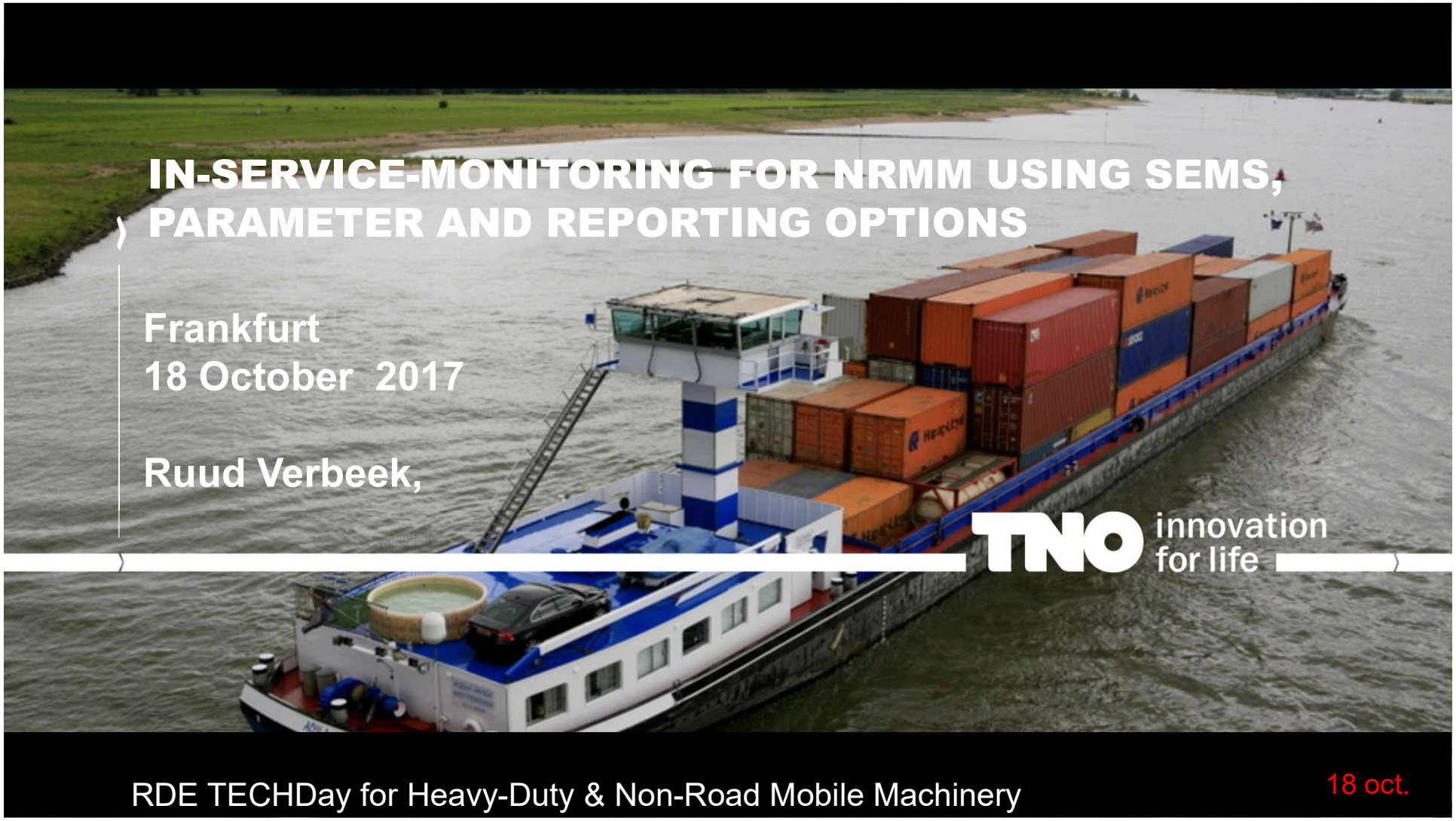
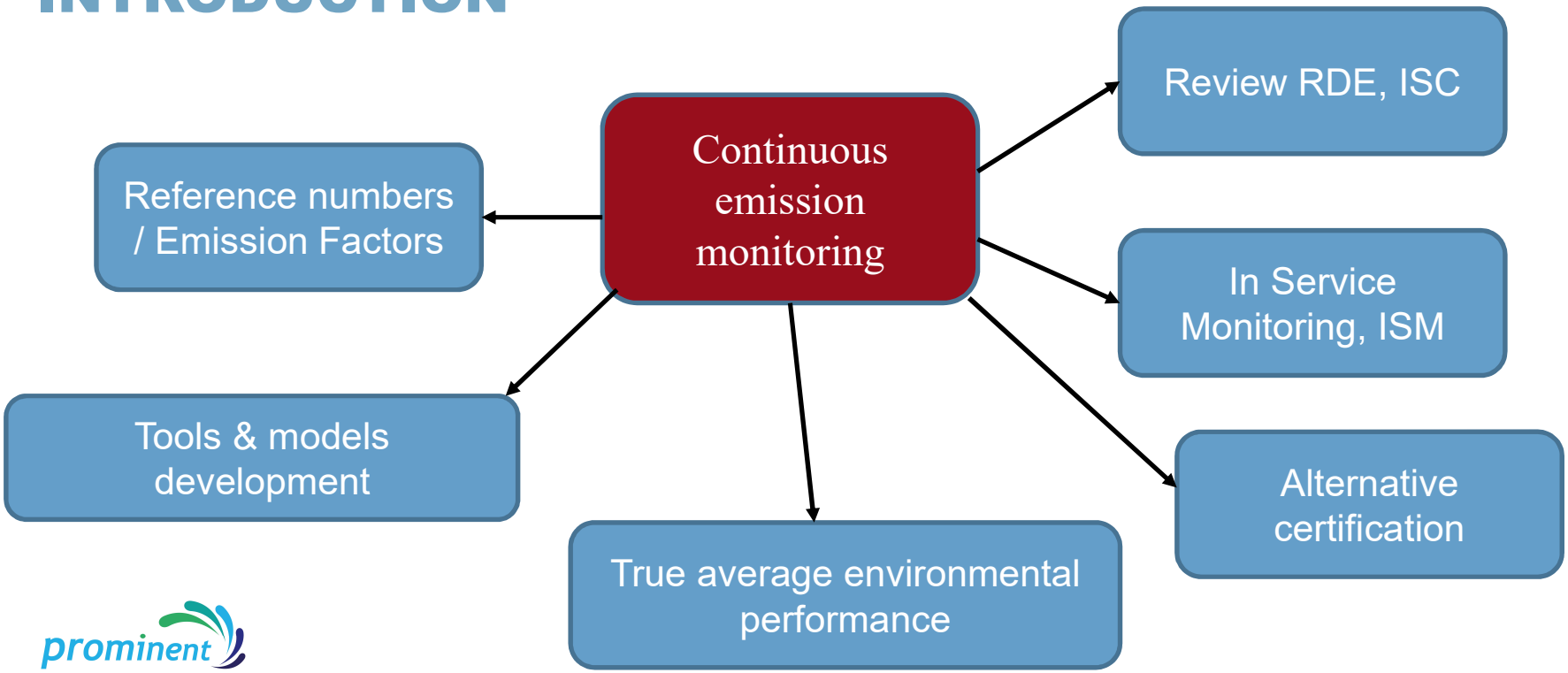

IN-SERVICE-MONITORING FOR NRMM USING SEMS, PARAMETER AND REPORTING OPTIONS
Frankfurt
18 October 2017
Ruud Verbeek,
TNO innovation for life
RDE TECHDay for Heavy-Duty & Non-Road Mobile Machinery
18 oct.

CONTENTS

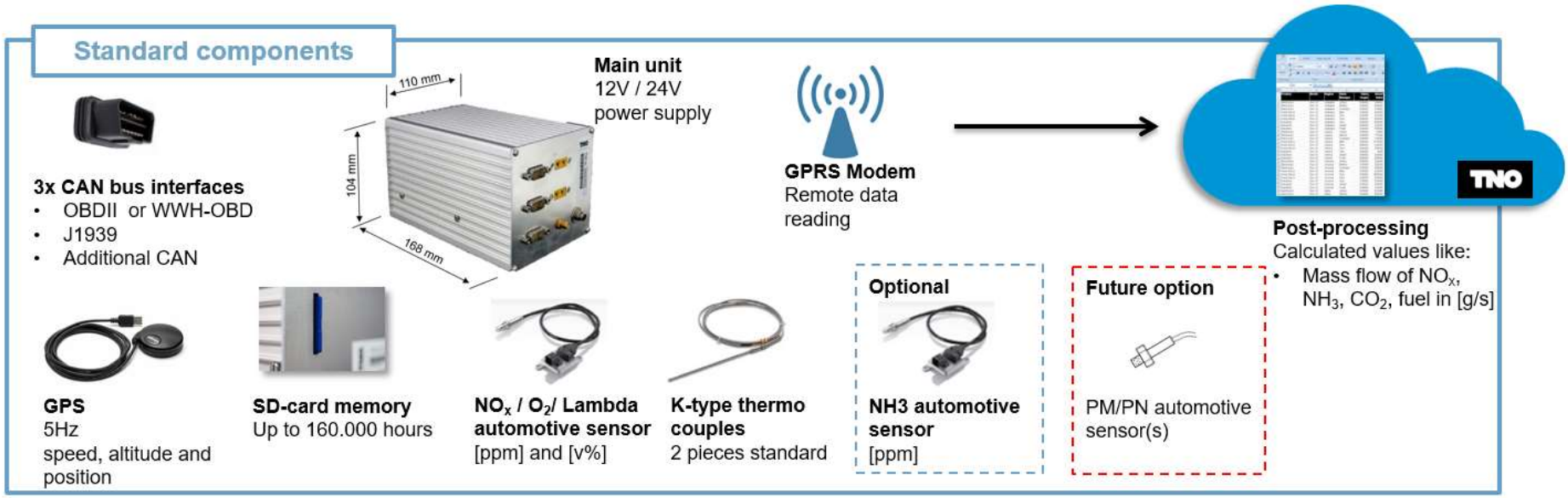
- Introduction
- SEMS measurement system
- Long term monitoring
  - Inland ships (PROMINENT project)
  - Rail locomotive
- Conclusions

INTRODUCTION



prominent

SEMS MEASUREMENT SYSTEM



Research and monitoring tool for determination of real world emissions

SEMS MEASUREMENT SYSTEM

COOPERATION HORIBA - TNO

HORIBA
Explore the future

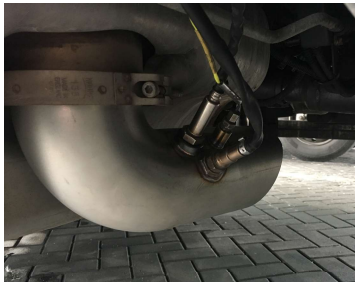
- Worldwide leading manufacturer of emission measurement technology
- 8.500 employees in 27 countries in Asia, Europe and America
- “ONE STEP AHEAD” with the spirit of “JOY AND FUN”

TNO innovation for life

- An independent Dutch research organization, more than 30 years experience in measurement of emissions of vehicles
- More than 3.500 employees worldwide
- “INNOVATION FOR LIFE”

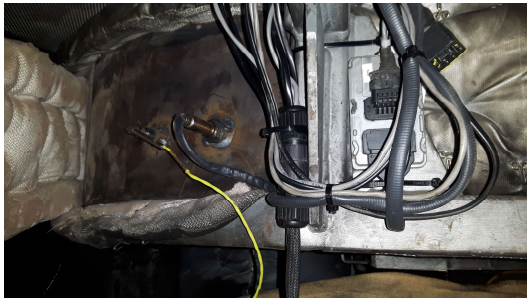
SEMS MEASUREMENT SYSTEM

Cars/Trucks

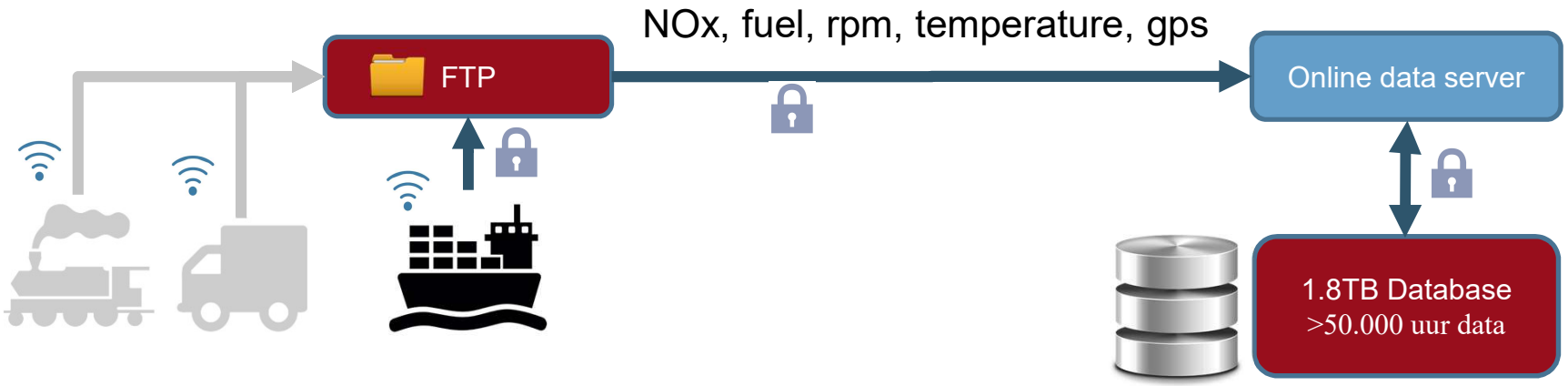


Ships

Rail-locomotive



NRMM



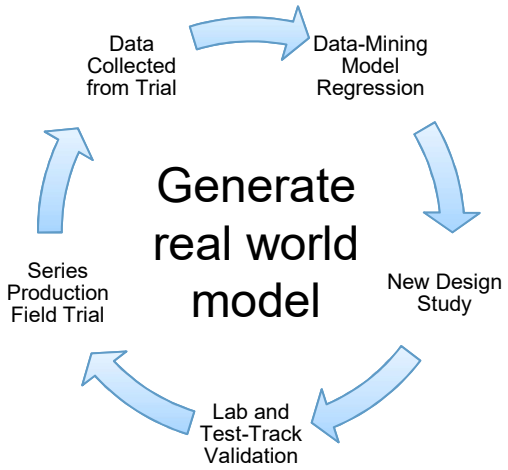
Data processing:

- Screening
- Filtering
- Calculation of CO_2, NO_x, NH_3 in g/s, g/kWh, g/km
- Averaging and visualisation

INPUT DATA FOR EMISSION MODELS

Real world issues can be virtually assessed, validated and solved

Measure real world situations with SEMS



Fast assessment and validation

SCR

ENGINE

VEHICLE

FLEET

SEMS DATA APPLICATIONS

- **RDE, ISC, ISM tool** (NO_x, NH_3, CO_2)
- Low costs alternative to PEMS testing
- Screening tool for TAA
- Long period fleet test
- SCR/LNT efficiency
- Input data for emission models

Road, NRMM, ships, rail:

For the same amount of money, much more engines can be tested than with PEMS and also during a long period

→ Find weak spots

→ Increase RDE robustness

SEMS MEASUREMENT SYSTEM

Comparison PEMS and SEMS

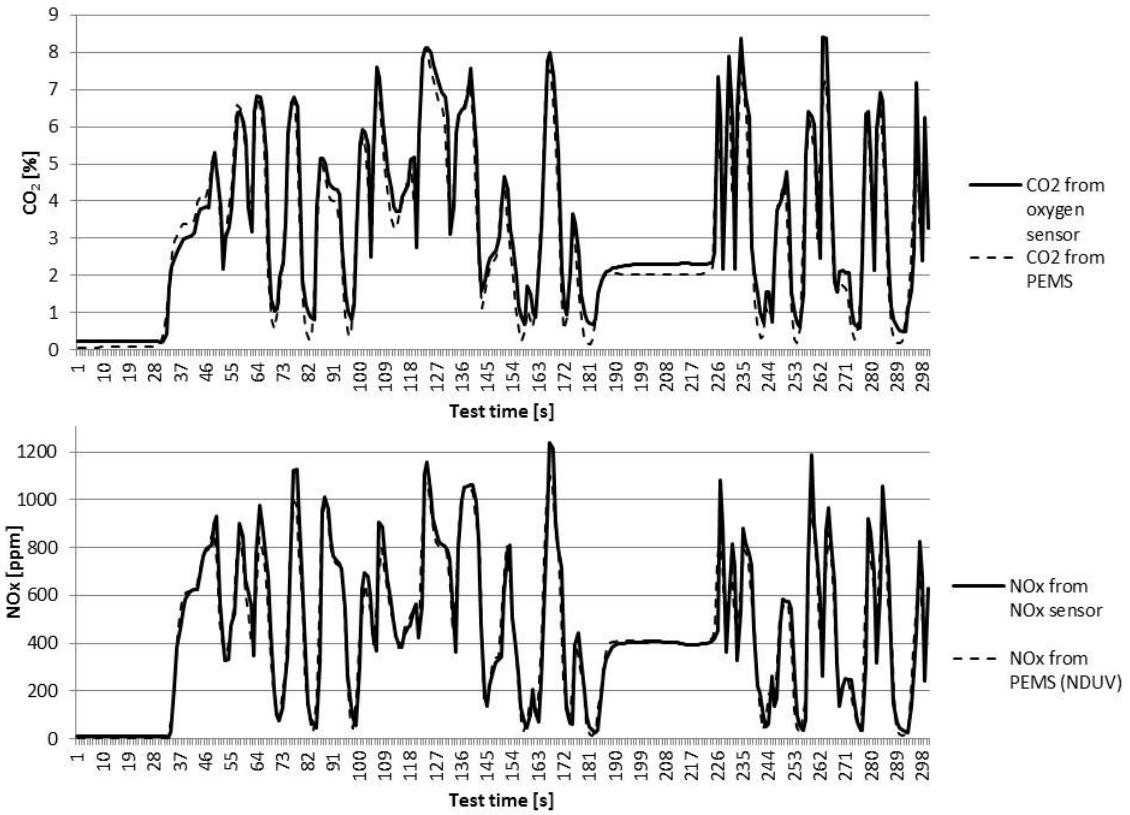
	PEMS	SEMS (sensor based)
Main Parameters	Gas analysers for NOx, HC, CO Exhaust Flow Meter (EFM)	NOx/O_2, NH3 sensors MAF or fuel flow / carbon balance
Averaging / visualisation	Work and CO_2 based windows	Time series, averaging, binning Work and CO_2 based windows

SEMS MEASUREMENT SYSTEM - VALIDATION

SEMS compared to PEMS concentrations

Compared with CVS bag:
CO_2: 1.5 – 4.1%
NOx: 1.7 – 6.9% higher

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



CONTENTS

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

PROMINENT PROJECT

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

Monitor/store ship and driveline parameters with periodic transfer to the database

NOx, fuel, rpm, temperatures, gps

*This project was made possible with the financial support of the European Commission; grand agreement 633929

CALCULATION & PARAMETER OPTIONS

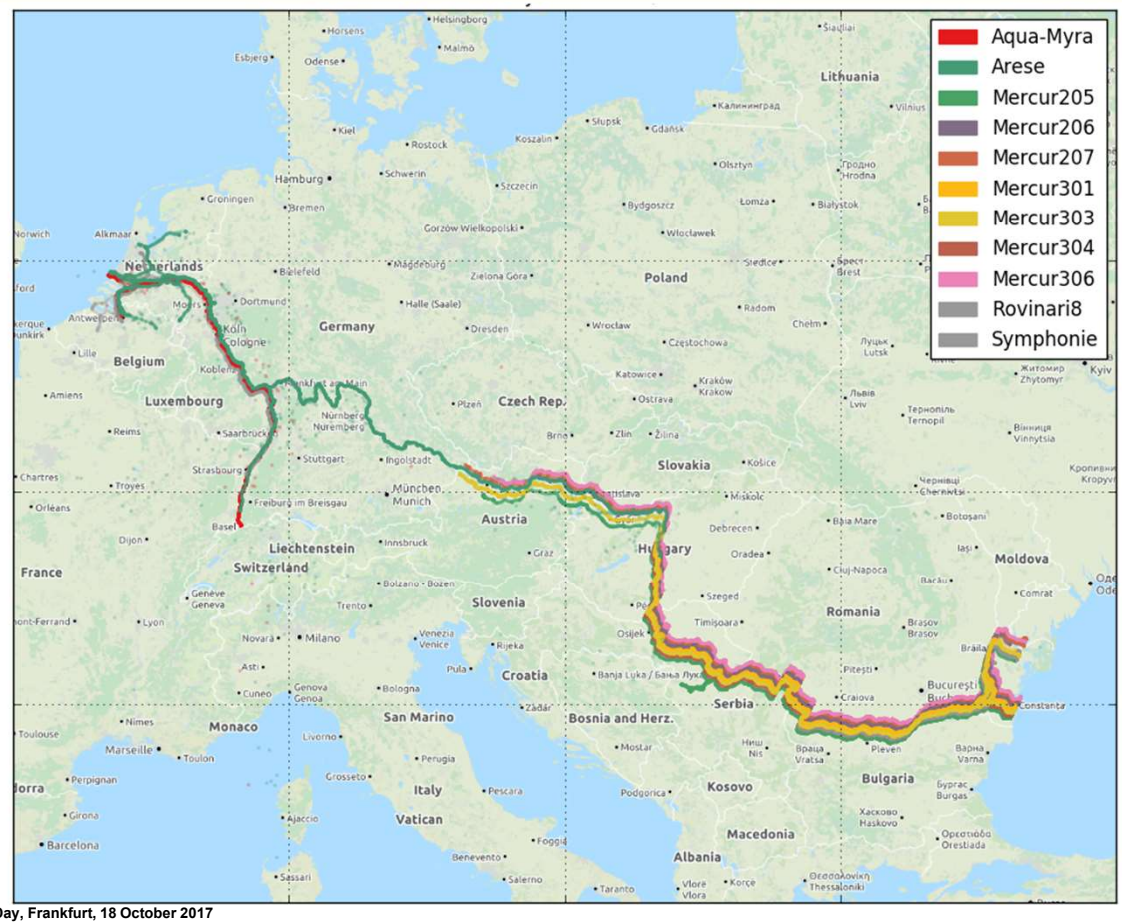
calculation options	Main parameters	NOx in
NOx mass flow based on exhaust or air flow	NOx, CO_2 concentrations Exhaust or inlet air flow Power	g/kWh
Carbon balance method (Used in PROMINENT)	NOx, CO_2 concentrations Fuel flow Power (fuel flow → Power)	g/kWh
Exhaust concentrations only	NOx, CO_2 concentrations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

PEMS procedure according to EU 2017/655

More practical alternatives for ships, especially for continuous monitoring

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

PROMINENT



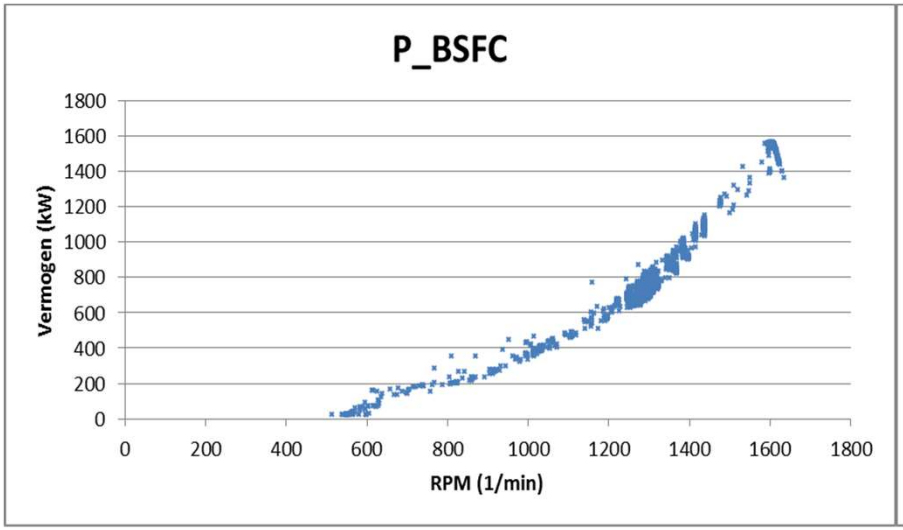
Rhine and Danube vessels

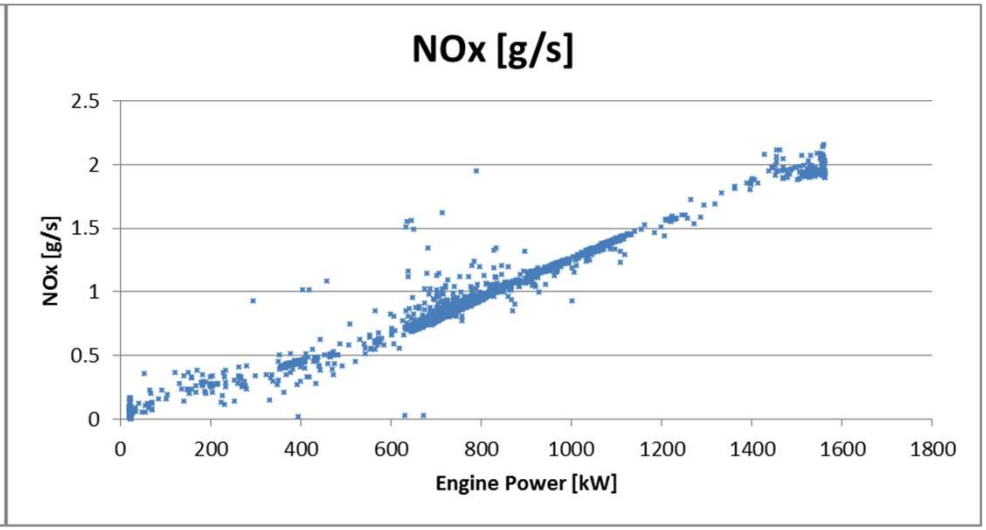
Data until December 2016

STANDARD REPORTING FORMAT

- Data checks

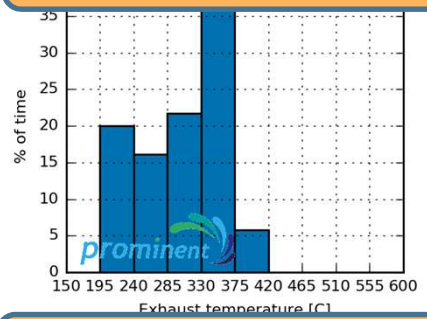
engine with SCR





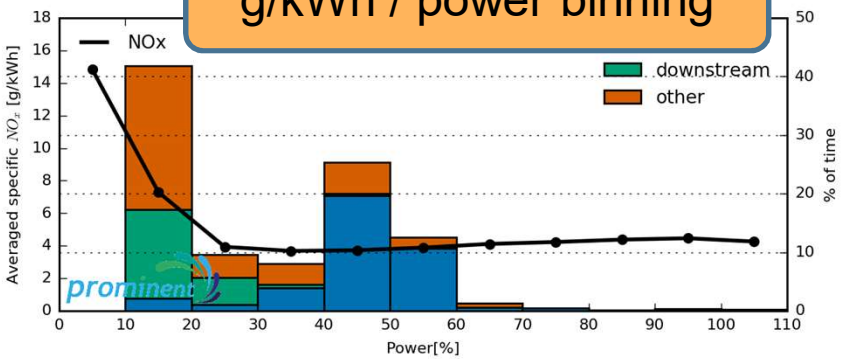
STANDARD REPORTING FORMAT

Exhaust gas temp.

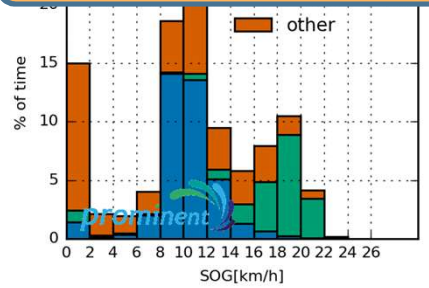


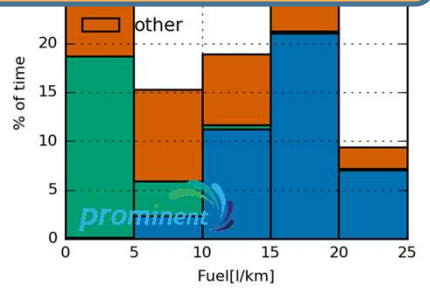
Vessel	1 Container 110m
Built	2005
Power[kW]	1492
Num. engines	1
Brand	Caterpillar
Type	3516
Features	CCNR 1-SCR / DPF
Area	Antw./Rot.
DWT	3200
Modelled	Temp.
Hours	924

g/kWh / power binning

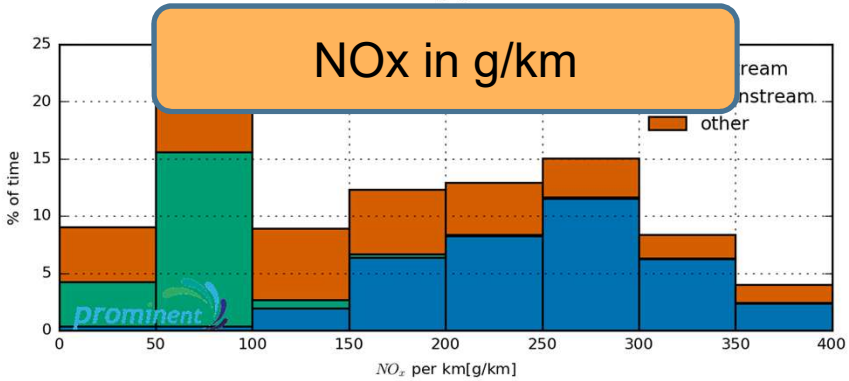


Sailing speed and fuel consumption

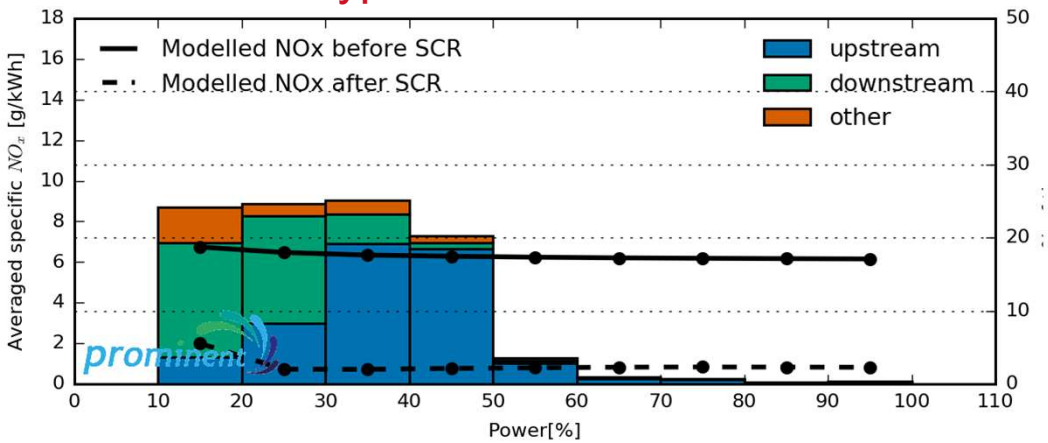


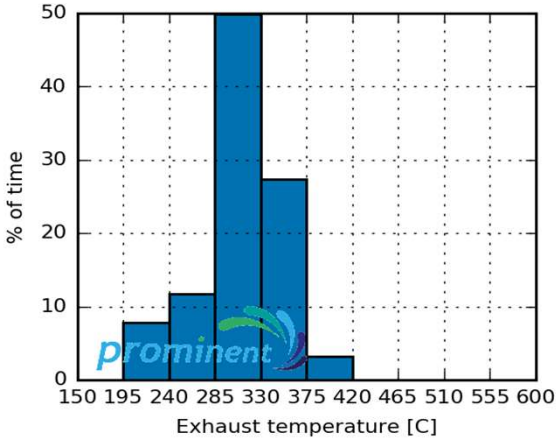


NOx in g/km

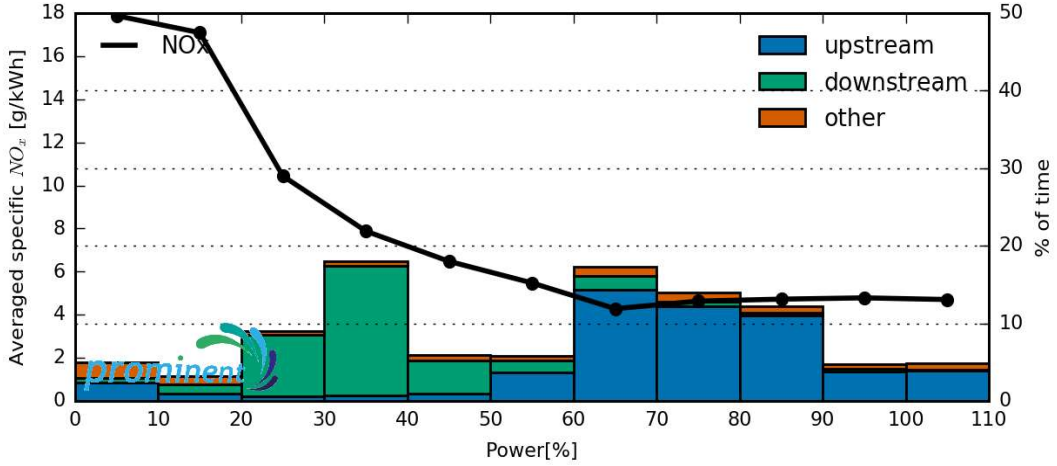


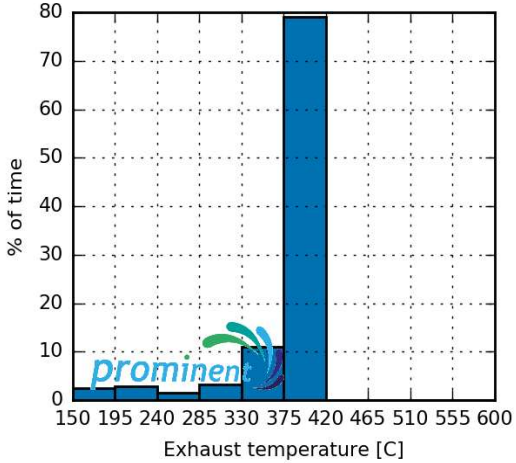
Typical load distribution - vessel 3





Good load distribution - vessel 2





STANDARD REPORTING FORMAT

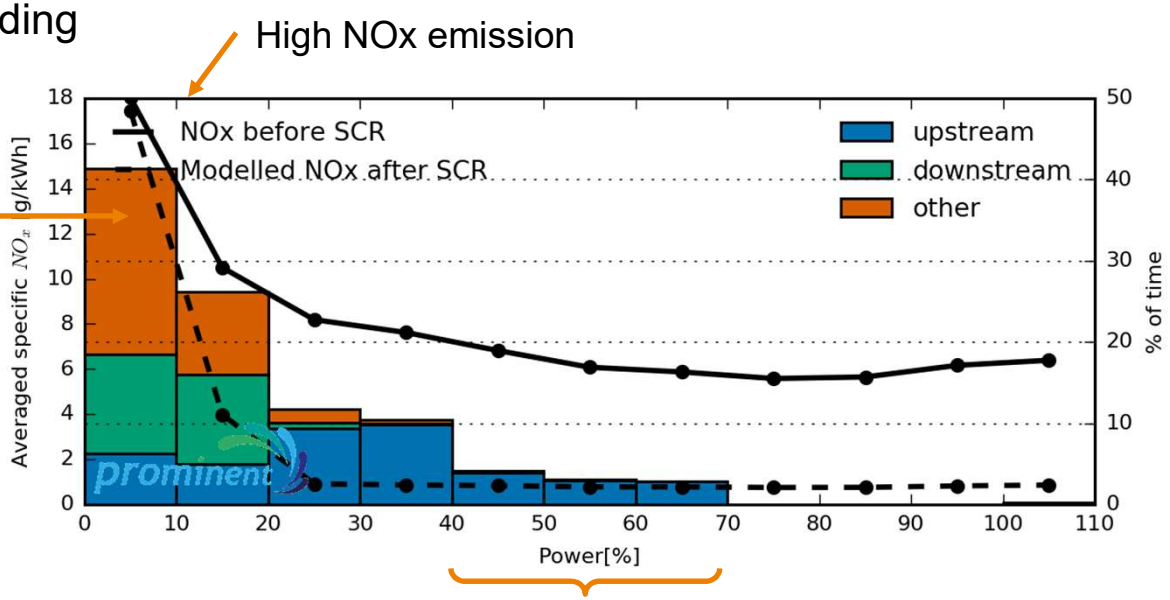
Problems with emission control:

- High NOx emissions
- Blocking of DPF

Poor NOx efficiency due to underloading

Smaller engine or hybrid recommended

Too cold for SCR

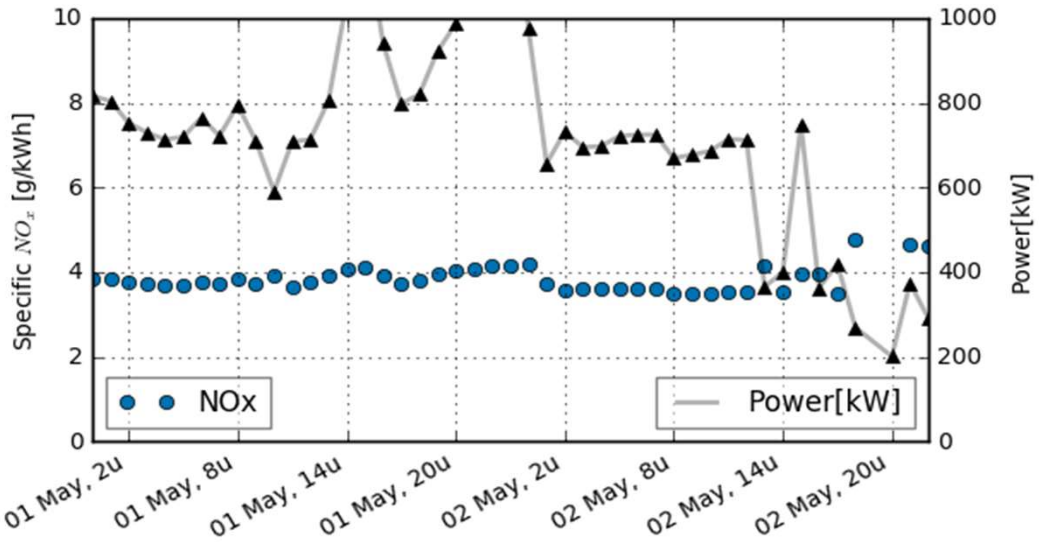


REPORTING FORMAT OPTIONS

- 1-hour average of NOx and power versus time

Engine ~ 1500 kW

CCNR I + SCR/DPF



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

PROMINENT

Rhine ships: average real world emissions

1000-2000 hrs Period:

		Container 110m	Container 135m	Dry Bulk 135m
Engine technology		CCR I + SCR/DPF	CCR I + SCR	CCR II
Max power[kW]		1500	2x1050	2x850
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

Simulated best real world NOx emissions with SCR, range from 1-2 g/kWh (13 Rhine and Danube ships evaluated)

CONTENTS

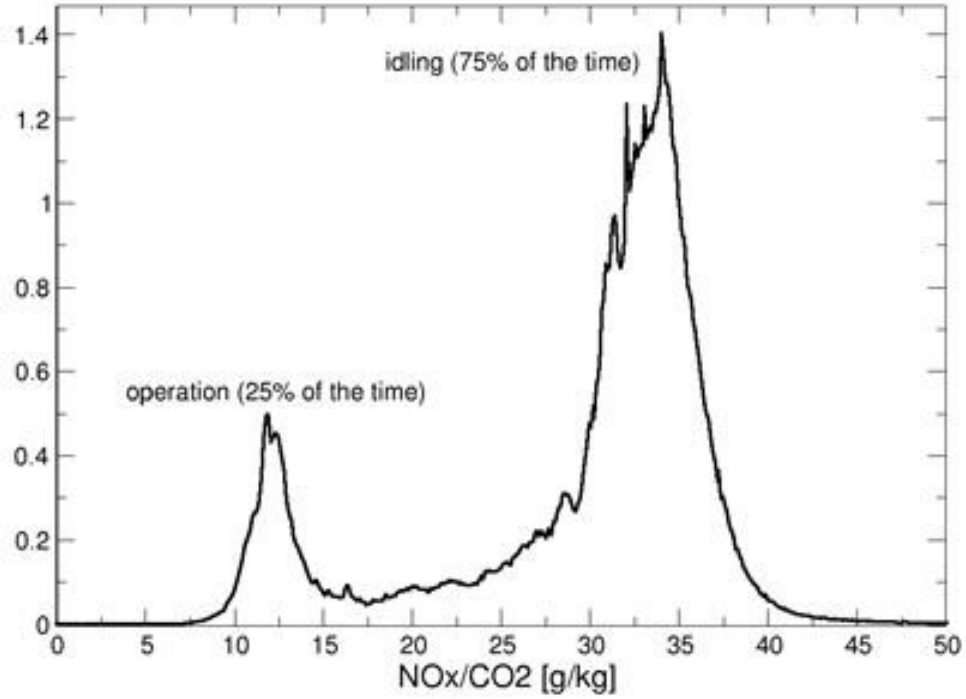
- Introduction
- SEMS measurement system
- Long term monitoring
  - PROMINENT inlet ships
  - Rail locomotive
- Conclusions

LOCOMOTIVE EMISSIONS MONITORING

Diesel locomotive:

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

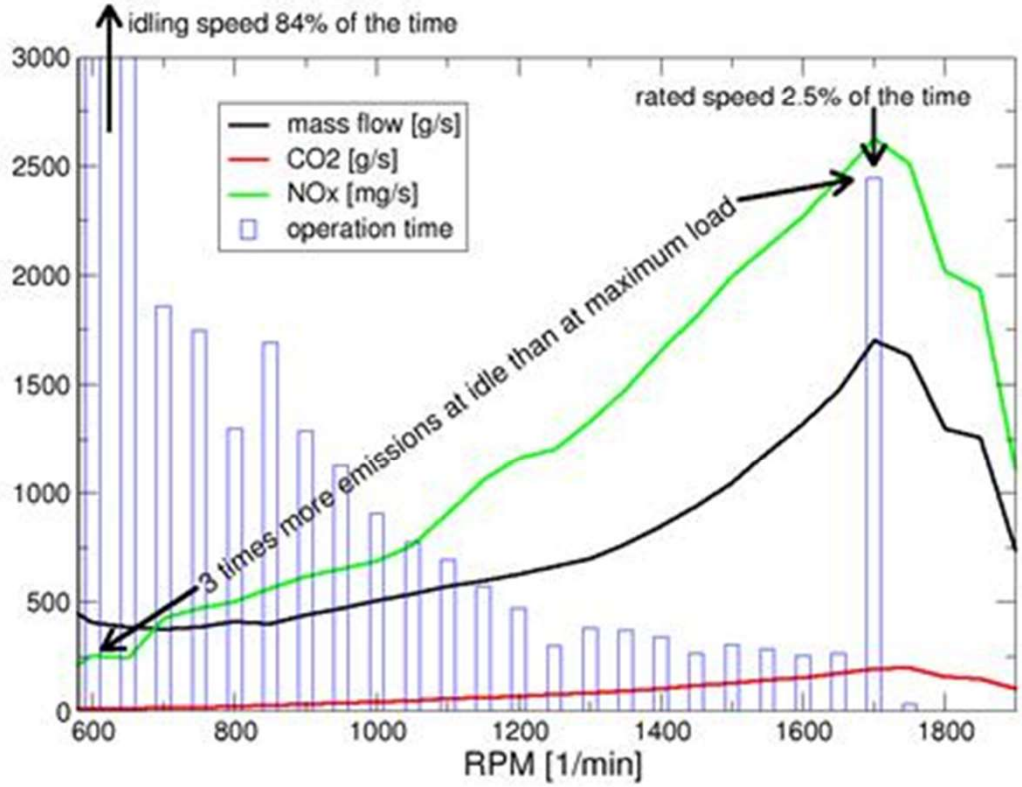
2nd Loc showed similar results but with 84% idle time (operation mostly around Rotterdam)



LOCOMOTIVE EMISSIONS MONITORING

NOx contribution at idle is ~ 50% of total NOx emissions

(three times more than at full power)



CONTENTS

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

CONCLUSIONS

- Real world (NOx) emissions can be factors higher than the emissions during a precisely defined ISC/ISM test. Reasons:
  - High share of idle and low load operation
  - Poor NOx control calibrations
- Continuous monitoring of emissions, such as with SEMS, is possible and useful for many purposes:
  - To find NOx calibration problems in day to day operation
  - To determine real-world emissions (with unrestricted conditions)
  - A cost efficient alternative to official PEMS measurements
- The total life span emissions may replace ISM / ISC testing in the future

THANK YOU FOR YOUR ATTENTION

- Contact:

- Ruud Verbeek
- TNO Sustainable Transport & Logistics
- Ruud.Verbeek@tno.nl
- Phone: +31 8886 68394 Cell phone +31 6 129 66882