UFP and Black Carbon Emissions from Real World Wood Stoves without and with Electrostatic Precipitators

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What is the Problem with UFP from Wood Stoves

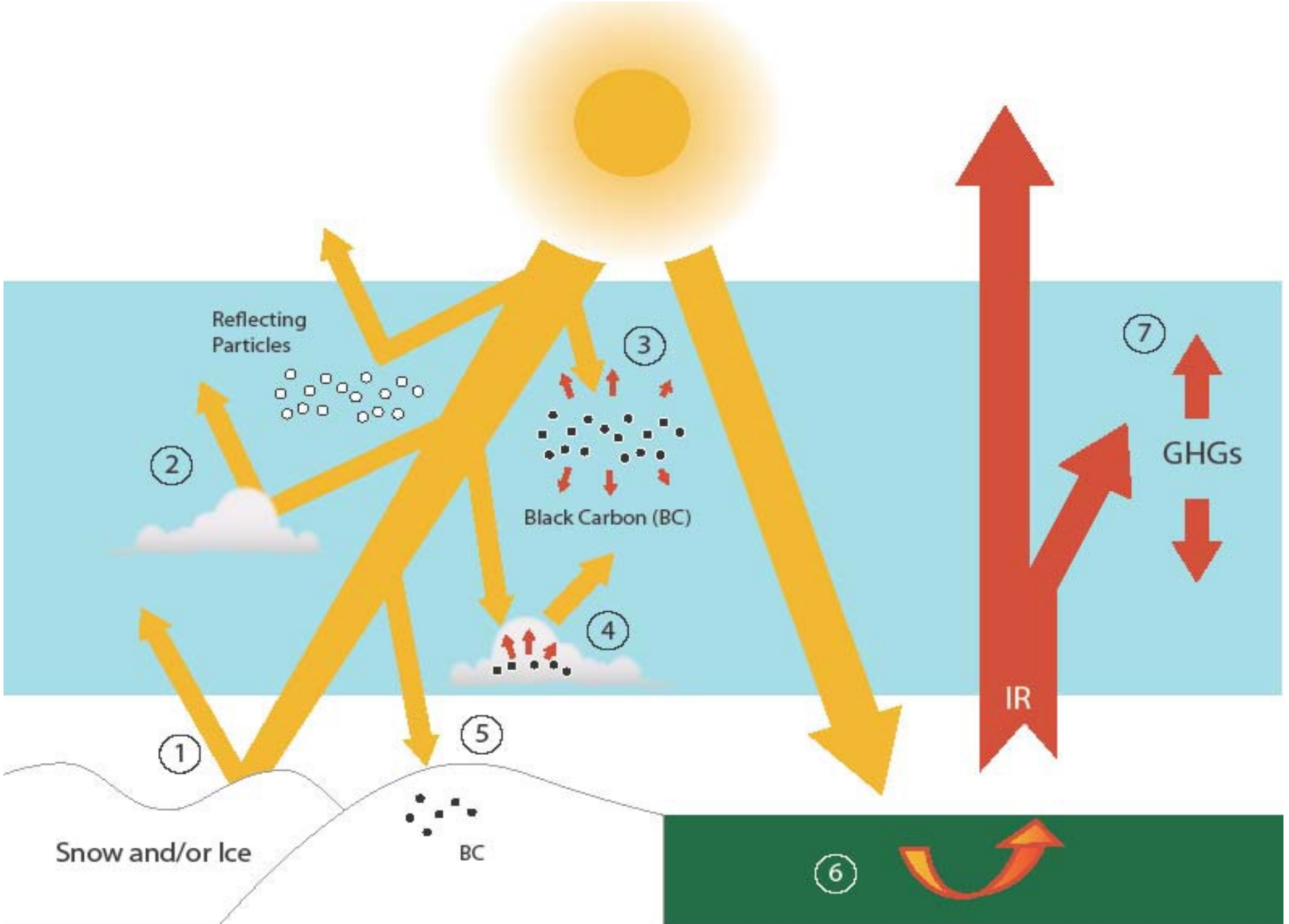
Yearly more than 63.000 premature death caused by $PM_{2,5}$ in Germany (EEA 2020)

Connection: Course of Covid-19 and by particle induced pre illnesses

Air pollution caused by wood stoves „under radar“: Position of measurement stations and focus on larger particles. Nearly no stations measures UFP and Black Carbon.

Existing measurement stations: WHO AQG often exceeded.

Effects of Black Carbon on Climate, as compared to Greenhouse Gases



Global Warming Potentials (GWP)		
Pollutants	**GWP 20 years**	**GWP 100 years**
Carbon dioxide	1	1
Carbon monoxide	18.6	5
Sulphur dioxide	-268	-71
Oxide of Nitrogen	-560	-149
Fossil methane	85	30
Nitrous oxide	264	265
Black carbon	3200	900
Organic carbon	-160	- 46
Sources: AR5 WGI		

Climate crisis

Global heating is turning white Alps green, study finds

Vegetated areas above treeline have increased by 77% since 1984, satellite data shows

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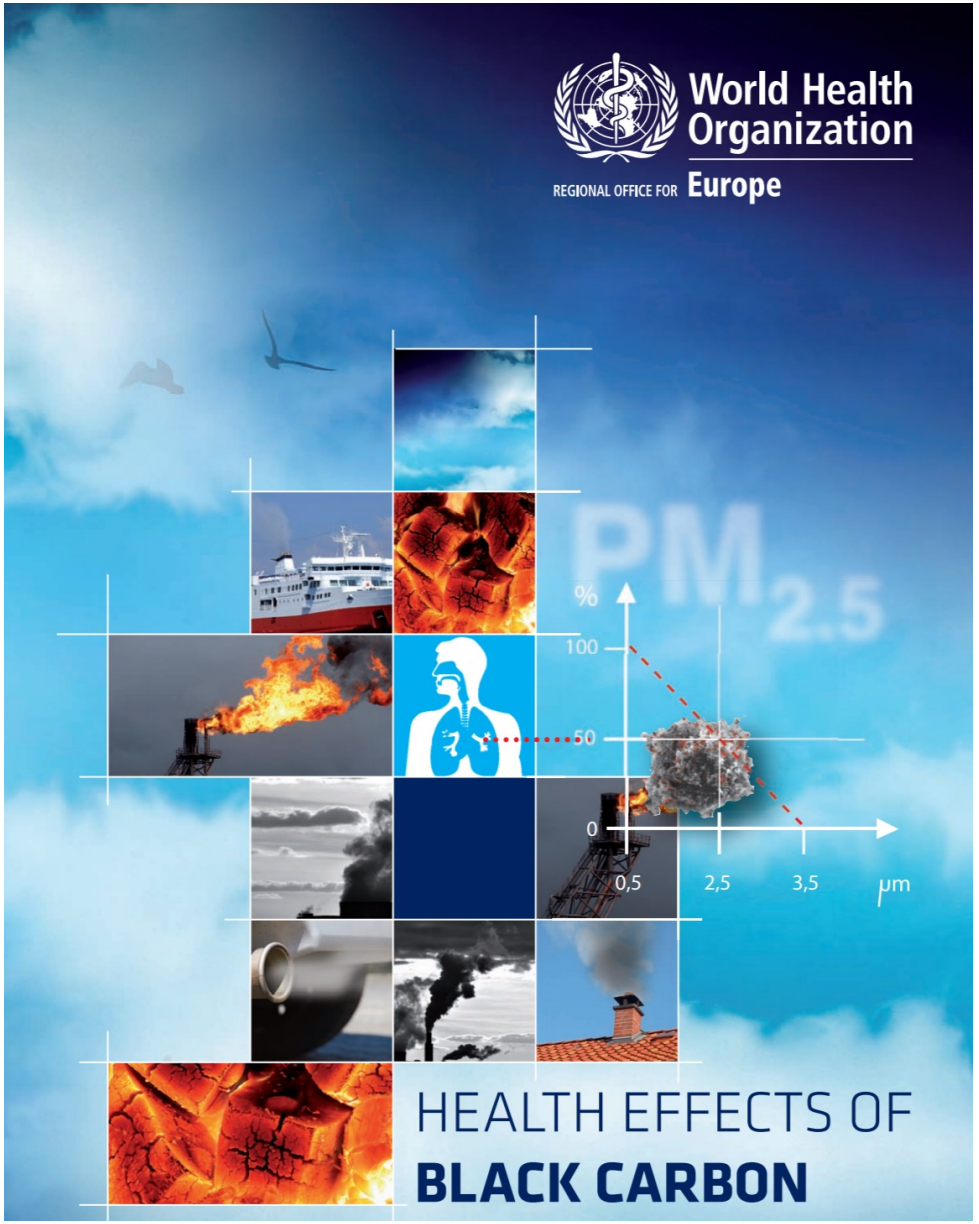
Rising temperatures from global heating and increased rainfall are prolonging the growing season on the Alps. Photograph: Philippe Desmazes/AFP/Getty Images

https://www.theguardian.com/environment/2022/jun/02/global-heating-is-turning-white-alps-green-study-finds?CMP=Share_iOSApp_Other



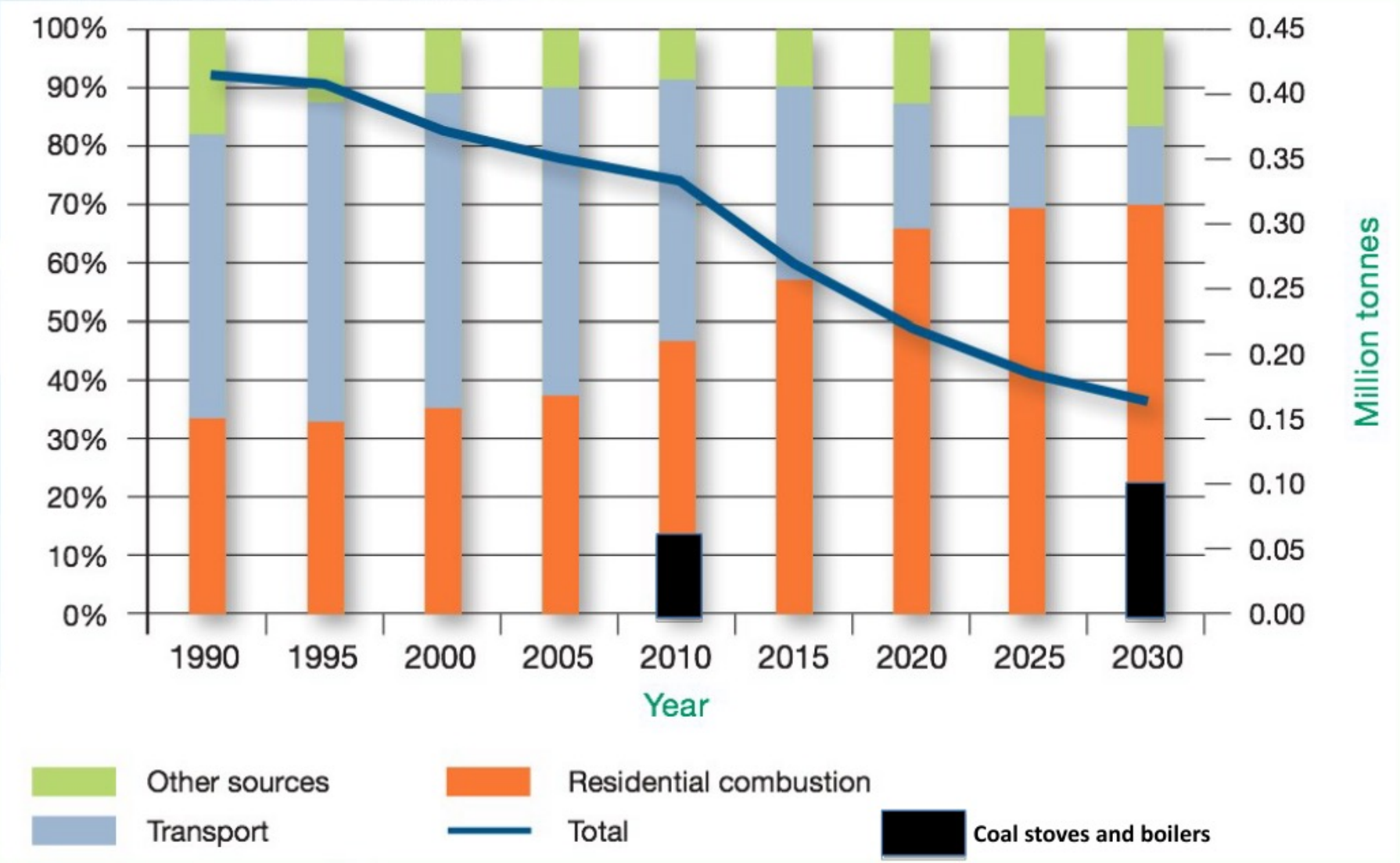
This report presents the results of a systematic review of evidence of the health effects of black carbon (BC). Short-term epidemiological studies provide sufficient evidence of an association of daily variations in BC concentrations with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions). Cohort studies provide sufficient evidence of associations of all cause and cardiopulmonary mortality with long-term average BC exposure. Studies of short-term health effects suggest that BC is a better indicator of harmful particulate substances from combustion sources (especially traffic) than undifferentiated particulate matter (PM) mass, but the evidence for the relative strength of association from long-term studies is inconclusive.

The main sources of BC are combustion engines (especially diesel), residential burning of wood and coal, power stations using heavy oil or coal, field burning of agricultural wastes, as well as forest and vegetation fires.

© World Health Organization 2012

Emissions of BC from key sources in the EU-28;

Source: WHO (2015), GAINS



Local space heaters (stoves)

Comparison: Current ecodesign standards vs. Blue Angel

		Ecodesign (firewood LSH)	Blue Angel
Limit values	**PM**	40 mg/m^3	15 mg/m^3
	PN	-	> 90 % reduction (< 3x10^6/cm^3)
	CO	1500 mg/m^3	500 mg/m^3
Test procedure		• Ignition phase ignored • Batch picking	• Ignition phase included • All batches count
Exhaust cleaning		Not required	Required: • Electrostatic precipitator (with counter of operating hours) • Catalytic converter
Electronic combustion air controls		Only bonus (for efficiency)	No manual setting of combustion air allowed (-> mandatory)
Tightness (indoor poll.)		-	Additional test procedure

„Blue Angel“ Eco-Label for Wood Burning Stove

Interlaboratory Tests for PN Measurements

In the reports the results of the validation of the measurement procedure for the determination of the particle number of stove flue gas provided for in the Blue Angel award criteria for stoves are described. The aim of the validation was to determine the performance parameters of the measurement procedure by means of an interlaboratory test (proficiency test) and to identify necessary adaptations of the process specification. The investigations also served to examine the suitability of the limit value for PN emissions. As a result, it could be determined that the measurement procedure basically provides reliable and comparable measured values. The investigations were carried out on a test stand set up specifically for the project at the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) in Kassel.

https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/51_2024_texte_partikelanzahlmessungen.pdf

Retrofit of Wood Stove Pilot Program

In Berlin a large pilot program started recently with the goal to retrofit up to 100 real world stove with electrostatic precipitators from four different manufactures in a small area in the Southwest of Berlin. The stoves were installed between 1998 and 2019. The three official chimney sweepers in the area support the project explicitly. On each stove measurements of ultra fine particle and black carbon emissions will be made after installation and after two years. For the UFP the test protocol of the German environmental label „ Blue Angel“ for wood stove are used. The first stove are installed in the mean time. The goal is to install the rest until the next heating period 2024.

Pilot Project Area

Measurement Instruments

Measurement of UFP: Sensors APA

PARTICLE NUMBER MEASUREMENT

AUTOMOTIVE PARTICLE ANALYZER

The low-cost Automotive Particle Bench (APB®) is fully integrated into the Sensors' Automotive Particle Analyzer (APA) as a complete turnkey, easy-to-use Periodic Technical Inspection (PTI) particle number measuring instrument.

Specifications

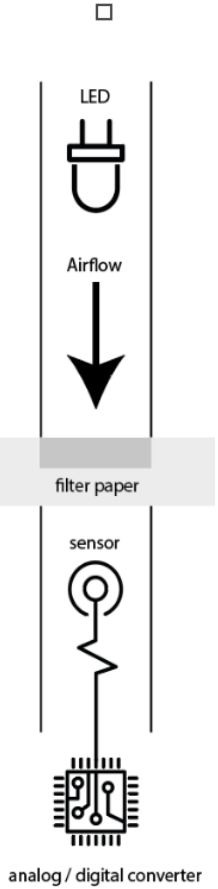
- Analyzer Range: 0 up to 1,000,000 #/cm^3; 0 up to 10,000,000 #/cm^3 with optional secondary dilution
- Minimum Particle Size: d_{50} approximately 23 nm; 10 nm optional upon request

https://sensors-inc.com/Products/Inspection_Maintenance/APA

Measurement Instruments (1)

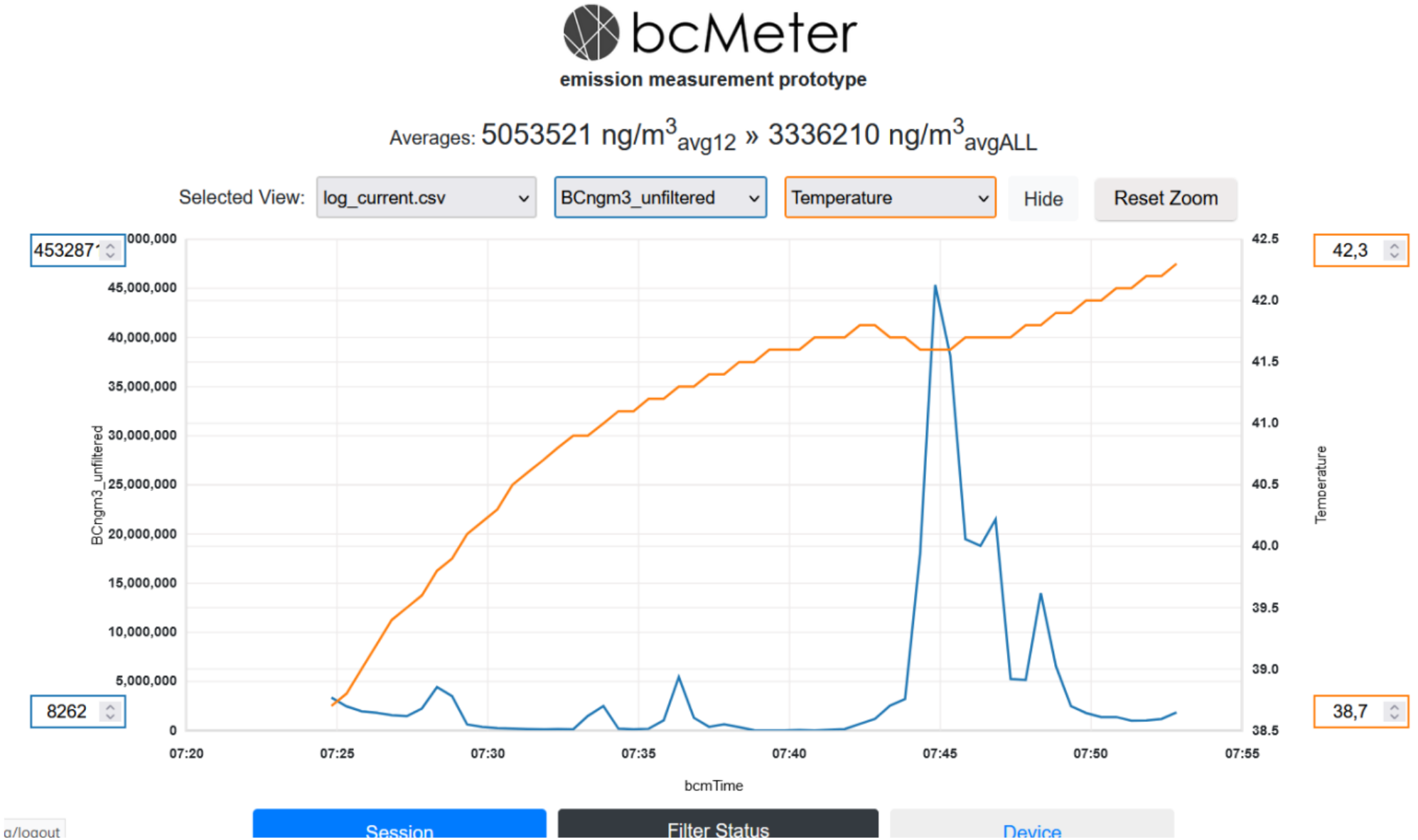
Measurement of Black Carbon (BC): eBCMeter

- Stove emission passes filter paper
- Black Carbon (Soot) is deposited on/in the paper
- Photometer measures attenuation at 880nm
- Blackening is evaluated per script
- Data can be seen via interface



The measurement device was developed by Jonas Dahl and Axel Friedrich

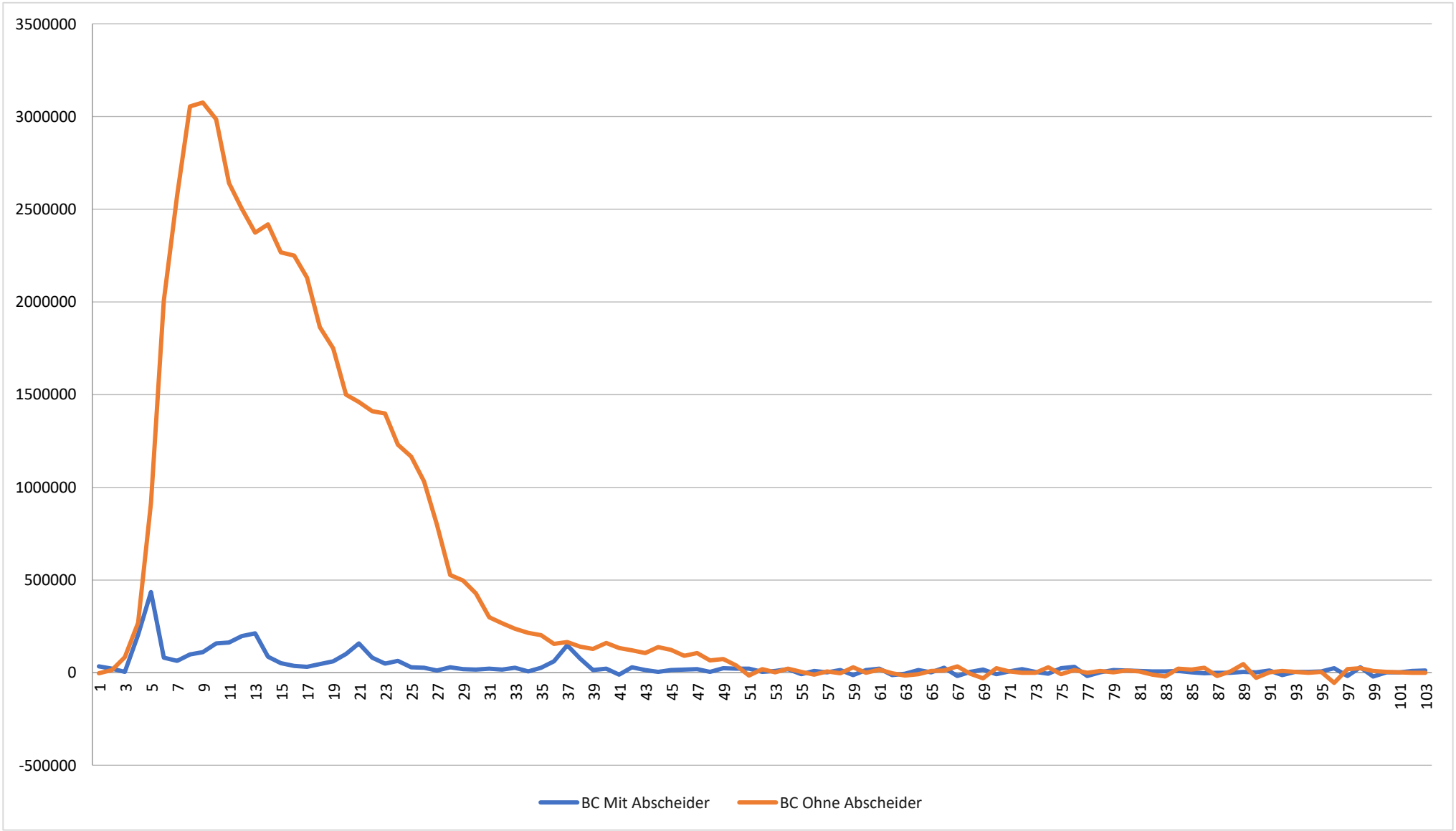
www.bcmeter.org



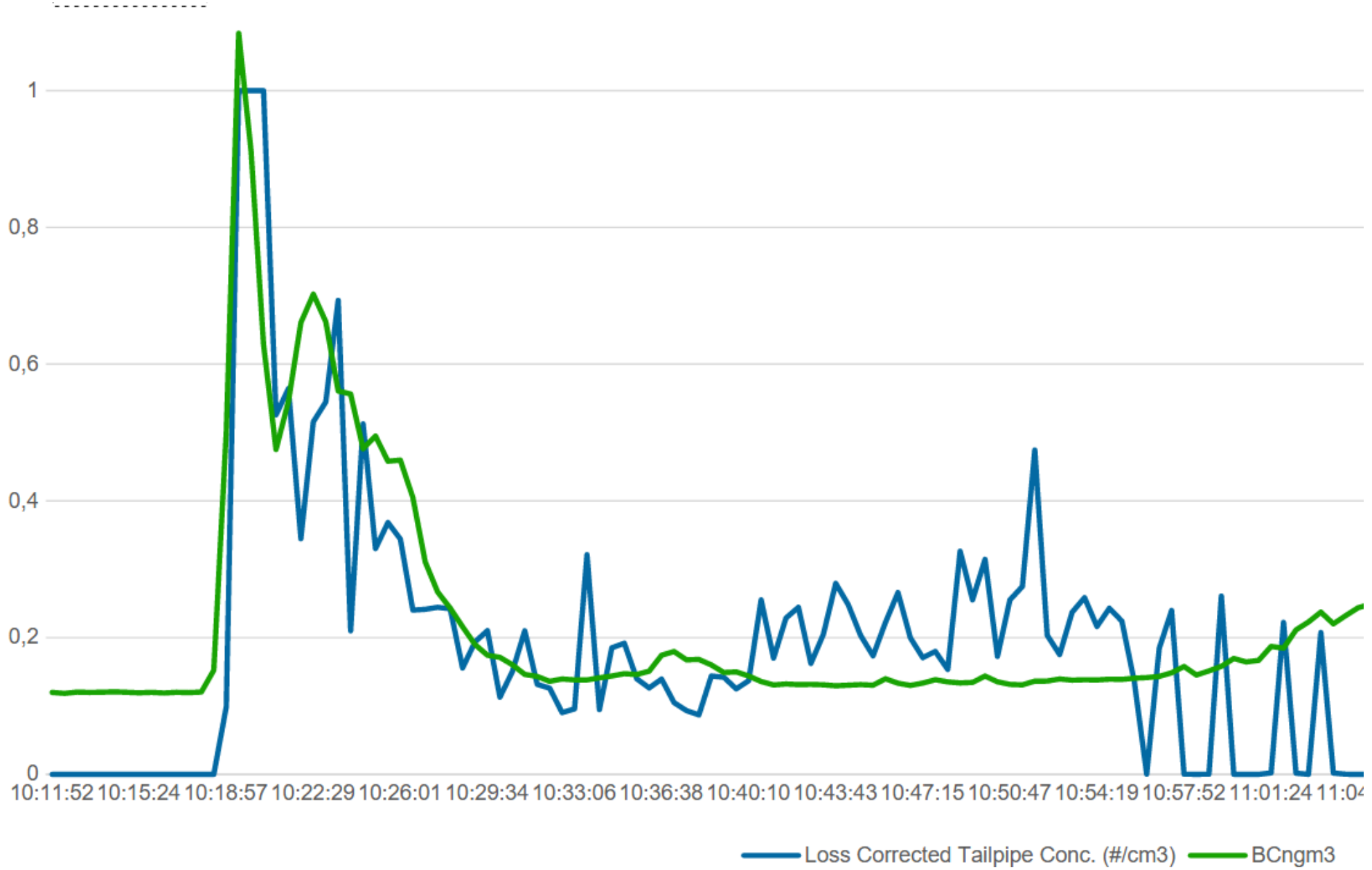
Abscheider bei 07:43 kurz ausgeschaltet.

Source: K+W

Black Carbon Emission Measurement
Wood Stove with and w/o Precipitator



Normalized PN and BC Concentration of a Wood Stoves w/o Emission Control



Particle Number Reduction by an Exodraft Particle Precipitators

Test Set-Up | Start PTI Test | Abort PTI Test | Data Files

OBD Not Connected - Is Key On?

PTI Phase 1

Parameter	Data	Units
RPM		R/min
Coolant Temp		°C
Mass Air Flow		g/s
Particles		#/cm3
Result		

PTI Phase 2

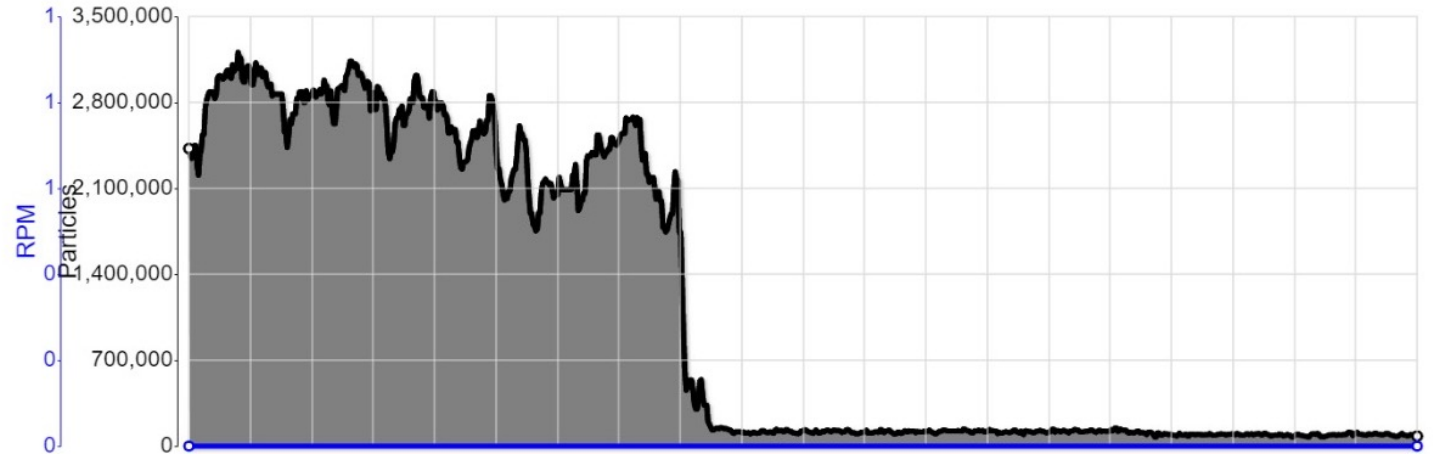
Parameter	Data	Units
RPM		R/min
Coolant Temp		°C
Mass Air Flow		g/s
Particles		#/cm3
Result		

PTI Phase 3

Parameter	Data	Units
RPM		R/min
Coolant Temp		°C
Mass Air Flow		g/s
Particles		#/cm3
Result		

PTI Results

Parameter	Data	Units
RPM		R/min
Coolant Temp		°C
Mass Air Flow		g/s
Particles		#/cm3
Result		



Sampling

Particles
8.09e+4

RPM
0

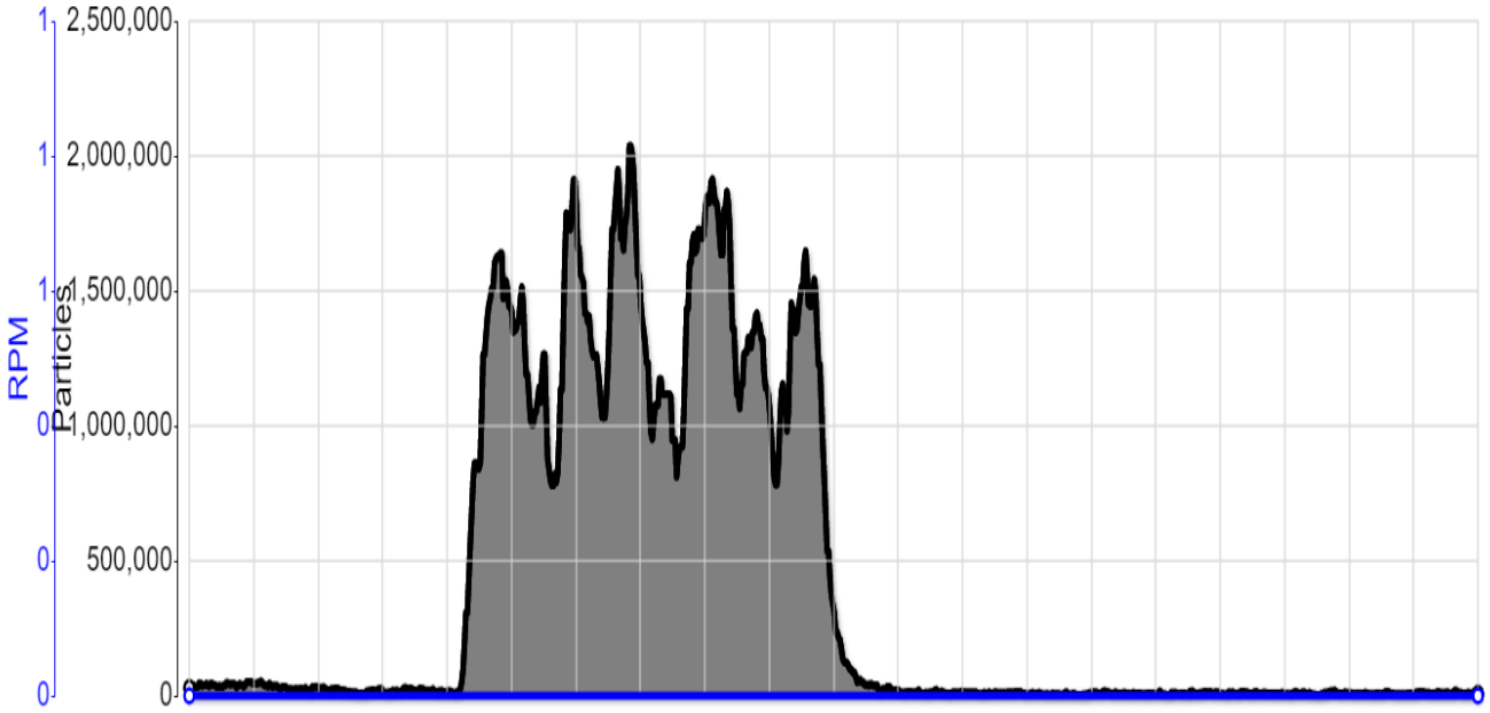
Coolant Temp, °C
0

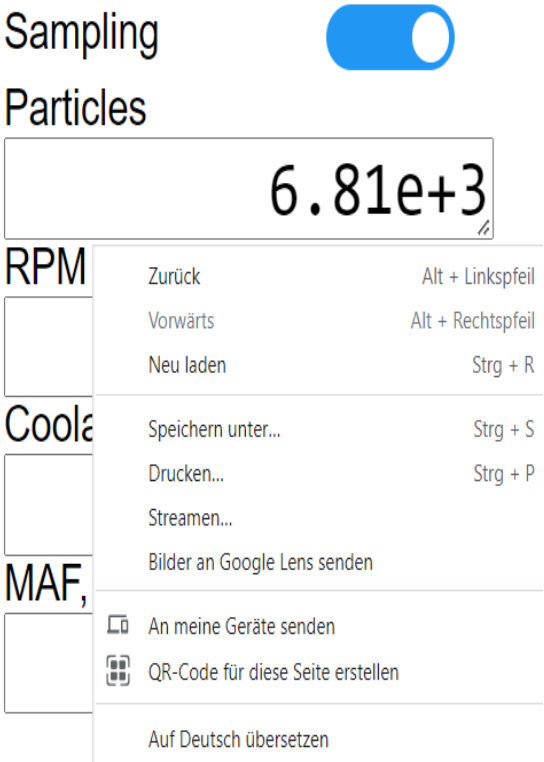
MAF, g/s
0.00

Measurement with Sensors APA instrument

Particle Number Reduction by an Kutzner+Weber Particle Precipitators

K+W Airjet Basic





Measurement with Sensors APA

OekoSolve

Umwelt. Energie.

KW

Kutzner + Weber

Partikelabscheider Airjekt 1 Basic®

SCHRÄDER

ABGASTECHNOLOGIE

exodraft