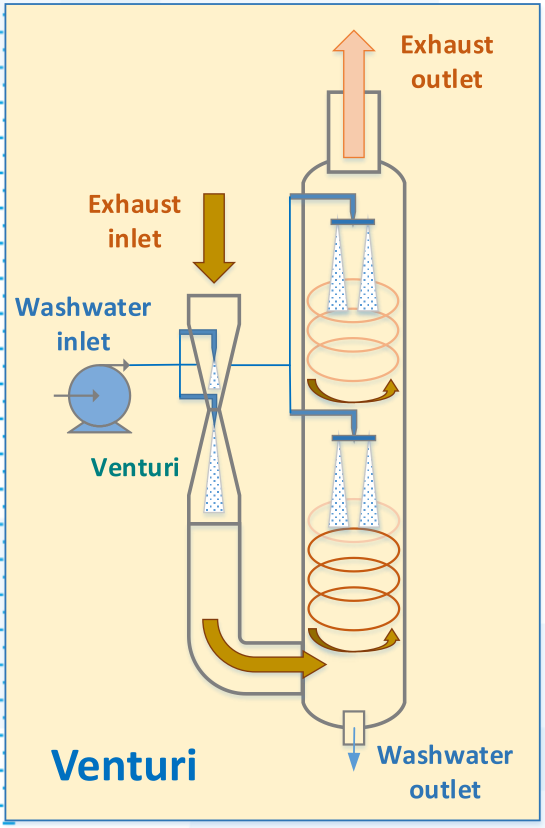
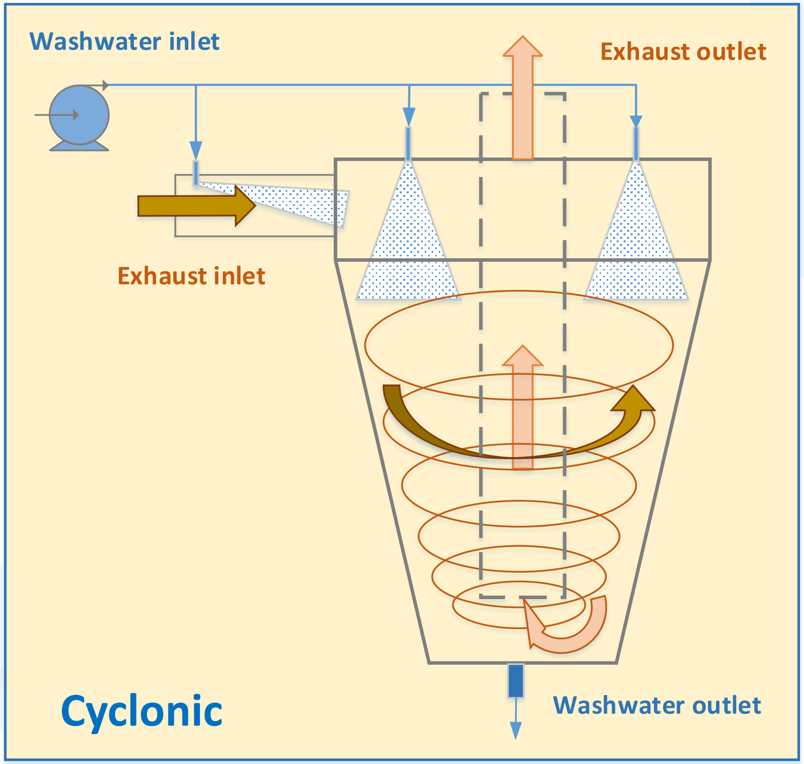
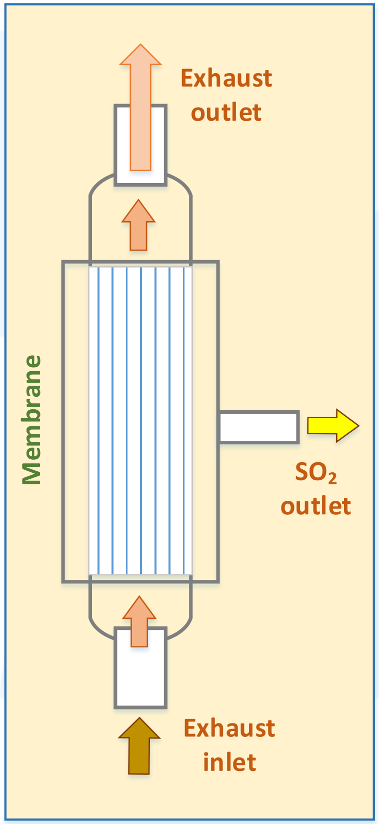
Wet scrubbers principle





Dry scrubber principle



Membrane

IMO Resolutions: MEPC.130(53), MEPC.170(57) and MEPC.184(59) 2009;
Guidelines for Exhaust Gas Cleaning Systems, adopted on 17 July 2009

Exhaust emissions compliance limits

For EGC systems operating on conventional fuel oils, exhaust emission compliance with the equivalent fuel oil sulphur content is verified from the measured **SO2/CO2** concentration ratio

Fuel Oil Sulfur Content ($\%_{m/m}$)	Emission Ratio SO_2 (ppm)/CO_2 ($\%_{v/v}$)
0.10	**4.3**

Washwater discharge and limits

1. **pH criteria**
   The pH of the discharged wash water from the scrubbing process should be no lower than **6.5** units
2. **PAH* concentration**
   The washwater maximum continuous PAH concentration is not to be greater than **50** µg/Ltr above inlet water PAH concentration
3. **Turbidity**
   The turbidity of the EGC unit washwater should not exceed **25** NTU above the inlet water turbidity

*Polycyclic Aromatic Hydrocarbons

EGCS in open loop mode – operation and compliance monitoring

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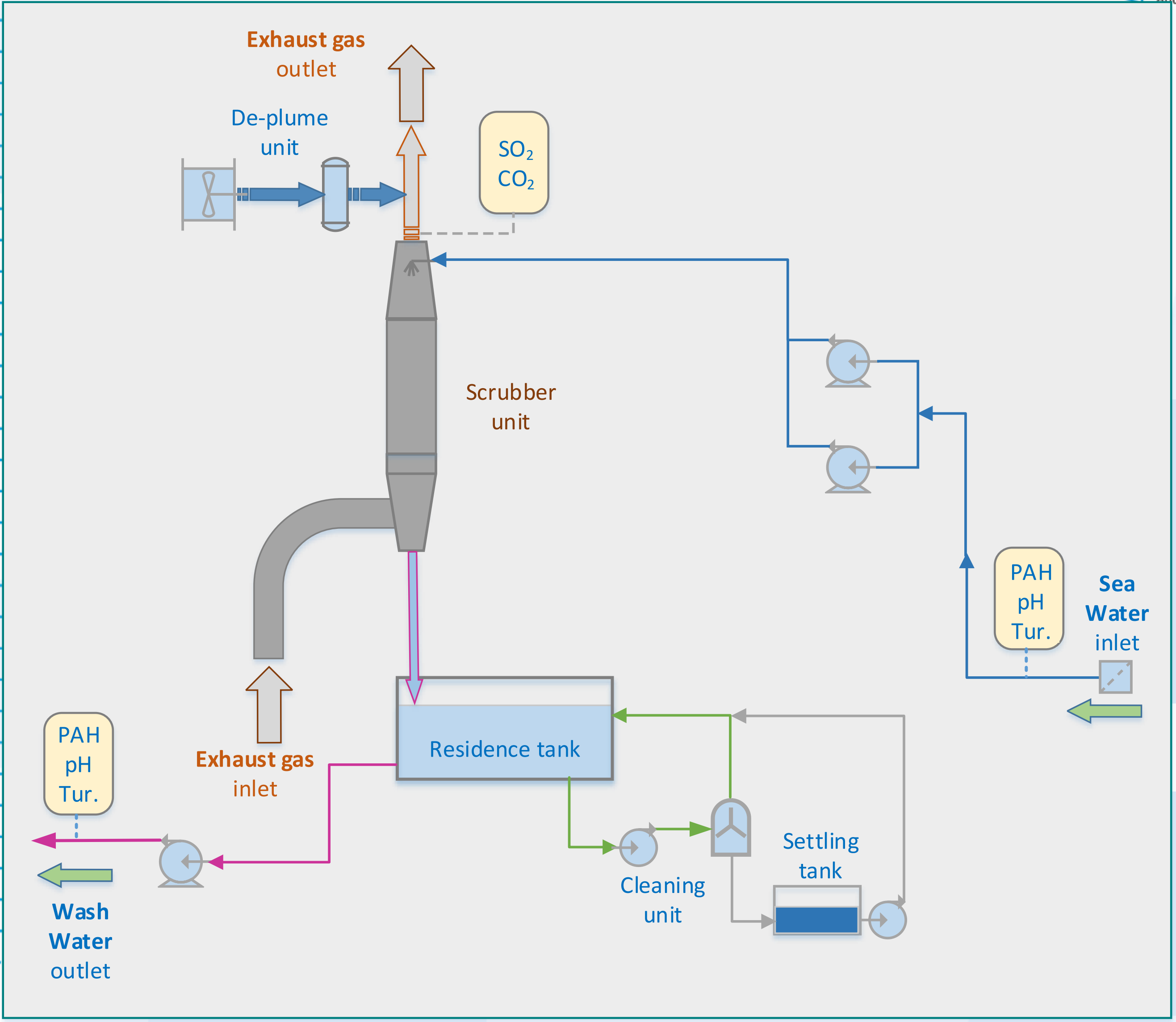

Engine sulphur combustion chemistry:

S + O2 → SO2 ~ 95%

SO2 + ½O2 → SO3 ~ 5%

SO_x reactions in Open Loop:

for **SO_2**

$SO_2 + H_2O \rightarrow H_2SO_3$

$H_2SO_3 \rightarrow H^+ + HSO_3^-$

$HSO_3^- \rightarrow H^+ + SO_3^{2-}$

$SO_3^{2-} + 0.5\,O_2 \rightarrow SO_4^{2-}$

for **SO_3**

$SO_3 + H_2O \rightarrow H_2SO_4$

$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$

$HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$

EGCS in closed loop mode – operation and compliance monitoring

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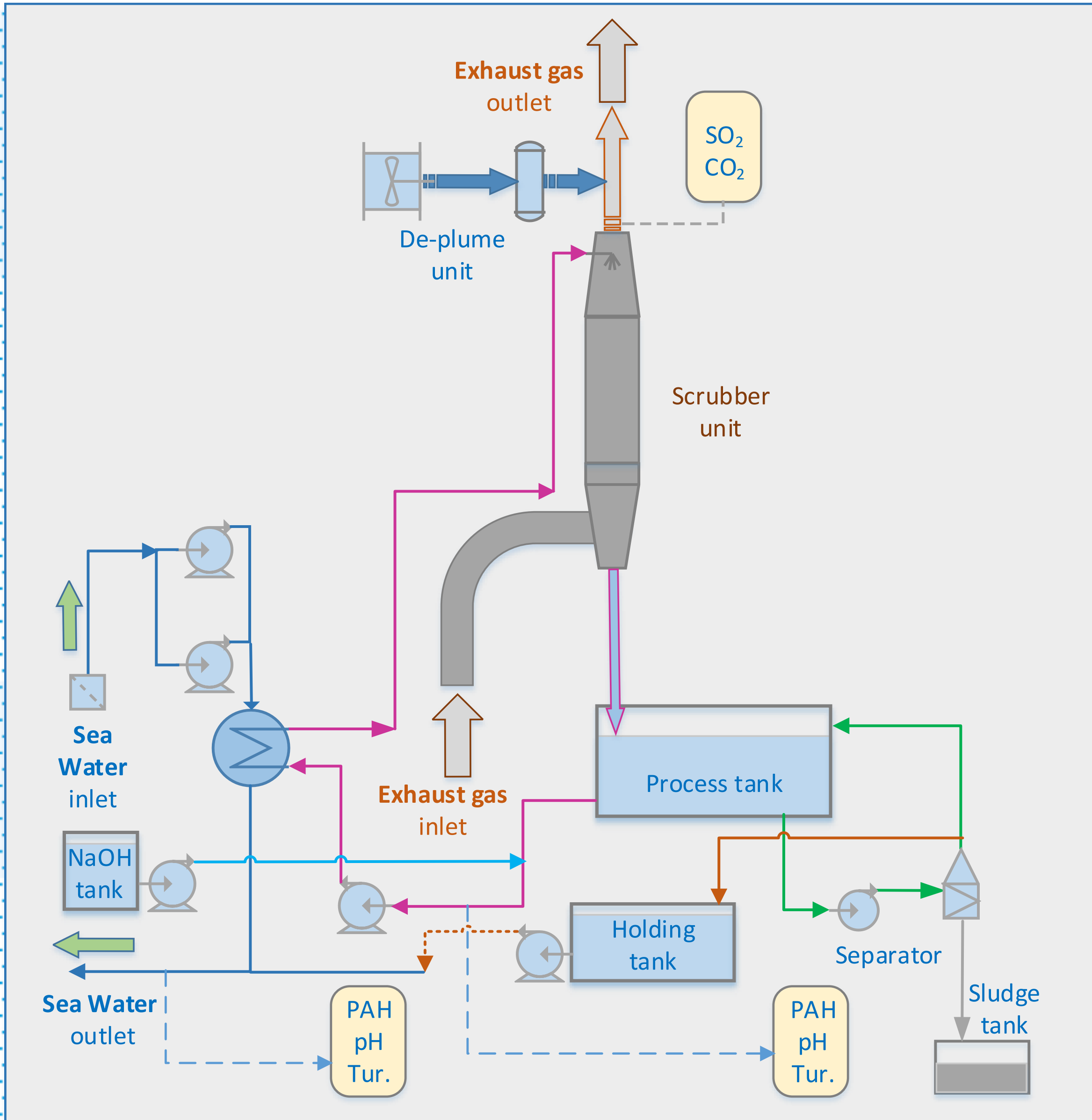

SO_x reactions in Closed Loop:

for SO_2

$Na^+ + OH^- + SO_2 \rightarrow NaHSO_3$

$2Na^+ + 2OH^- + SO^2 \rightarrow Na_2SO_3 + H_2O$

$2Na^+ + 2OH^- + SO_2 + 1/2\ O_2 \rightarrow Na_2SO_4 + H_2O$

for SO_3

$SO_3 + H_2O \rightarrow H_2SO_4$

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

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EGCS types comparison

	SWS, open loop	SWS, closed loop	SWS, hybrid	Dry
Operation without discharge to sea	NO	YES (limited time)	YES (limited time)	YES
Weight *	30 ÷ 55 T	30 ÷ 55 T	30 ÷ 55 T	~200 T
Power consumption	1÷2 %	0.5÷1 %	0.5 ÷2 %	0.15 ÷ 0.20 %
Chemical consumable	NO	NaOH	NaOH	$Ca(OH)_2$
Compatibility with WHR system	YES	YES	YES	YES
Compatibility with EGR system	YES	YES	YES	YES
Compatibility with SCR system	NO	NO	NO	YES
PM removal	YES	YES	YES	YES

WHR – Waste Heat Recovery

EGR – Exhaust Gas Recirculation

SCR – Selective Catalytic Reactor

SWS – Sea Water System

FWS – Fresh Water system

* Typical values for a 20 MW engine SOx scrubber

Actual EGCS costs and installation trends

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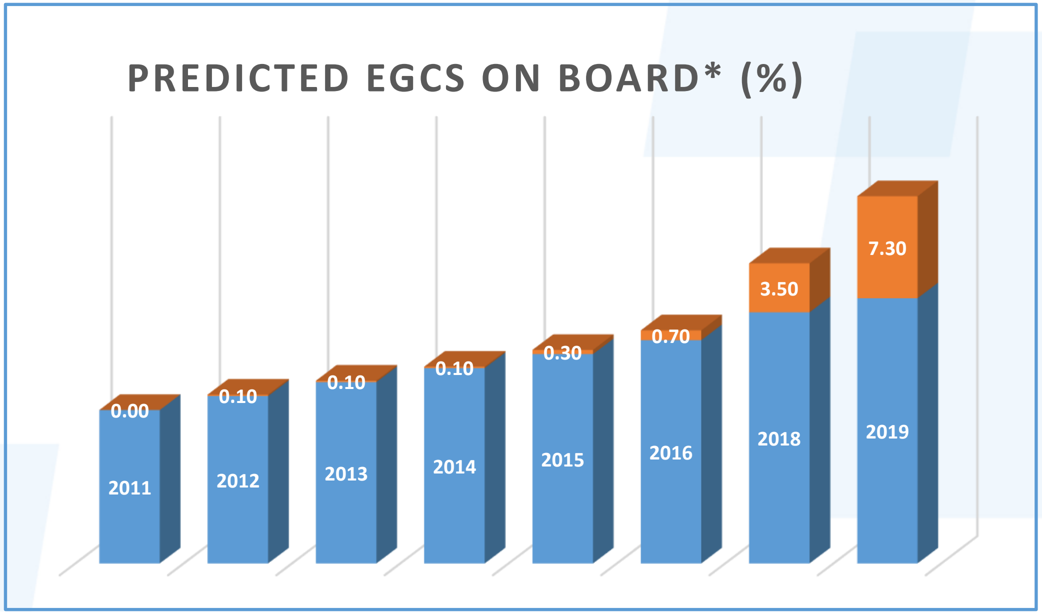
Estimated Investment ($): 3 - 8 million (varies with scrubber type and size)

$$\boldsymbol{CAPEX}(\$) = 2.9\ million + 58 \cdot Engine\ installed\ power\ (in\ kW)$$

$$\boldsymbol{OPEX}(\$) = 1300 + 0.6 \cdot Engine\ installed\ power\ (in\ kW) + 0.5\%\text{ fuel cost}$$



* (%) **23,892** ships candidates for scrubbers (total population of **107,749** - IMO's Supplemental Marine Fuel Availability Study, July 15, 2016)

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Marine fuels expectation

Marine fuel demand scenario - 2020

Fuel type	No **0.5%**	With **0.5%**
	Mtons/year	
High Sulphur Fuel HFO	**253**	**48**
Ultra Low Sulfur ECA + Global	**88**	**283**
LNG	**11**	**11**
Total	**352**	**342**

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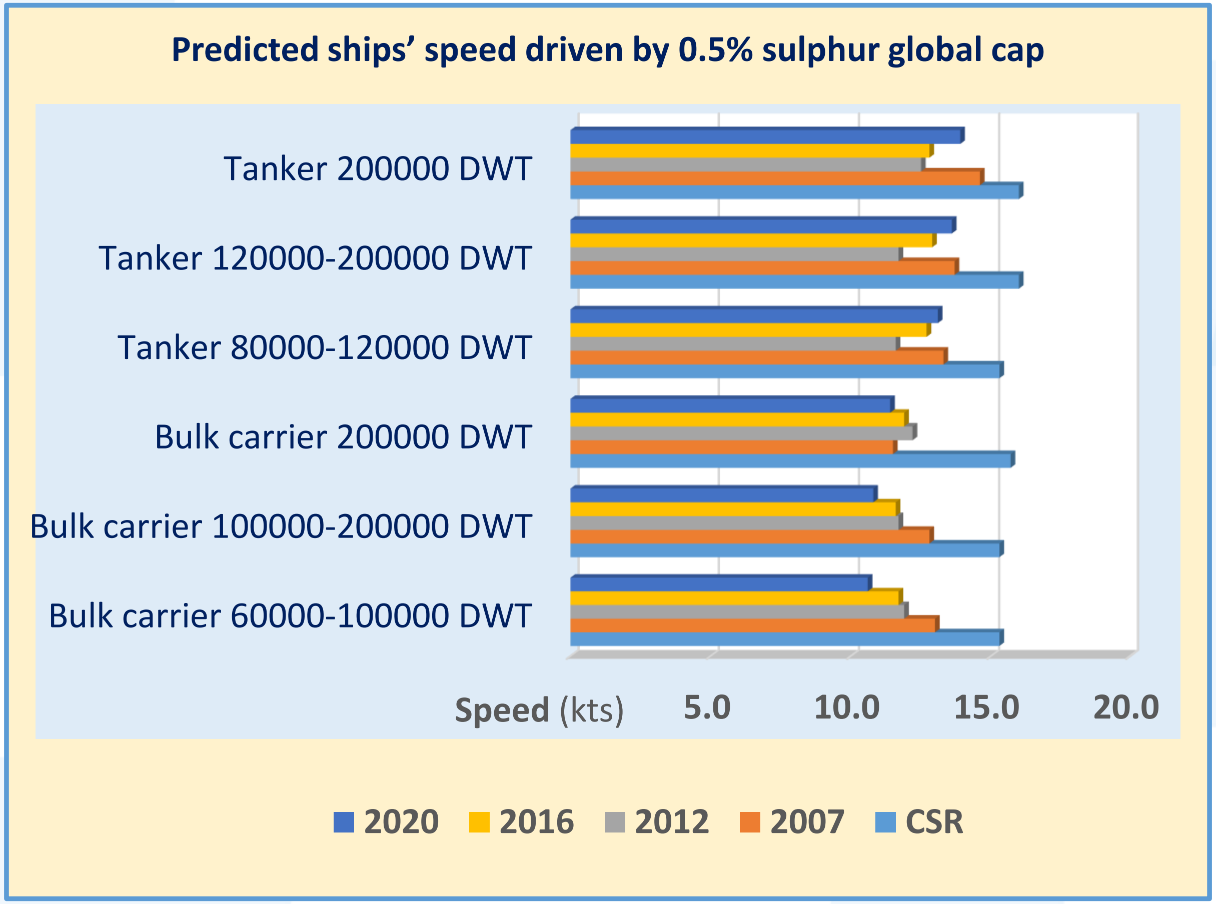
Effects of 0.5% sulphur limit



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Conclusions

- Implemented marine environmental programs, gradually bring positive effects improving air quality and decreasing pollution.
- The implementation costs are fairly high - investment and operating alike, which in turn increases transport costs, making maritime transport less competitive.
- Planned final phase of SO_X emissions reduction in 2020 (0.5% Sulphur), on a global scale and for all ships, once again force the ship owners on a difficult choice to meet this limit.
- New ships construction – already ordered, does not indicate a significant increase of EGCS due to their high investment and operating costs.
- The current EGCS technologies, despite proven long-term efficiency and reliability in land applications, are in the process of evolving and improving their quality of operation, which is also one of the reasons for a large reserve of ship owners to use them.
- It is therefore quite likely the 2020 – 0.5% sulfur scenario, which predicts a strong increase in demand for low sulfur fuels will result in an increase price difference of these fuels relative to - high sulfur residual fuels.

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