


BC emissions at different air pollution abatement measures

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EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND

CSHIPP Clean Shipping Project Platform

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Studies on BC emissions at different air pollution abatement measures

- Overview of studies performed onboard
  - SECA complient fuels: hybrid fuel, MGO, LNG, methanol
  - Abatement techniques: scrubber SCR
- Results from plume measurements – impact of SECA 2015
- Future outlook

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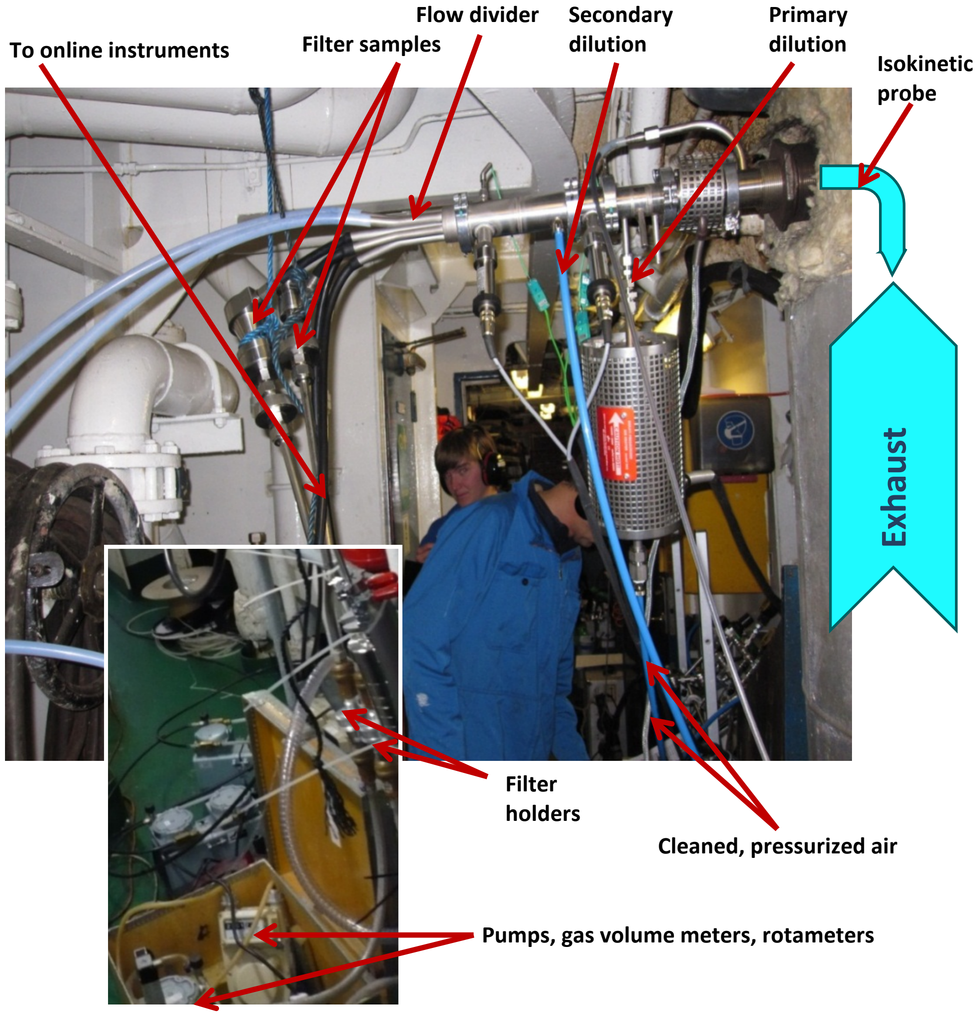
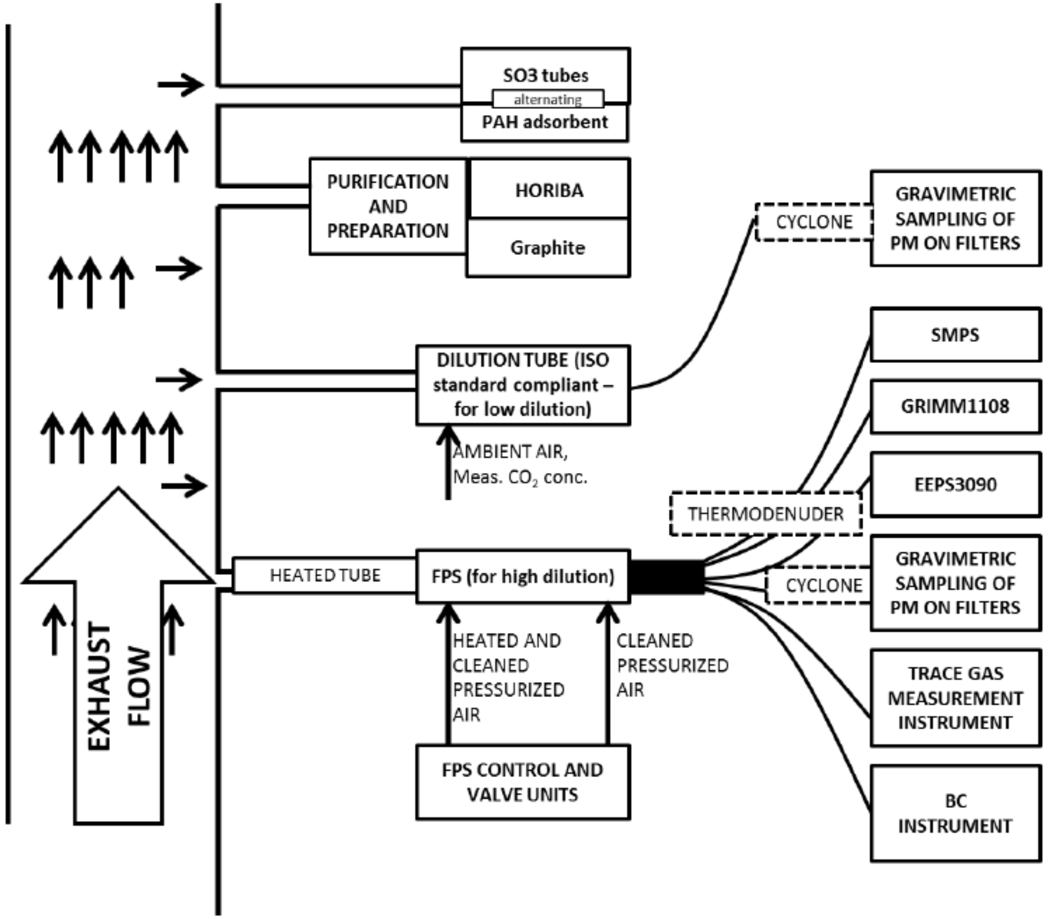
On-board measurements





On-board measurements - PM

Species	Instrument	Comment	Instrument potential measurement range
Particulate:			
PM_{tot}	Teflon Filter	Gravimetric analysis, analyses of elemental contents by ICP-MS, sulphate content	
$PM_{2.5}$	Teflon Filter + cyclone	Gravimetric analysis, analyses of elemental contents by ICP-MS sulphate content	
Particle number	EEPS	Electric charging of particles	32 channels; size distr. 5.6-560nm
Particle number	Grimm	Optical	15 channels; size distr. >0.30µm – 20 µm
Particle number	SMPS		Variable (1 nm to 1000 nm)
Black Carbon (BC)	AE33, Aethalometer	Continuous measurements of attenuation of transmitted light	
Elemental Carbon / Organic Carbon (EC/OC)	Quartz filter		

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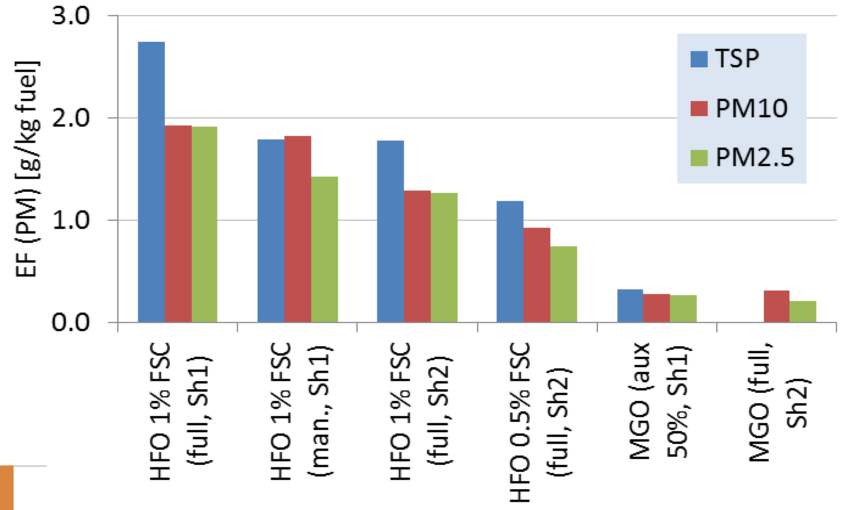
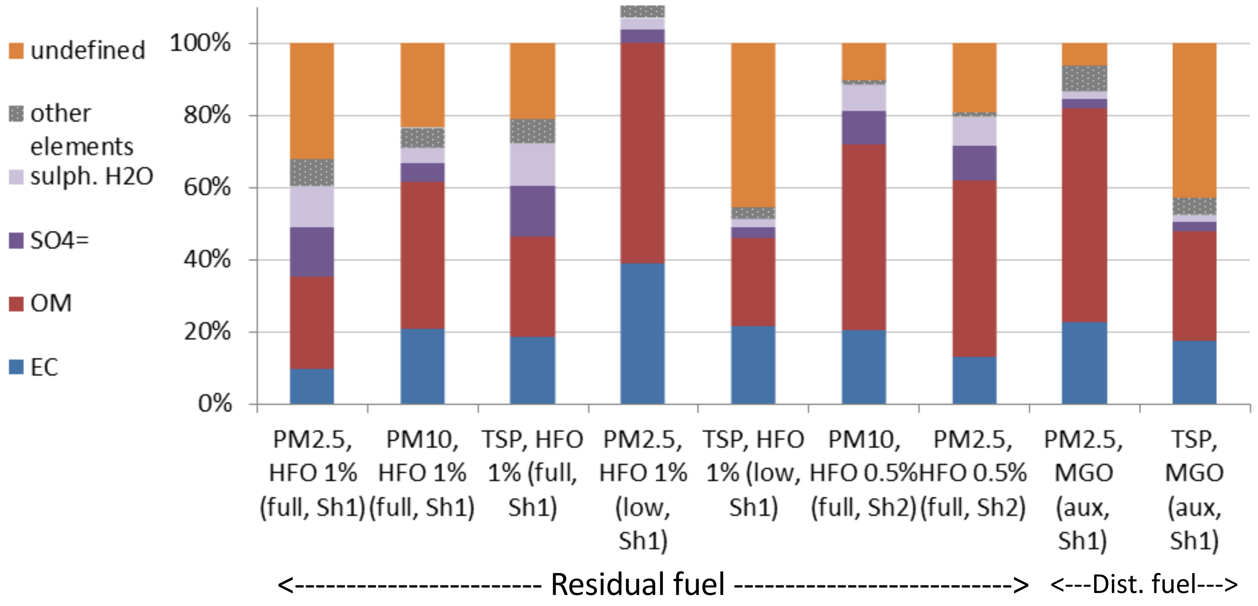
Comparison HFO - MGO





Variability of PM composition – fuel type, engine load

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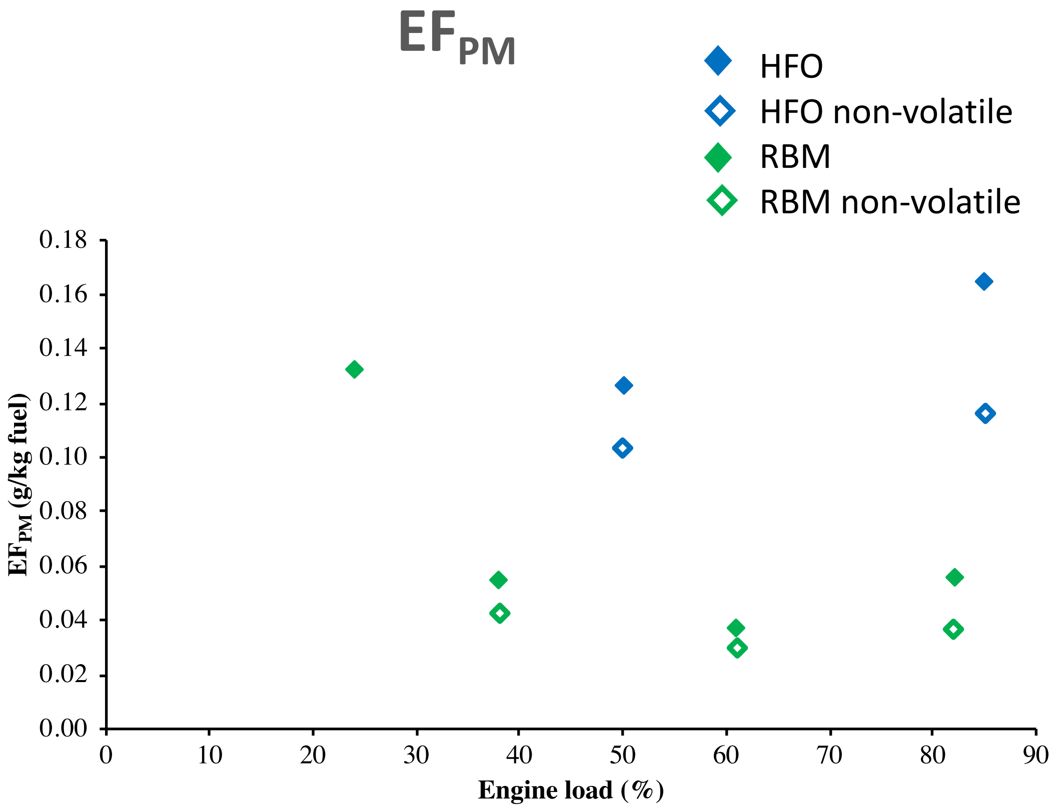
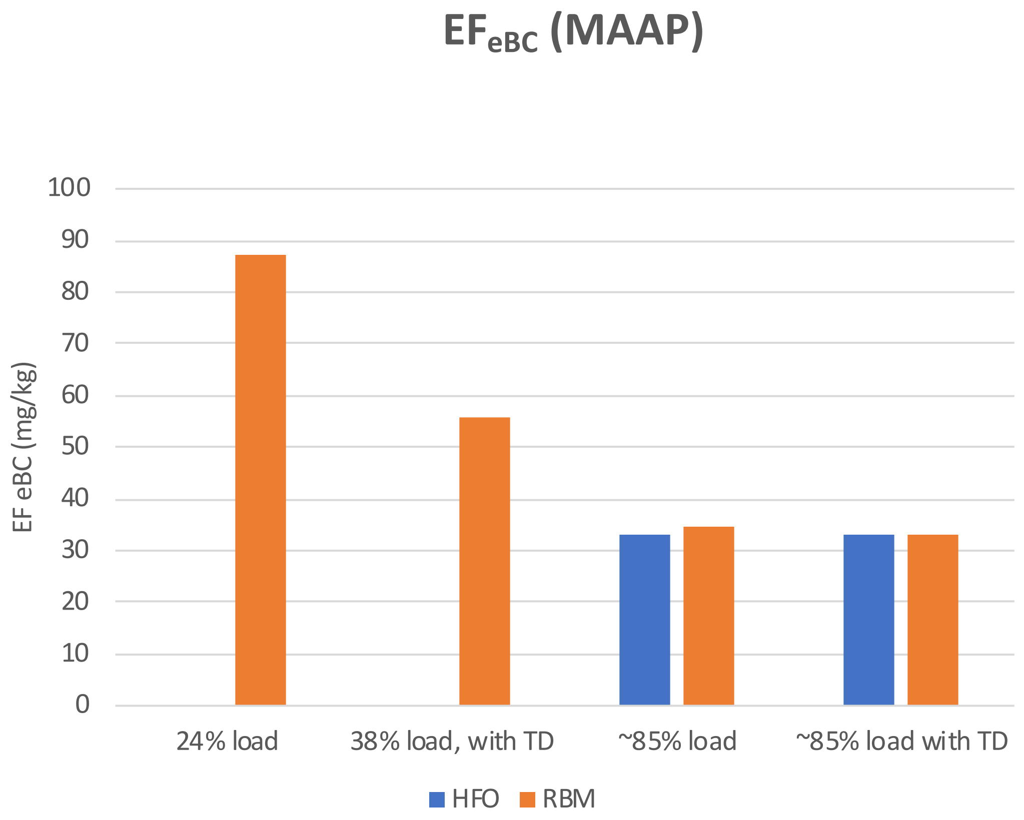
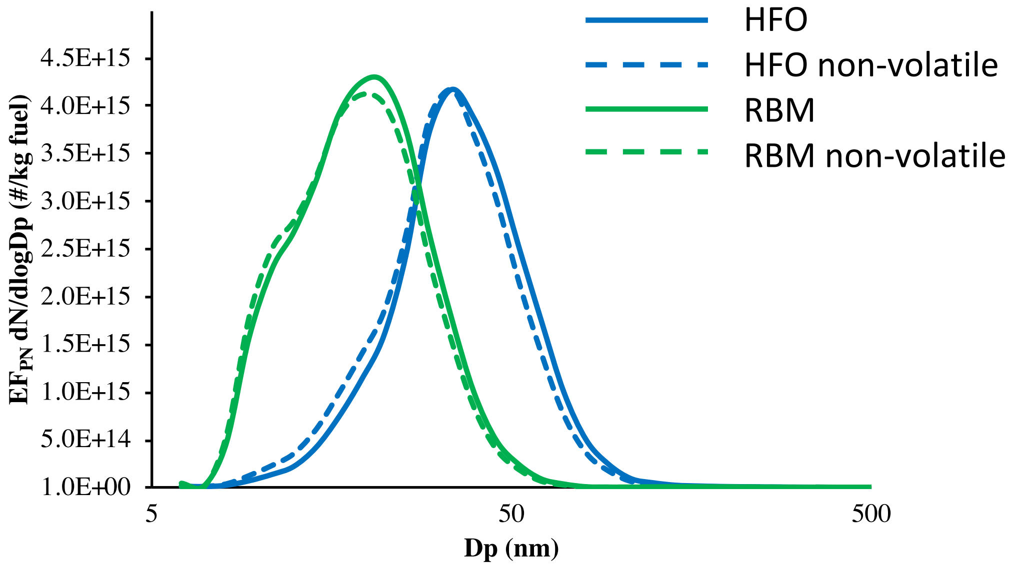
Hybride low sulphur fuel (cruise ship)



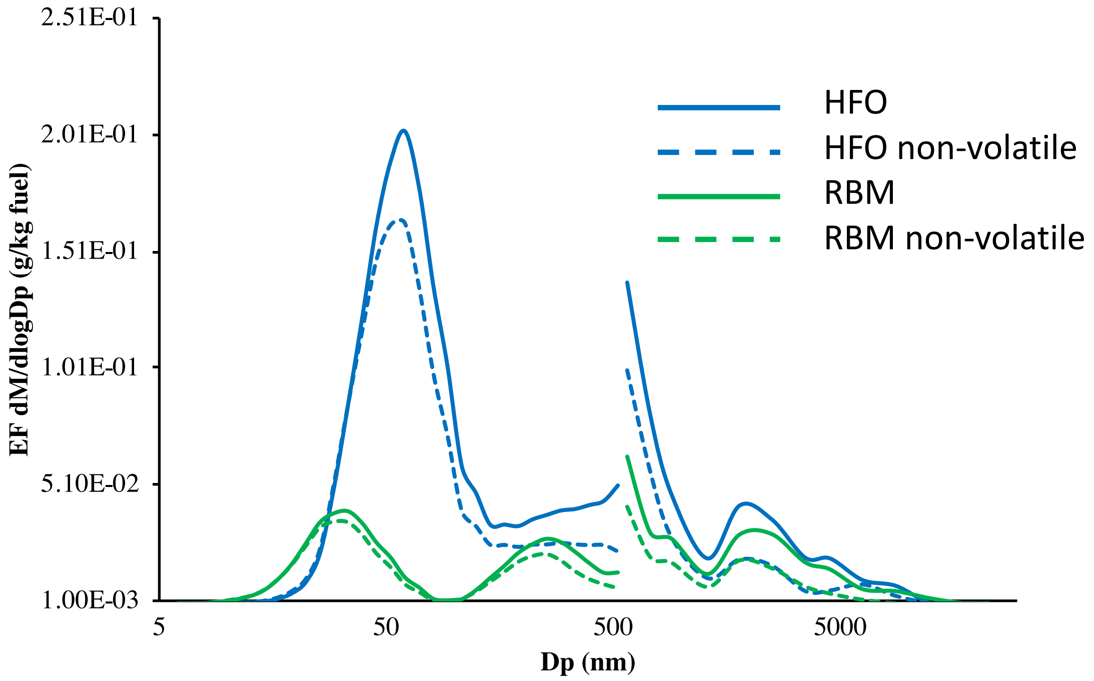


Hybride low-sulphur fuel (cruise ship)

Size-resolved EF_{PN}



Size-resolved EF_{PM}



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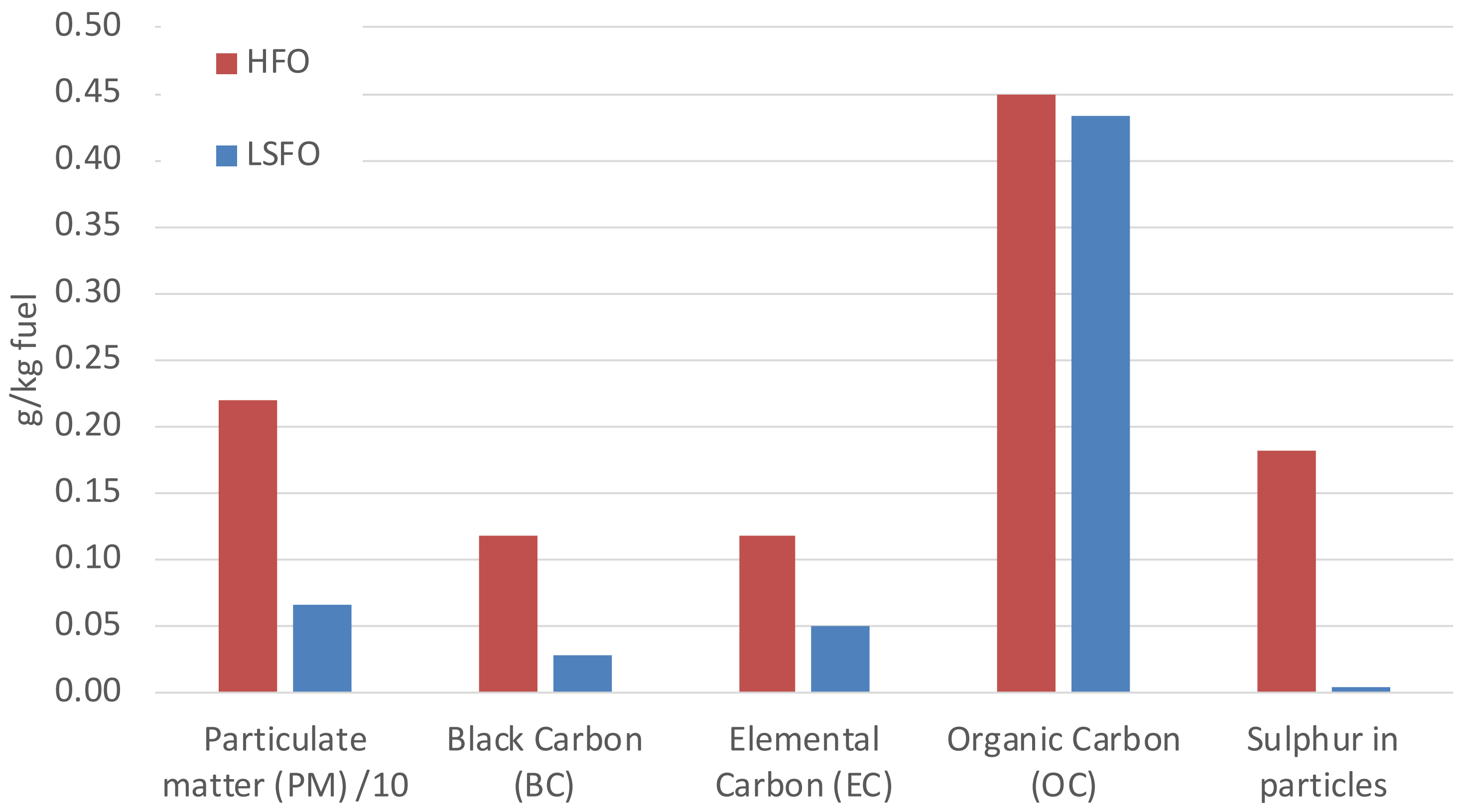
Hybride low-sulphur fuel – scrubber ship, upstream scrubber



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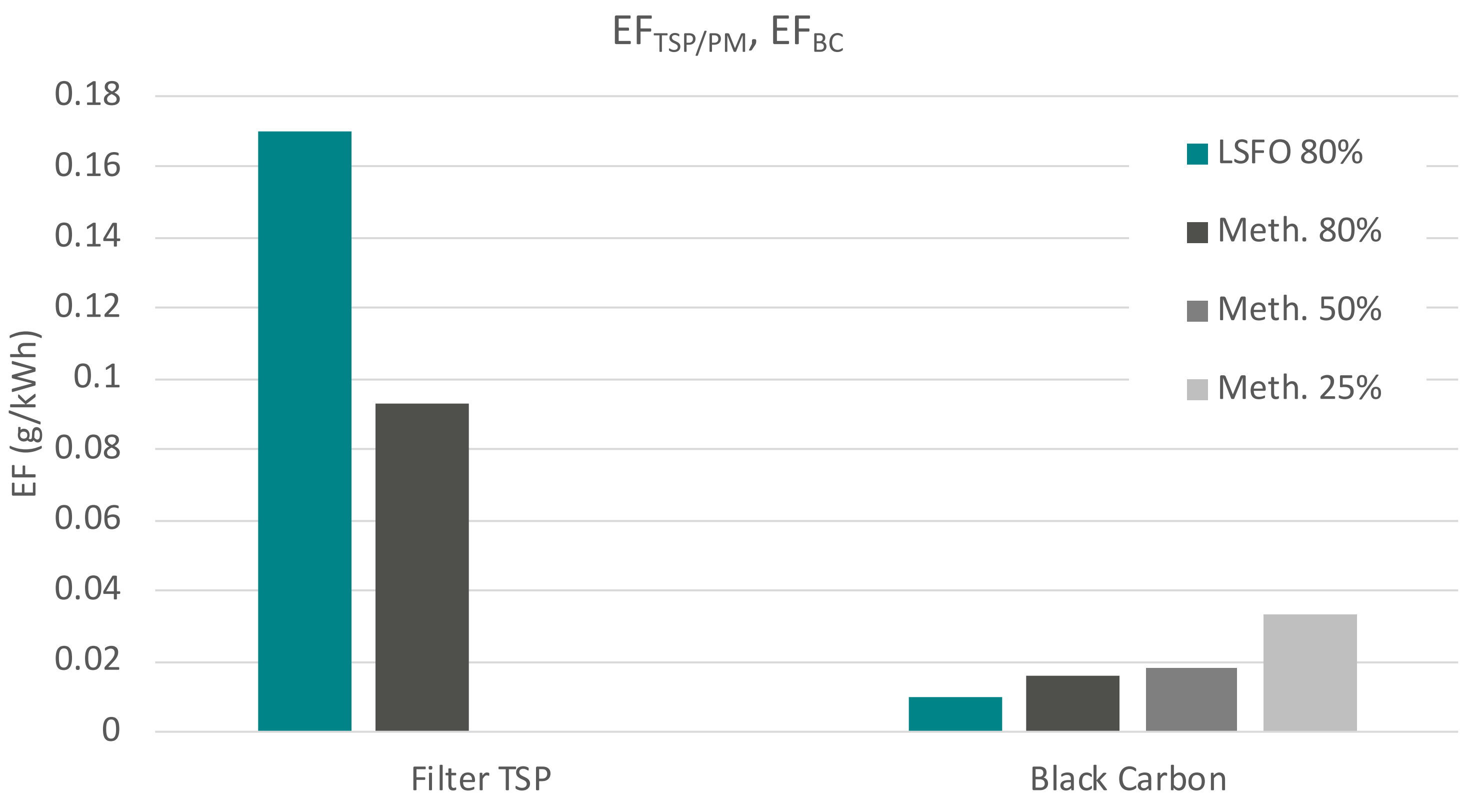
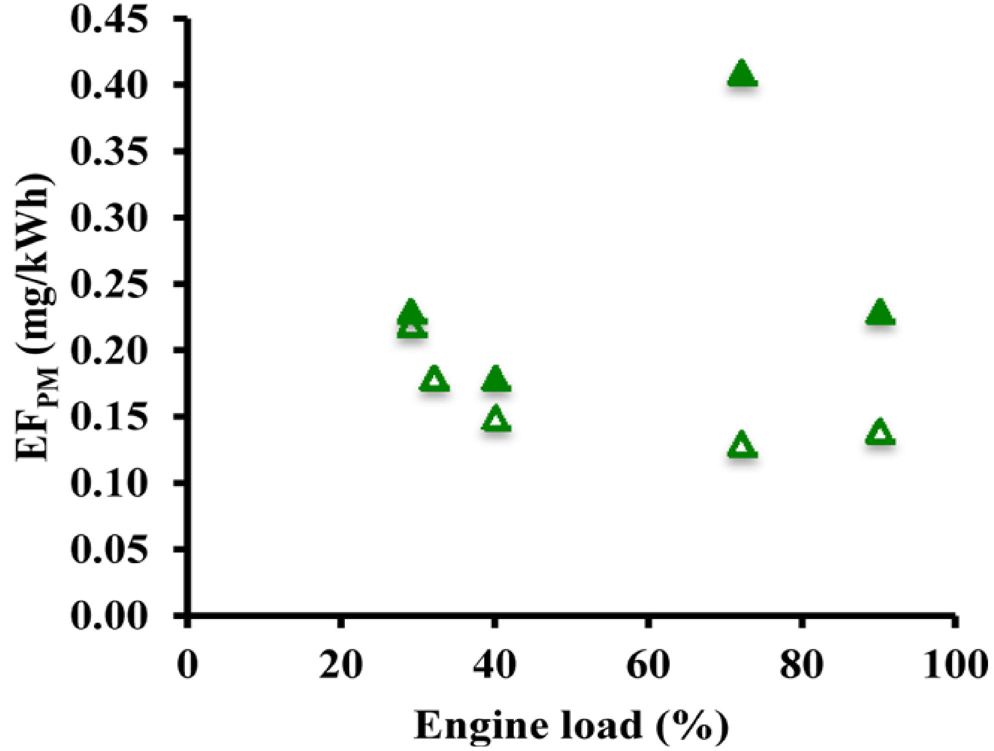
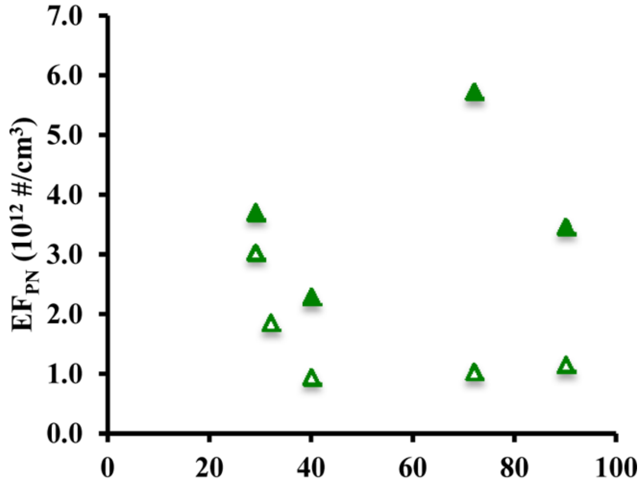
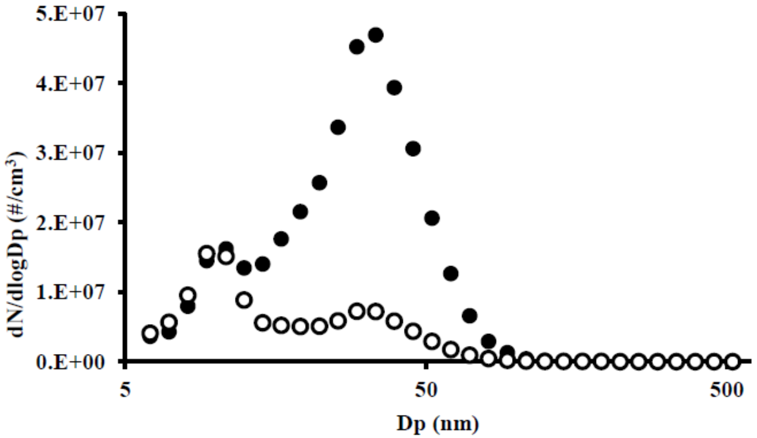
Methanol


$EF_{TSP/PM}$, EF_{BC}
EF (g/kWh)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Filter TSP
Black Carbon
LSFO 80%
Meth. 80%
Meth. 50%
Meth. 25%

LNG







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Scrubbers from an environmental perspective:

'Scrubbers: Closing the Loop'

Hulda Winnes (hulda.winnes@ivl.se)

SVENSKA MILJÖINSTITUTET

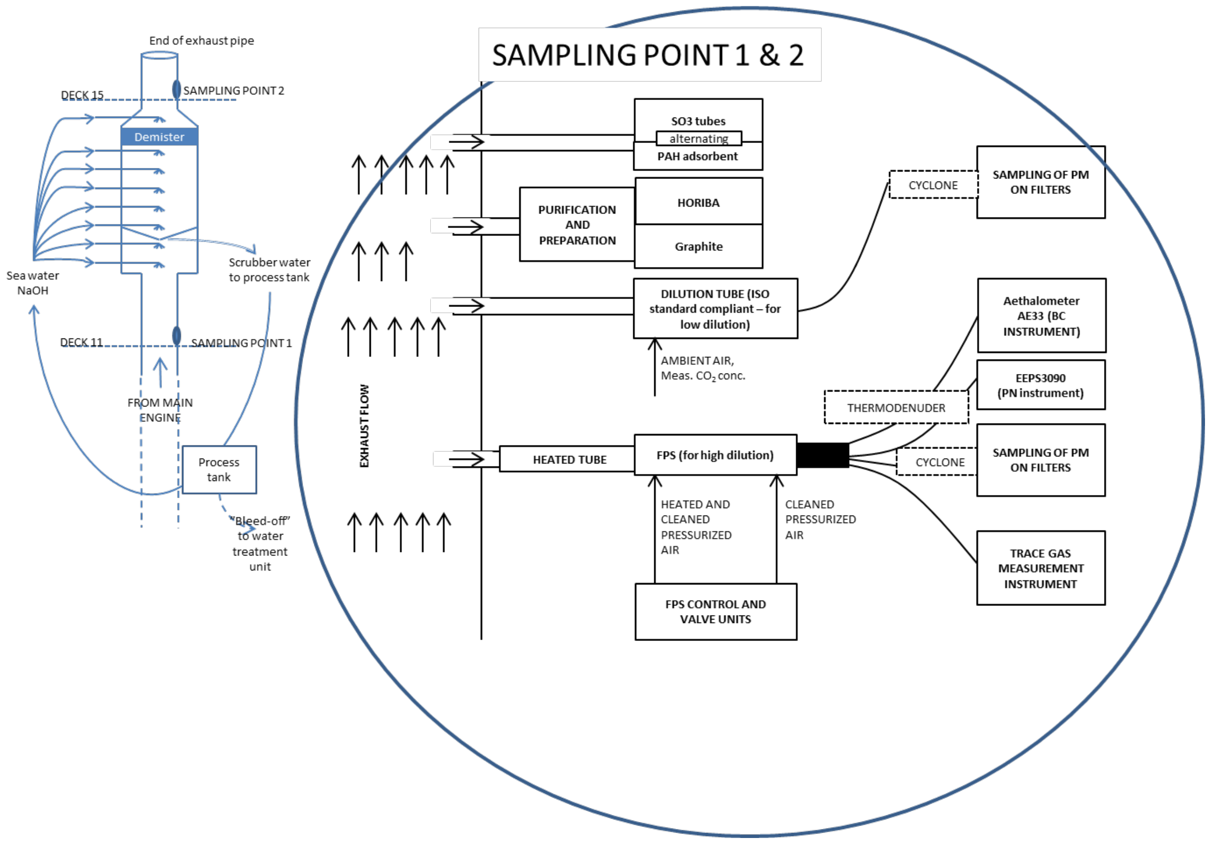
CEF programme

Emissions to air

LSFO, HFO upstream and downstream the scrubber

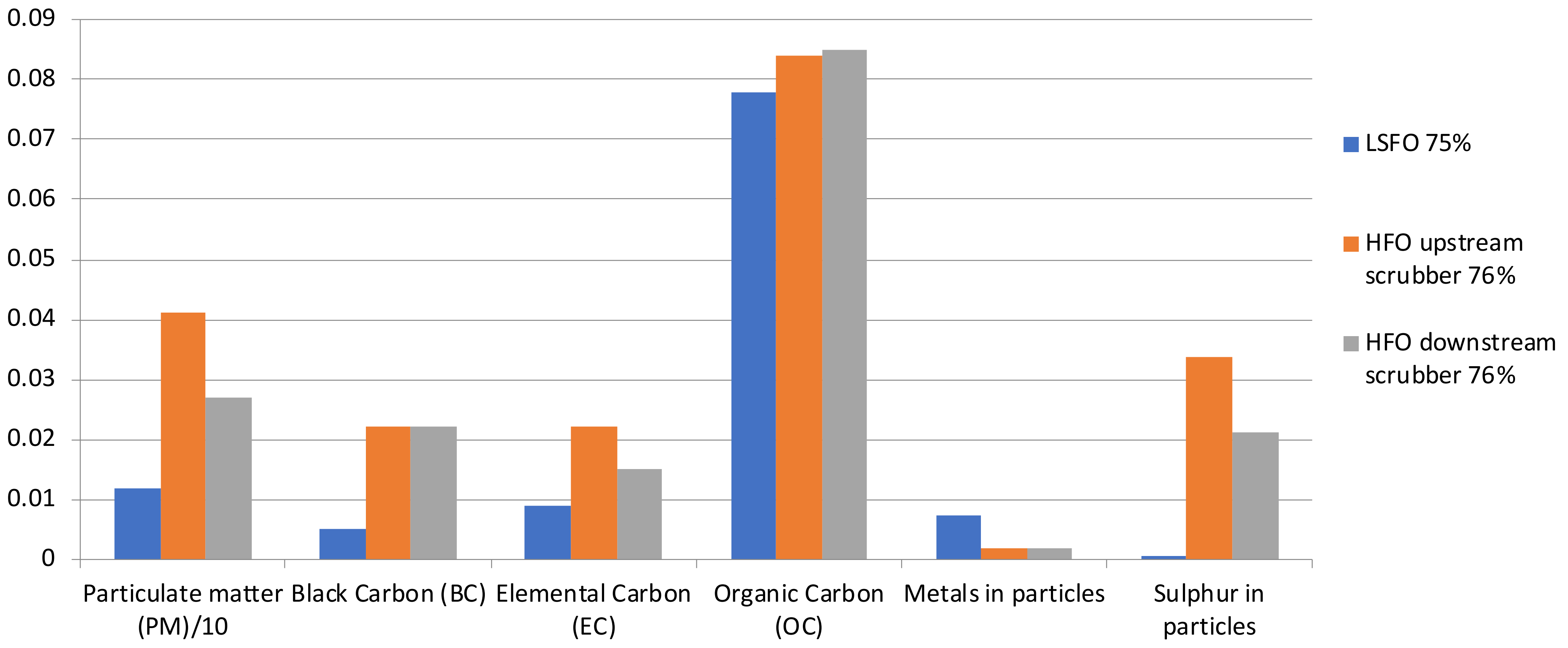
Two viewpoints:

1. Function and efficiency of the scrubber
2. Environmental perspective, differences between emissions from the scrubber and the LSFO

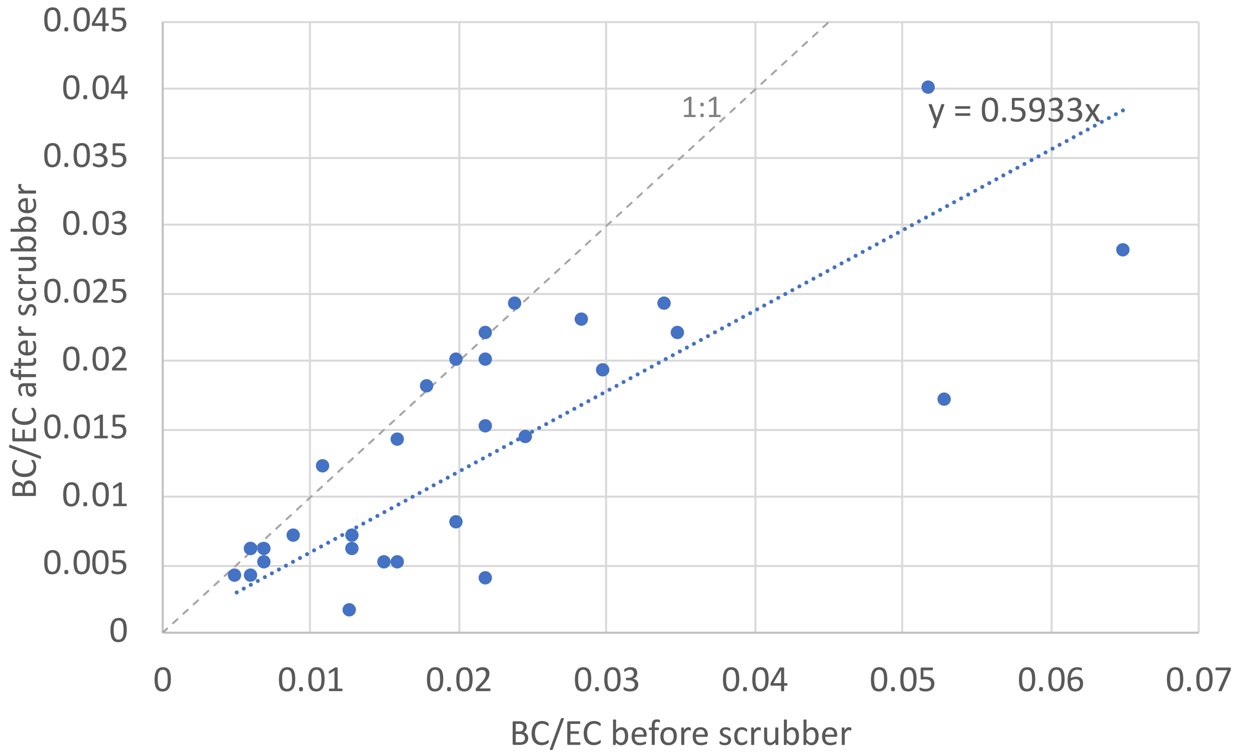


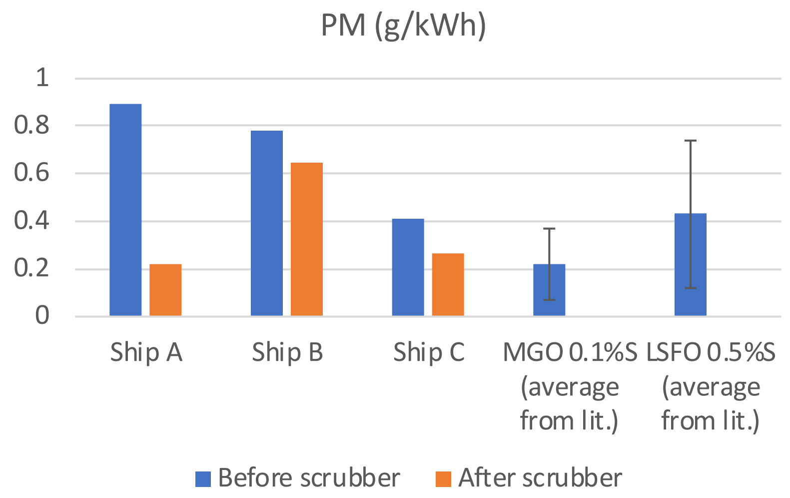
Schematic overview of the instrumentation setup

Impact of scrubber



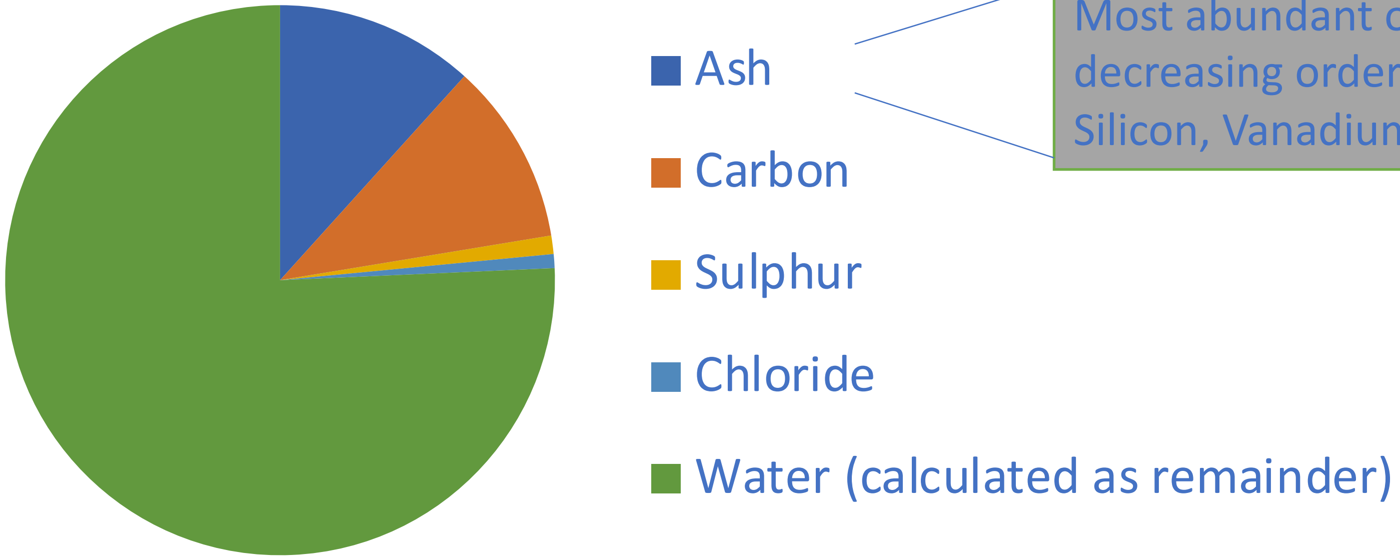
Change of EFEC/BC in scrubber - review





With courtesy of Erik Fridell

Bleed Off Treatment Unit: Sludge compostition, Britannica

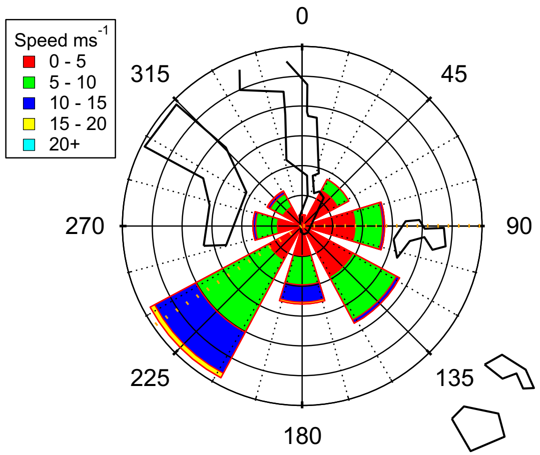


Most abundant of analysed elements in decreasing order: Sodium, Aluminum, Silicon, Vanadium

Note on sulphur:
Most sulphur ends up in the effluent water. Not acidic, acids are neutralised
Appr 10% ends up in the sludge
~3% stays in exhausts as SO_2, SO_3 or particle bound S.

Measurement campaigns

2010-2015



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2010

2013, 2014 and 2015

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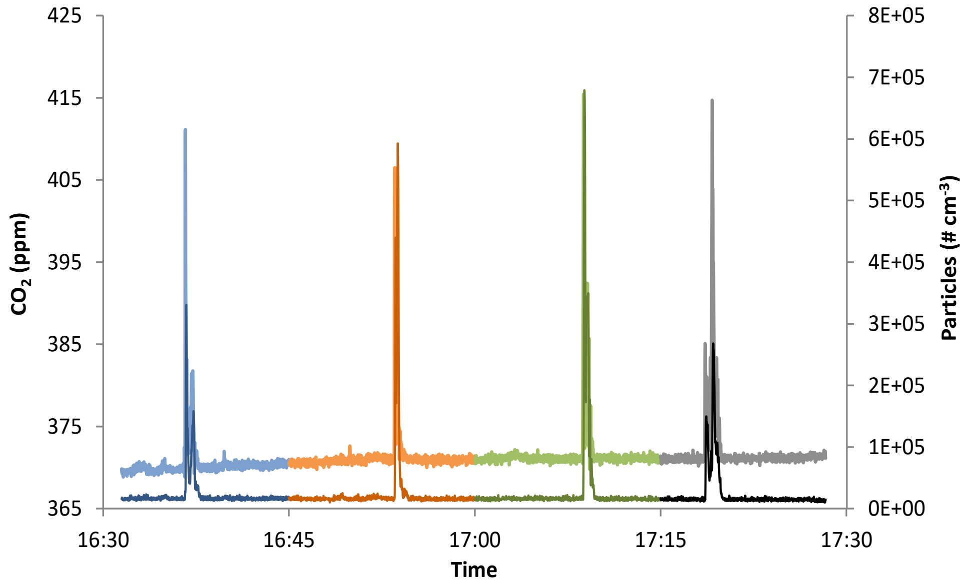
Stationary ship plume measurements

Jonsson et al., 2011 GRL

- CO_2 as a tracer of combustion
- AIS-data
  - Identity, course, speed
- Instrumentation
  - Particles EEPS (5.6-560 nm) 10Hz
  - CO_2 (non-dispersive IR) 1Hz
  - Volatile/non-volatile fraction thermodenuder (523 K) and CPC (3775)
- Filter data depending on wind direction and wind speed



- Ex. of 1h measurements
- PN and CO_2 signals from 4 consecutive ship passages

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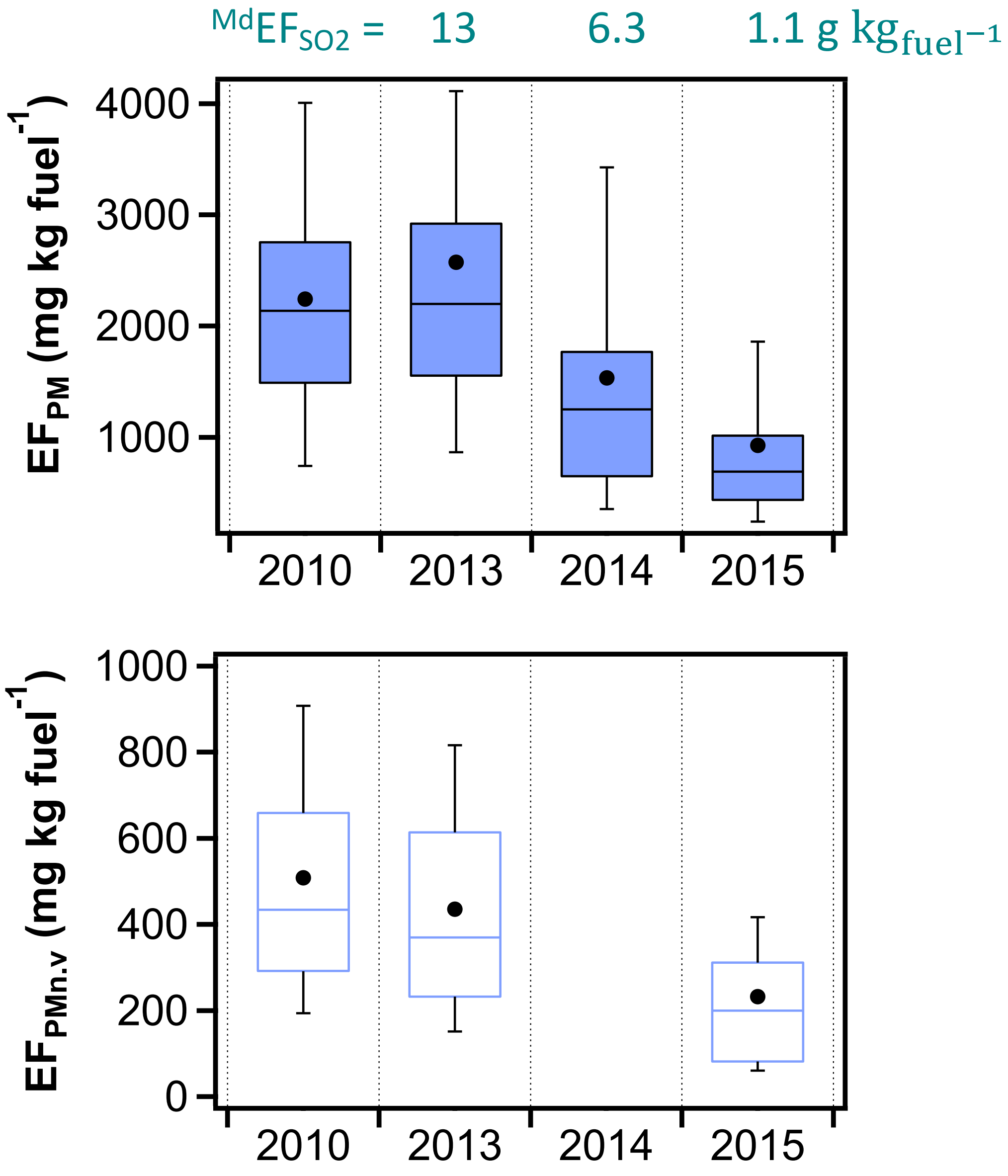
Change in EF_{PM} EF_{PMnv} 2014-2015

FSC 1 → 0.1 %

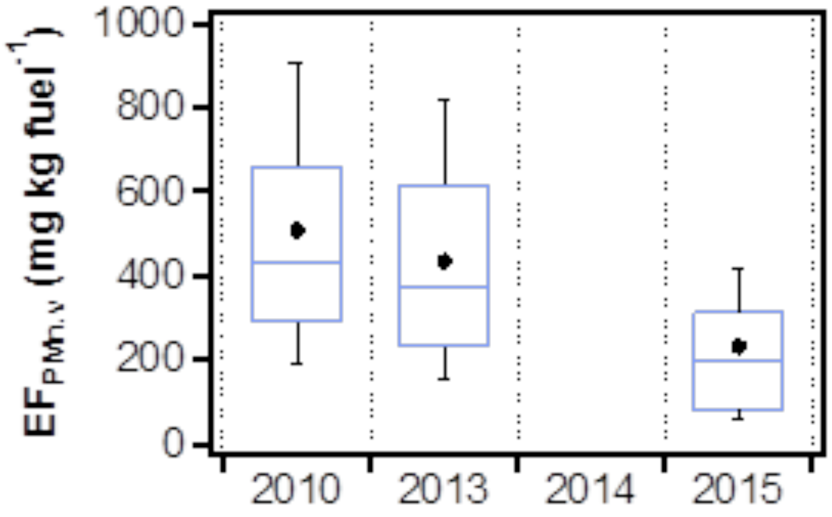
$^{Md}EF_{PM}$ ↓ 2-3

$^{Md}EF_{PM\_n.v}$ ↓ ~2

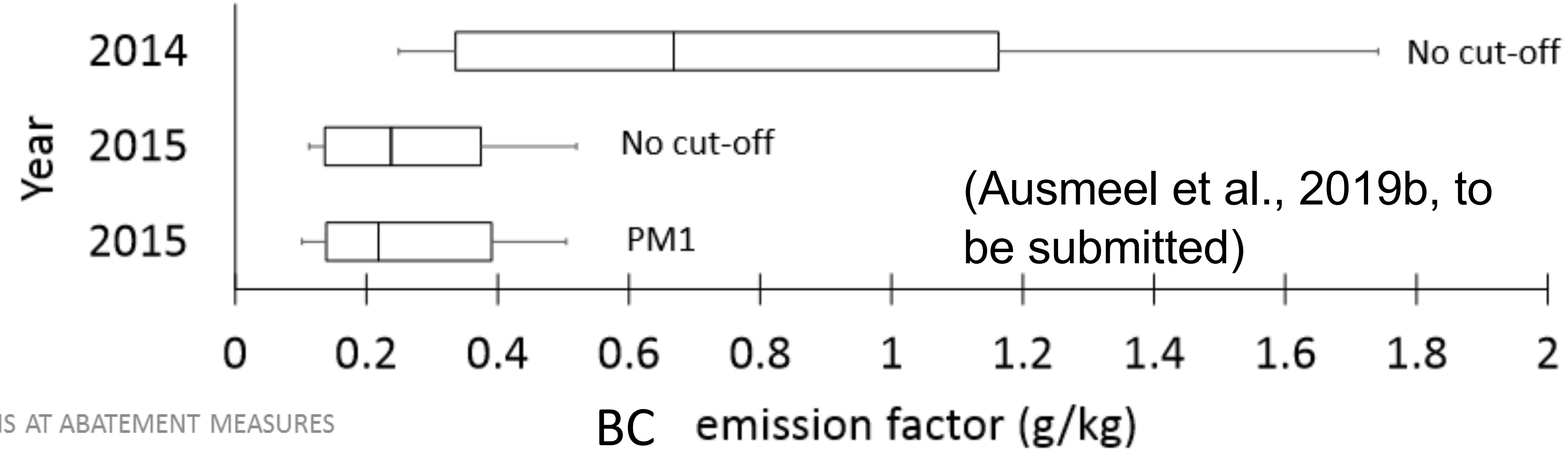
Hallquist et al., 2019, Manuscript for JGR



Change in EF_{PMnv} and EF_{BC} 2010-2015



(Hallquist et al., 2019, to be submitted)



(Ausmeel et al., 2019b, to be submitted)

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Summary

- The low-sulphur fuels comparison to HFO:
  - MGO: decrease in PM mass and BC
  - Hybrid fuels: large variability in fuel quality – decrease in PM mass, same or lower BC
  - Ethanol: Lower PM mass and BC comparing to HFO, similar BC to hybrid fuels
  - LNG: Large decrease in PM mass, total and non-volatile, likely originating from lubricant
- Scrubber: decrease in PM, BC decrease varies from no decrease to ca ½
- Plume measurements: EF for non-volatile particles decreased ca by factor 2 from 2010 to 2015; BC decreased ~factor 3

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Thank you for listening!