IN-SERVICE-MONITORING FOR NRMM USING SEMS, PARAMETER AND REPORTING OPTIONS

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TNO innovation for life

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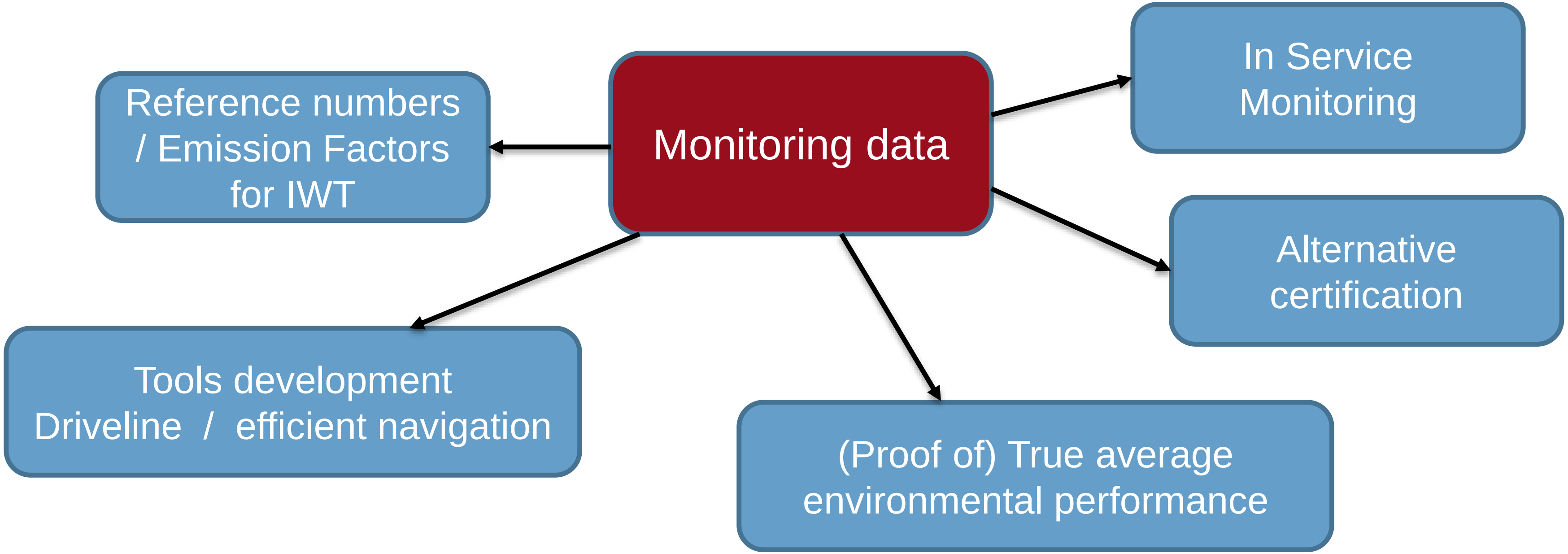
- Introduction
- SEMS measurement system
- Long term monitoring
  - PROMINENT inlet ships
  - Rail locomotive
- Conclusions

INTRODUCTION



http://www.prominent-iwt.eu/

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INTRODUCTION

- Formal In Service Monitoring (EU 2017/655) is only applicable to categories V5 and V6 land based engines

In Service Monitoring	EU 2017/655 - PEMS	SEMS (sensor based)
Main Parameters	Gas analysers for NOx, HC, CO Exhaust Flow Meter (EFM)	NOx/O_2, NH3 sensors Fuel flow / carbon balance
Averaging / visualisation	Work and CO_2 based windows	Long term averaging, binning Work and CO_2 based windows

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SEMS

SEMS: Smart Emissions Measurement System

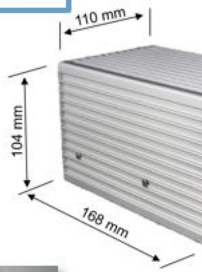
NOx, fuel, rpm, temperatures, gps

prominent

SEMS MEASUREMENT SYSTEM

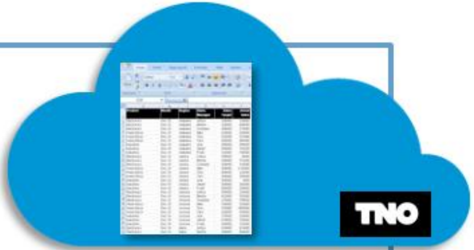
Standard components

3x CAN bus interfaces
- OBDII or WWH-OBD
- J1939
- Additional CAN



Main unit
12V / 24V
power supply

GPRS Modem
Remote data
reading



Post-processing
Calculated values like:
- Mass flow of NO_x, NH_3, CO_2, fuel in [g/s]

GPS
5Hz
speed, altitude and
position

SD-card memory
Up to 160.000 hours

NO_x / O_2/ Lambda automotive sensor
[ppm] and [v%]

K-type thermo couples
2 pieces standard

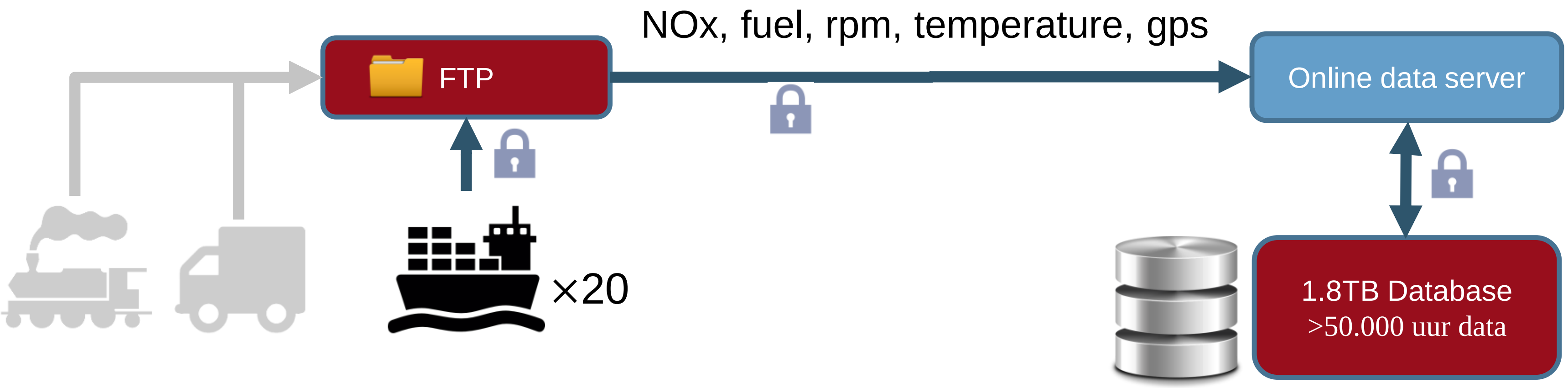
Optional

NH3 automotive sensor
[ppm]

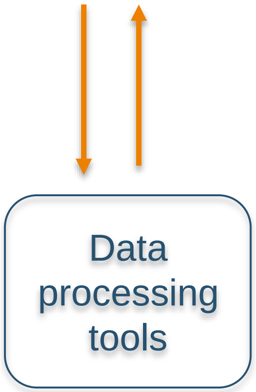
Future option

PM/PN automotive
sensor(s)

SEMS MEASUREMENT SYSTEM



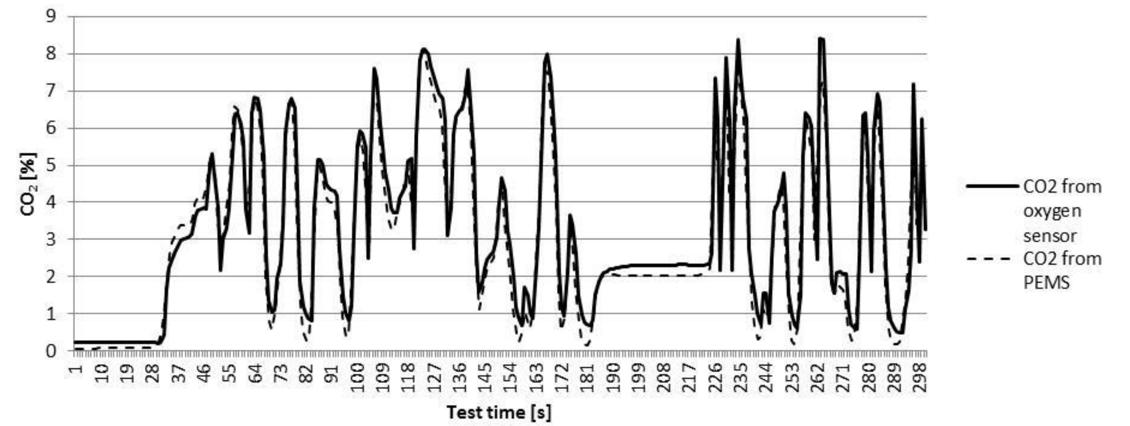
Data processing:
- Screening
- Filtering
- Periodic inspection and calibration of sensors
- Tables with averaging and visualisation

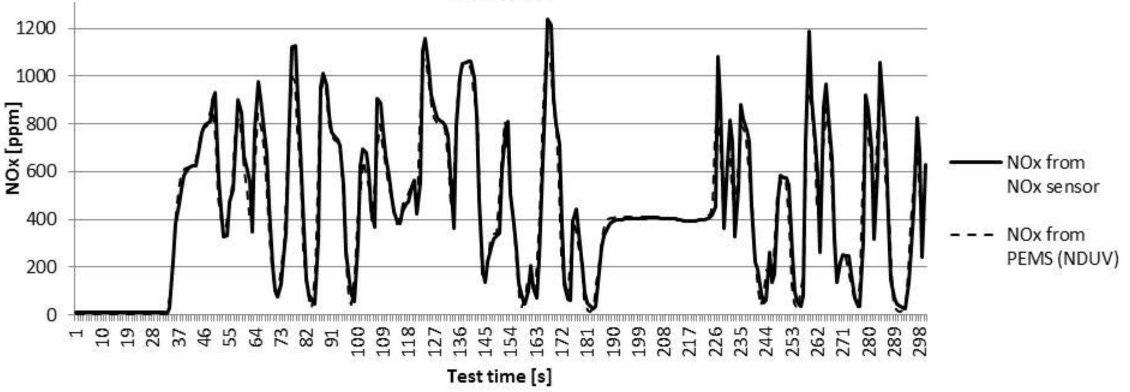


Data access of partners / clients (secured)

SEMS MEASUREMENT SYSTEM

SEMS compared to PEMS concentrations





R.J. Vermeulen, N.E. Ligterink, et.al. Transport and Air Pollution TAP 2012.

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CALCULATION & PARAMETER OPTIONS

calculation options	Main parameters	NOx in
NOx mass flow based on exhaust or air flow	NOx, CO_2 concentrations Exhaust or inlet air flow Power	g/kWh
Carbon balance method Used in PROMINENT	NOx, CO_2 concentrations Fuel flow (re-calibrated) Power fuel flow → Power	g/kWh
Exhaust concentrations only	NOx, CO_2 concentrations	'g/kg' CO_2

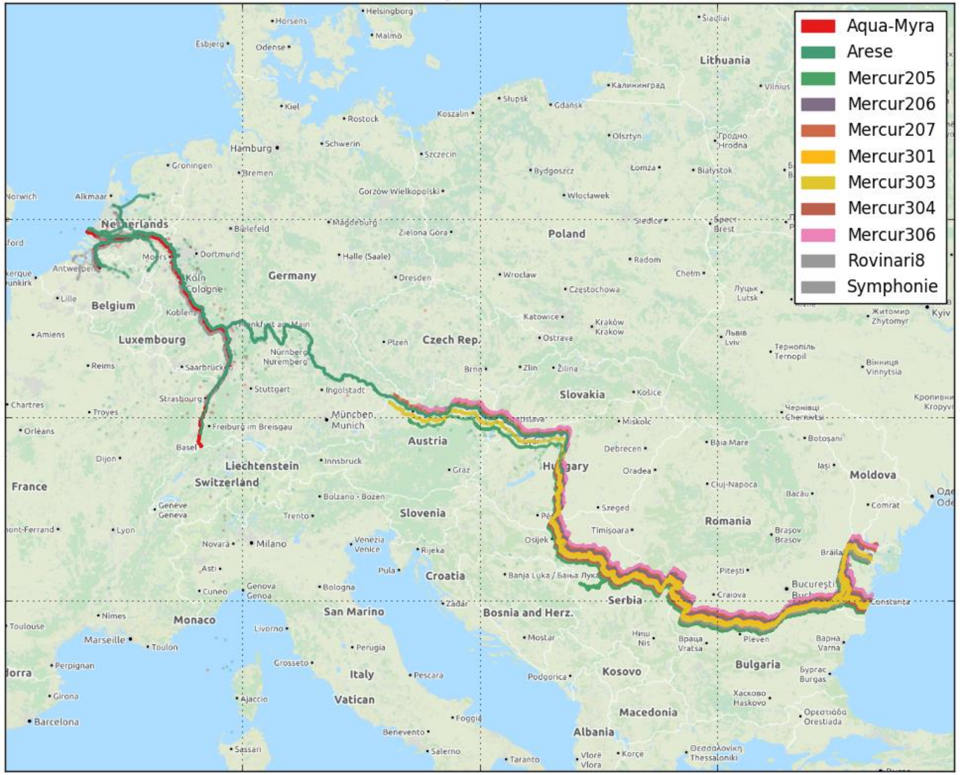
According to EU 2017/655

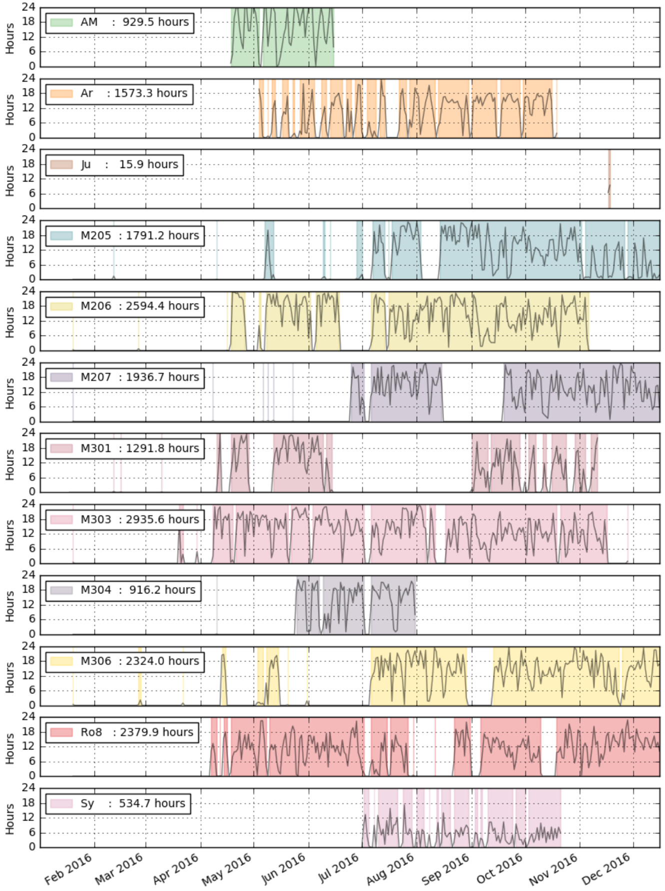
More practical alternatives for ships

Refer to PROMINENT deliverable D5.8: http://www.prominent-iwt.eu/ (end 2017)

PROMINENT

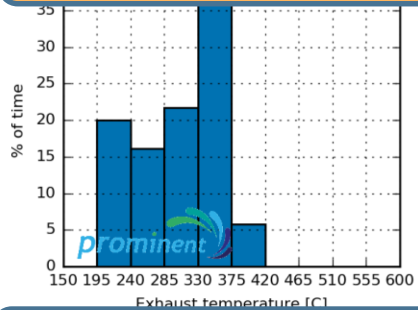
Data until December 2016





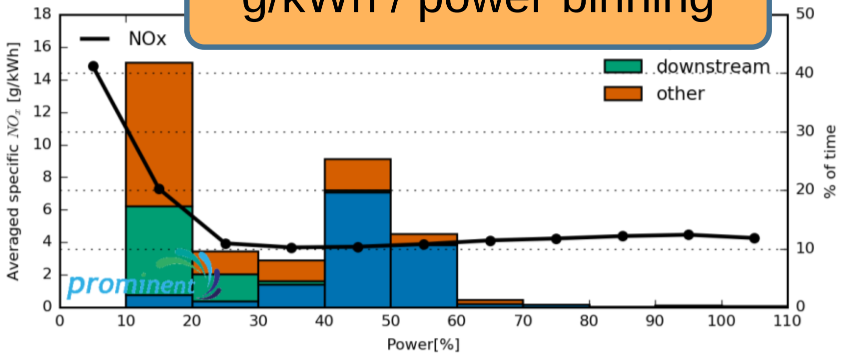
STANDARD REPORTING FORMAT

Exhaust gas temp.

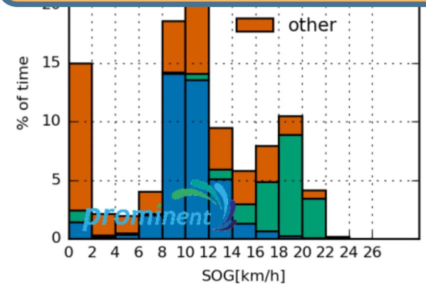


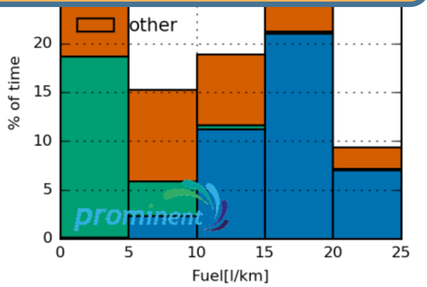
Vessel 1	Container 110m
	2005
Power[kW]	1492
Num. engines	1
Brand	Caterpillar
Type	3516
Features	CCNR 1-SCR / DPF
Area	Antw./Rot.
DWT	3200
Modelled	Temp.
Hours	924

g/kWh / power binning

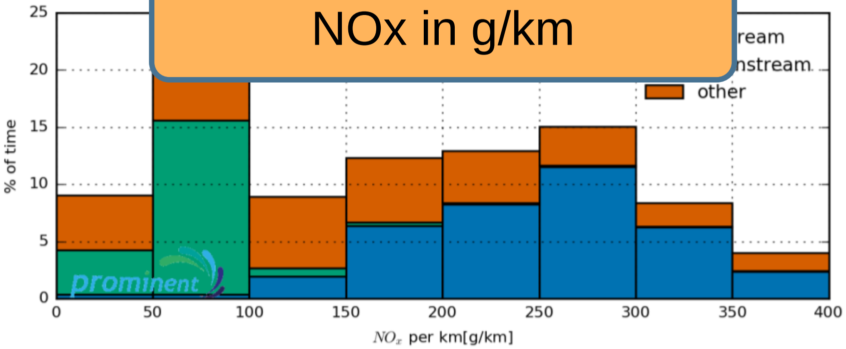


Sailing speed and fuel consumption





NOx in g/km

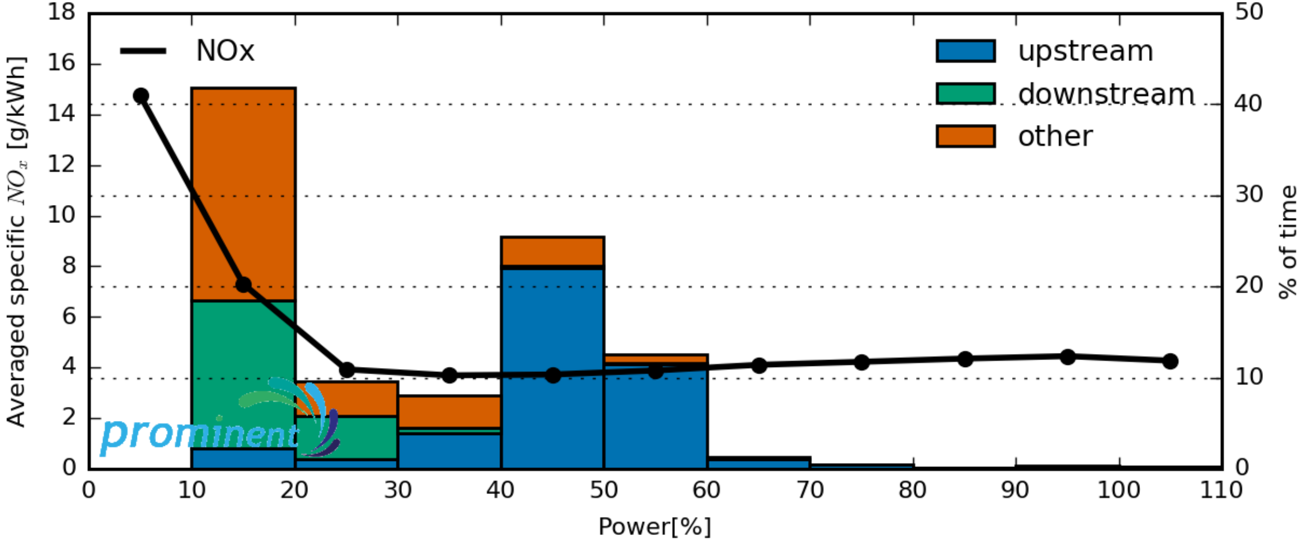


REPORTING FORMAT OPTIONS

Power binning

Container vessel 110m

CCNR I + SCR/DPF



Non-working Events

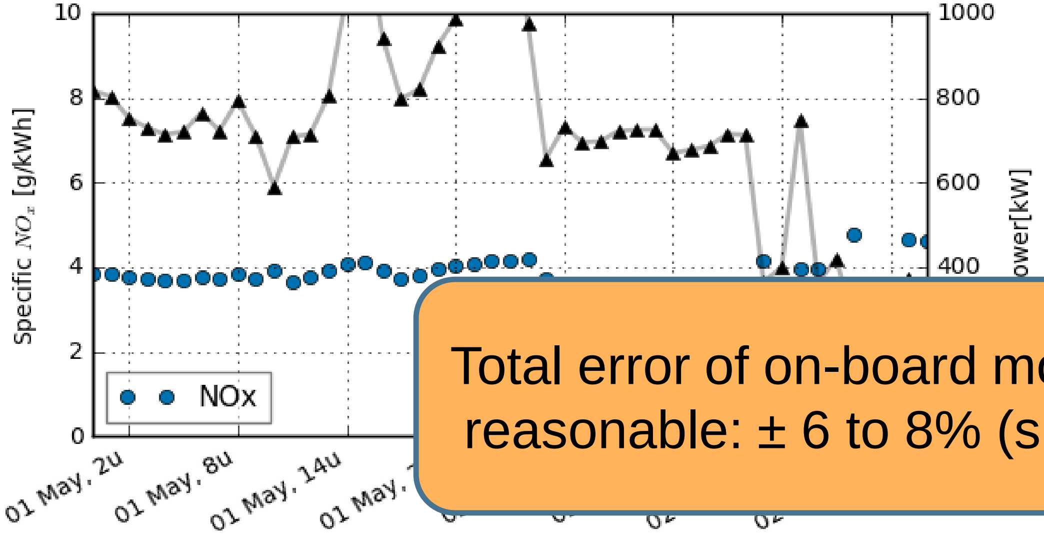
Working Events

REPORTING FORMAT OPTIONS

- 1-hour average of NOx and power versus time

Engine ~ 1500 kW

CCNR I + SCR/DPF



Total error of on-board monitoring is quite reasonable: ± 6 to 8% (similar to PEMS)

- Other options: one day, one week, one month averages versus time

PROMINENT

Rhine ships:
average emissions

1000-2000 hrs
Period:

Inland vessels		Container 110m	Container 135m	Dry Bulk 135m
Engine technology		CCR I + SCR/DPF	CCR I + SCR	CCR II
Max power[kW]		1500	1050	850
NOx	[g/kWh]	4.1	5.4	8.6
NOx/CO_2	[g/kg]	6.3	8.2	12.3
NOx	[g/km]	171	515	281
CO_2	[kg/km]	27	63	23

Refer to PROMINENT deliverable D5.7 & D5.8
(end 2017): http://www.prominent-iwt.eu/

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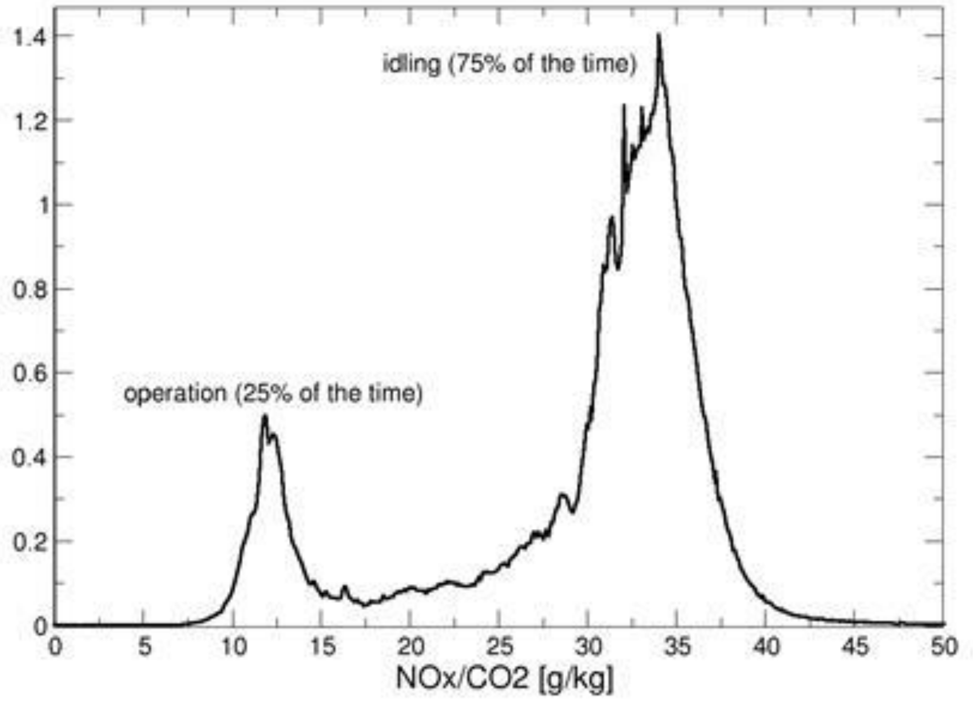
LOCOMOTIVE EMISSIONS MONITORING

Diesel locomotive:

- 656 hours of monitoring December 201 February 2017
- Netherlands – Nordrhein-Westfalen

NOx emissions:

- Normal operation: 12 g/kg NOx/CO_2 (Comparable Euro I)
- Idling: 35 g/kg NOx/CO_2



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CONCLUSIONS

- Continuous monitoring of emissions is possible and useful for many purposes:
  - Insight in long term environmental performance
  - Complementary as low costs alternative to PEMS measurements
  - Non-working events can be separated in several ways
  - The total life span emissions may replace ISM / ISC testing in the future

- Fuel flow or inlet air flow form excellent alternatives to exhaust mass flow, in order to calculate mass emissions (also for ISC/ISM)

- Extremely long idle periods with relatively high NOx emissions are seen with rail. This creates a gap between real-world emissions and ISM results.

THANK YOU FOR YOUR ATTENTION

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SPARE SHEETS

CALCULATION & PARAMETER OPTIONS

Consider alternative to g/kWh for ISM:

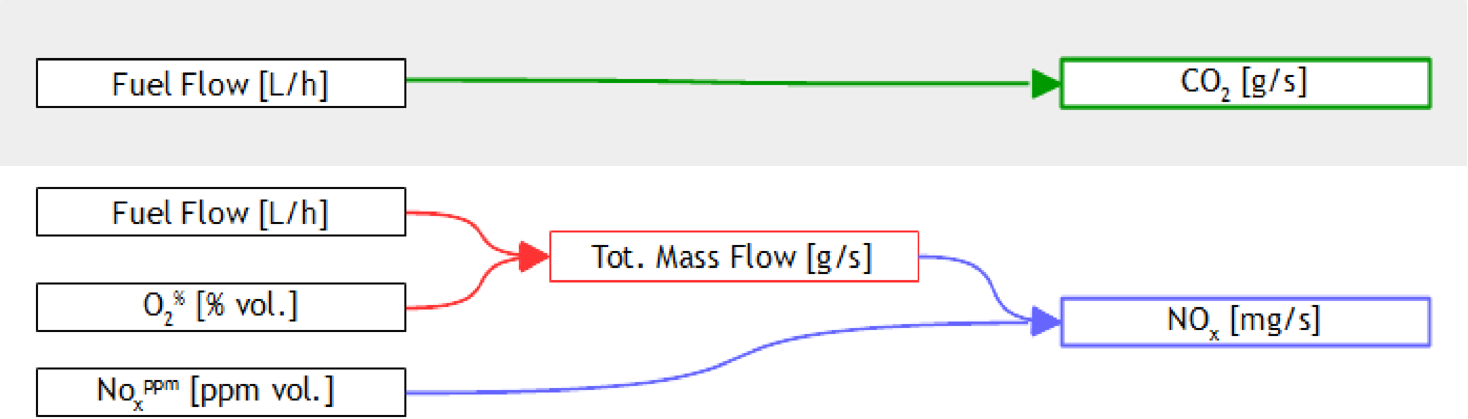
- Monitor NOx/CO_2 ratio based on concentrations only
- Conversion to g/kg CO_2 with molecular masses: $$= \frac{NO_x^{ppm}}{CO_2^{\%} \cdot 10} \cdot \frac{M_{NO_x}}{M_{CO_2}} .$$
- Plot NOx/CO_2 as a function of engine speed, indicative power or exhaust gas temperature. Determine limit value in g/kg CO_2.

Advantages:

- Stable relation with NOx in g/kWh
- Less susceptible to errors
- No amplification of values at low power

CALCULATION & PARAMETER OPTIONS

- Carbon balance method



- Following steps: NOx in g/kWh, g/kg CO_2 or g/km

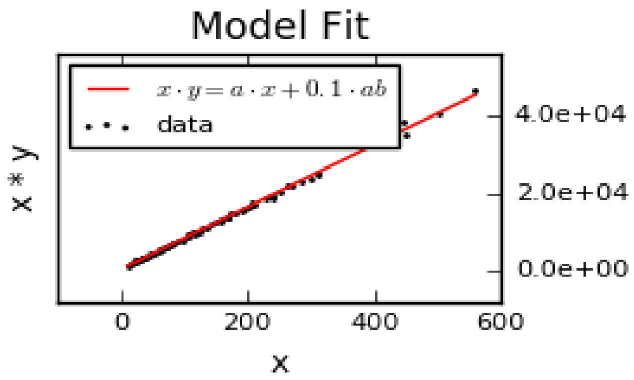
CALCULATION & PARAMETER OPTIONS

Power based on fuel consumption

- Either per engine of for a group of engines

$$P_{engine} = \frac{3600}{BSFC} \cdot mF_{fuel}$$

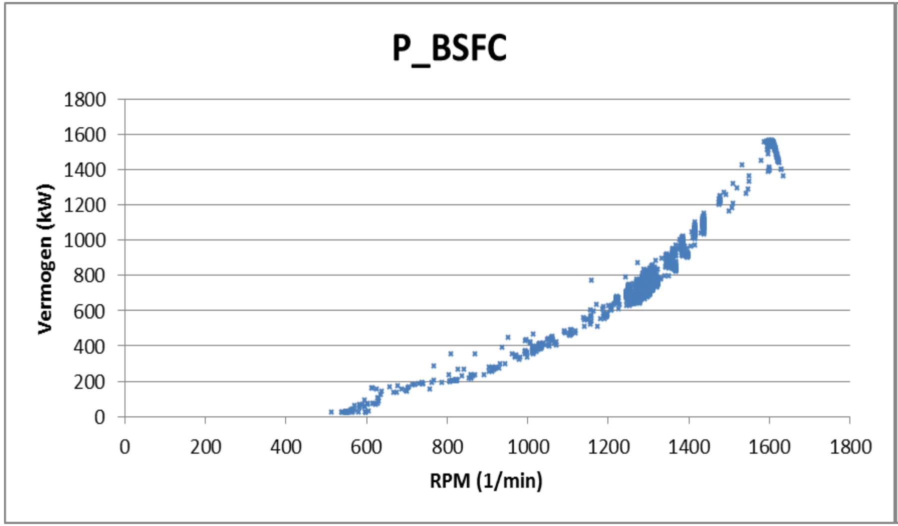
$$BSFC(LFE) = a \cdot \left(1 + 0.1 \cdot \left(\frac{b}{mF_{fuel}}\right)\right)$$

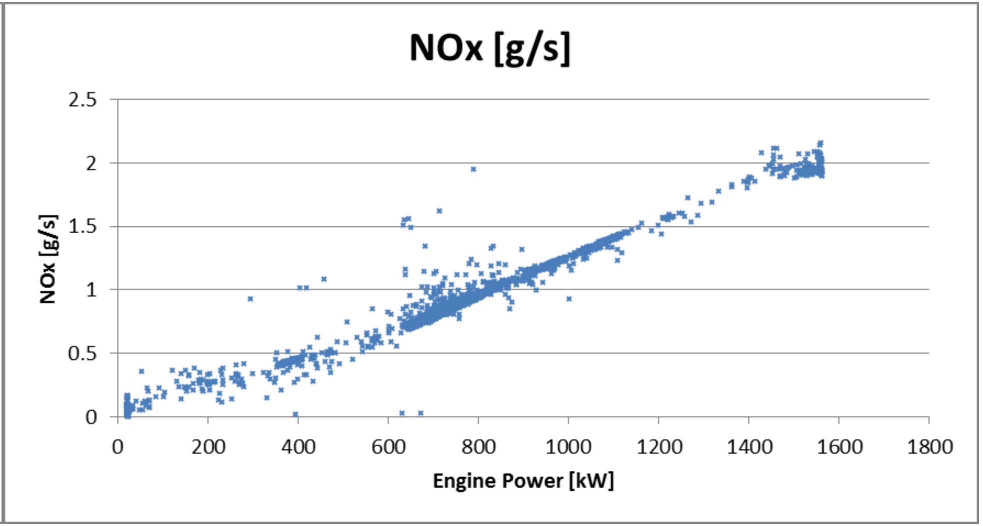


DATA PRESENTATION OPTIONS

- Data checks

engine with SCR





ACCURACY ESTIMATION

Accuracy estimation

$(\text{sum of errors}^2)^{0.5}$

Refer to PROMINENT deliverable D5.7 & D5.8: http://www.prominent-iwt.eu/ (end 2017)

	g/h NOx		g/kWh NOx		g/kg CO2
	ISO 8178 laboratory	On-board monitoring	ISO 8178 laboratory	On-board monitoring	On-board monitoring
NOx concentration	2%	2%	2%	2%	2%
02/CO2 concentration		2%		2%	2%
calibration gas	2%	2%	2%	2%	2%
cross sensitivity NH3, NO/NO2 ratio	2%	3%	2%	3%	3%
measuring point NOx inhomogienity	1%	3%	1%	3%	3%
pressure sensitivity		2%		2%	2%
Engine speed			1%		
Engine torque /power			2%		
Engine power					
Air	2%		2%		
Fuel flow		4%			
BSFC/engine efficiency		3%		3%	
Fuel carbon content		1%		1%	1%
Total accuracy ±	**4%**	**8%**	**5%**	**7%**	**6%**