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# Retrofitting diesel particulate filters on a ferry – practical experiences and measurement results

10th VERT FORUM, 14th of March 2019





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# Danish Technological Institute

Independent, non for profit institution with  $\approx 1000$  employees and a annual turnover of  $\approx 150$  mio. EUR

We develop and test solutions for the transport sectors that contribute to a cleaner, safer and more sustainable society.







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# Purpose of lighthouse project

"Adaption, integration, demonstration and validation of full-scale solutions for reducing particulate emissions and  $\text{NO}_x$  from existing ships in coastal waters"

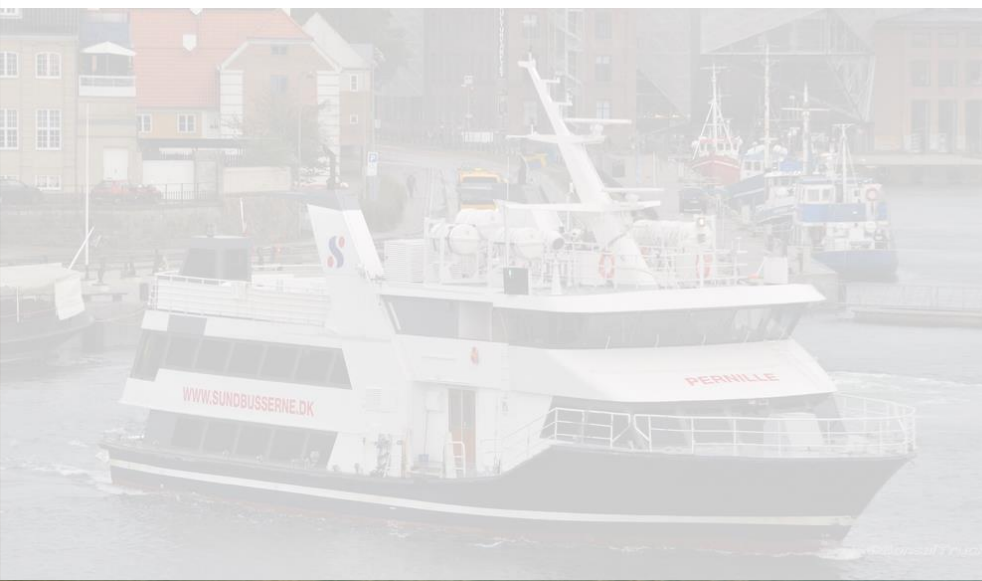




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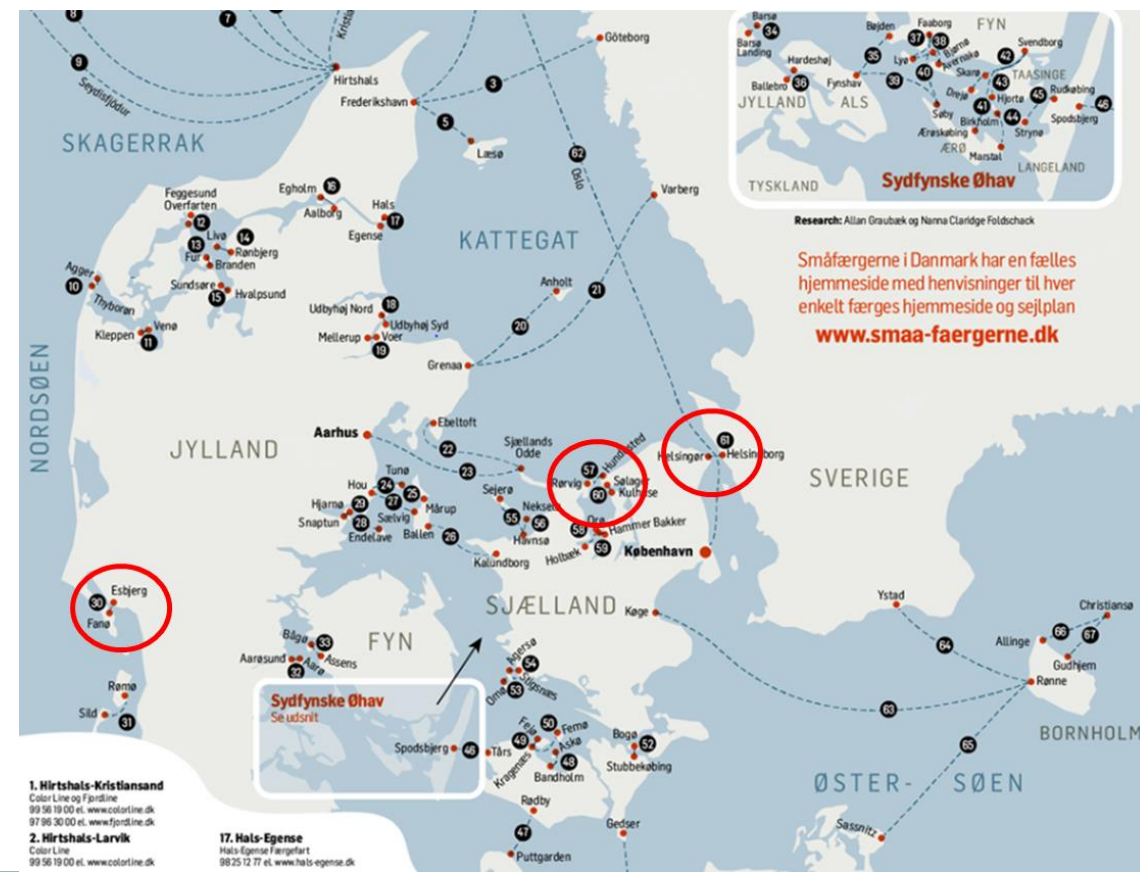






# Why reduce ship emissions?

- Pollution from ships in Danish waters costs the society ~500 million EUR (15-20 % of the total air pollution costs<sup>1</sup>)
- More than 1000 islands
  - 70 of which are inhabited
- 67 ferry routes
  - Several have more than one ferry

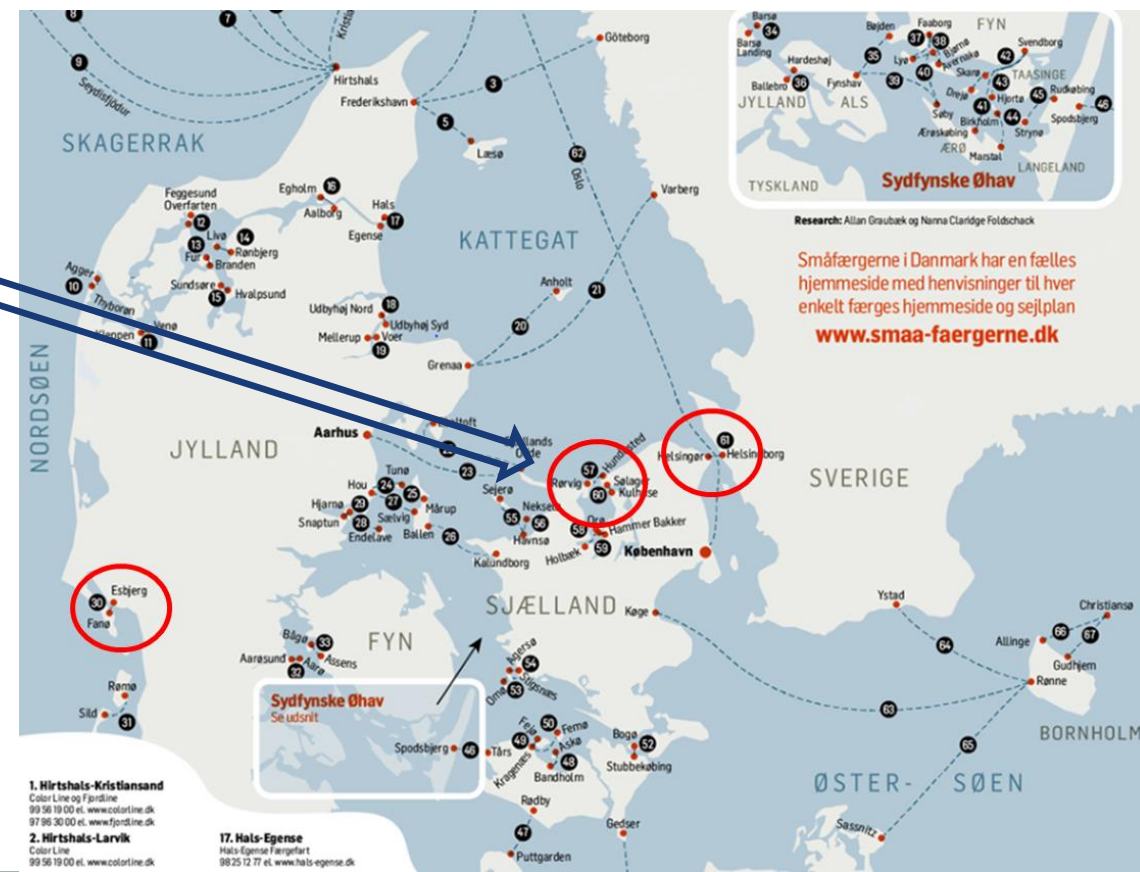


<sup>1</sup> "Air pollution impact on health in Denmark", DCE 2014



# Lighthouse project (2017-2020)

- **Hundested-Rørvig Færgefart – Car ferry**
  - Exilator installs DPF on all engines
- World Marine Offshore – Windturbine Service Vessel
  - Purefi A/S installs urea based SCR and DPF on all engines operating up to 1000 PPM Sulphur
- Partrederiet Sundbusserne – Passenger ferry
  - Amminex installs  $NH_3$  (pure ammonia) based SCR and DPF on all engines





# Success Criteria

- **M/F Isefjord (Car Ferry)**
  - **98% reduction in particle number**
  - **30-35dB(A) noise reduction**
- **M/F Pernille (Passenger Ferry)**
  - 98% reduction in particle number
  - 80% reduction in NO<sub>x</sub>
- **World Mistral (Service Vessel)**
  - 98% reduction in particle number
  - 80% reduction in NO<sub>x</sub>







# Reference measurements performed on the three ships during normal operation

	M/F Isefjord (Built 2013)	WMO Mistral (Built 2013)	M/S Pernille (Built 1981)
NO <sub>x</sub> [ppm]	500-700	900-1400	1700-2200
PN [number/cm <sup>3</sup> ]	4-5 x 10 <sup>7</sup>	4-8 x 10 <sup>6</sup>	2-3 x 10 <sup>7</sup>
PM <sub>2.5</sub> [mg/m <sup>3</sup> ]	25-30	10-15	Not measured
IMO regulation	TIER II	TIER II	Pre IMO regulation

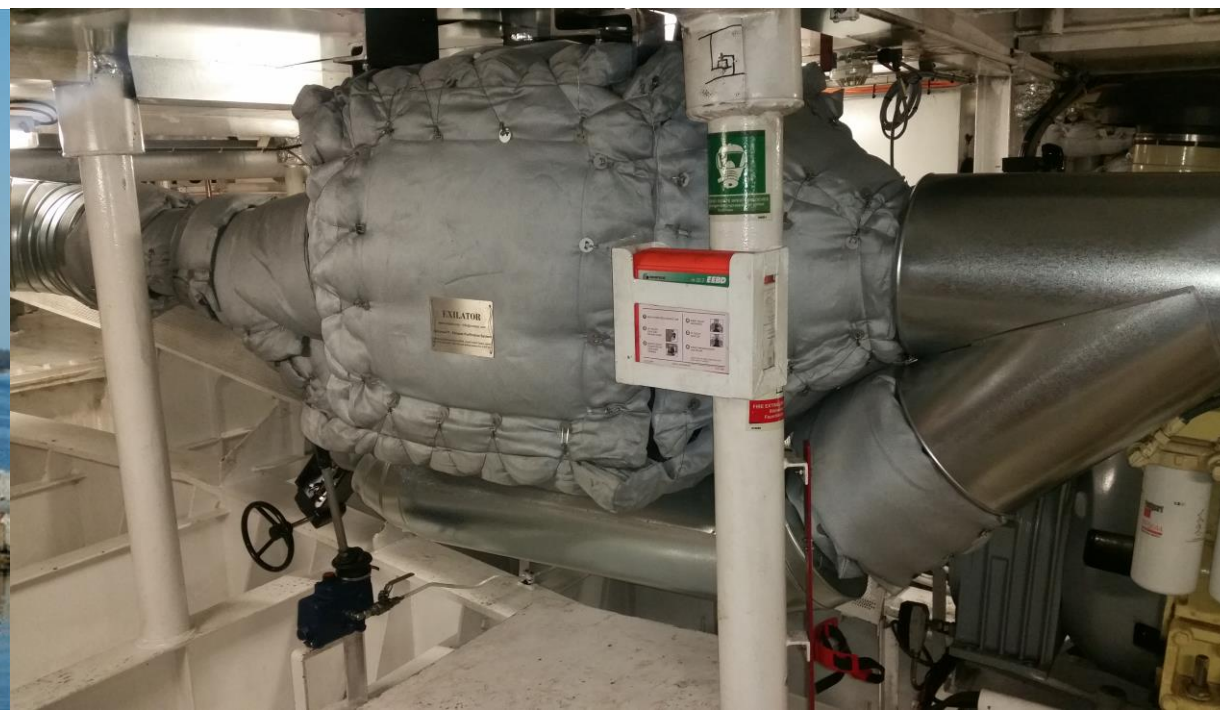






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# Results from M/F Isefjord with Exilator DPF on all engines

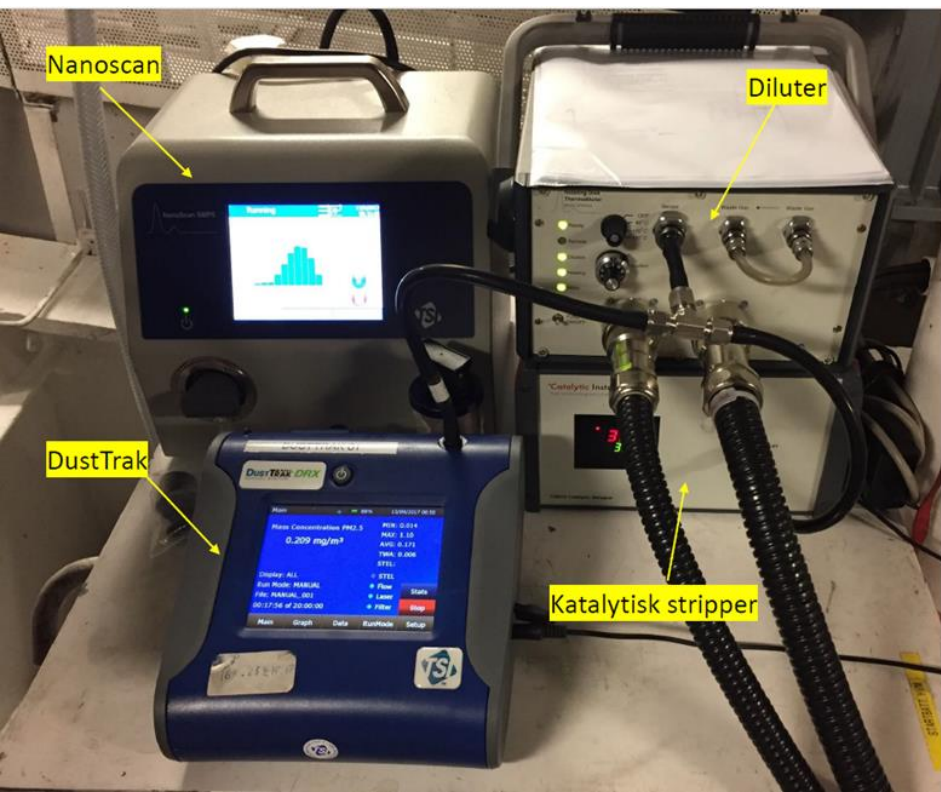






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# Used equipment for PM / PN measurement

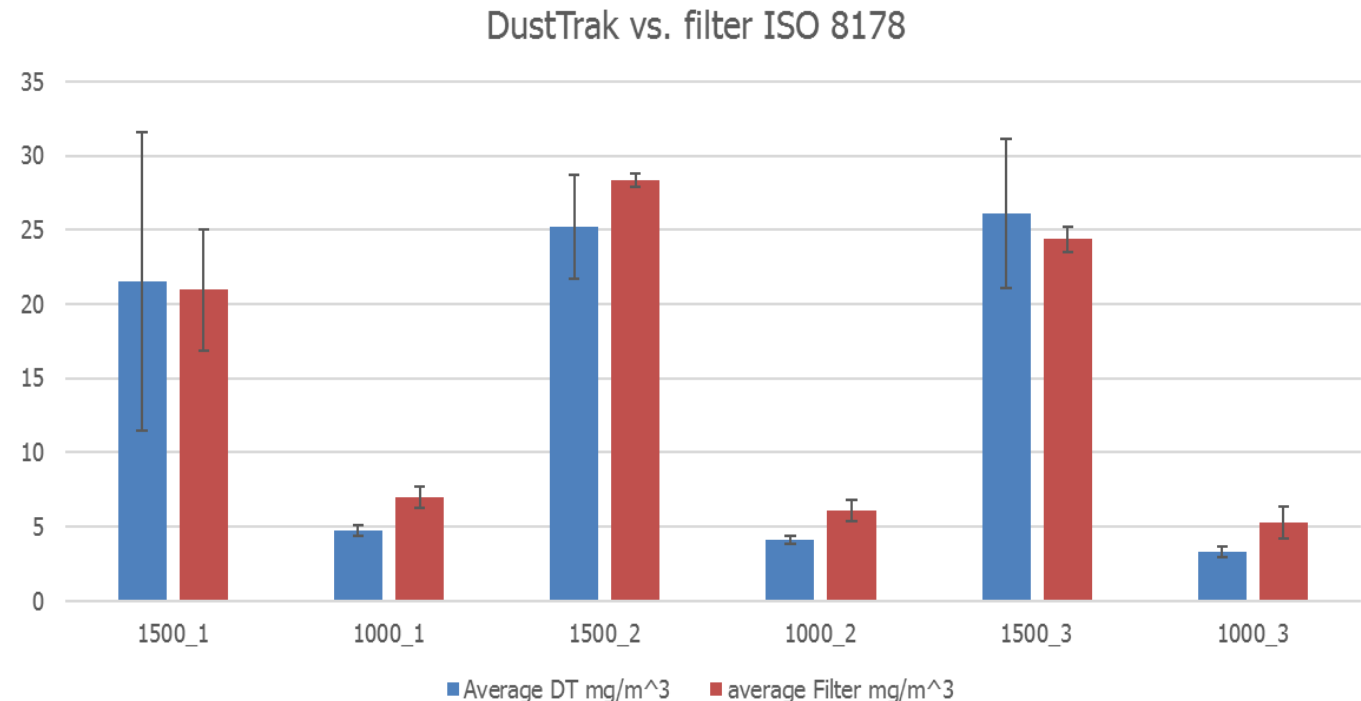






# PM measurement on M/F Isefjord ISO 8178 vs. Dust track

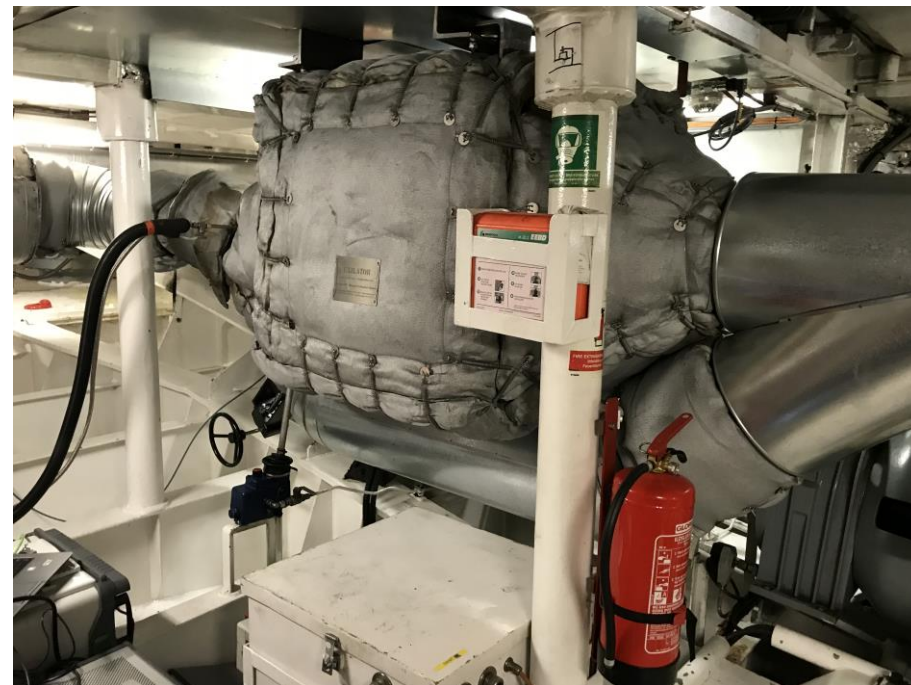
- PM measurement with filter collection for short periods of time is challenging
- PM measurement after DPF is challenging - almost no PM
- Optical measurements provide reproducible results both before and after DPF
- Good correlation between real-time optical measurement and traditional PM filter collection





# First experience from M/F Isefjord

- More than 99% reduction of PM og PN
- The systems are maintenance-free on a daily basis
  - DPF on main engines burns soot in normal operation
  - DPF on generators burns soot at periodically increased load (controlled automatically and using electric resistor)
  - Expected emptying for ash approx. once a year.
- About 22 dB (A) reduction of exhaust pipe noise
  - Effective ambient reduction in combination with existing exhaust muffler
  - In particular, the absence of noise has provided positive feedback







# Measured particle reduction (PN)

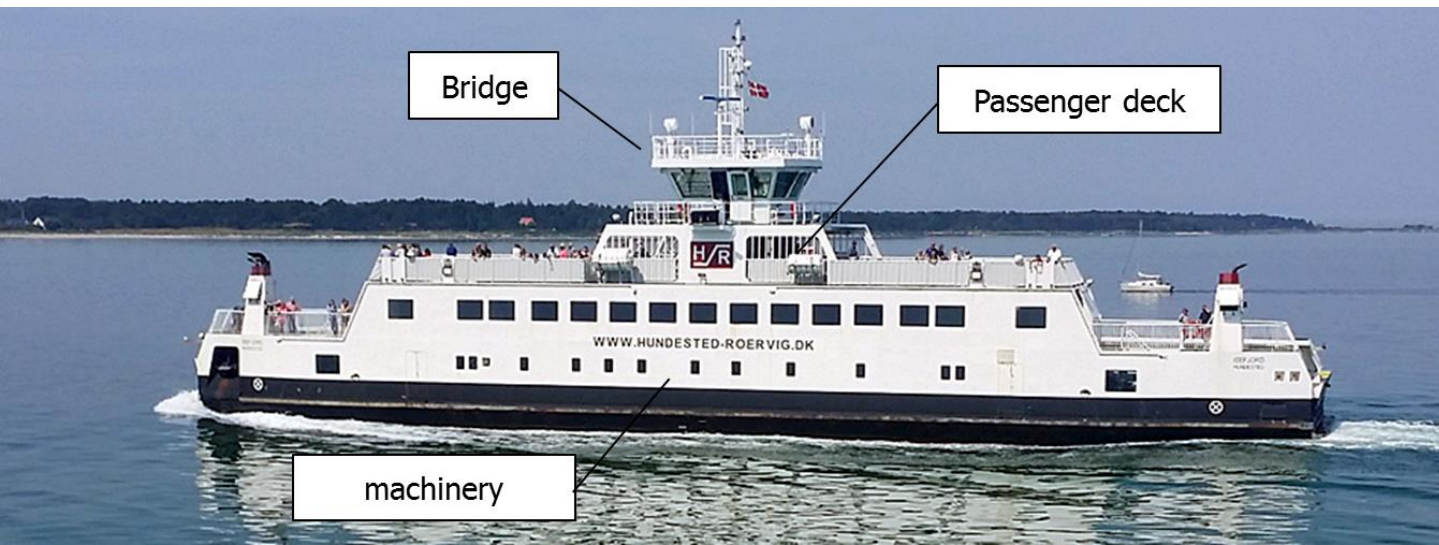
Motor	Retning	Reduktion (antal) [%]
Main engine	Hundested-Rørvig	99.7
	Rørvig-Hundested	99.6
	Hundested harbor	99.6
Auxiliary engine	-	99.8*

\* Efficiency lower from the start



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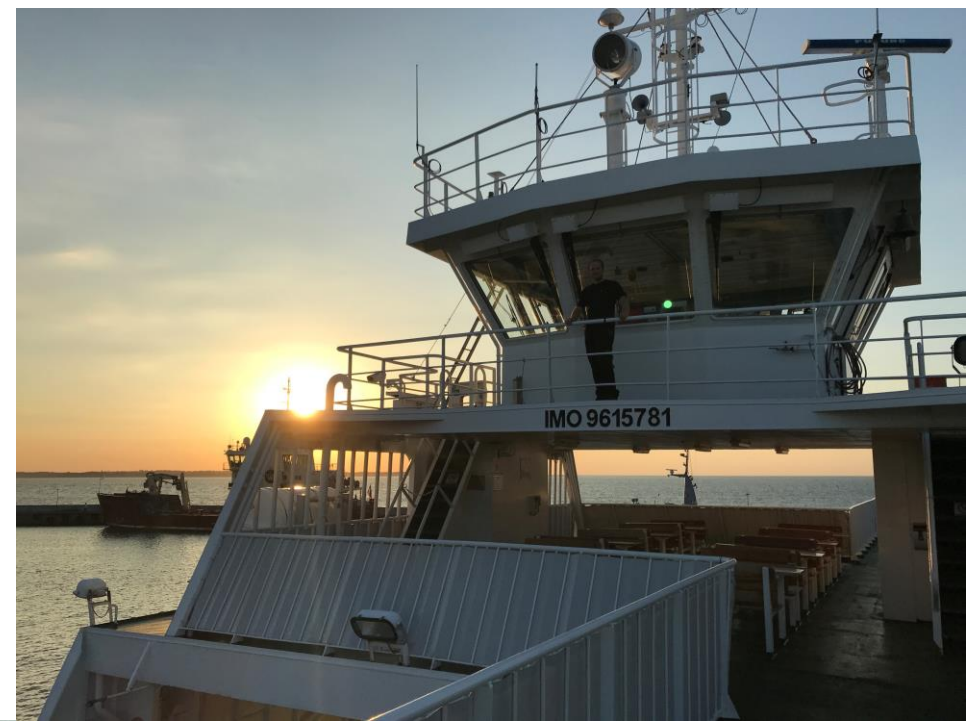
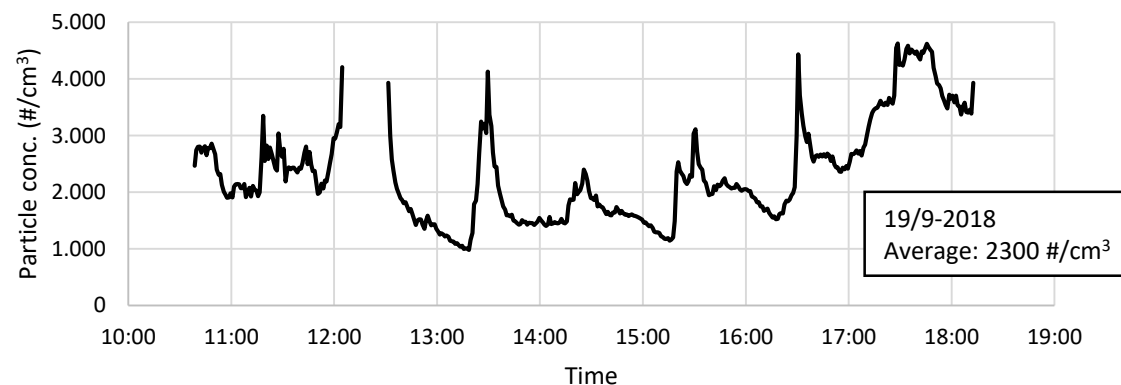
# Measurements of particle concentration in ambient air







# Particle measurement on the bridge

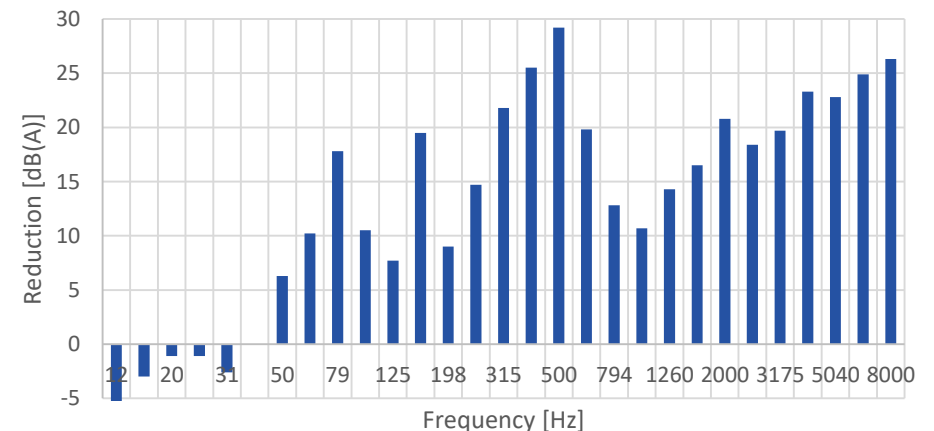




# Determination of noise reduction

- DPF is mounted between engine and original muffler and absorbs most of the sound energy before the muffler
- A reduction of approx. 22 dB (A) reduction measured
  - approx. 1.5 meters from the discharge pipe
  - Sound pressure determined with noise meter
  - The sound is recorded and analyzed in 1/3 octave bands
- Sound energy is reduced by approx. 98% and experienced (subjective) sound pressure is estimated to approx. 75%

Noise reduction – Frequency distribution







# Summary

- DPF is effective on both auxiliary and main engine (> 99% reduction of PM and PN).
- Seamless operation
- Significant noise reduction - both measured and experienced
- Follow-up measurement campaign in autumn 2019 with focus on PM efficiency and status of the filters' catalytic efficiency

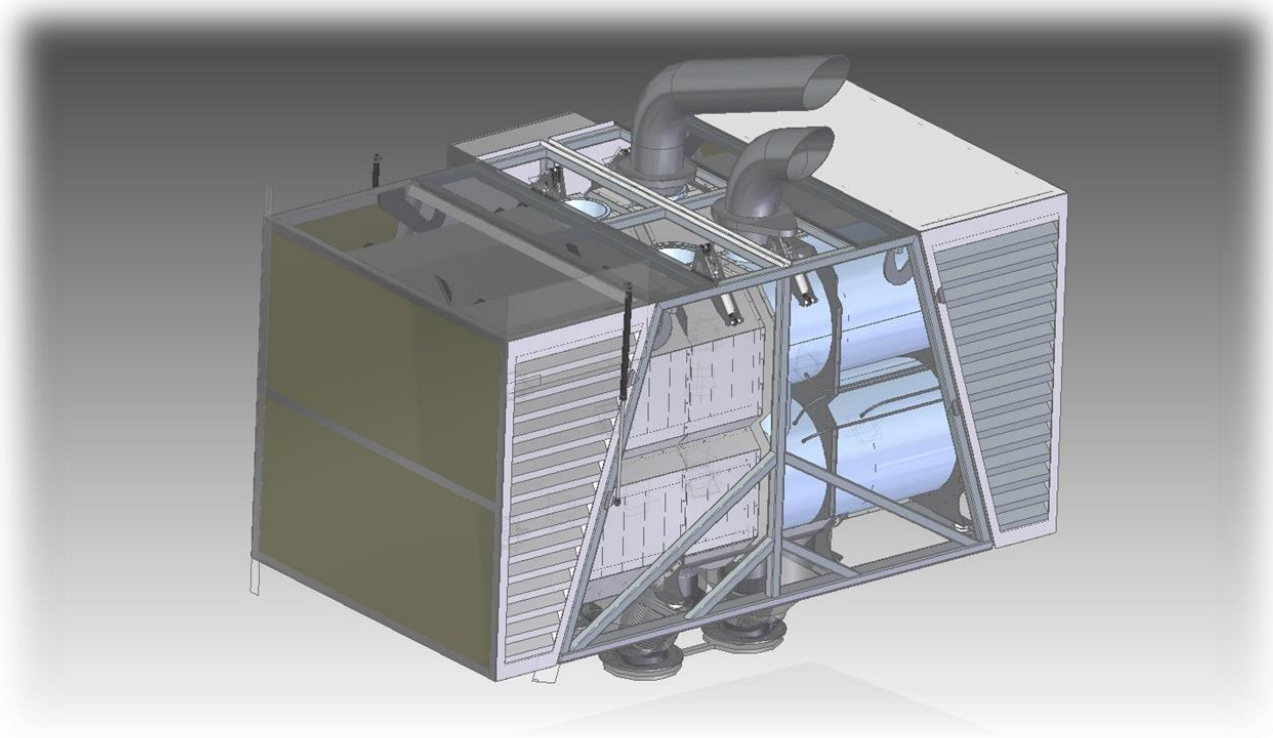
*Local citizen from Rørvig  
complained that "the ferry  
could no longer be used to  
set the clock"*





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# Next demo - Purefi SCR and DPF on World Mistral - in process with approvals







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- Shipping Companies
  - Hundested Rørvig Færgefart
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  - Purefi
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  - Danish Maritime
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Transportens  
Innovationsnetværk  
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Ministry of Environment  
and Food of Denmark  
Environmental  
Protection Agency



# Thank you for your attention

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