AECC Technical Seminar on Emissions from Non-Road Mobile Machinery

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AECC NRMM & REC sub-group

AECC Test Program
Small Hand-held Equipment
Results

Brussels – 27 November 2012

Association for Emissions Control by Catalyst AISBL

Forschungsgesellschaft für
Verbrennungskraftmaschinen und
Thermodynamik mbH

Erratum note

(regarding PM measurements on small hand held machinery carried out by order of Association for Emissions Control by Catalyst AISBL in the period from Oct. 16th 2012 to Nov. 15th 2012)

The calculation of the absolutely emitted particulate mass based on the mass adherent to the filter plates shows a basic error. To be able to calculate the entire particulate mass, the overall volume through the dilution tunnel, as well as the partial flow over the filter plate is required.

The used CVS system records both volumes separately. The record of the overall volume being collected throughout an entire test is stopped after bag sampling time is over and is then automatically transferred to the data logging system.

To achieve sufficient deposits on the filter plates, the particulate mass sampling time had to be increased from 3 minutes (standard bag sampling time) to 10 minutes.

The automatic transfer of volume information derived from the bag sampling process (instead of the information from the particulate mass sampling process) led to a wrong dilution ratio which was used for the calculation of the overall particulate mass.

Since this calculation error is systematic and was not detected during the test campaign, all the results of particulate mass per volume, and kWh respectively, are incorrect. The effective PM values are by the factor 3.333 (10/3) higher than the previously published data. The relative relations between the different test carriers are not affected by this error.

Sincerely,

Ass.Prof. Dr. R. Kirchberger

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Association for Emissions Control by Catalyst (AECC) AISBL

AECC members: European emissions control companies

Technology for exhaust emissions control on all new cars (OEM and Aftermarket) and an increasing number of buses & commercial vehicles, non-road applications and motorcycles.

Content

- Introduction
- Test Plan and Selection of Engines
- Emissions Measurement
- Results
- Conclusions

Introduction

- Small hand-held equipment are regulated through the NRMM Directive 97/68/EC (chainsaws, leaf blowers, etc.)
- Contribution to air pollution inventory may not be predominant but occupational health is of primary concern with hand-held Non-Road Mobile Machinery.
- Objective of test program was to demonstrate emission levels of small hand-held state-of-the art equipment available in Europe, including low-cost import from Asia.

Test Plan and Selection of Engines

- Evaluate state-of-the-art engines used in SHH applications.
- Regulated pollutant (HC, CO, NOx) according to Directive 97/68/EC.
- PM mass and number according to LD-PMP protocol.
- PM size distribution by SMPS on engines N°2 and 3.

		Specifications		rpm		rpm certification	Mixture preparation	Oil/Fuel mixture ratio	Catalyst
1	4 stroke dry sump lubricated without catalyst	Engine displ. [cm^3] Power rating [kW]	25.0 0.74	max idle	11000 2800	7000	carburetor	separated lubrication 10W30	NO
2	4 stroke fuel/oil mixture lubricated without catalyst	Engine displ. [cm^3] Power rating [kW]	28.4 0.96	max idle	10200 2800	8000	carburetor	synthetic oil 1:50	NO
3	2 stroke fuel/oil mixture lubricated with catalyst	Engine displ. [cm^3] Power rating [kW]	22.0 0.62	max idle	9000 2800	7900	carburetor	synthetic oil 1:50	wiremesh catalyst
4	2 stroke fuel/oil mixture lubricated with catalyst	Engine displ. [cm^3] Power rating [kW]	45 1.41	max idle	8000 2800	8000	carburetor	synthetic oil 1:50 mineral oil 1:40	wiremesh catalyst
5	2 stroke fuel/oil mixture lubricated stratified scavening without catalyst	Engine displ. [cm^3] Power rating [kW]	59.0 3.4	max idle	13000 2800	10000	carburetor	synthetic oil 1:50	NO
6	2 stroke fuel/oil mixture lubricated fuel injection system without catalyst	Engine displ. [cm^3] Power rating[kW]	72.2 4.03	max idle	10100 2500	9500	fuel injection	synthetic oil 1:50	NO

Directive 97/68/EC as amended

Class/category	Displacement (cubic cm)
Hand-held engines Class SH:1	< 20
Class SH:2	≥ 20 < 50
Class SH:3	≥ 50
Non-hand-held engines Class SN:1	< 66
Class SN:2	≥ 66 < 100
Class SN:3	≥ 100 < 225
Class SN:4	≥ 225

1 2 3 4 5 6

4. TYPE-APPROVALS STAGE II

Member States shall refuse to grant type-approval for an engine type or engine family and to issue the documents as described in Annex VII, and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine is installed:

after 1 August 2004 for engine classes SN:1 and SN:2

after 1 August 2006 for engine class SN:4

after 1 August 2007 for engine classes SH:1, SH:2 and SN:3

after 1 August 2008 for engine class SH:3,

if the engine fails to meet the requirements specified in this Directive and where the emissions of gaseous pollutants from the engine do not comply with the limit values as set out in the table in section 4.2.1.1 of

Notwithstanding the first subparagraph, an extension of the derogation period is granted until 31 July 2013, within the category of top handle machines, for professional use, multi-positional, hand-held hedge trimmers and top handle tree service chainsaws in which engines of classes SH:2 and SH:3 are installed.

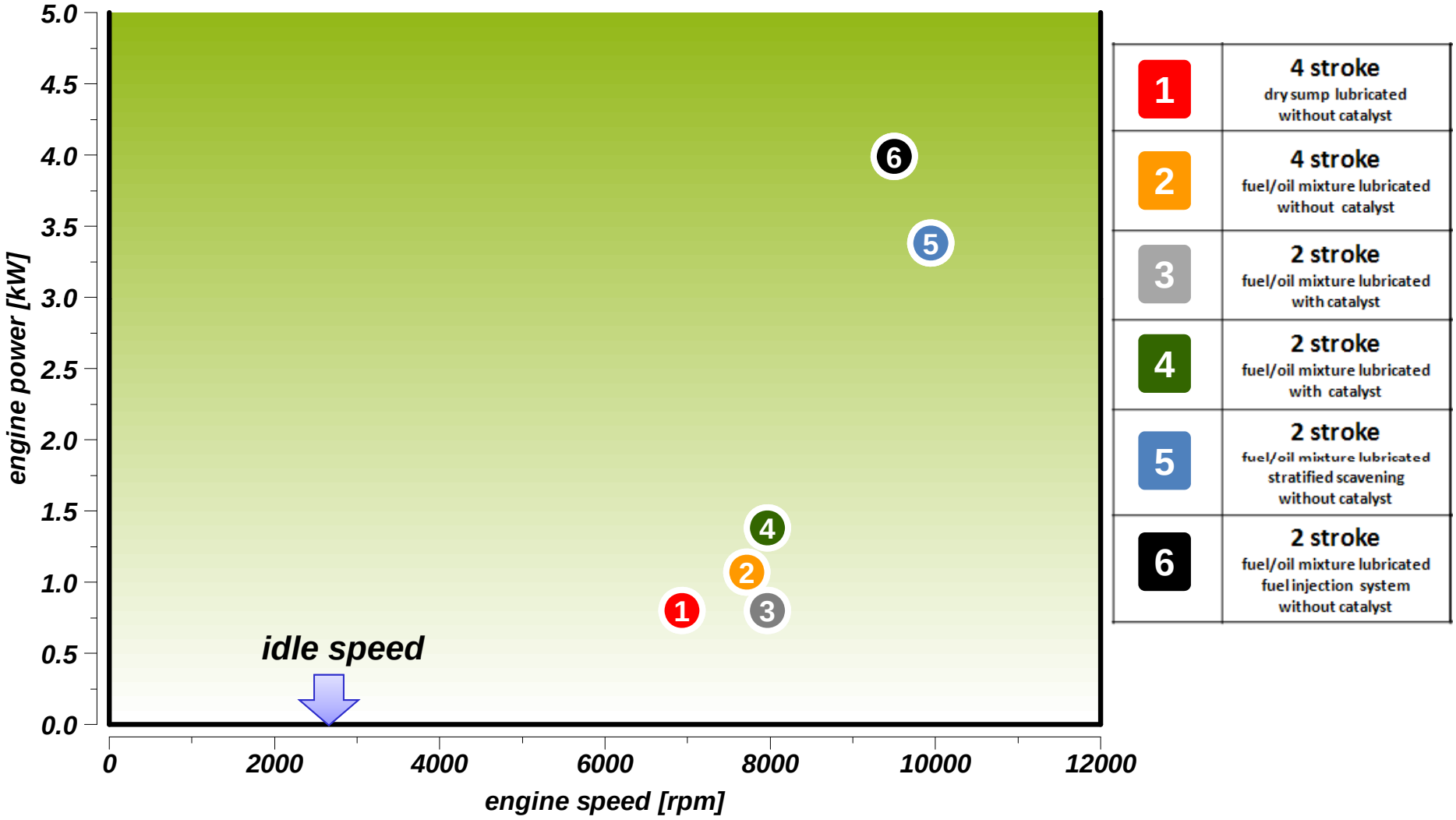
Stage II (*)		
Class	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (g/kWh)
		HC + NO_x
SH:1	805	50
SH:2	805	50
SH:3	603	72
SN:1	610	50,0
SN:2	610	40,0
SN:3	610	16,1
SN:4	610	12,1

(*) See Annex 4, Appendix 4: deterioration factors included.

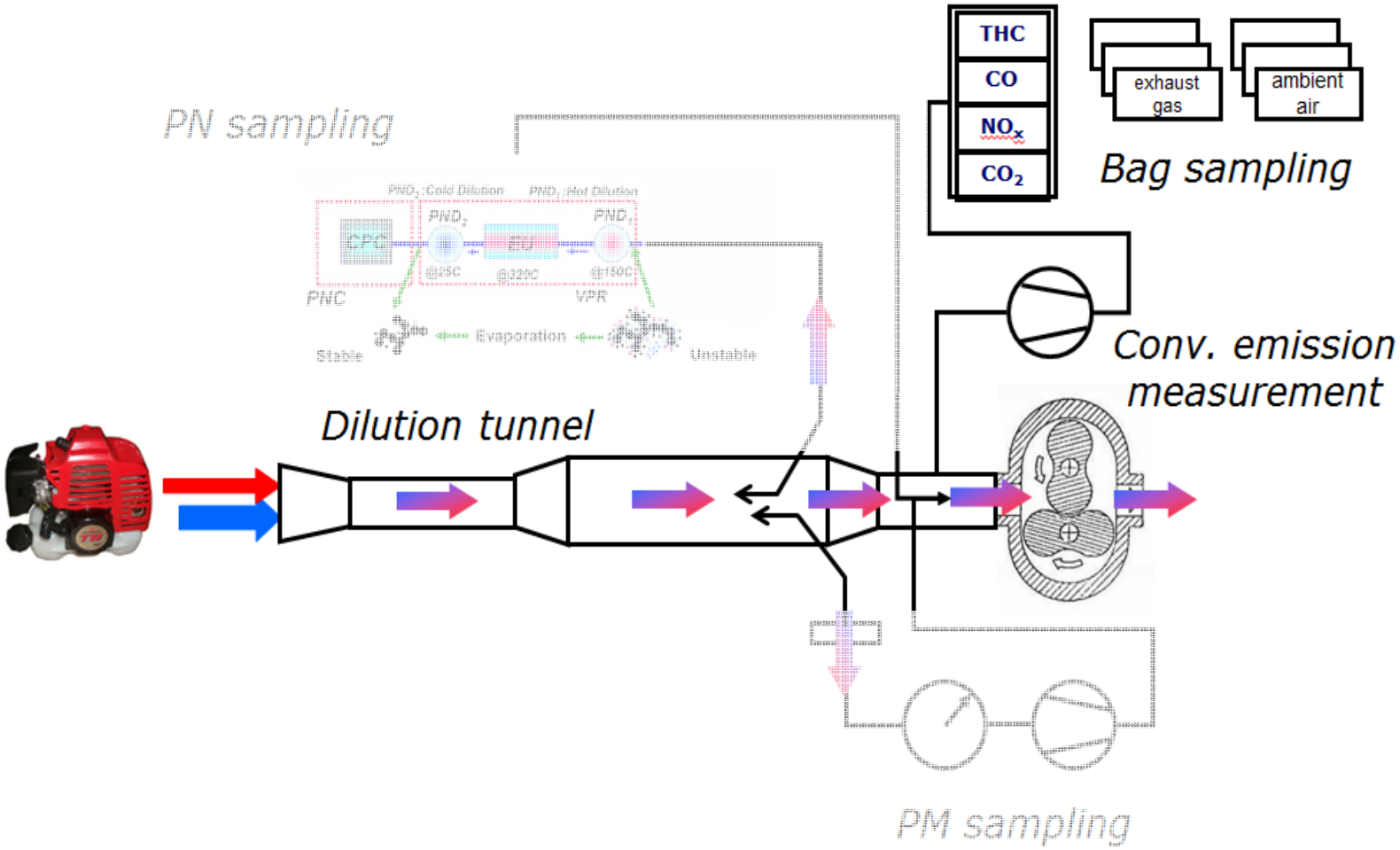
The NO_x emissions for all engine classes must not exceed 10 g/kWh.

Cycle G3											
Mode number	1										2
Engine speed	Rated speed					Intermediate Speed					Low-idle speed
Load %	100										0
Weighting factor	0,85 (*)										0,15 (*)

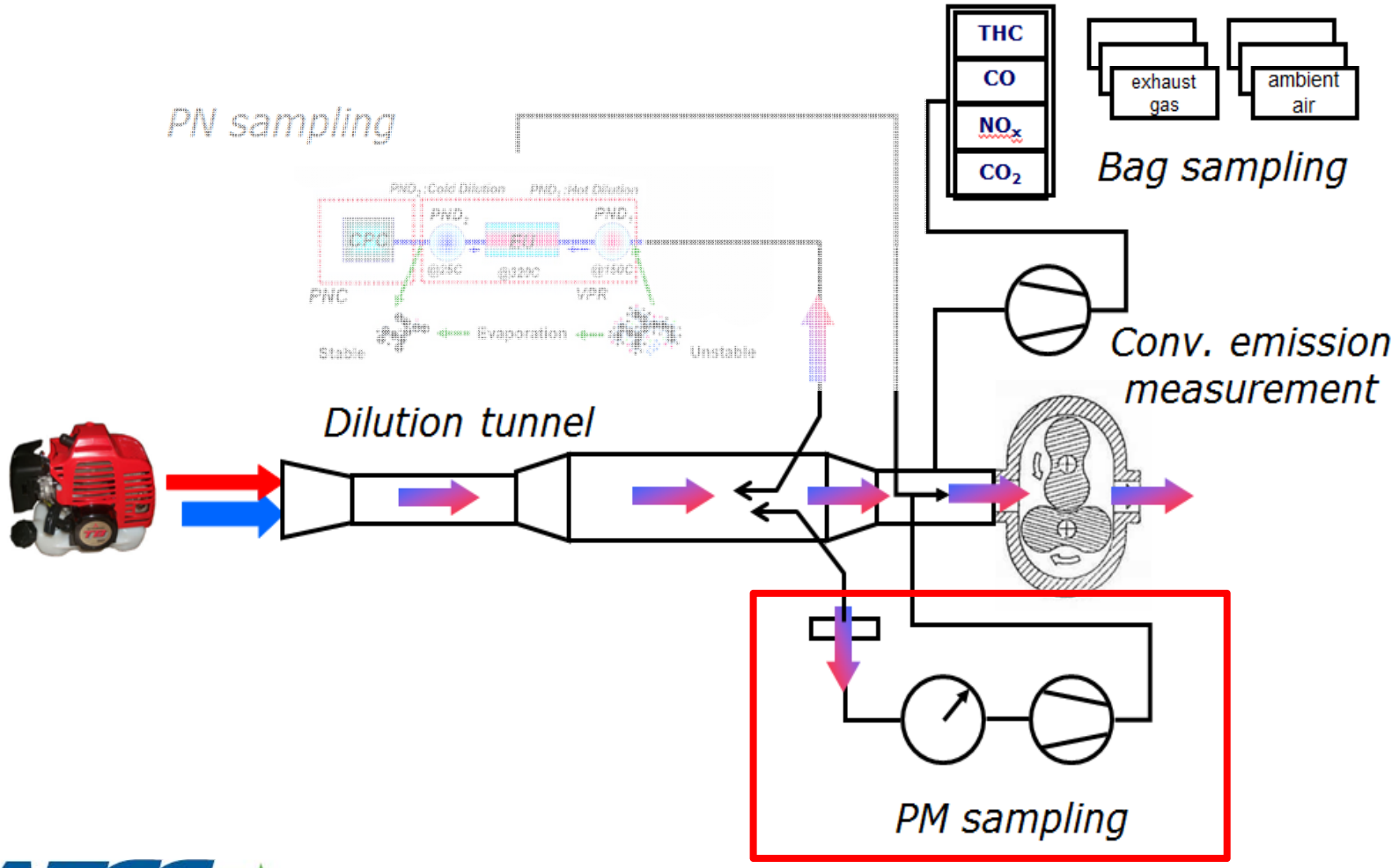
Engine Power at Rated Speed



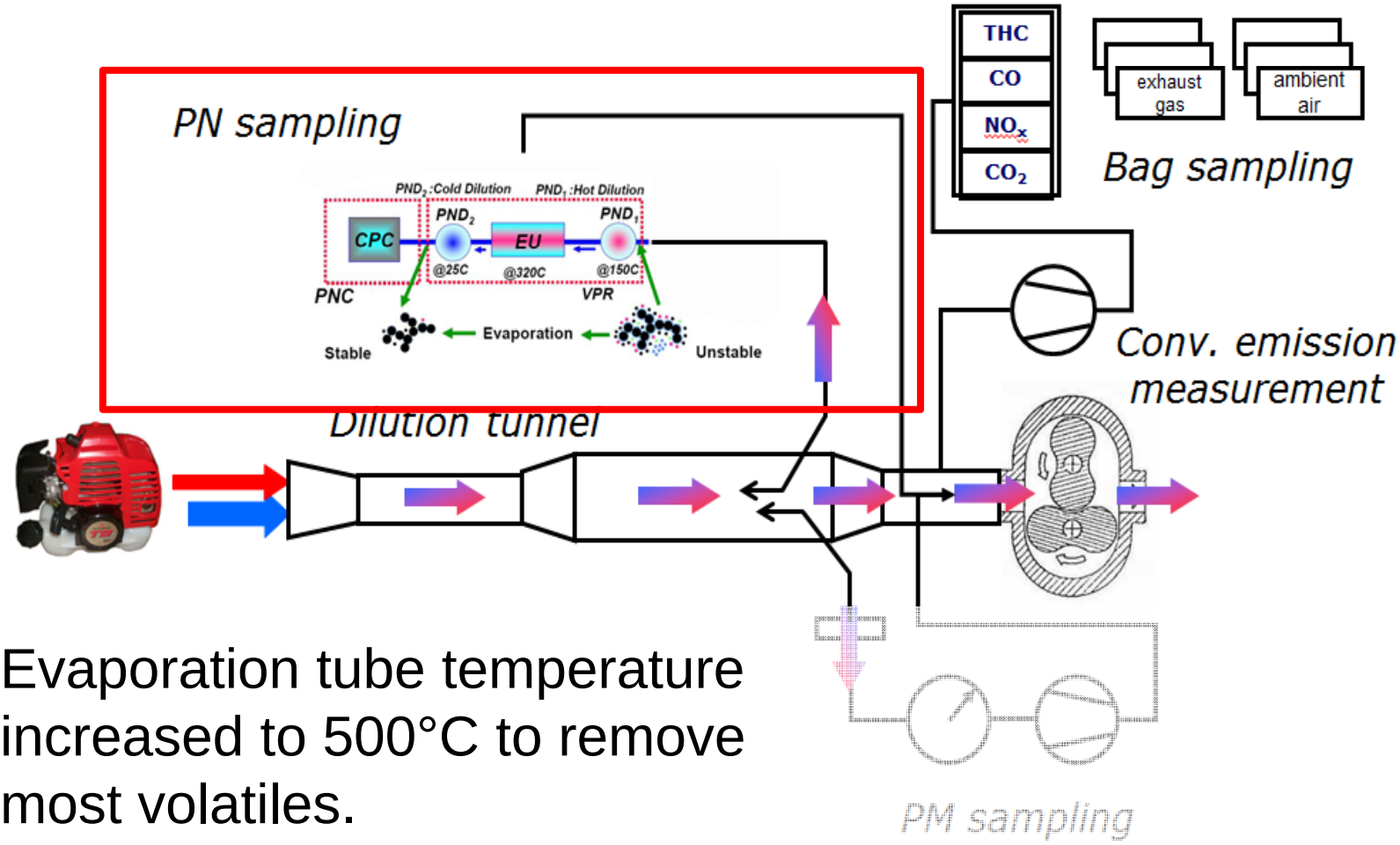
Open Constant Volume Sampling



Open Constant Volume Sampling



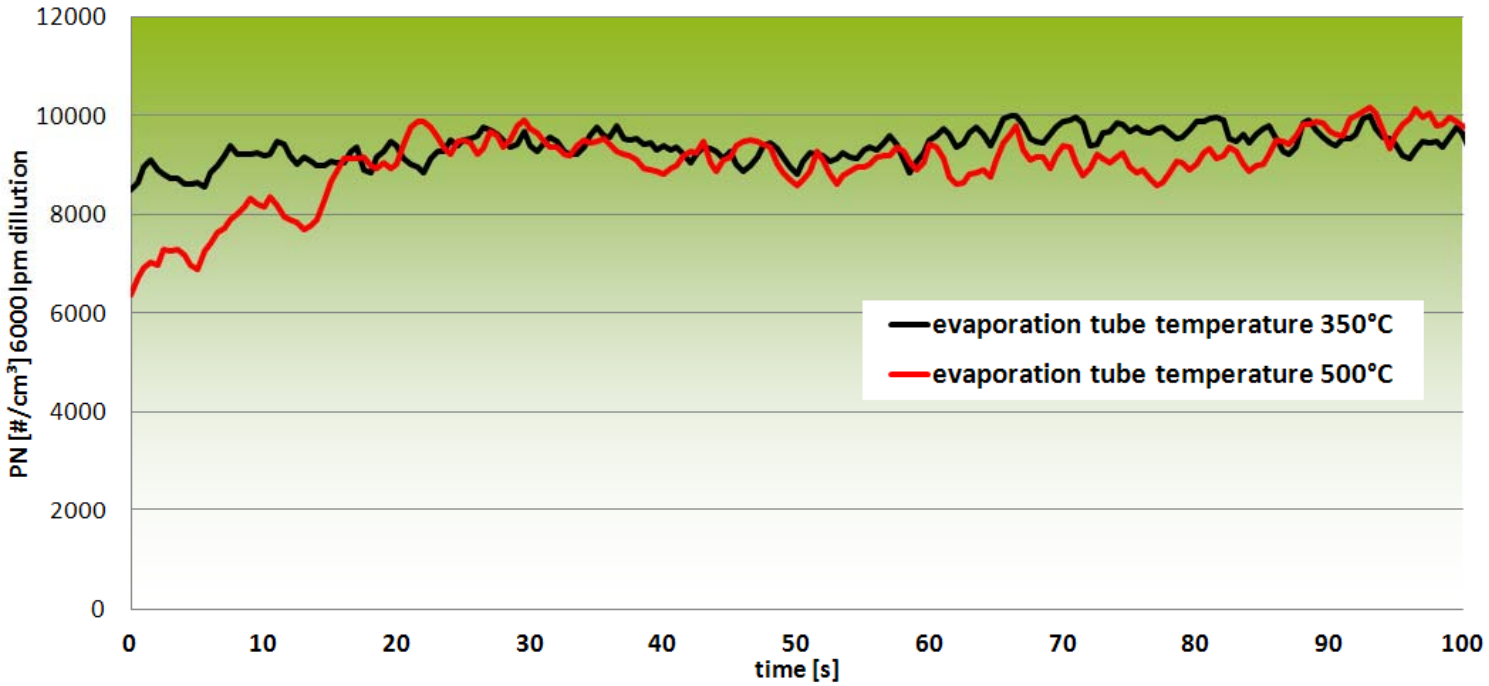
Open Constant Volume Sampling



- Evaporation tube temperature increased to 500°C to remove most volatiles.

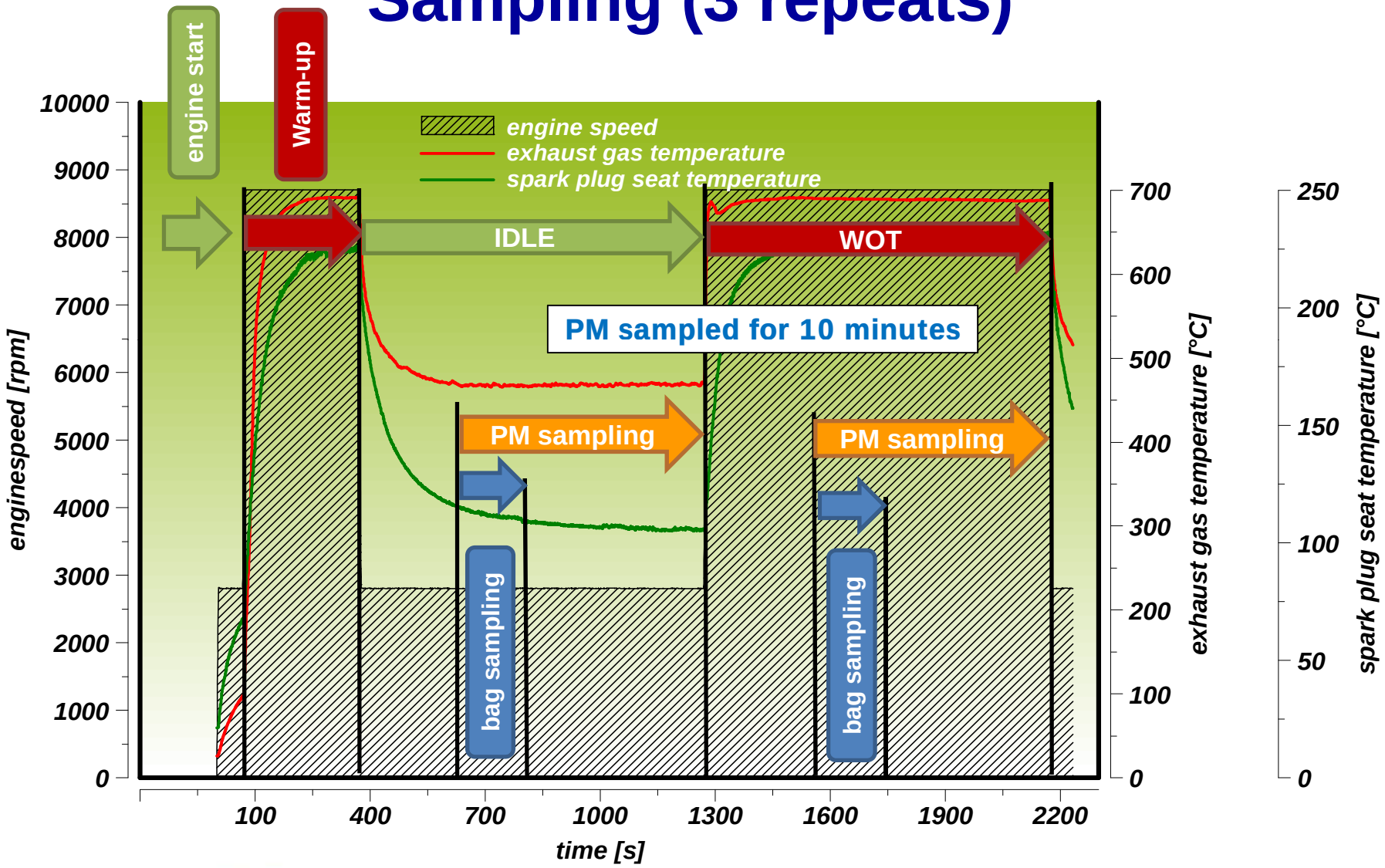
Evaporation Tube Temperature Impact

- Because of high quantity of volatiles adsorbed to PM, the PM number was measured in 2 configurations of the evaporation tube: 350°C (LD-PMP procedure) and 500°C.
- Gas temperature was 220°C and 300°C respectively

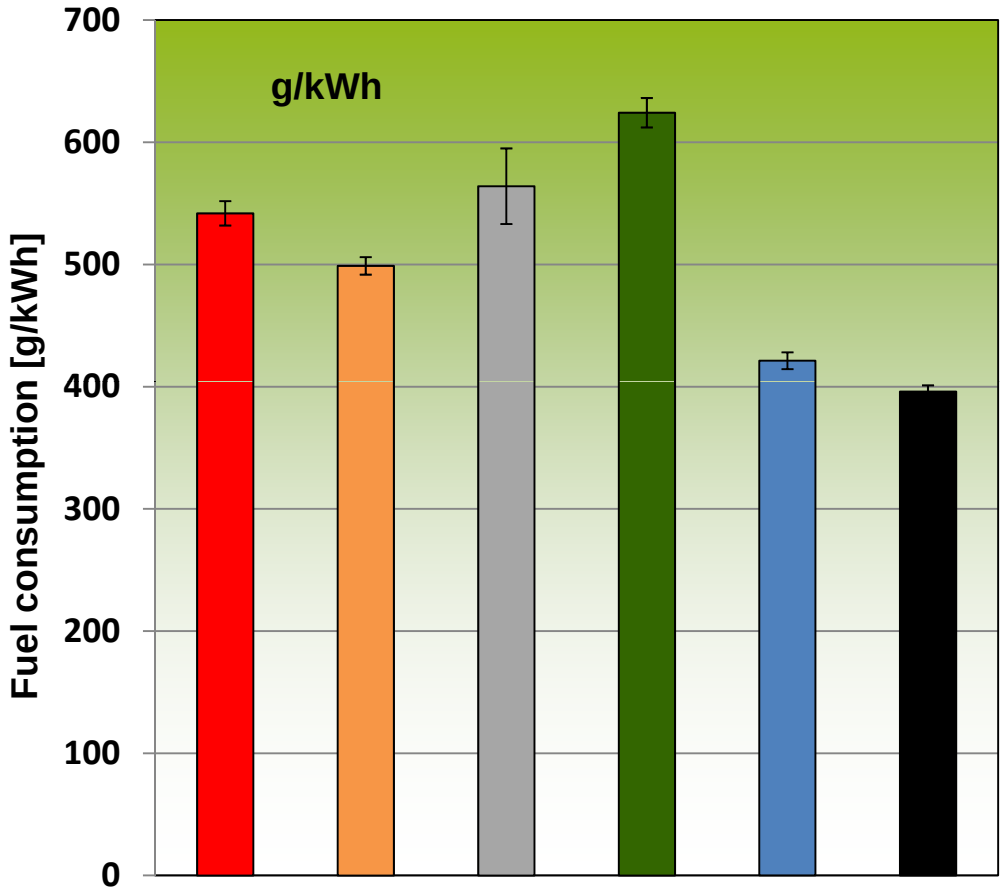


- No impact on PM number measured.

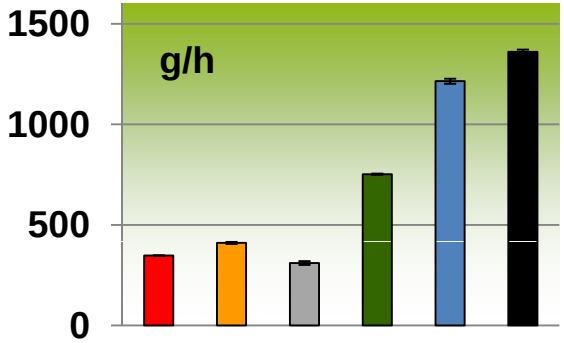
Measurement Procedure adapted for PM Sampling (3 repeats)



Tests Results: Fuel Consumption



1	**4 stroke** dry sump lubricated without catalyst
2	**4 stroke** fuel/oil mixture lubricated without catalyst
3	**2 stroke** fuel/oil mixture lubricated with catalyst
4	**2 stroke** fuel/oil mixture lubricated with catalyst
5	**2 stroke** fuel/oil mixture lubricated stratified scavening without catalyst
6	**2 stroke** fuel/oil mixture lubricated fuel injection system without catalyst



Tests Results: calculated Air-Fuel Ratio

- All engines run rich, between 0.7 and 0.9.
- A/F ratio of the low-cost engine is the richer and the less controlled (larger error bar).

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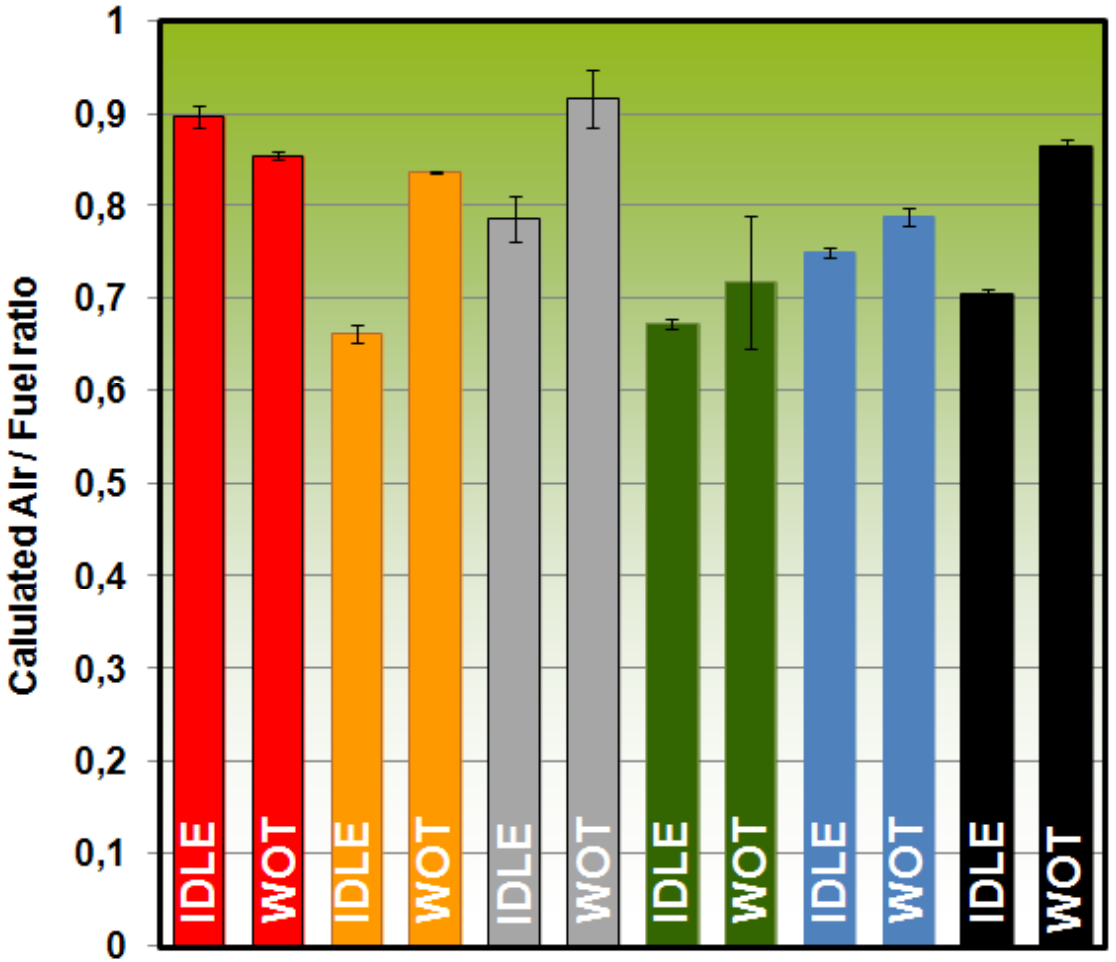
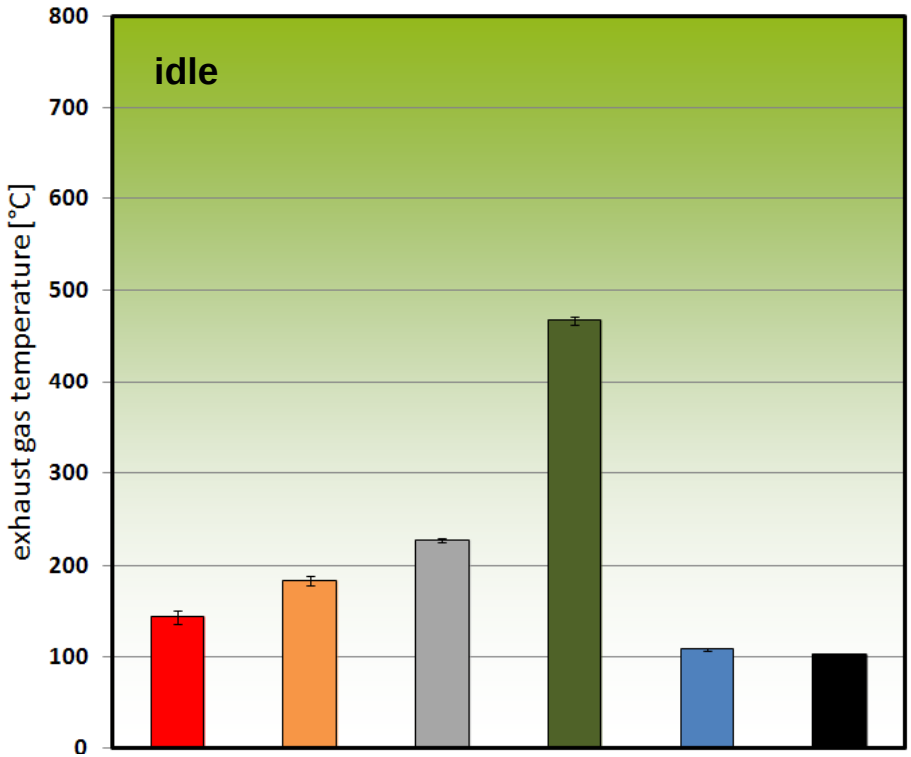
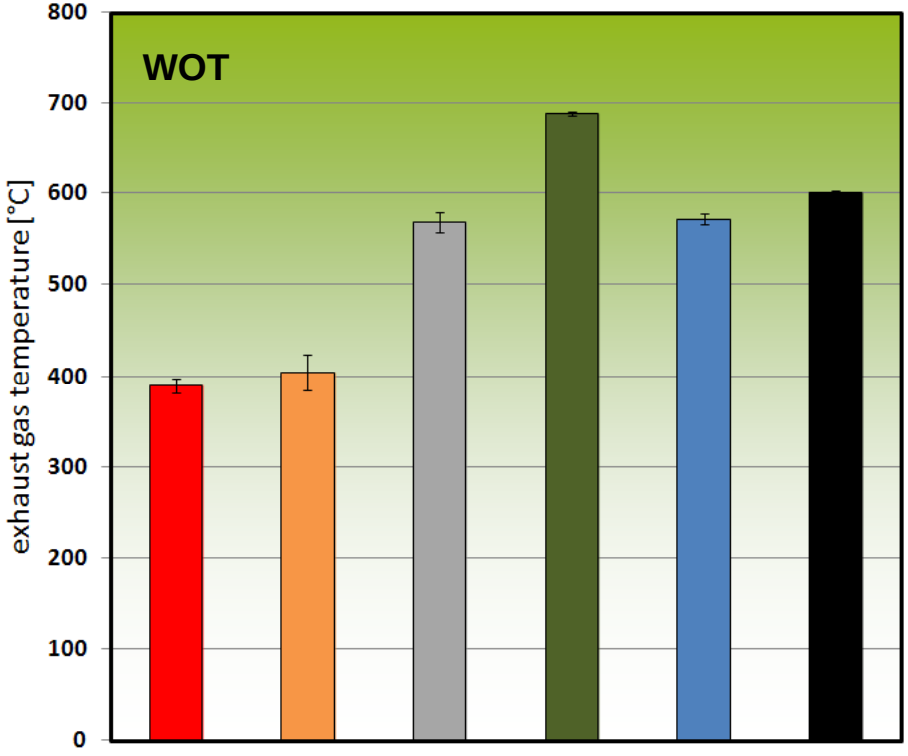


Tests Results: Exhaust Gas Temperature





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3	2 stroke fuel/oil mixture lubricated with catalyst
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5	2 stroke fuel/oil mixture lubricated stratified scavening without catalyst
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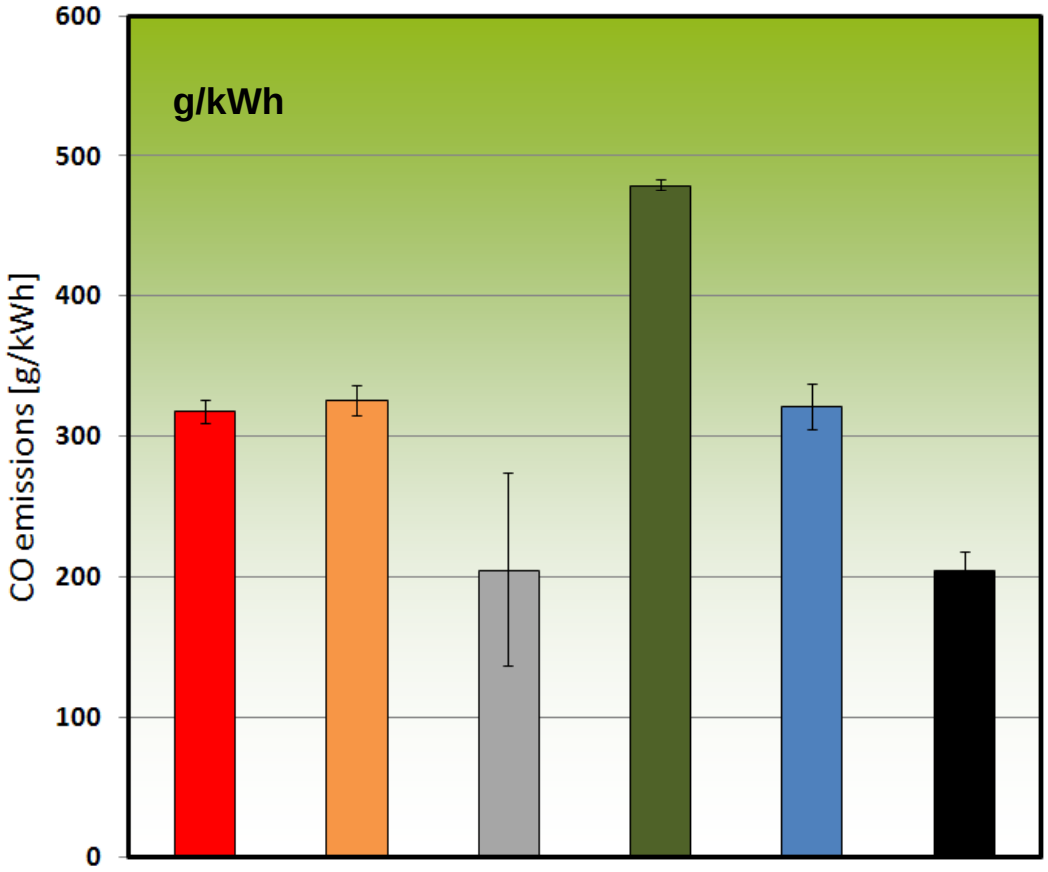
Tests Results: CO Emissions



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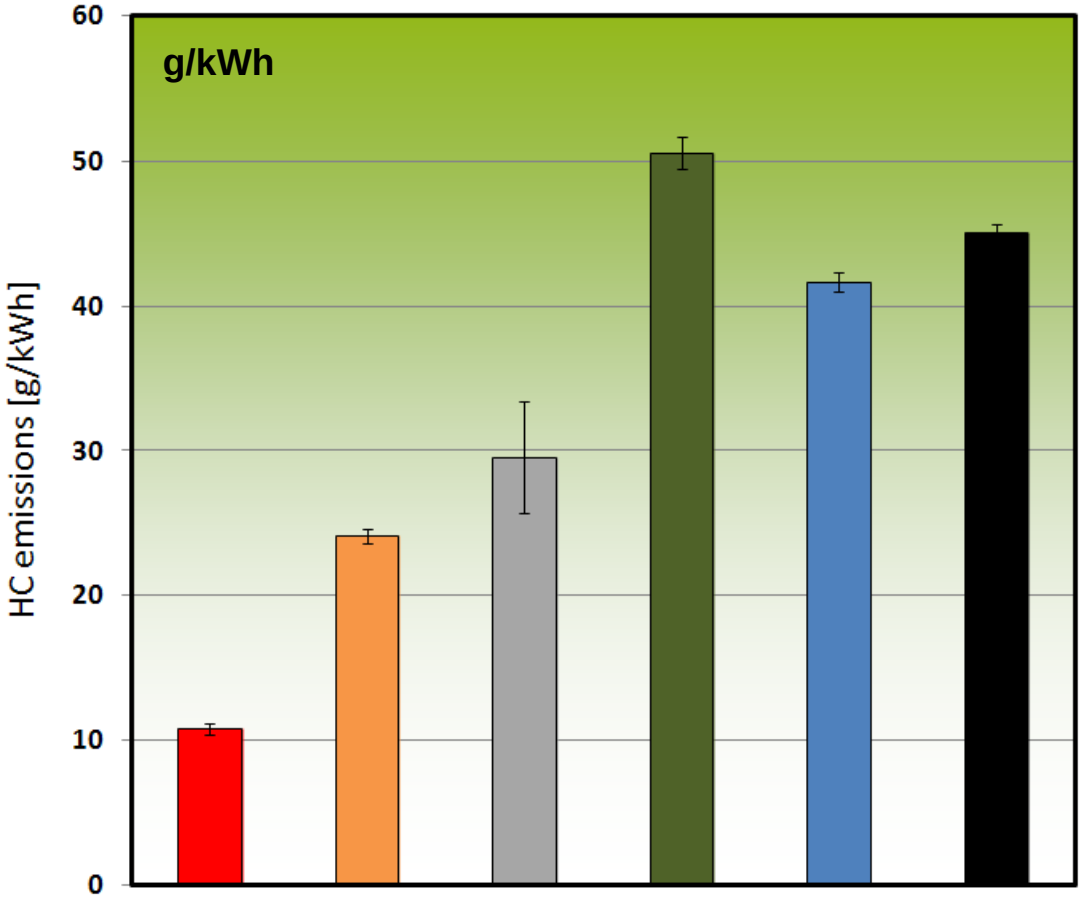
6	**2 stroke** fuel/oil mixture lubricated fuel injection system without catalyst

- CO emissions are of similarly high level for most engines.
- The low-cost engine emitted the highest CO emissions.
- 2S fuel injection showed reduced CO emissions

Tests Results: HC Emissions



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5	**2 stroke** fuel/oil mixture lubricated stratified scavening without catalyst
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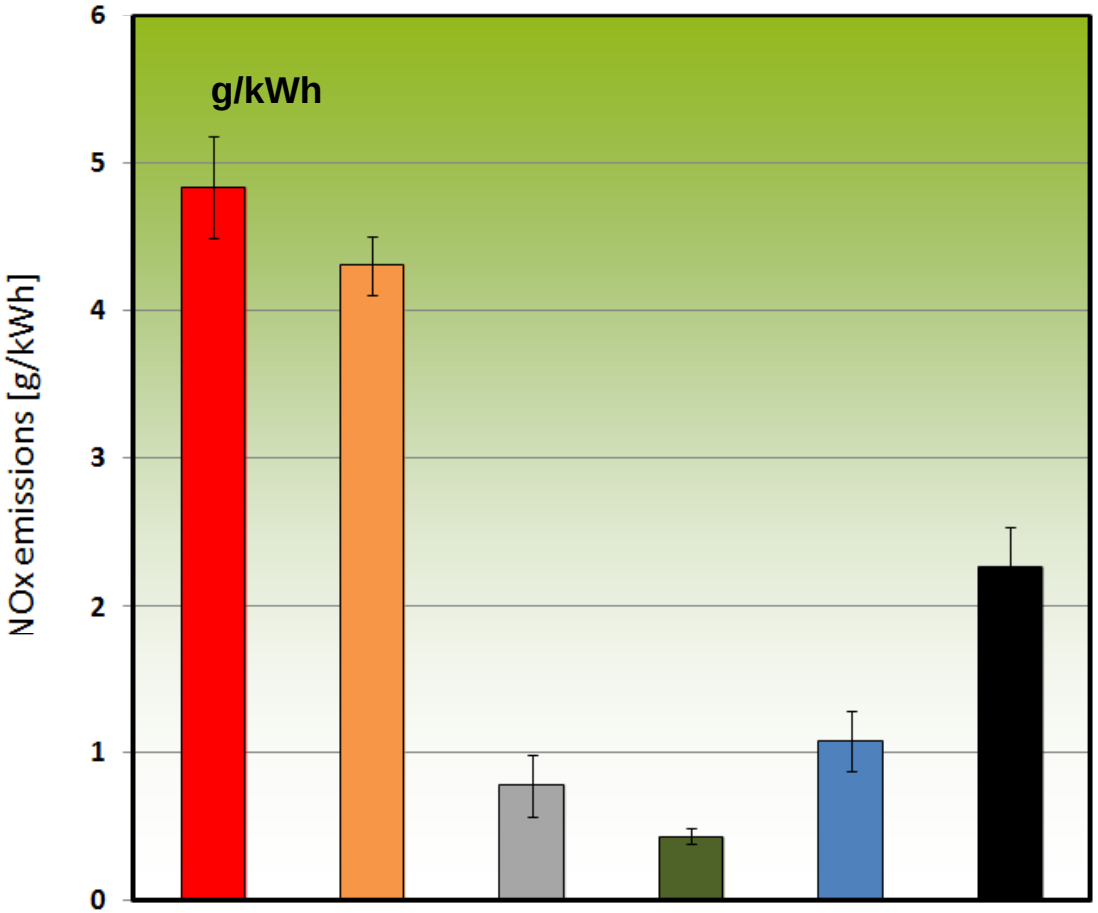
- HC emissions are lower for 4S engines than for 2S.
- The catalyst reduced HC emissions on 2S engine.

Tests Results: NOx Emissions



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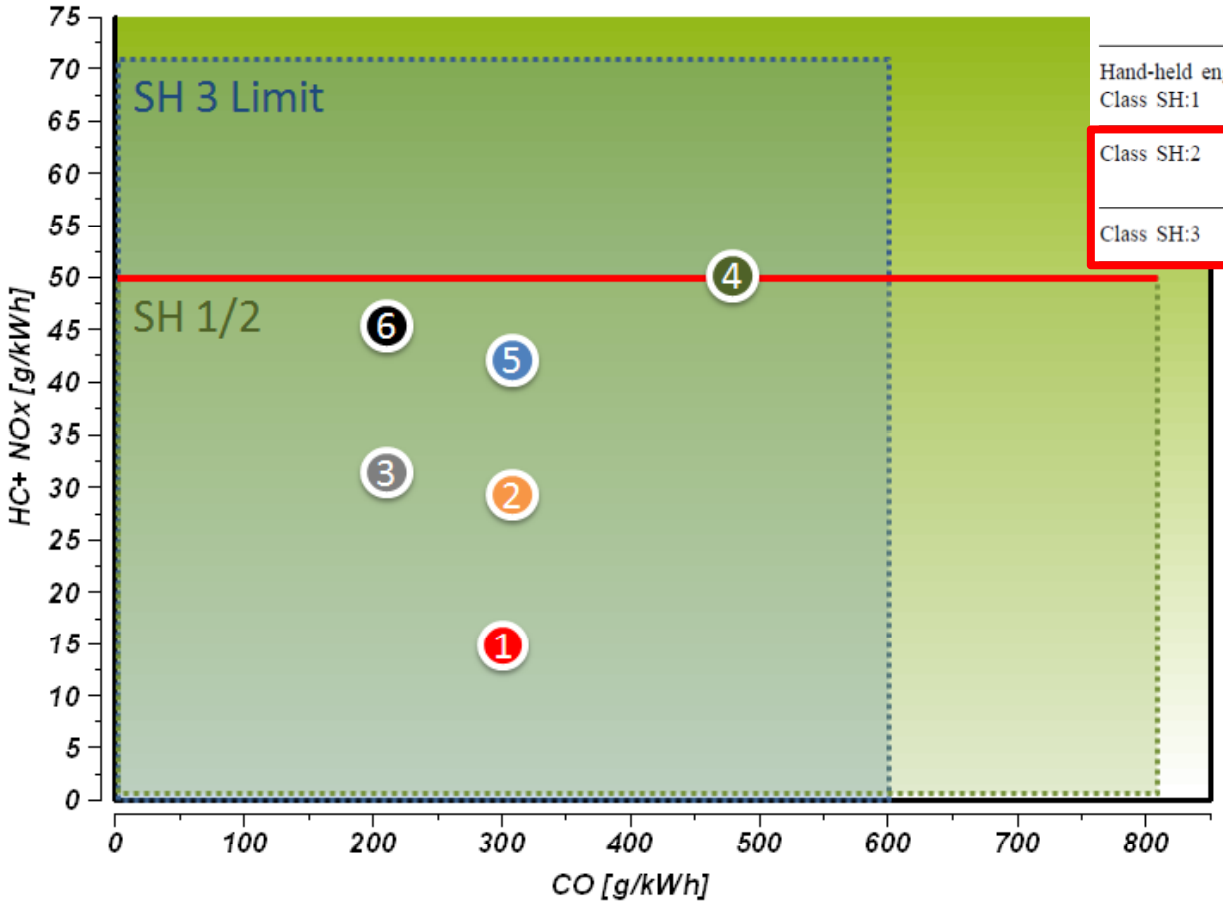
6	**2 stroke** fuel/oil mixture lubricated fuel injection system without catalyst

- NOx emissions are lower for 2S engines than for 4S.
- NOx emissions contribute relatively little to regulated HC+NOx (from 1 to 30%)

Tests Results: Emissions vs. Stage II Limits



Class/category	Displacement (cubic cm)
Hand-held engines Class SH:1	< 20
Class SH:2	≥ 20 < 50
Class SH:3	≥ 50

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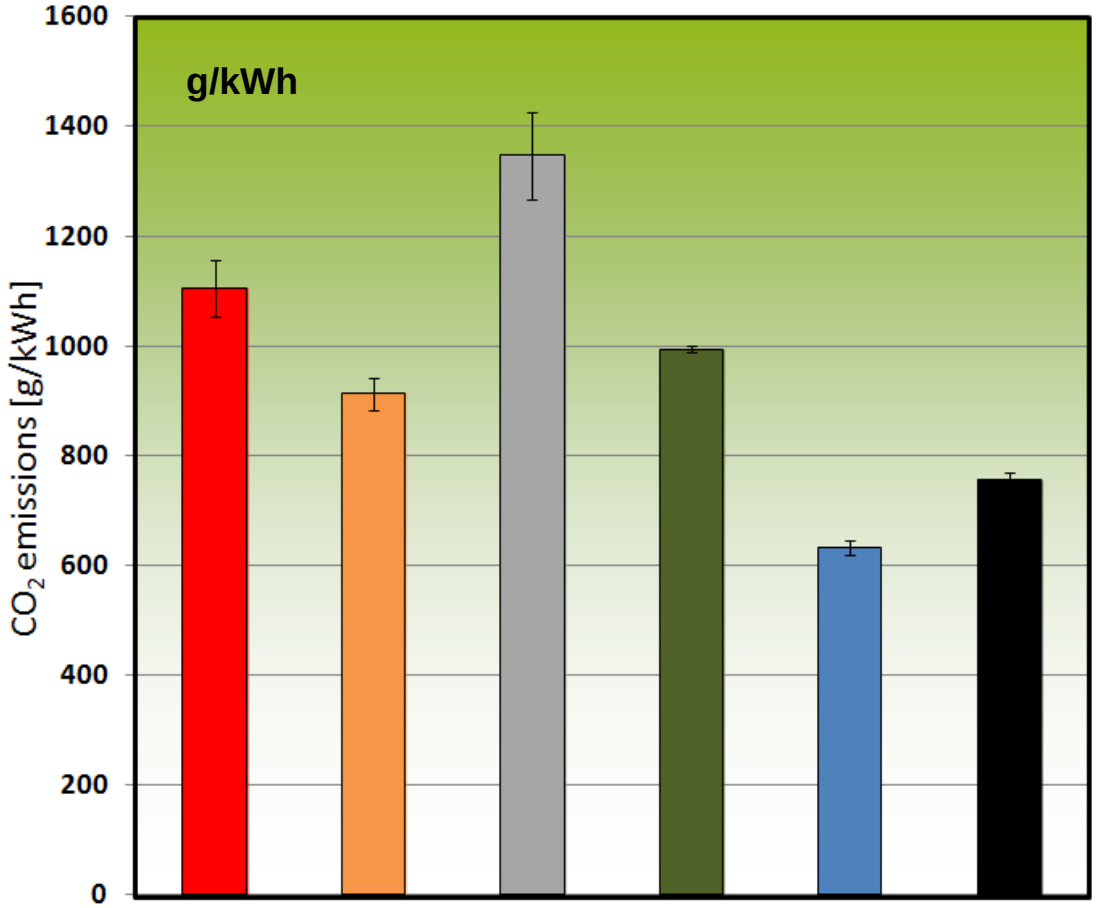
- All engines met Stage II emissions limits but the low-cost model (N°4) is at the limit.

Tests Results: CO_2 Emissions



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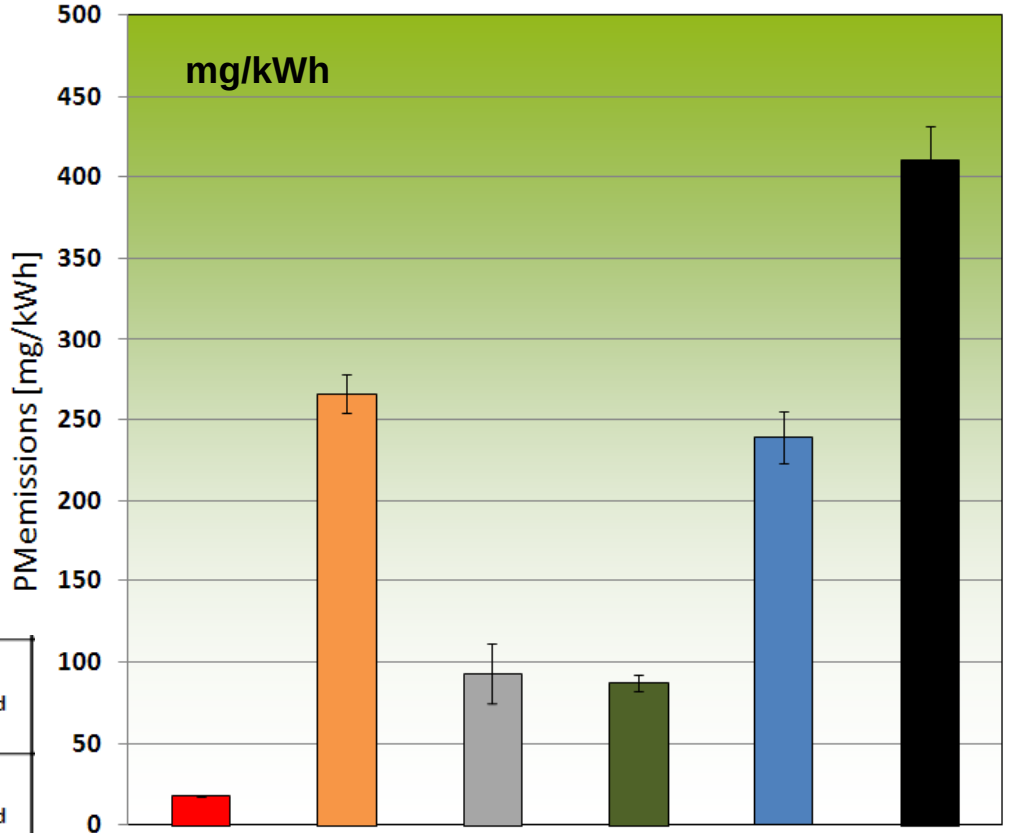
6	**2 stroke** fuel/oil mixture lubricated fuel injection system without catalyst

- CO_2 emissions of engine N°3 are higher because of CO conversion by catalyst

Tests Results: PM Mass Emissions

- PM mass results are repeatable.
- PM mass level depends on engine working principle.
- PM vary from 18 to 410mg/kWh.
- Presence of catalyst on 2S engine reduces PM mass.



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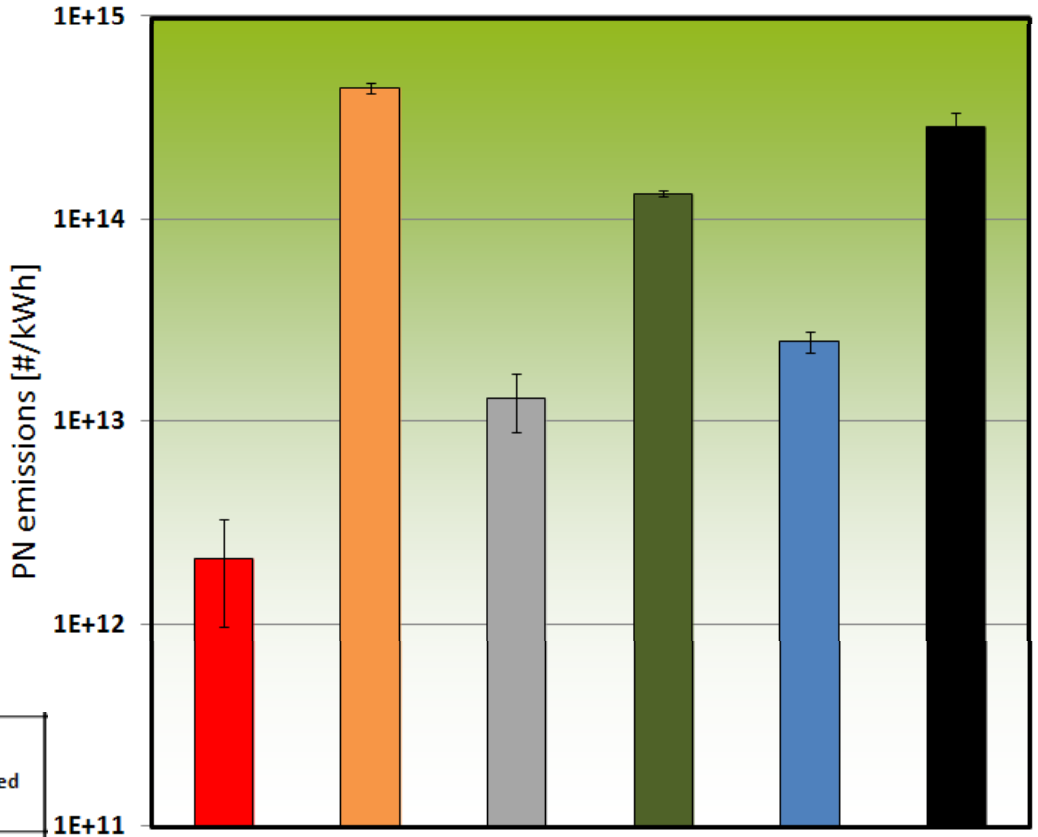
6	**2 stroke** fuel/oil mixture lubricated fuel injection system without catalyst

Tests Results: PM Number Emissions

- PN vary from $2x10^{12}$ to $5x10^{14}$/kWh.
- PN emissions level depends on engine working principle.
- PN levels are of the order of magnitude of non-DPF equipped diesel engines.
- Presence of catalyst on 2S engine reduces PN.



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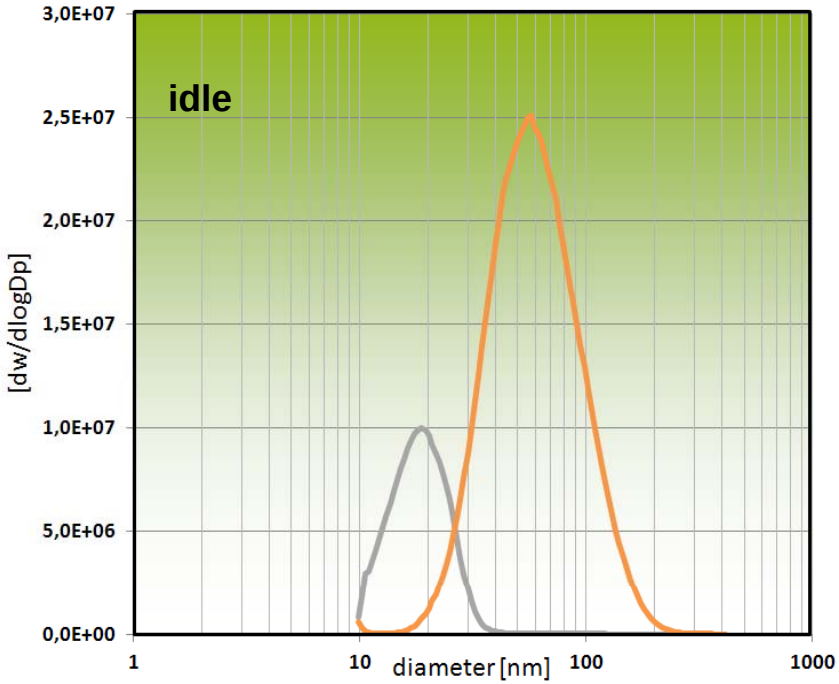
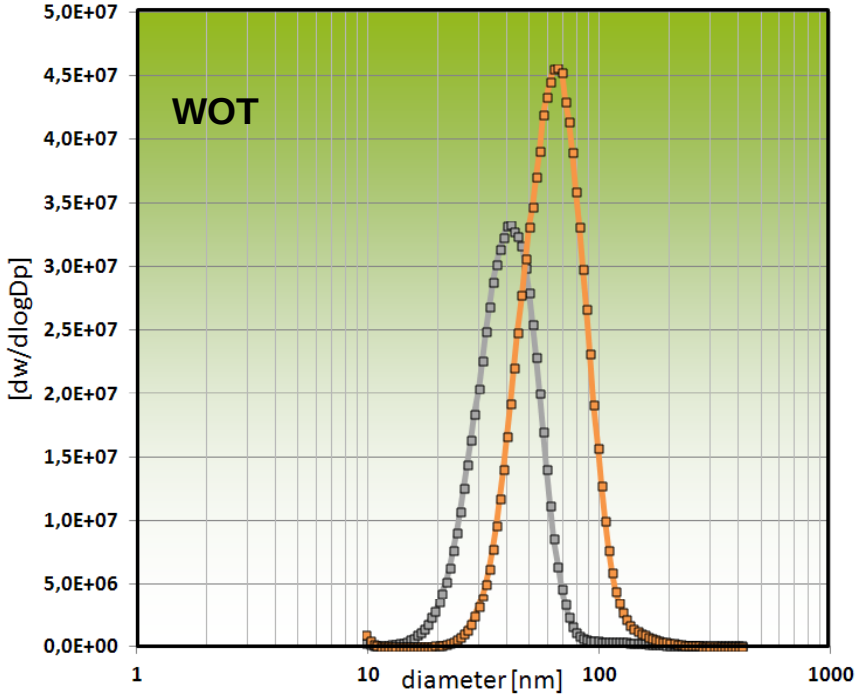
PM Size Distribution

- Size distribution of PM emissions from engines N°2 and 3 were evaluated with an SMPS. PM were sampled directly from the CVS.



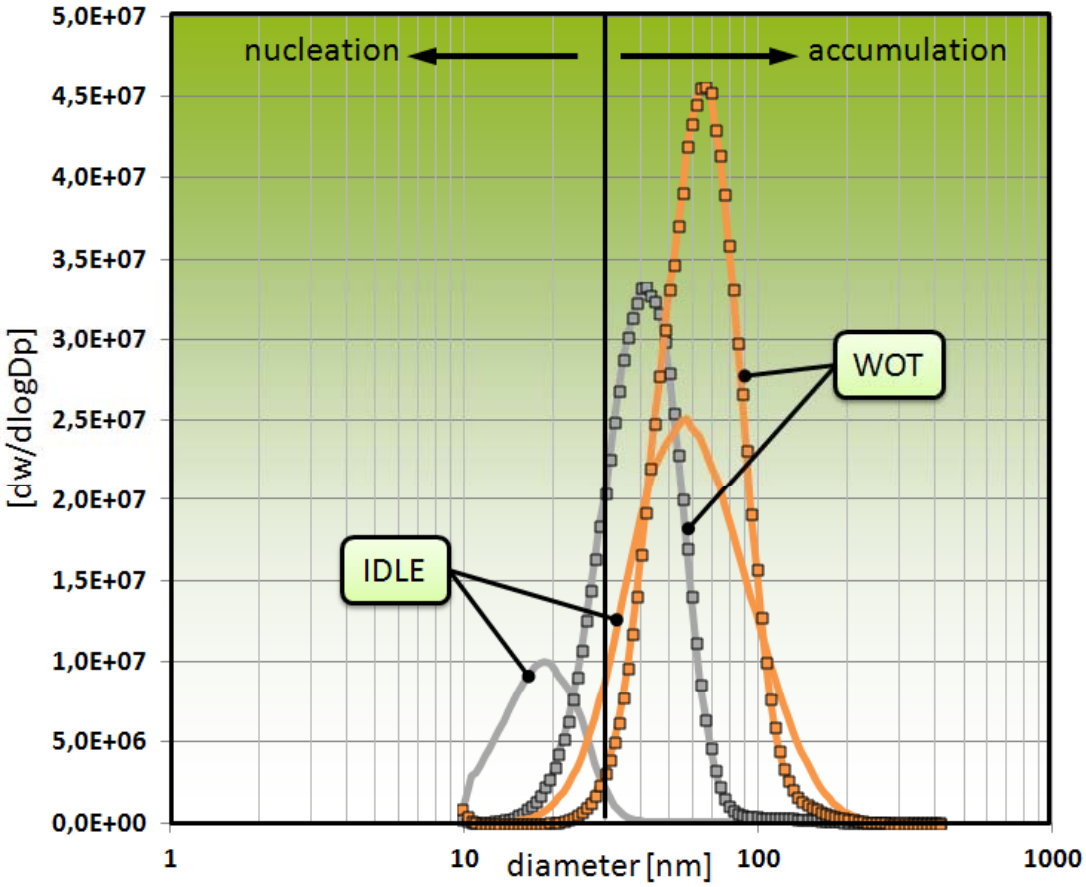


2	**4 stroke** fuel/oil mixture lubricated without catalyst
3	**2 stroke** fuel/oil mixture lubricated with catalyst

PM Size Distribution

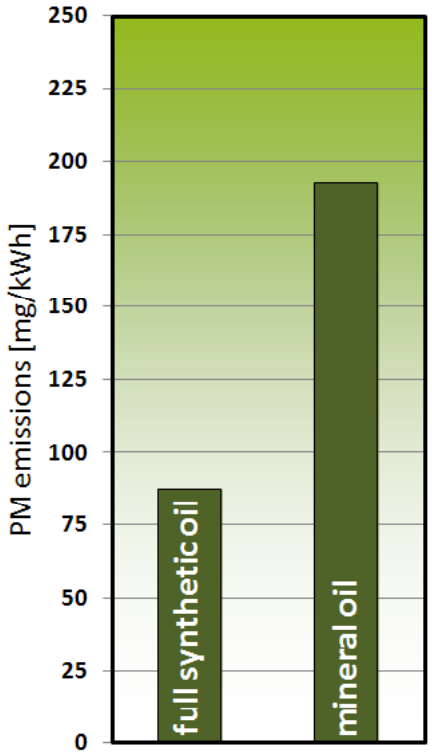
- Particles emitted at idle are smaller than those emitted at full load.
- There is no clear evidence if the difference in mean particle size is based on the different combustion process or on the oxidation of SOF by the catalyst

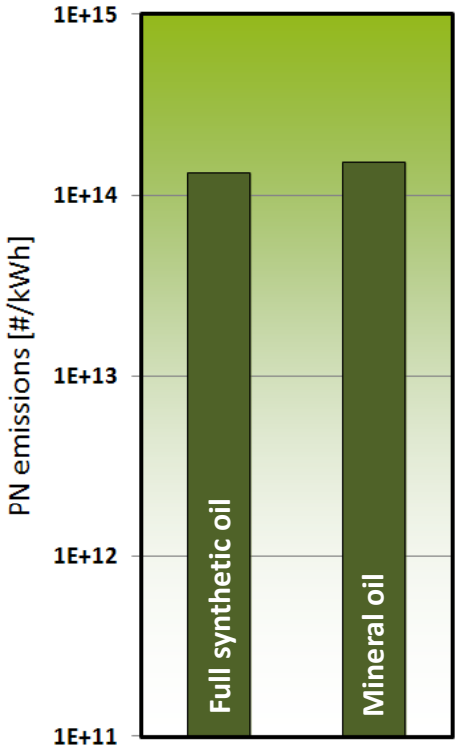
2	**4 stroke** fuel/oil mixture lubricated without catalyst
3	**2 stroke** fuel/oil mixture lubricated with catalyst



Effect of Oil on PM/PN Emissions

- The low-cost 2S engine was tested also with mineral oil (OEM recommendation).
- Compared to synthetic oil, PM mass doubled but PM number was stable when mineral oil was used.



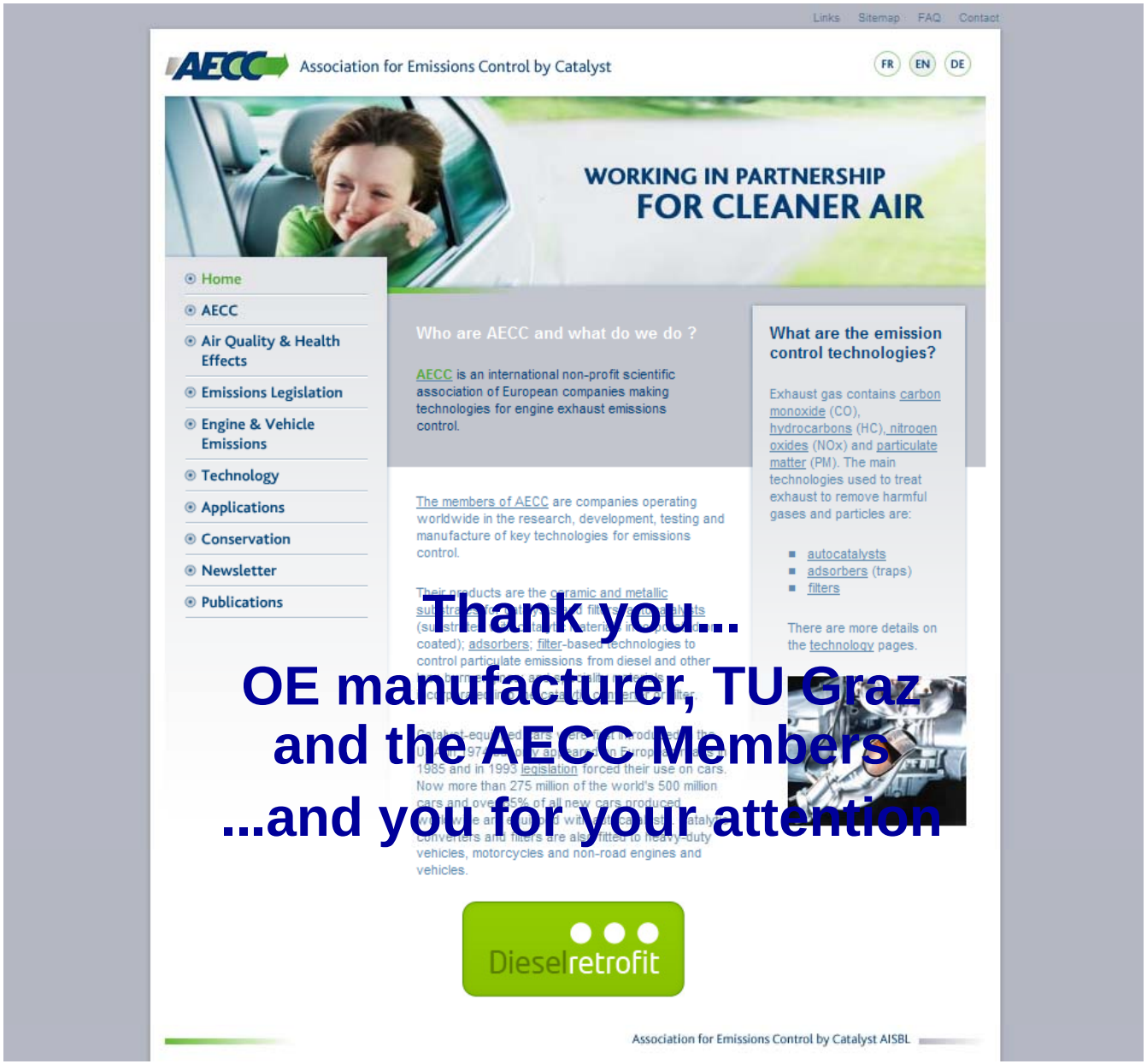


Conclusions I

- 6 state-of-the-art engines of Small Hand-Held equipment available in EU have been evaluated.
- All engines met the Stage II emissions limits with some margin except for the low-cost product that was borderline after 3h of degreening.
- Regulated emissions do not directly relate to engine technology and combustion principle (2-stroke vs. 4-stroke).
- Stage II emissions levels can be reached without catalyst. Catalysts can help reduce further HC and CO emissions.

Conclusions II

- Adapted emissions measurement method provided repeatable results also for PM mass and number.
- EC/OC analysis of sampled PM still underway.
- PM and PN emissions depend on working principle and on lubrication method and oil quality.
- The use of catalyst can help reducing PM and PN emissions.
- PM mass and number were high due to the rich operation of the engines. Results were equivalent or higher than for typical diesel engines without DPF.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Who are AECC and what do we do ?
AECC is an international non-profit scientific association of European companies making technologies for engine exhaust emissions control.
The members of AECC are companies operating worldwide in the research, development, testing and manufacture of key technologies for emissions control.
What are the emission control technologies?
Exhaust gas contains carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM). The main technologies used to treat exhaust to remove harmful gases and particles are:
autocatalysts
adsorbers (traps)
filters
There are more details on the technology pages.
Thank you...
OE manufacturer, TU Graz
and the AECC Members
...and you for your attention
Dieselretrofit
Association for Emissions Control by Catalyst AISBL