Ecological and economic assessment of scrubbers

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CE Delft

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Content

- Introduction
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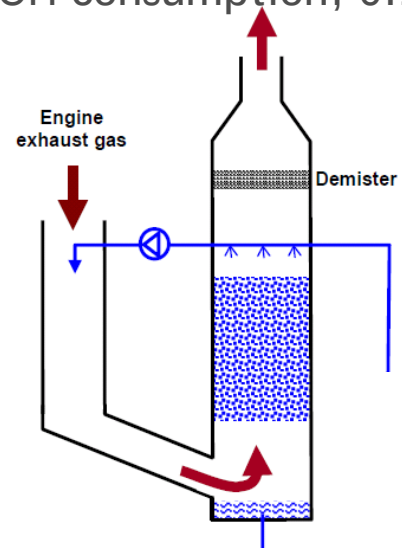
Four different types of scrubbers

- Open loop / sea water scrubber (45 m^3/MWh)
- Closed loop / fresh water scrubber (NaOH consumption, 0.1 m^3/MWh
- Hybrid scrubber
- Dry scrubber

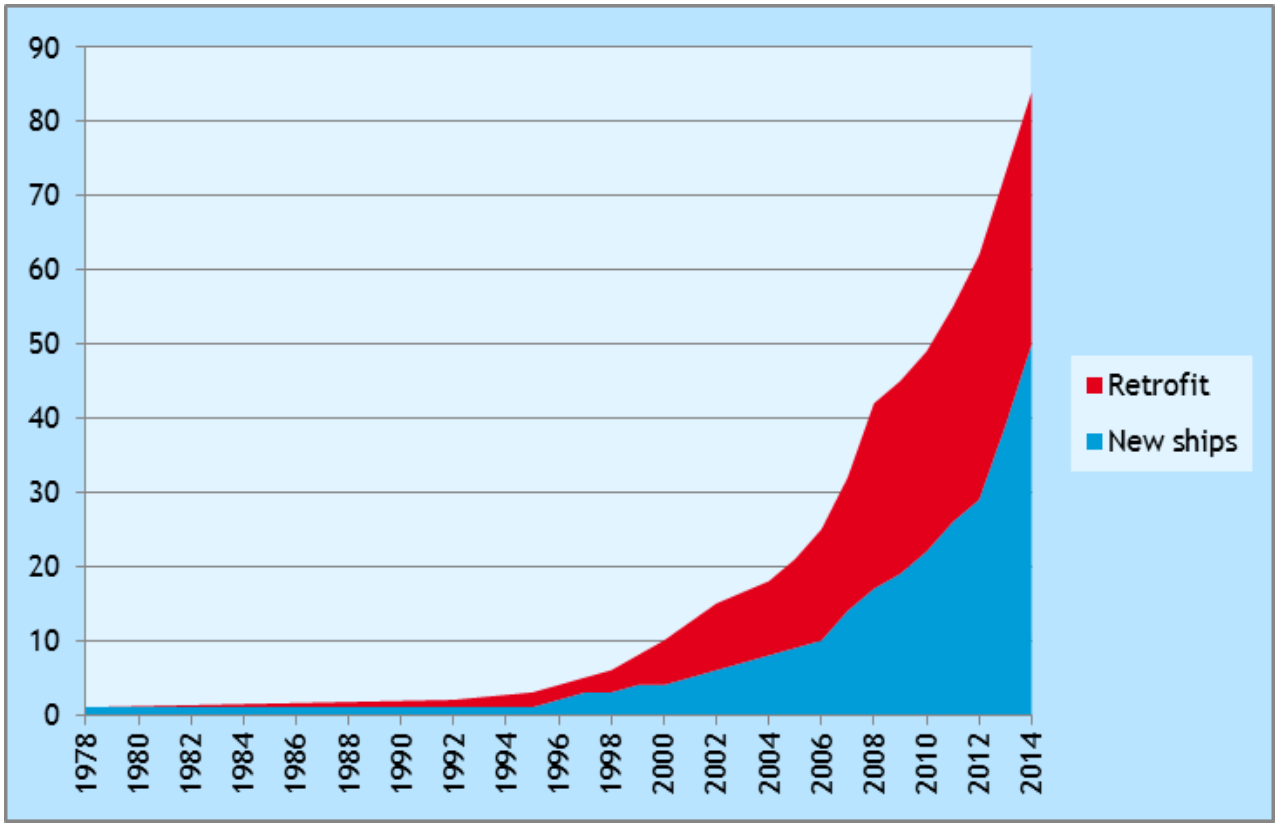


- Exhaust gas cleaning
- Wash water treatment plant
- Sludge handling

SO_2 (gas) + H_2O + ½O_2 → SO_4^{2-} + 2H^+

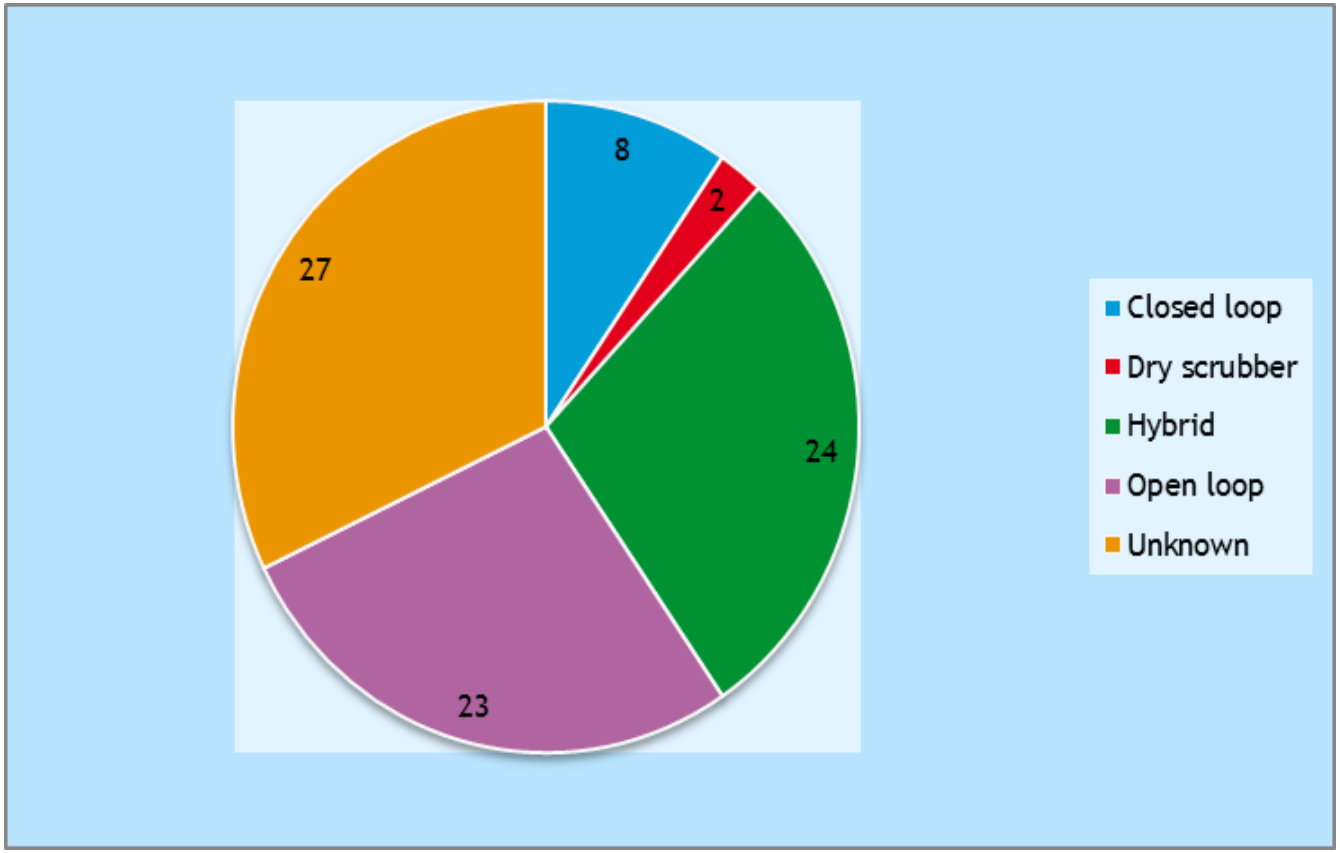
HCO_3^- + H^+ → CO_2 + H_2O

Number of scrubbers installed on ships (world fleet)



Scrubbers are installed on Ro-Ro ships (22), offshore service ships (17), cruise/passenger (15) gas carriers (13) and tankers (5)

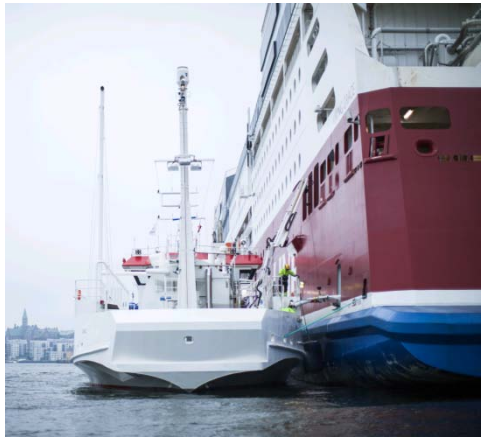
Distribution of scrubber types over the fleet



Future options to meet SECA requirements

Various surveys provide the following picture:

- All options will be used in the long term
- Low-sulphur distillate fuel oil is seen as a short-term option
- Scrubbers are seen as a medium term option
- Gas engines (LNG) are a viable option in the medium and long term



Environmental comparison of scrubber and MGO

Pollutant	Scrubber	MGO
SO_x	>-90%	>-90%
PM (mass)*	-60 to 90%	-30 to 80%
NO_x	<-10%	--
GHG emissions	+1.5-3.5%	~+6.5%

*PM number impact larger for MGO

Ecological impacts of scrubbers are due to discharge of:

- Heavy metals
- Acids (pH)
- Nitrates
- Particles/PAH

2009 IMO Guidelines:

- » Turbidity (particles)
- » pH
- » Polycyclic Aromatic Hydrocarbons (PAH) concentration
- » Nitrate concentration

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Ecological impacts – comparison of seawater (SWS) and freshwater scrubber (FWS)

- All scrubbers tested meet 2009 IMO guidelines (MEPC 59/24)
- The impact of seawater scrubbers on the water quality is significantly higher than the impact of freshwater scrubber
- SWS concentration lower, but the flux of hazardous substances is higher

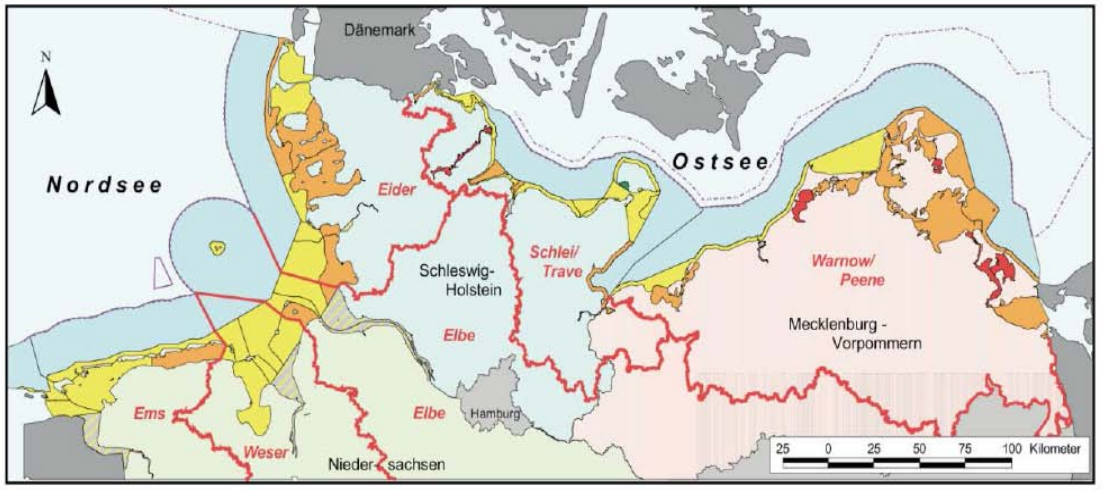
Hazardous substances discharged via wash water (in g)

	Scubber type	Kiel-Gothenburg (230 nm)
Vanadium	SWS	685
	FWS	0.03
Lead	SWS	55
	FWS	0.03
Arsene	SWS	0.8
	FWS	0.08
PAH	SWS	3.4
	FWS	0.0
Nickel	SWS	173
Mercury	SWS	0,4
Copper	SWS	486
Zinc	SWS	840
Oil (kg)	SWS	1.68
Nitrate	SWS	546

Source: (UBA, 2014).

Ecological impacts – coastal zones

- Impacts of scrubbers at open sea are estimated to be limited
- In coastal areas and ports the water mixing is limited and potential impacts have not been studied. Several countries (Belgium, Germany) prohibited the discharge of scrubber wash water
- The water quality of coastal waters is safeguarded by the Marine Strategy Framework Directive ('good environmental status by 2020')



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Ecological impacts – ports and coastal zones

- The concentration of various substances found in the wash water of scrubbers is higher than the Environment Quality Standards (EQS) listed in EU Water Framework Directive 2013/39

Comparison of SW scrubber discharge water and water quality standards (EQS)

	AA-EQS(µg/l)	MAC-EQS(µg/l)	SWS wash water (µg/l)
Lead	1.3	14	13-21
Mercury		0.07	0.08-0.12
Nickel	8.6	34	41-43

Source: UBA (2014) referencing, Danish EPA (2012) and COWI (2012).

Comparison of scrubber SWS discharge water with Danish EQS

	Danish MAC-EQS (µg/l)	SWS wash water (µg/l)
Lead	2.8	21
Copper	2	260
Vanadium	57.8	180
Zinc	8.4	450

- To avoid impacts of accumulation of non degradable substances, monitoring and modelling should be performed.

Scrubber business case

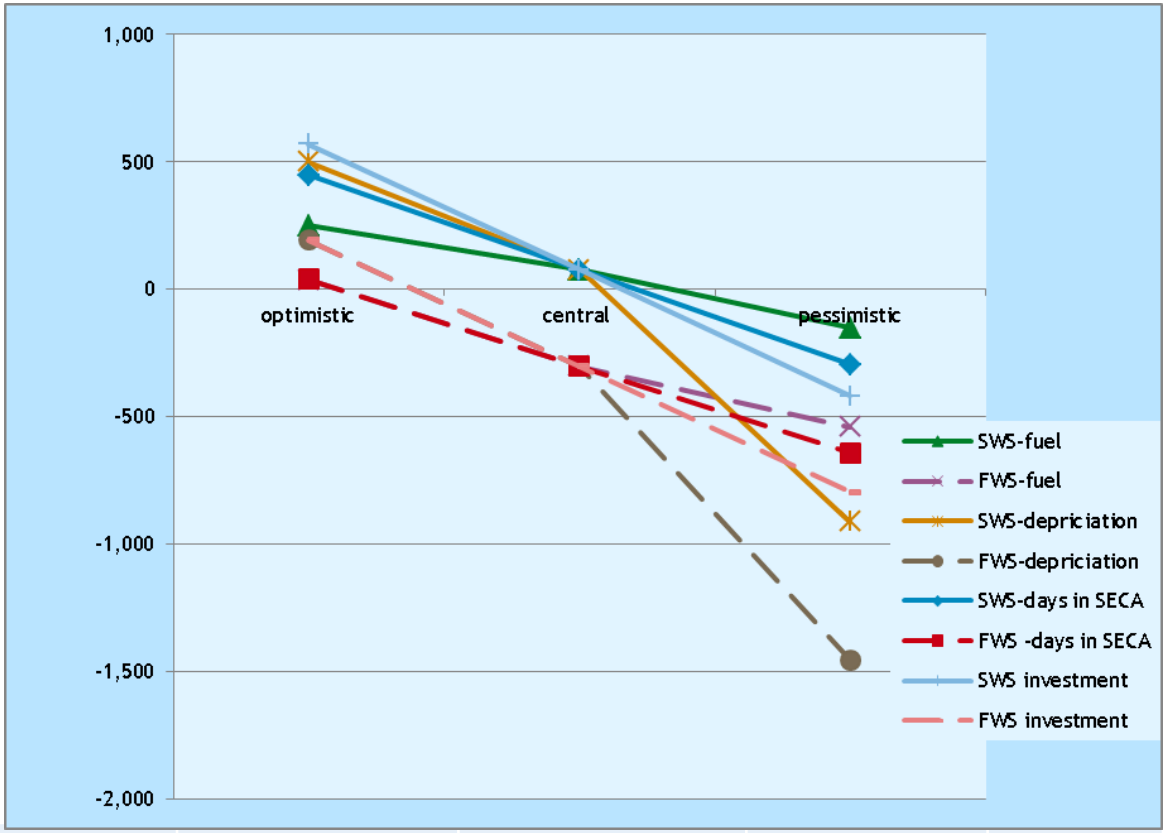
- Case study: 38,500 DWT product tanker MS Nord Buttarly

Results case study product tanker MS Nord Buttarly (x 1000 Euro)

	Seawater scrubber	Freshwater scrubber
Additional costs MGO fuel use	**1,662**	**1,662**
Scrubber costs		
Annual investment costs	1,482	1,854
Caustic soda consumption		153
Additional fuel costs	69	46
Slurry disposal costs	11	11
Maintenance	22	22
Total scrubber costs	**1,586**	**2,087**

- Cost differential between HFO and MGO (240 – *300* - 350$/ton)
- Number of days in SECA/at sea (154 - *220* - 286 days at sea)
- Depreciation period (1.5 - *2.5* - 3.5 years)
- Investment costs (200 – *300* - 400 €/kW)

Annual benefits of scrubber installation x1000€ (vs. MGO)



	optimistic	central	pessimistic	
fuel price differene ($/ton)	350	300	240	
days in SECA	286	220	154	
depriciation period (yrs)	3.5	2.5	1.5	
investments (€/kW)	200	300	400	

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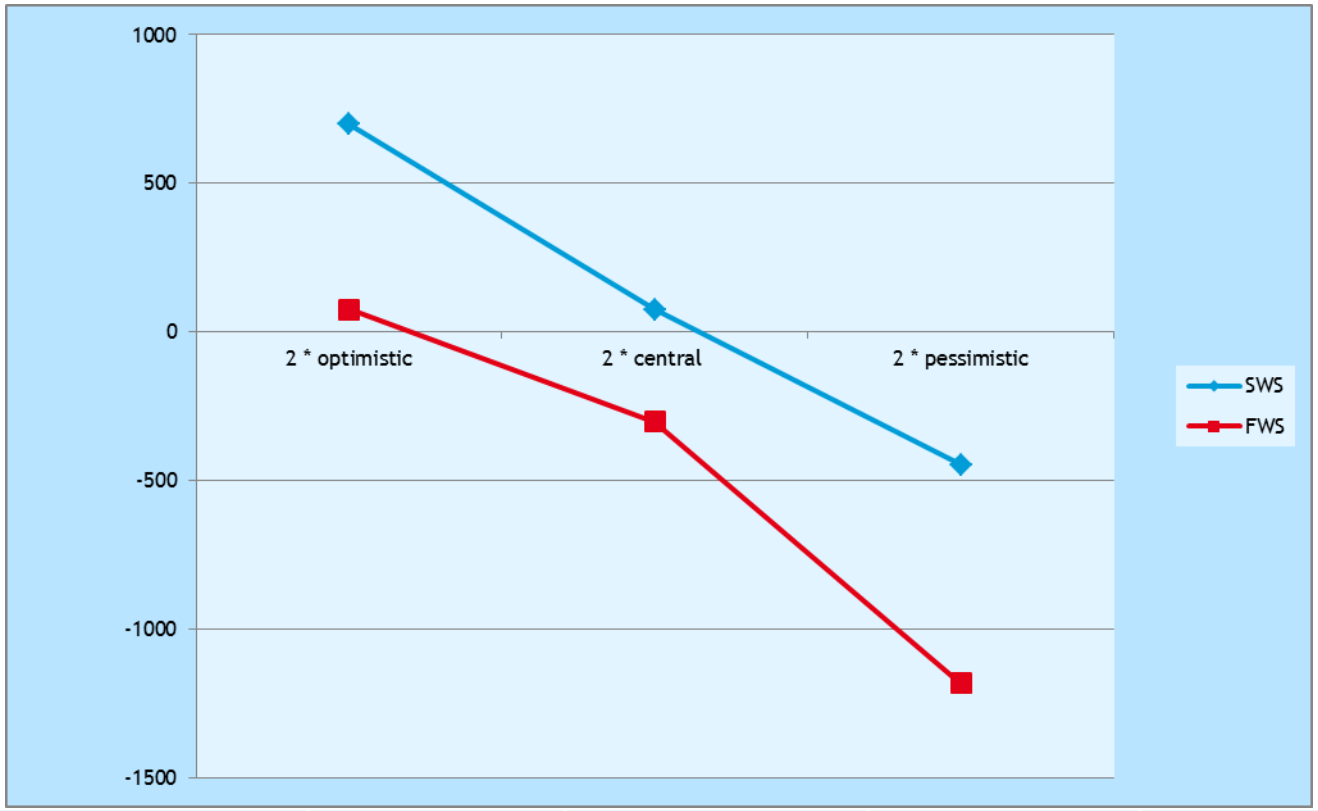
Annual benefits of scrubber installation x1000€ (vs. MGO)



	optimistic	central	pessimistic	
fuel price differene ($/ton)	350 (2008)	300 (2014)	240 (2015)	
days in SECA	286	220	154	

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Conclusions (1/2)

- About 80 scrubbers are installed at the moment, with greatest interest for hybrid and open loop scrubbers. The number of orders amounts 300 now. Hybrid scrubbers will be used in open loop where possible.
- Scrubbers reduce the emissions of sulphur and PM. NOx is reduced less than 10%. GHG emissions increase between 1.5 and 3.5%, including caustic soda consumption.
- All measured pollutant wash water concentrations are well below the IMO wash water guideline thresholds.
- Open loop scrubbers have a larger impact on ecosystems than closed loop scrubbers
- Scrubbers may have an impact on acidification and accumulation of hazardous substances like heavy metals and PAHs, especially in vulnerable coastal areas.

Conclusions (2/2)

- It should be evaluated if scrubbers can be used in accordance with the European Water Framework Directive, especially in the near of vulnerable estuaries.
- it is not clear if objectives set by the Marine Strategy Framework for achieving 'good environmental status' can be met by the year 2020 with the operation of scrubber in open loop.
- The installation of scrubbers requires significant investment costs. Typical installation costs range between 200 and 400 €/kW.
- The benefit of scrubber investments is differs from case to case and depends on operational profiles, depreciation period, days at sea, but also strongly depends on the future fuel price difference.
- A socio economic analysis can inform about all costs and benefits, taking into account the potential harmful impact of scrubbers on vulnerable coastal ecosystems and the additional GHG emissions of MGO use.