TAMPERE UNIVERSITY OF TECHNOLOGY

Total particle number concentration and particle size distribution of nanoparticles from real-scale pulverized solid fuel combustion

F. Mylläri[1], P. Karjalainen[1], E. Saukko[1], E. Asmi[2], V. Niemelä[3], R. Taipale[4], H. Lihavainen[2], J. Maunula[5], P. Aalto[6], A. Häyrinen[7], J. Rautiainen[7], R. Hillamo[2], L. Pirjola[8], J. Keskinen[1], T. Rönkkö[1]

[1] Tampere University of Technology, [2] Finnish Meteorological Institute, [3] Dekati Ltd., [4] VTT Technical Research Centre of Finland Ltd., [5] Valmet Technologies Oy, [6] University of Tampere, [7] Helen Oy, [8] Metropolia University of Applied Sciences

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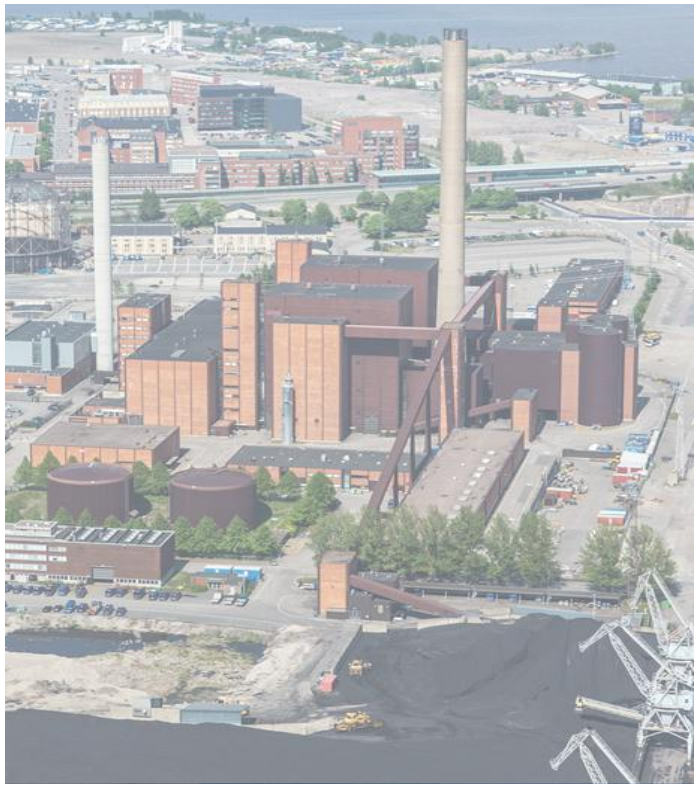
Total particle number concentration and particle number size distribution: In boiler, stack and atmosphere

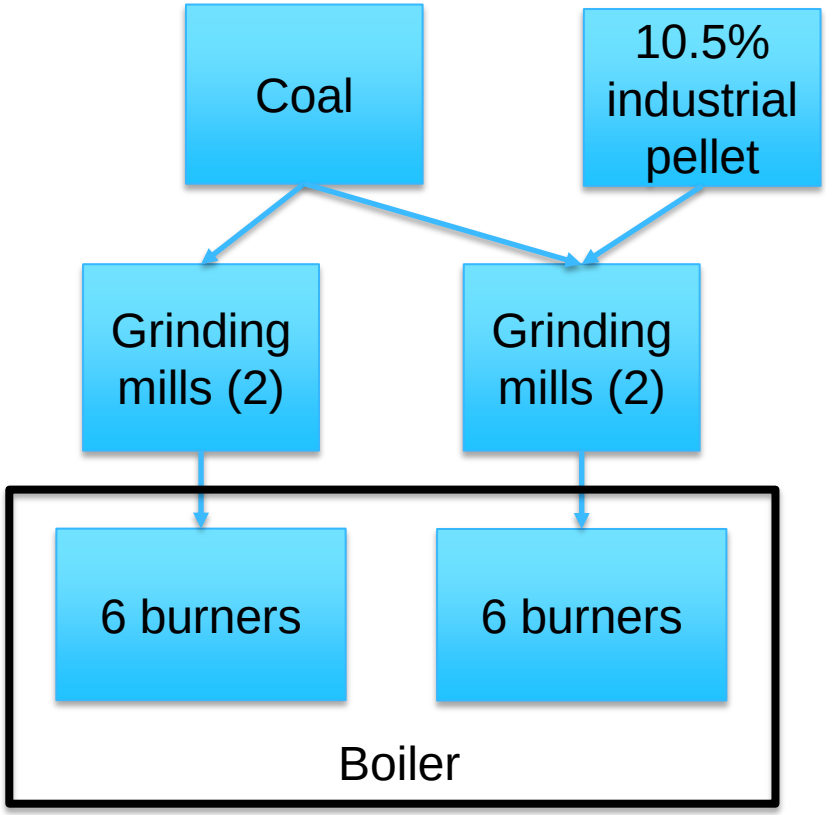


Motivation

- Biofuels are needed to reduce CO_2 emissions in combustion processes
- No specific policy or limits for co-combustion emissions
- Separate emission limits for SO_2, NO_x, ammonia, volatile organic compounds and PM_{10} (including black carbon) [1] from coal and biomass combustion
- Co-combustion of coal and biomass is identified as one pathway in European Industrial Bioenergy Iniative [2]
- 20% increase in co-combustion from 2010 to 2024 is expected by The Energy Information Administration (in USA)
    - expectations / policy have changed?

The power plant

- Combined heat and power plant
- Base-load power station with two boilers
- 365 MW_{th} per boiler
- 12 pulverized fuel low-NO_x burners (6 with coal, 6 with fuel mixture)



Chemical composition of fuels

		industrial pellet	coal
Moisture	%	6.7	11-11.3
Ash	%	0.8	10.5-11.4
Volatiles	%	78.1	32.8-33.1
Heating value	GJ/t	17.7	24.6-24.9
C	%	47.4	62.3-63.1
H	%	5.6	4.1-4.2
O	%	39.4	0
S	mg/kg dry	180	3100-4600
Cl	mg/kg dry	39	236
Na	mg/kg dry	69	1400-1600
K	mg/kg dry	760	2500-2900
Ca	mg/kg dry	2300	4300-4800
Mg	mg/kg dry	280	1700-1900

Instrumentation: particles in boiler

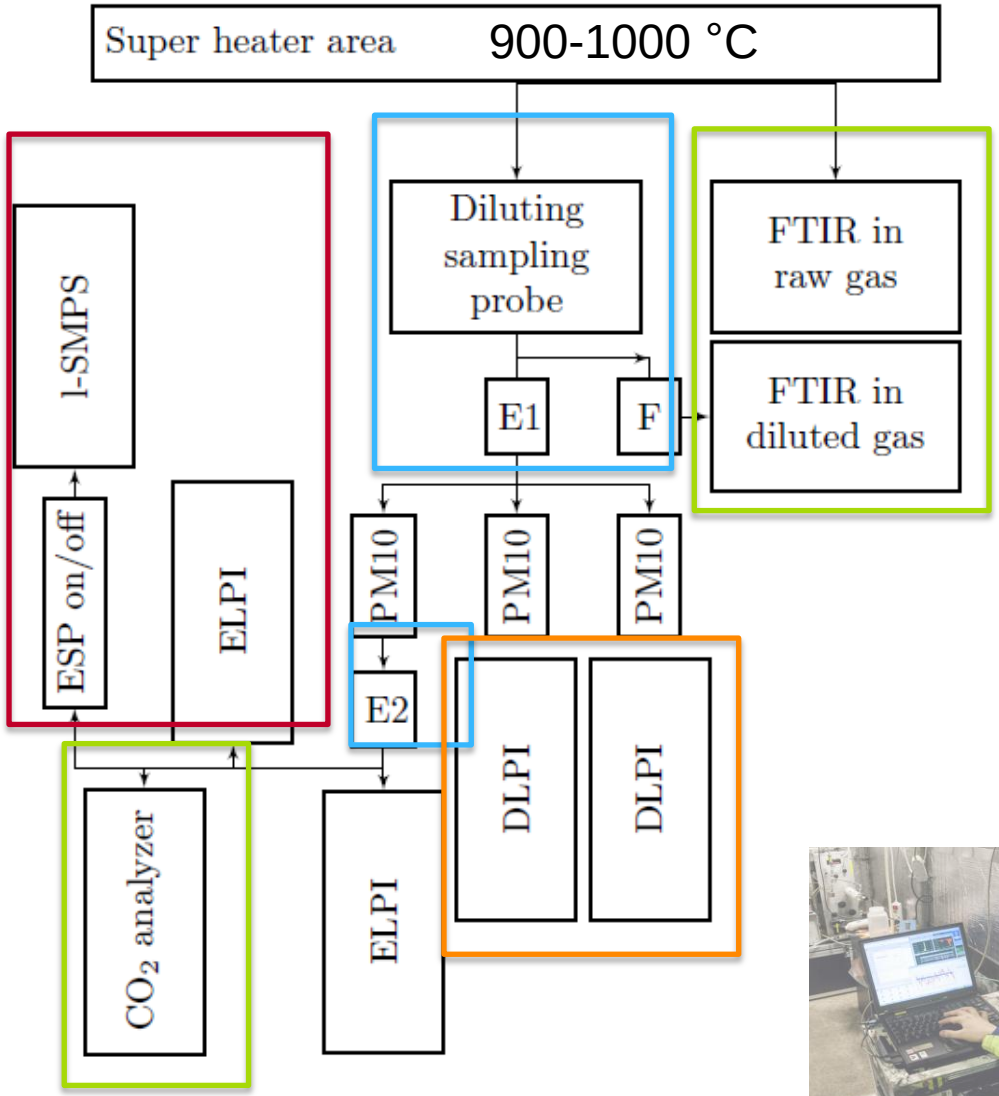
Dilution
- Porous tube type primary dilution, DR ~11

→ Ejector diluter DR_{tot}~300

Concentration of gaseous compounds

Particle number size distribution
- ELPI+ (6 nm - 10 µm)
- SPMS (10.8 - 410 nm)

Particle mass size distribution



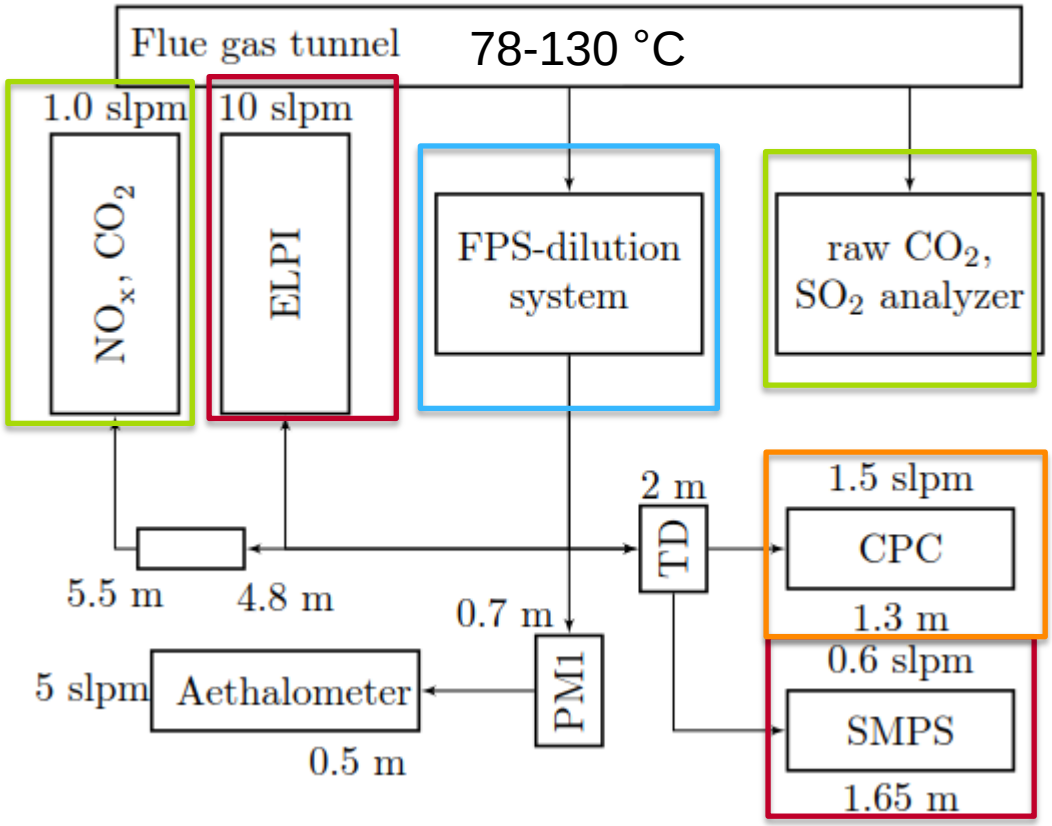
Instrumentation: flue gas in stack

Dilution
- Porous tube type primary dilution
- Ejector diluter DR~21-27

Concentration of gaseous compounds

Particle number size distribution
- ELPI+ (6 nm - 10 µm)
- SPMS (10.8 - 410 nm)

Particle number concentration

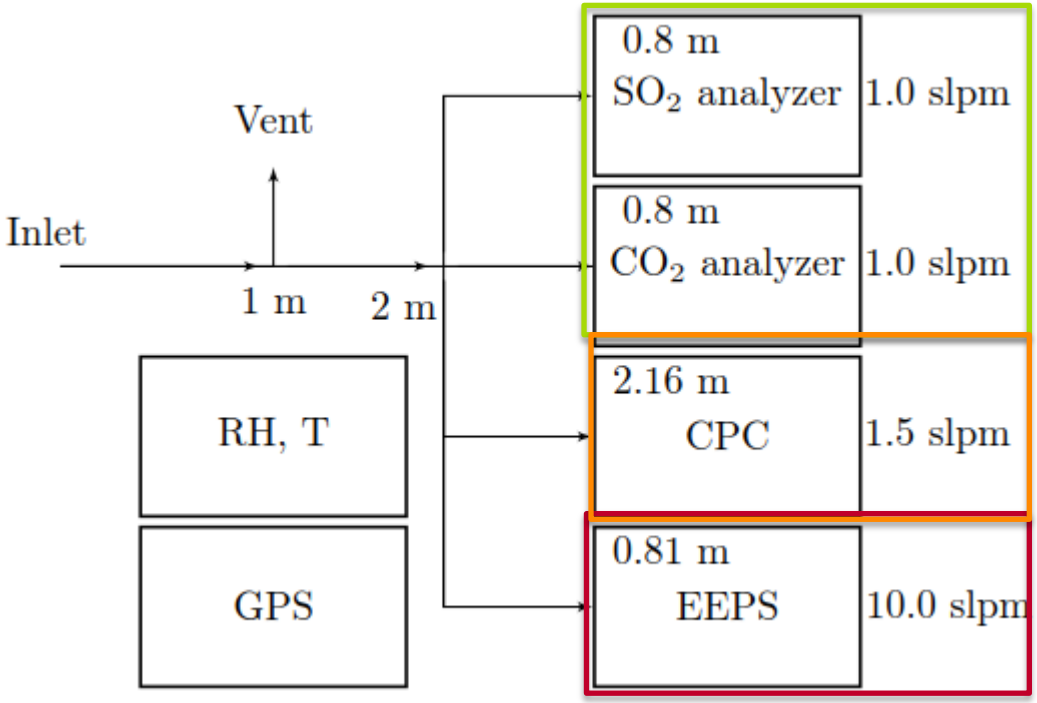


Instrumentation: flue-gas plume in atmosphere

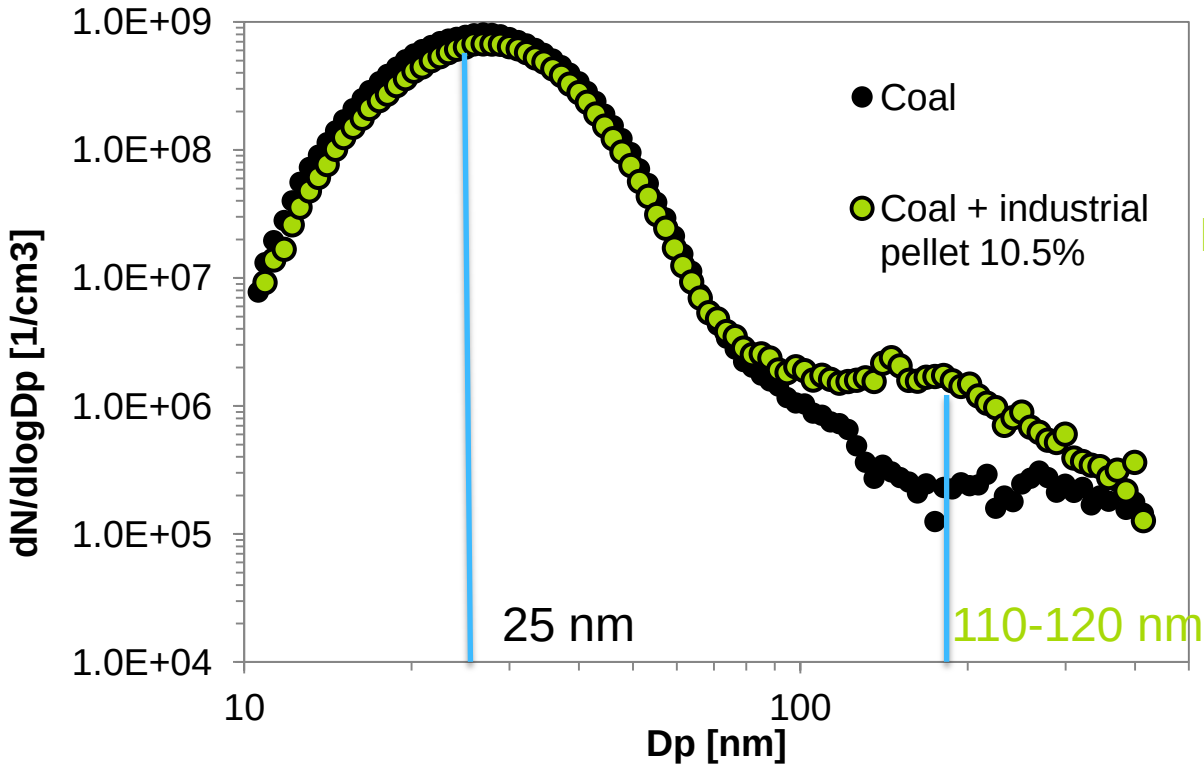
Concentration of gaseous compounds

Particle number size distribution
- EEPS (5.6 nm – 560 nm)
- SPMS (10.8 - 410 nm)

Particle number concentration



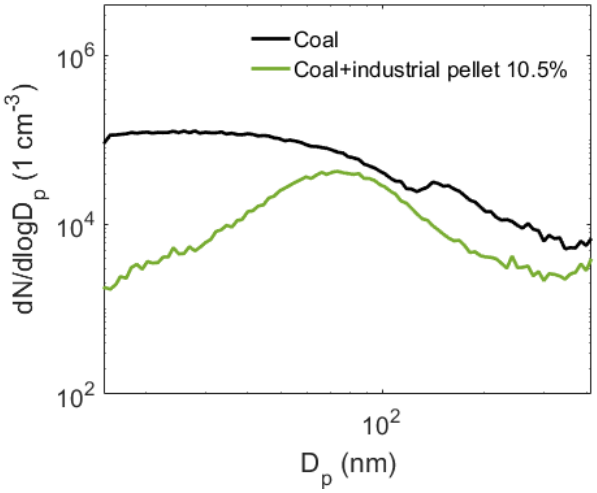
Particle number concentration and size distribution, boiler [3]



N_{tot} 2.76·10^{8} cm^{-3}

N_{tot} 2.20·10^{8} cm^{-3}

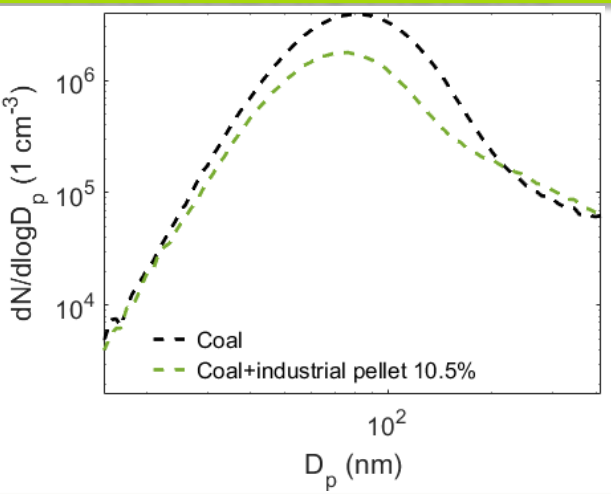
Particle number concentration and size distribution, stack [3]



N_{tot} 420 cm^{-3} (CPC)

N_{tot} 354 cm^{-3} (CPC)

After ESP, FLUE GAS DESULPHURIZATION AND FABRIC FILTERS



N_{tot} 1.8·10^6 cm^{-3} (CPC)

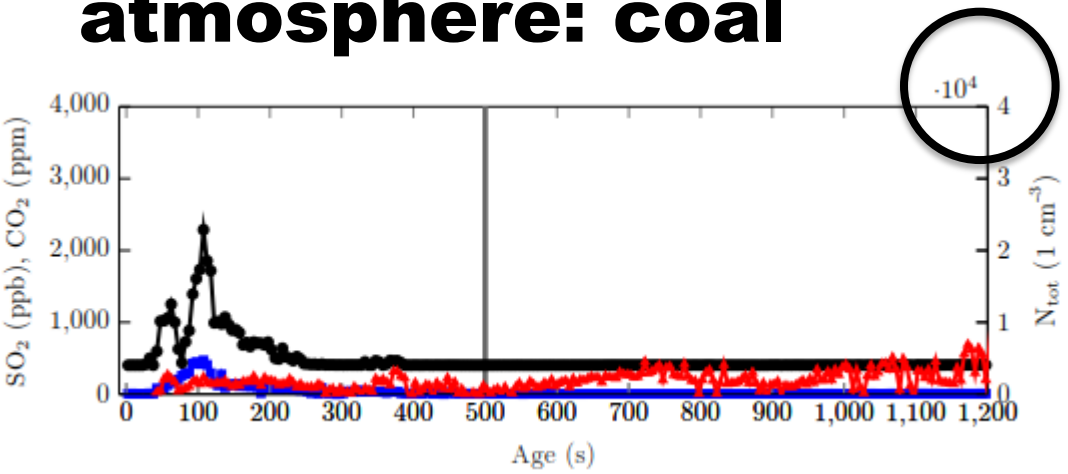
N_{tot} 0.74·10^6 cm^{-3} (CPC)

After ESP

[4,5]

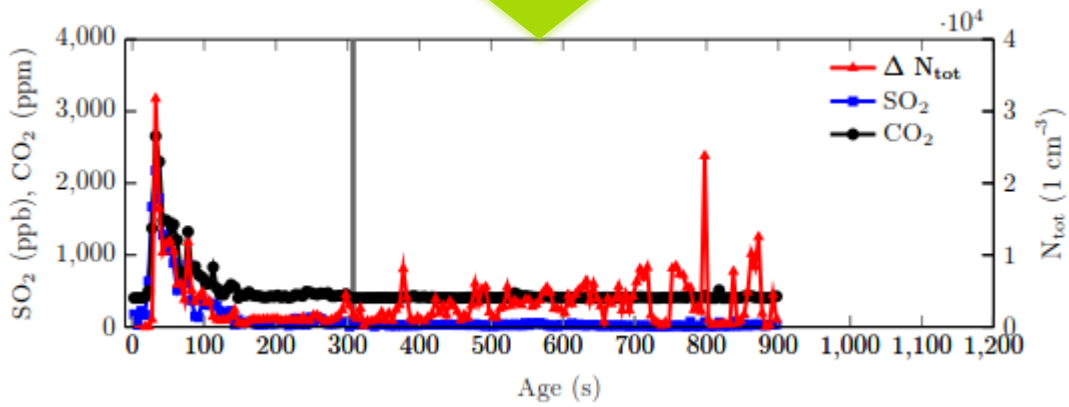
Particle number concentrations in the atmosphere: coal

N_{tot} 420 cm^{-3} in stack



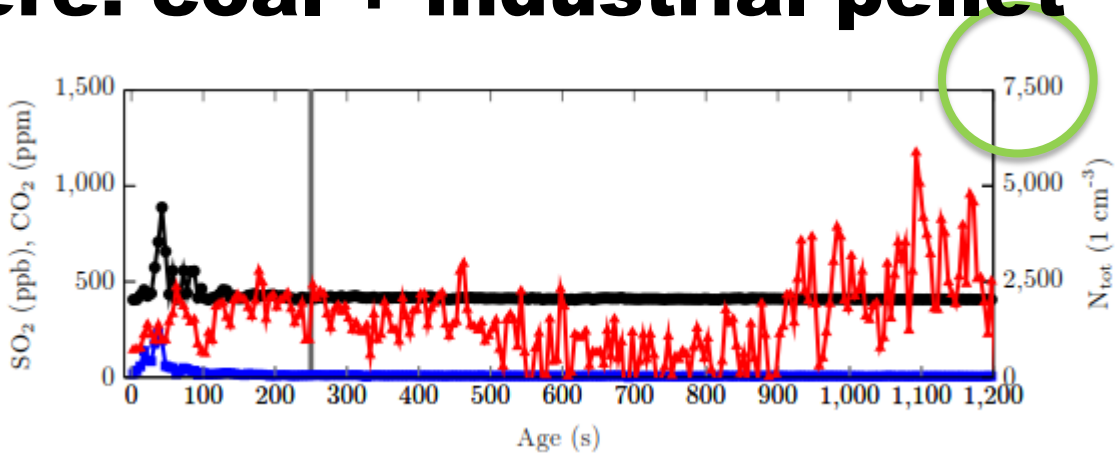
BYPASSING FLUE GAS DESULPHURIZATION AND FABRIC FILTERS **IN ONE DUCT**

N_{tot} $1.8 \cdot 10^6$ + 420 cm^{-3} in stack



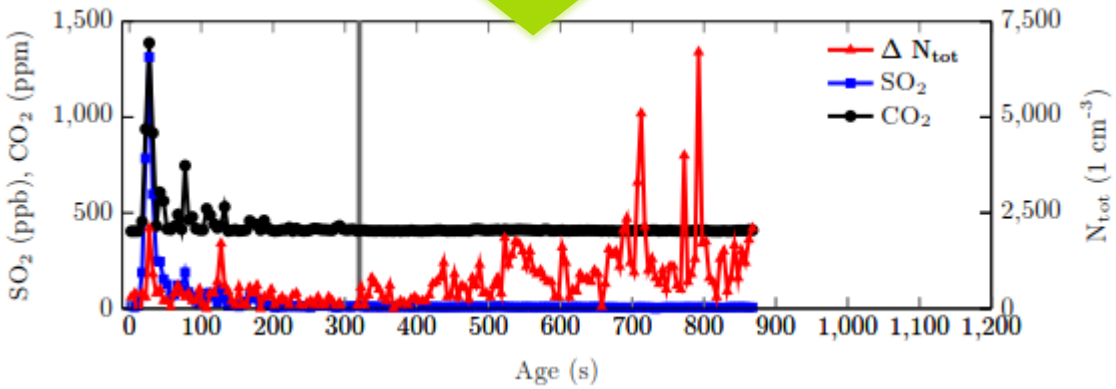
Particle number concentrations in the atmosphere: coal + industrial pellet

N_{tot}
354 + 420 cm^{-3}
in stack

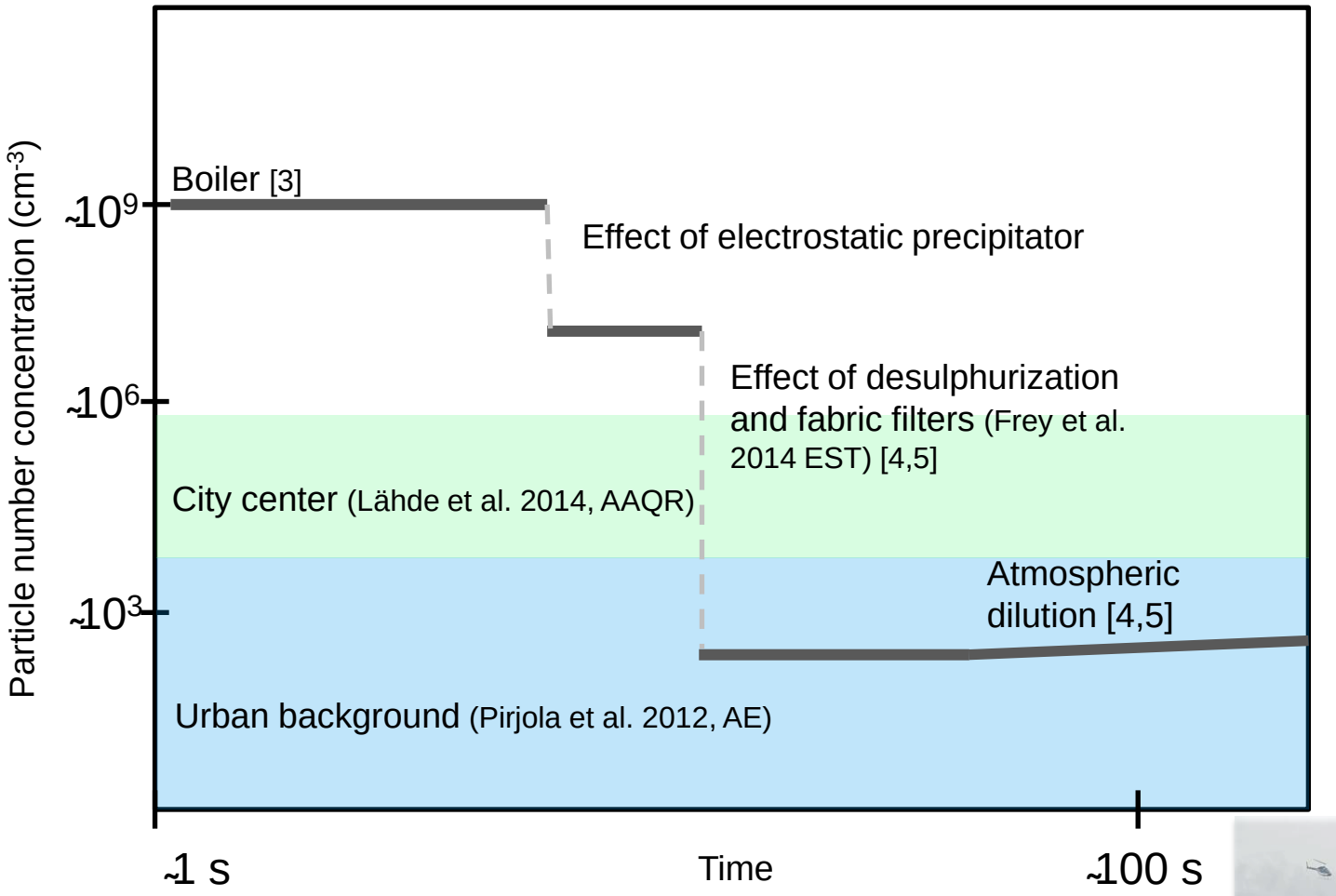


BYPASSING FLUE GAS DESULPHURIZATION AND FABRIC FILTERS **IN ONE DUCT**

N_{tot}
$0.74 \cdot 10^6$ + 420 cm^{-3}
in stack



Summary


Particle number concentration (cm-3)
~10^9
~10^6
~10^3
Boiler [3]
Effect of electrostatic precipitator
Effect of desulphurization and fabric filters (Frey et al. 2014 EST) [4,5]
City center (Lähde et al. 2014, AAQR)
Atmospheric dilution [4,5]
Urban background (Pirjola et al. 2012, AE)
~1 s
Time
~100 s

Acknowledgements

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References

[1] United Nations Economic Commission for Europe [UN-ECE], 1999 protocol to abate acidification, eutrophication and ground-level ozone to the convention on long-range transboundary air pollution, as amended on 4 May 2012, ECE/EB. AIR/114, United Nations Economic Commission for Europe [UN-ECE], 6 May 2013.

[2] The European Industrial Bioenergy Initiative, Boosting the contribution of Bioenergy to the EU climate and energy ambitions: implementation plan 2013–2017, Version of 24 January 2014, p. 3.

[3] Mylläri et al. (2017) Physical and chemical characteristics of flue-gas particles in a large pulverized fuel-fired power plant boiler during co-combustion of coal and wood pellets. Combustion and Flame, vol. 176, pp. 554-566

[4] Mylläri et al. (2016) New particle formation in the fresh flue-gas plume from a coal-fired power plant: effect of flue-gas cleaning, Atmos. Chem. Phys., vol. 16, pp. 7485-7496

[5] Mylläri et al. (2017) Characteristics of particle emissions and their atmospheric dilution during co-combustion of coal and wood pellets in large combined heat and power plant, to be submitted