



Particulate Matter (PM) from biomass combustion

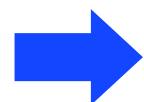
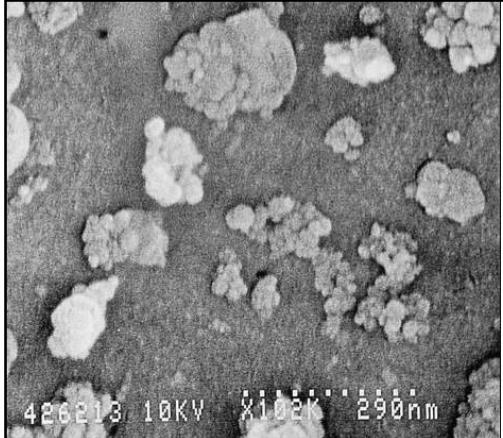
An overview on particle types and
measures to reduce particle emissions

Thomas Nussbaumer^{1,2}

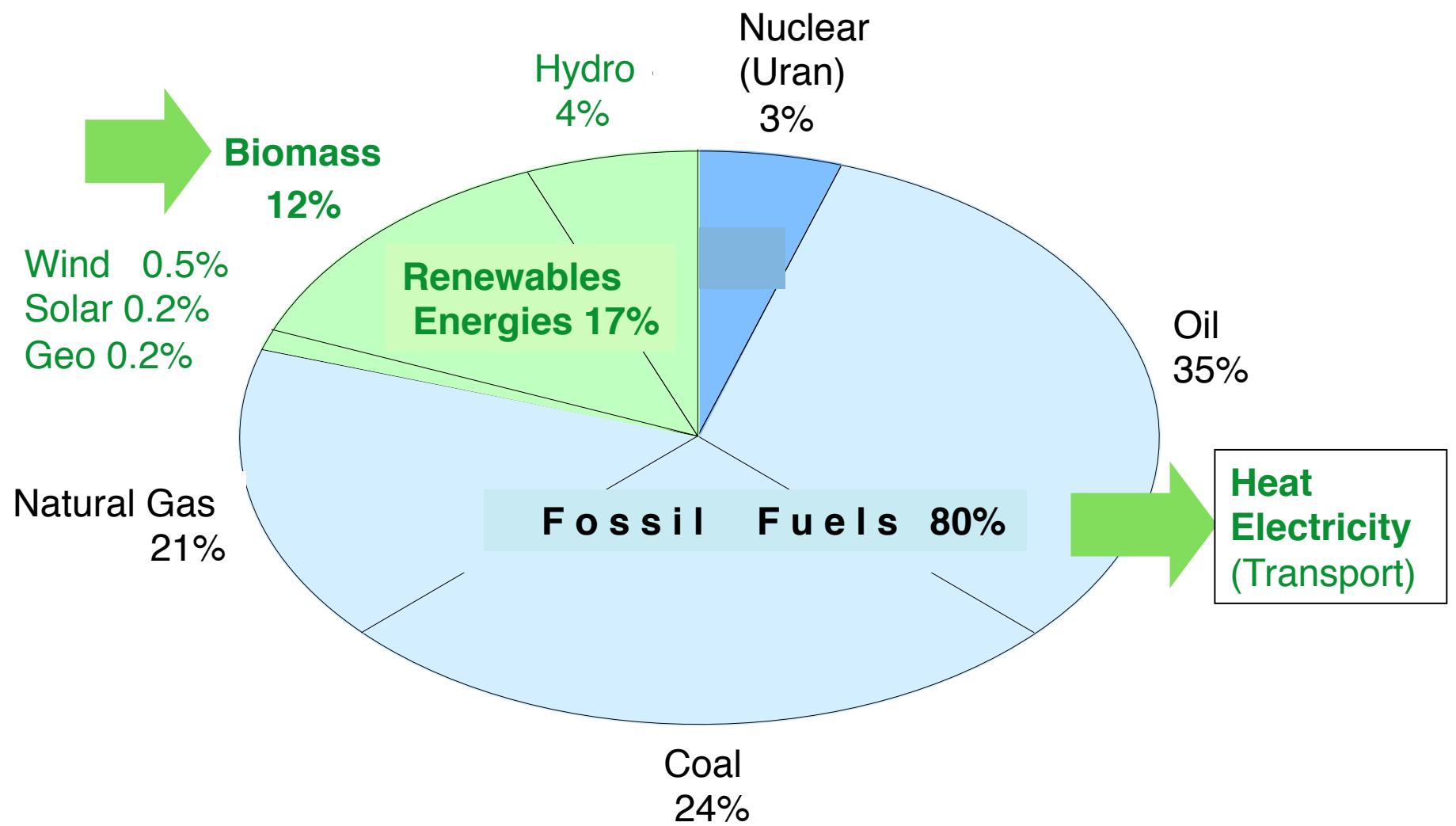
¹Lucerne University of Applied Sciences and Arts, Horw

²Verenum Research, Zürich

20th ETH-Conference on Combustion Generated Nanoparticles
Zürich, June 13–16 2016



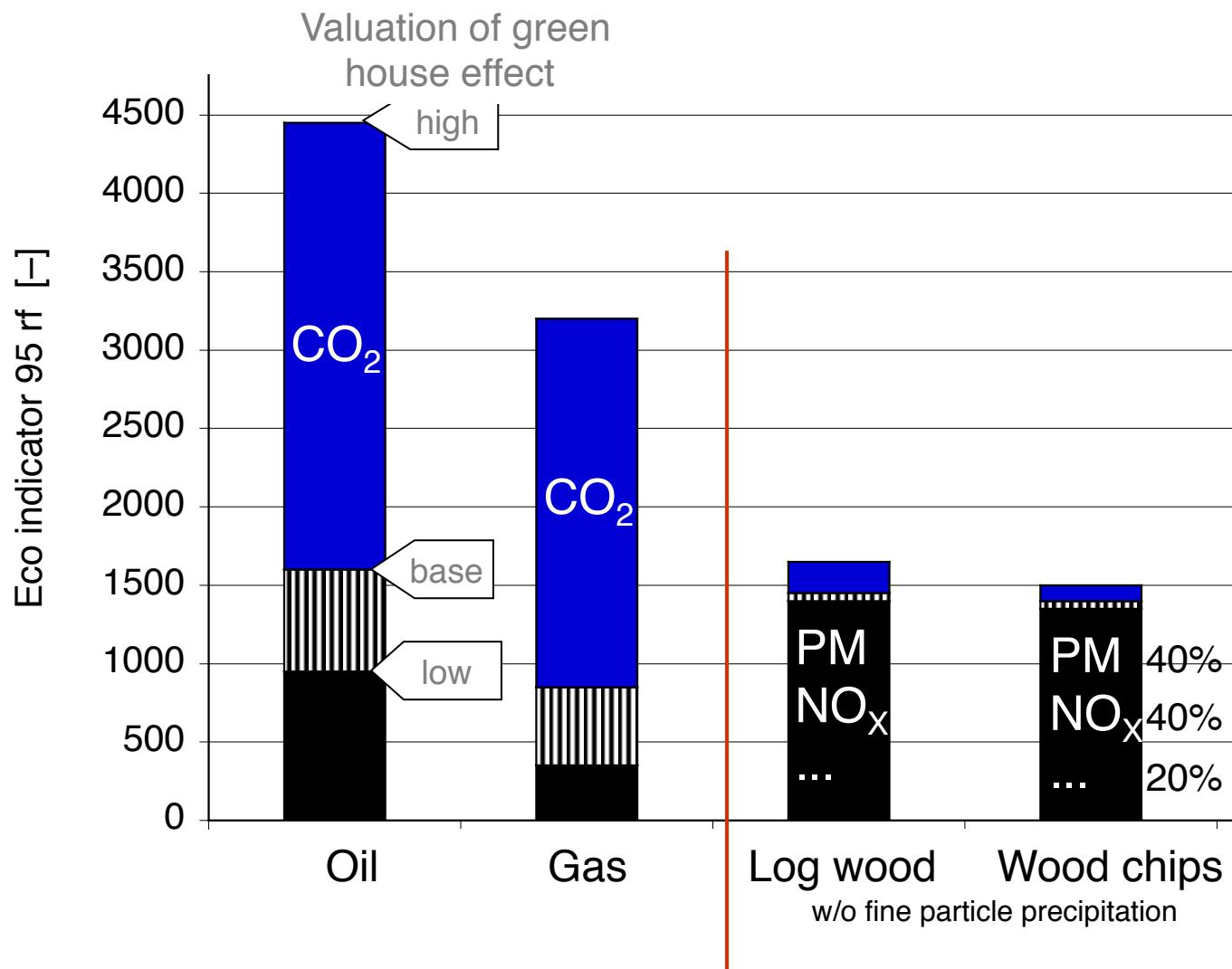
1. Biomass – what else ?
2. Biomass combustion and particle formation
3. Measures to reduce particle emissions
4. Conclusions



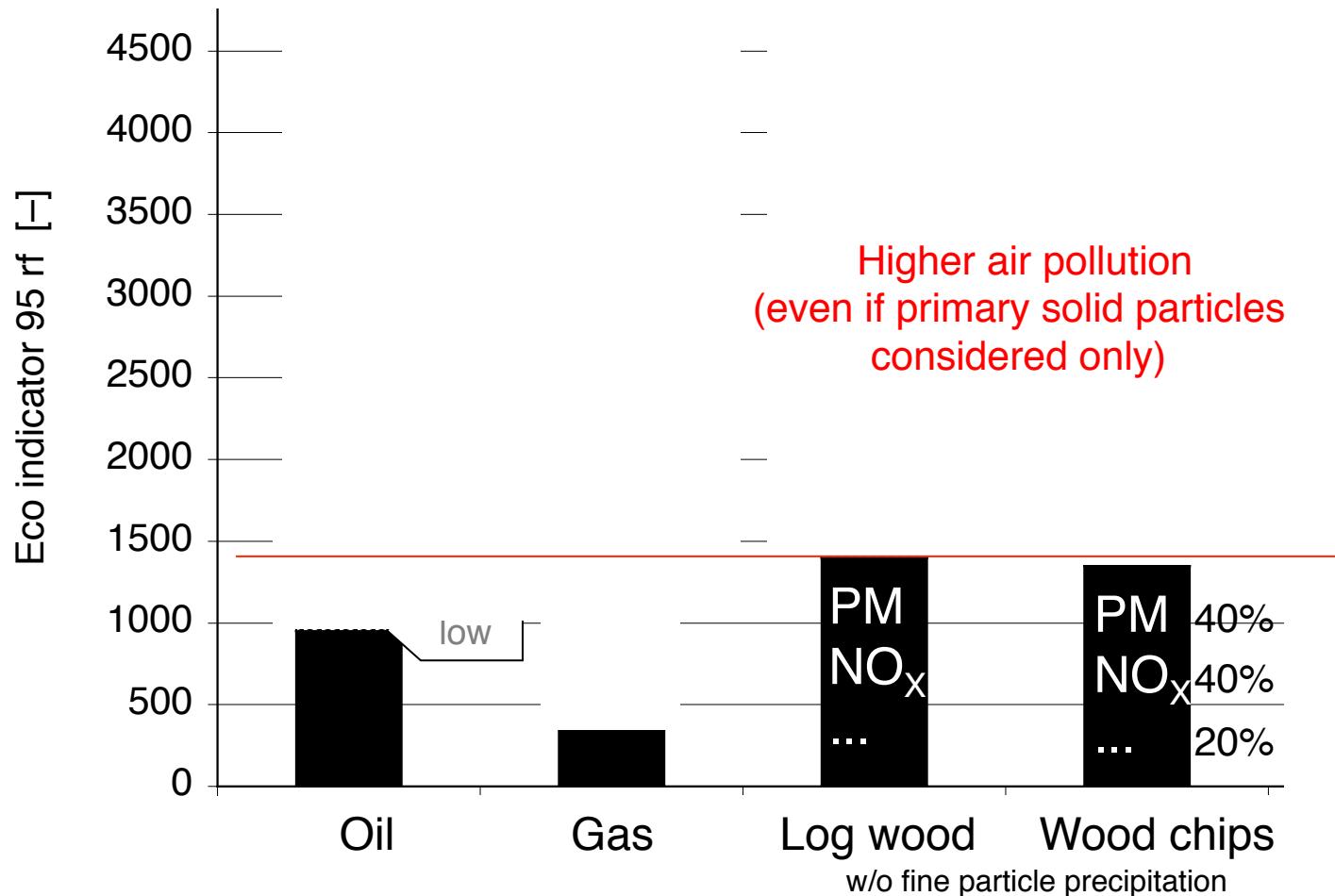
[REN 21, 2014: Renewables 2014 Global Status Report, Paris REN 21 Secretariat ISBN 978-3-9815934-2-6]

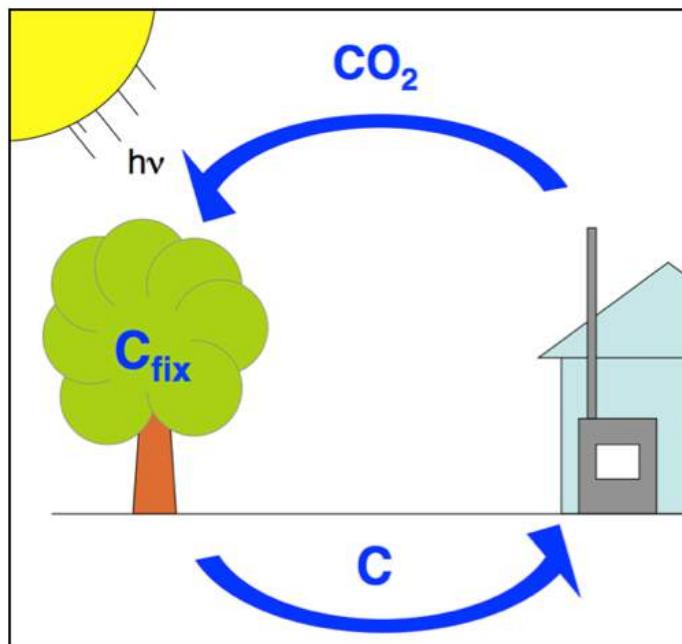
[IEA Global Energy Outlook 2006] www.worldenergyoutlook.org

Environmental Impact of Residential Heating



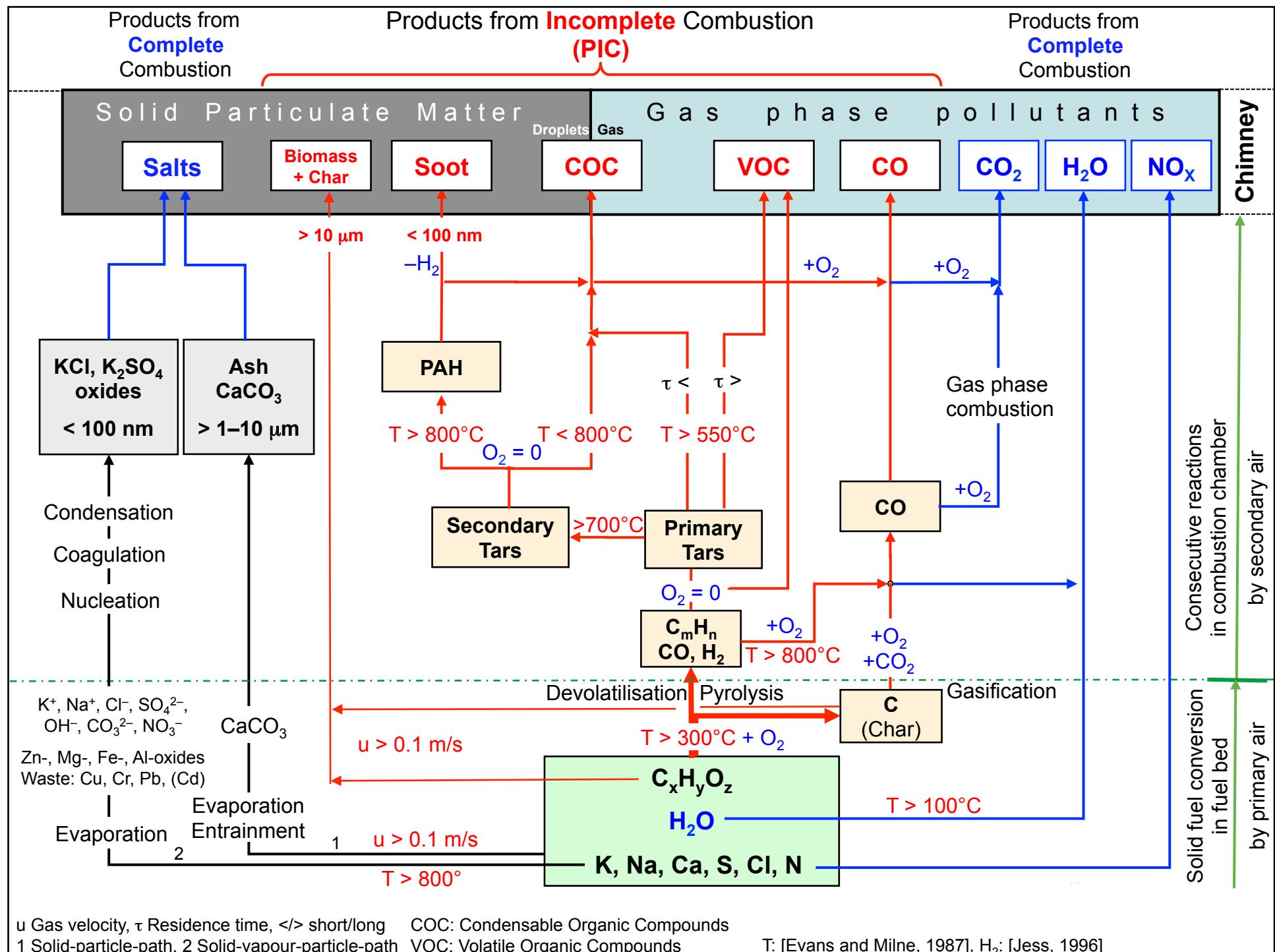
Environmental Impact of Residential Heating

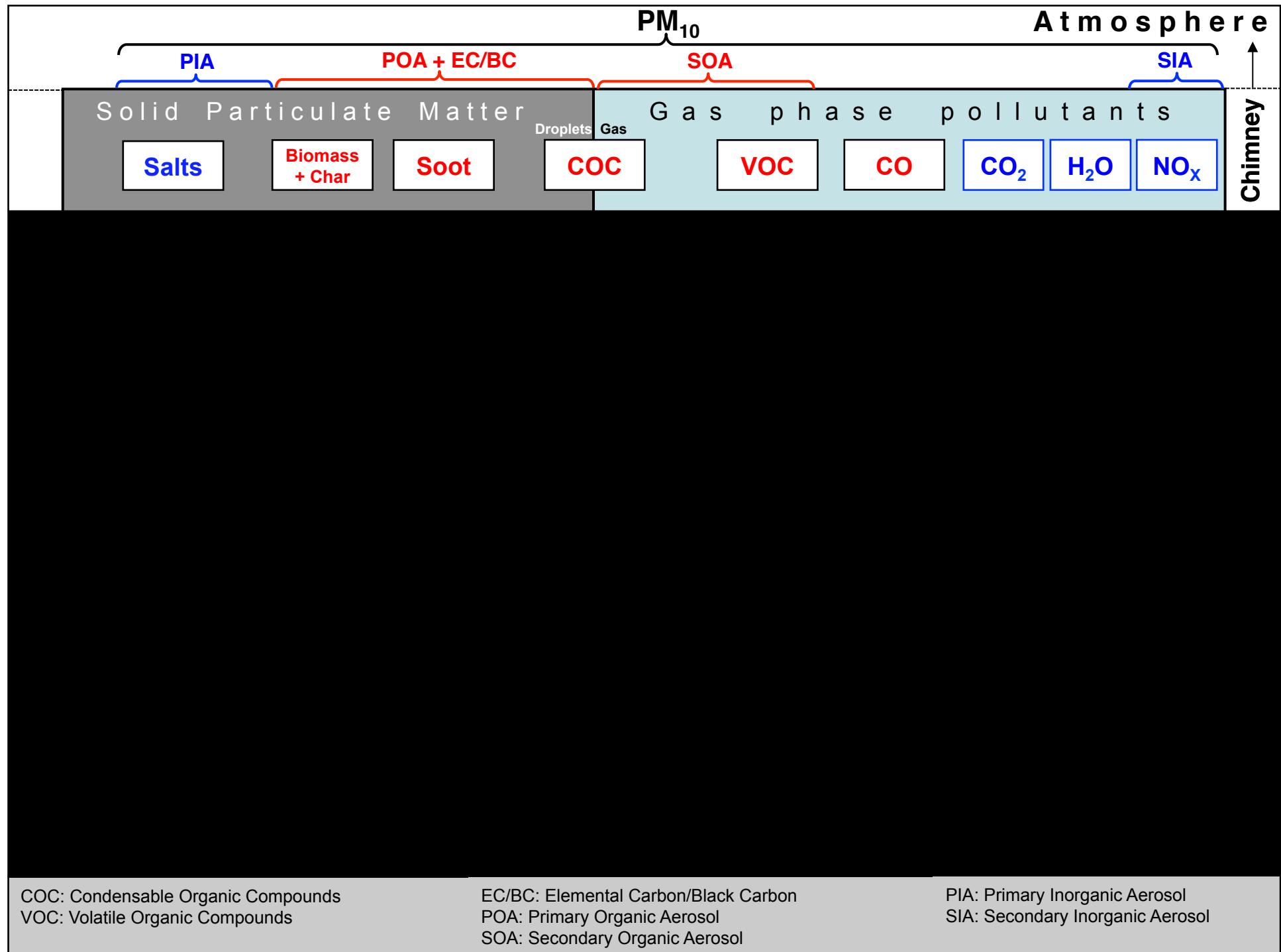


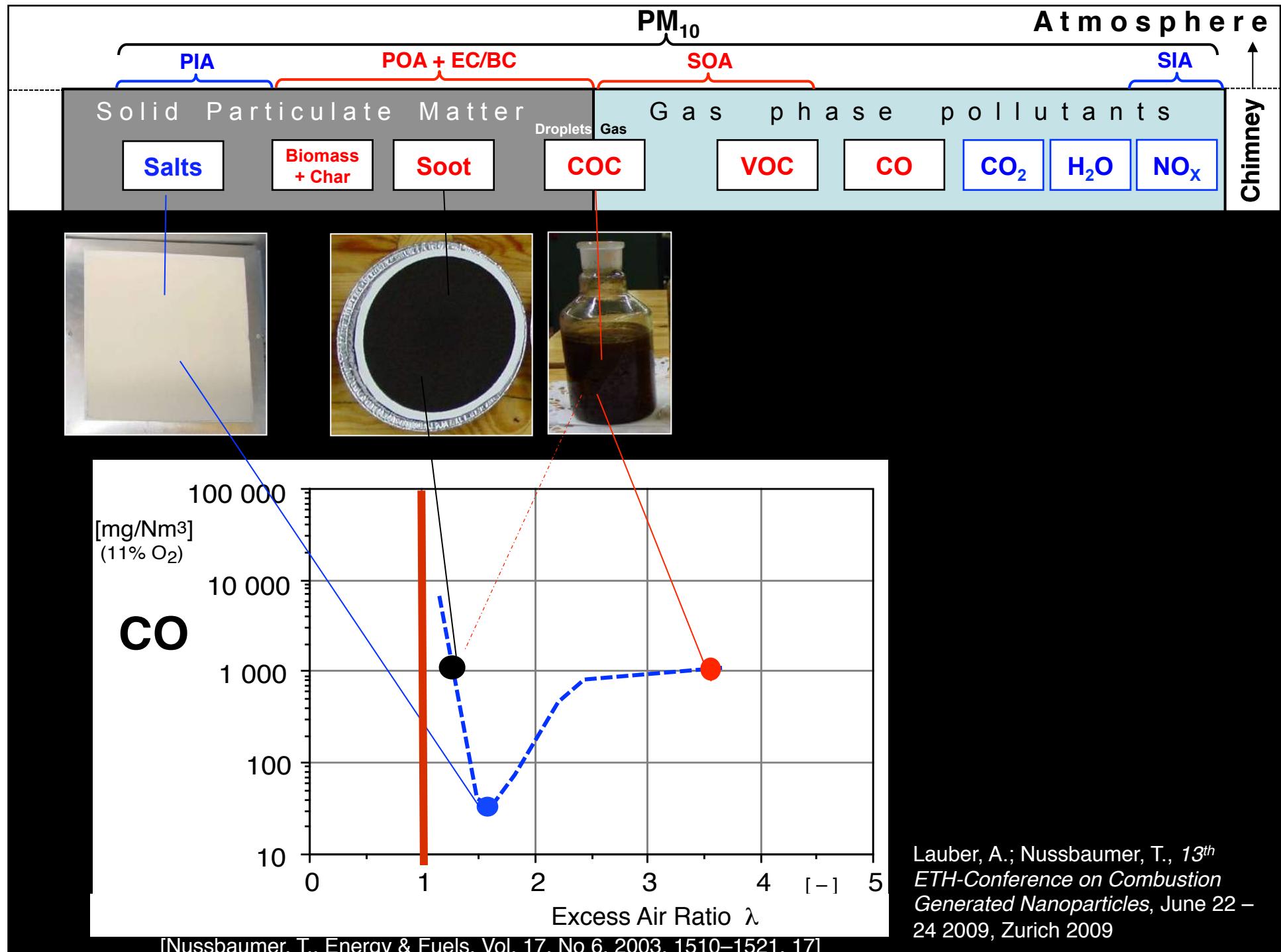


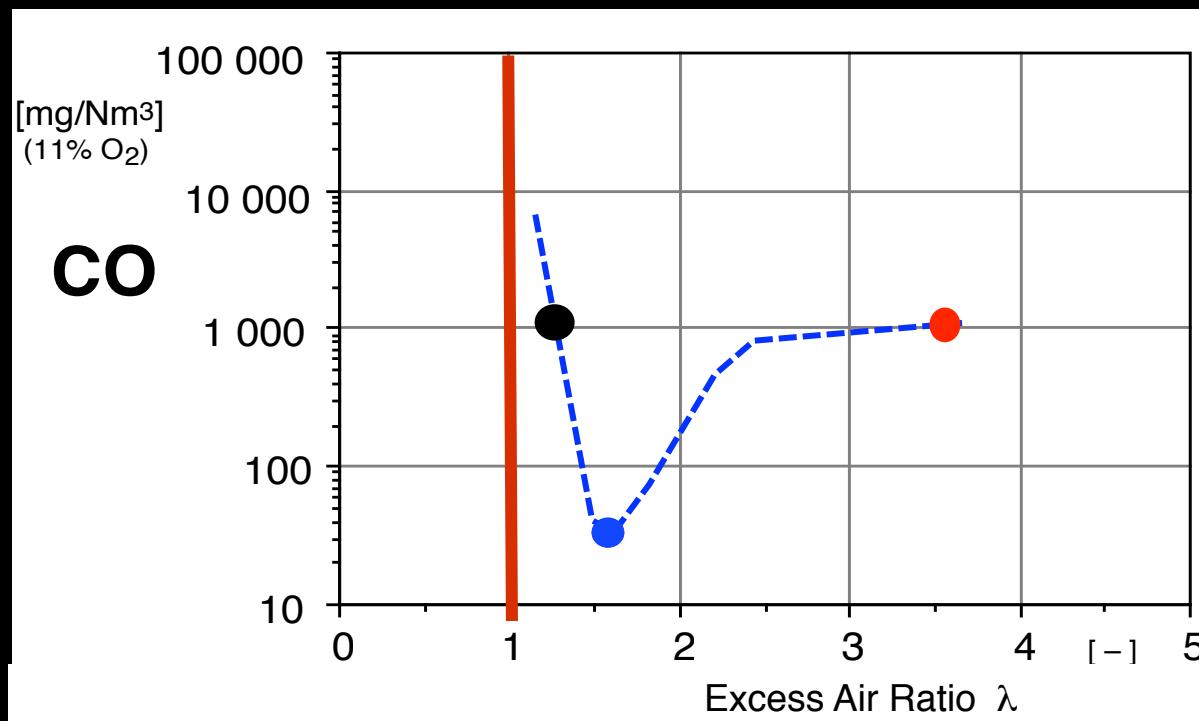
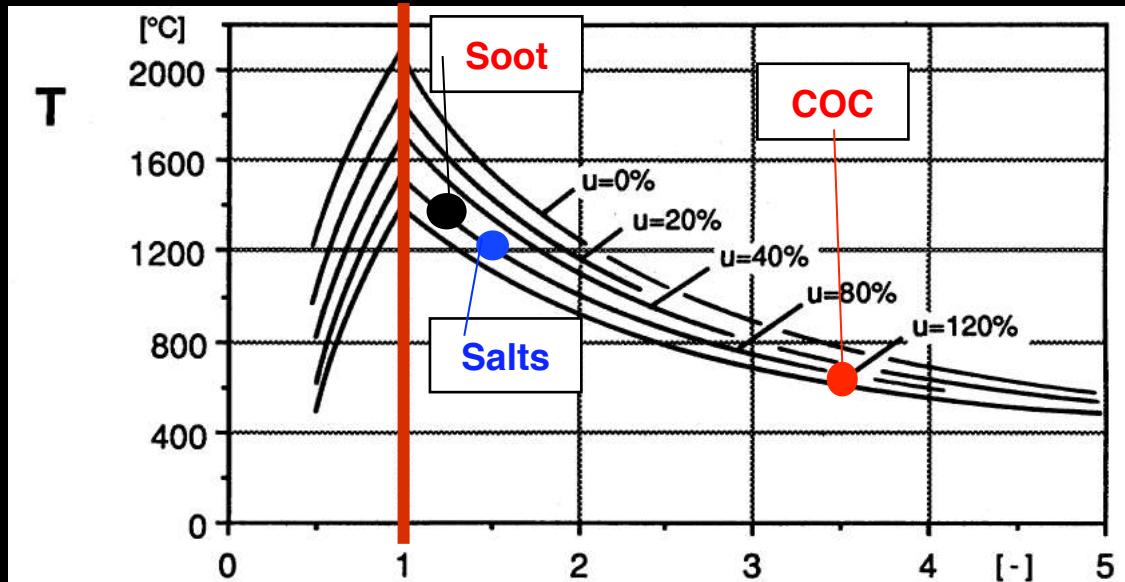


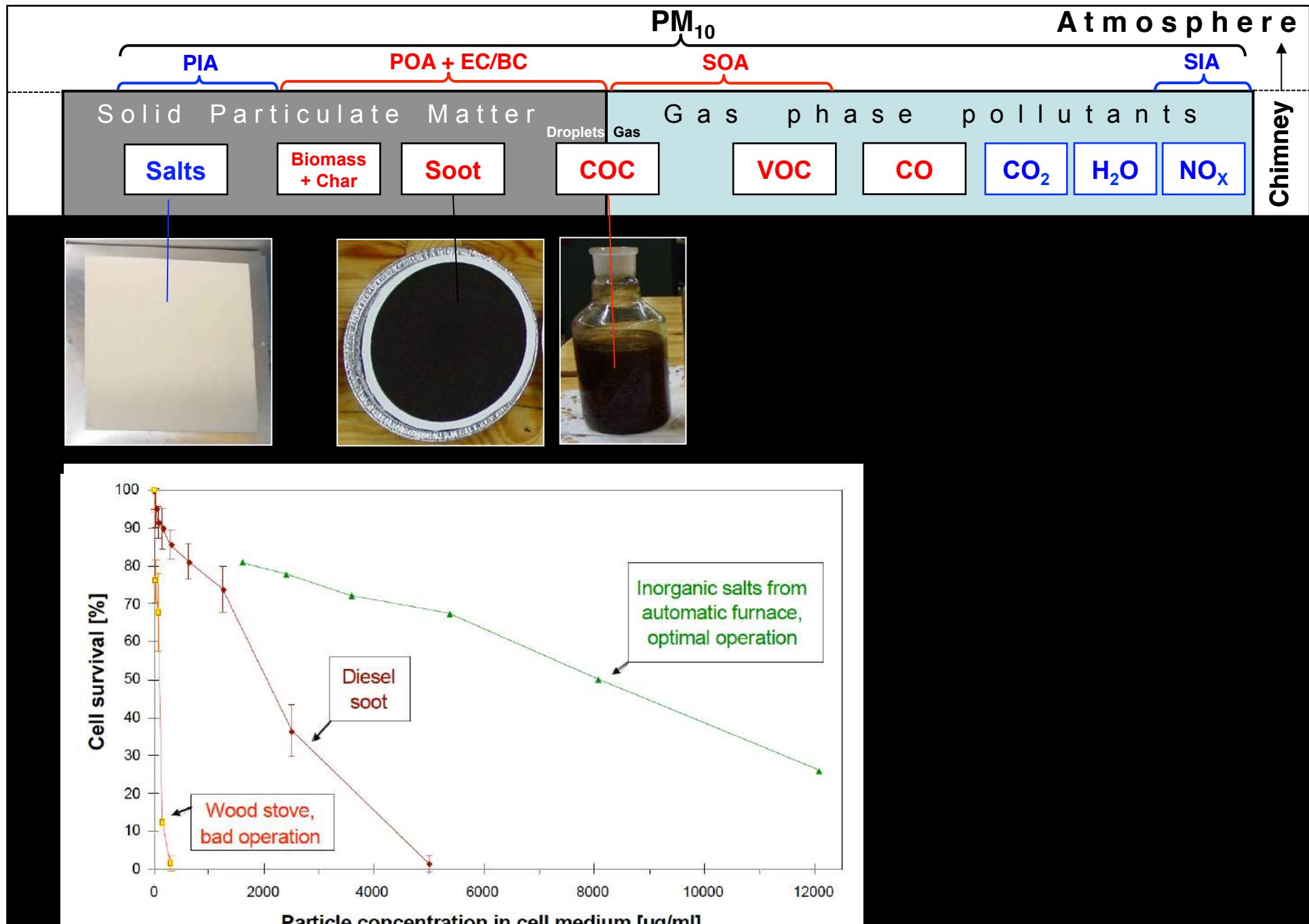
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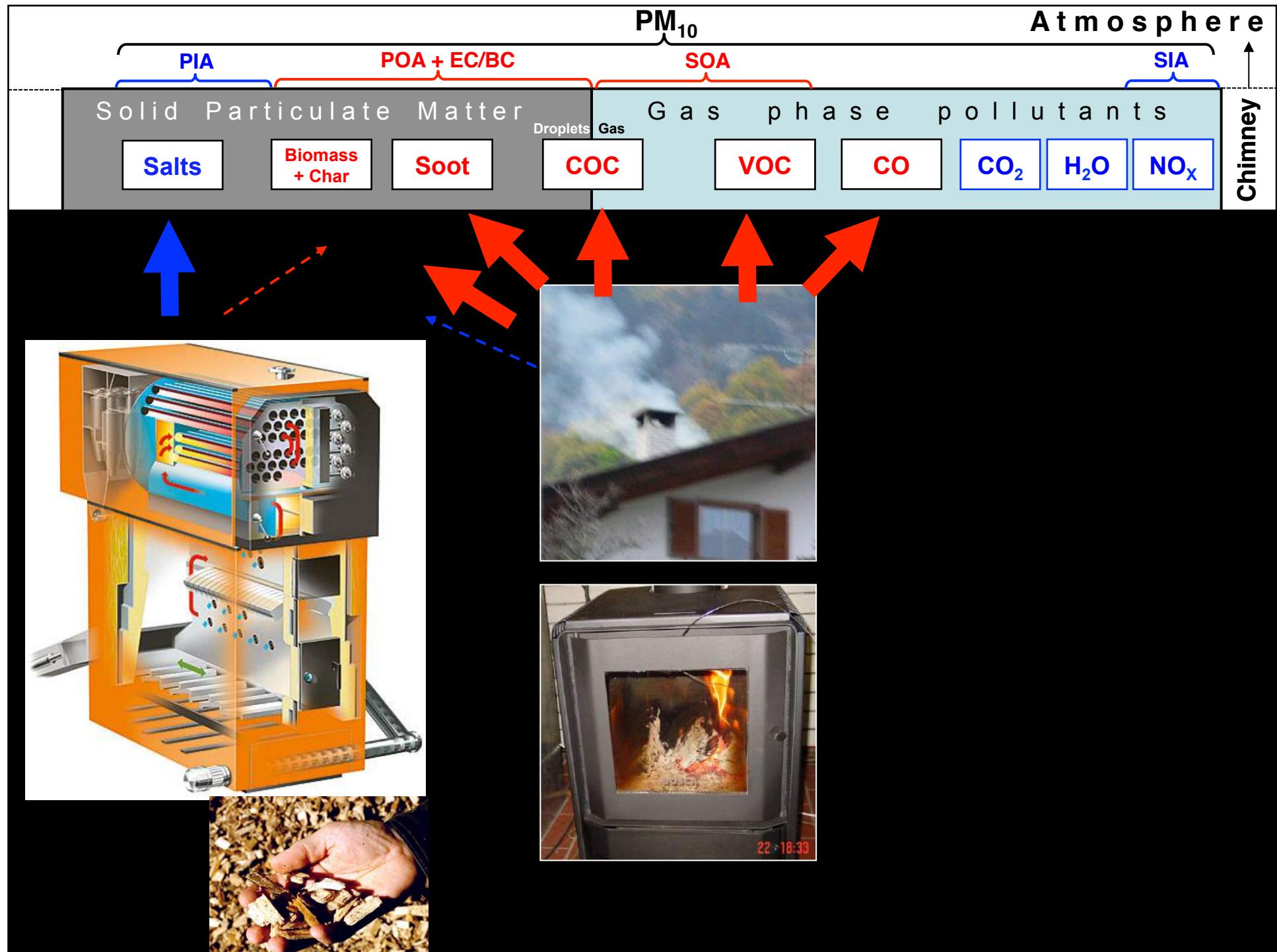


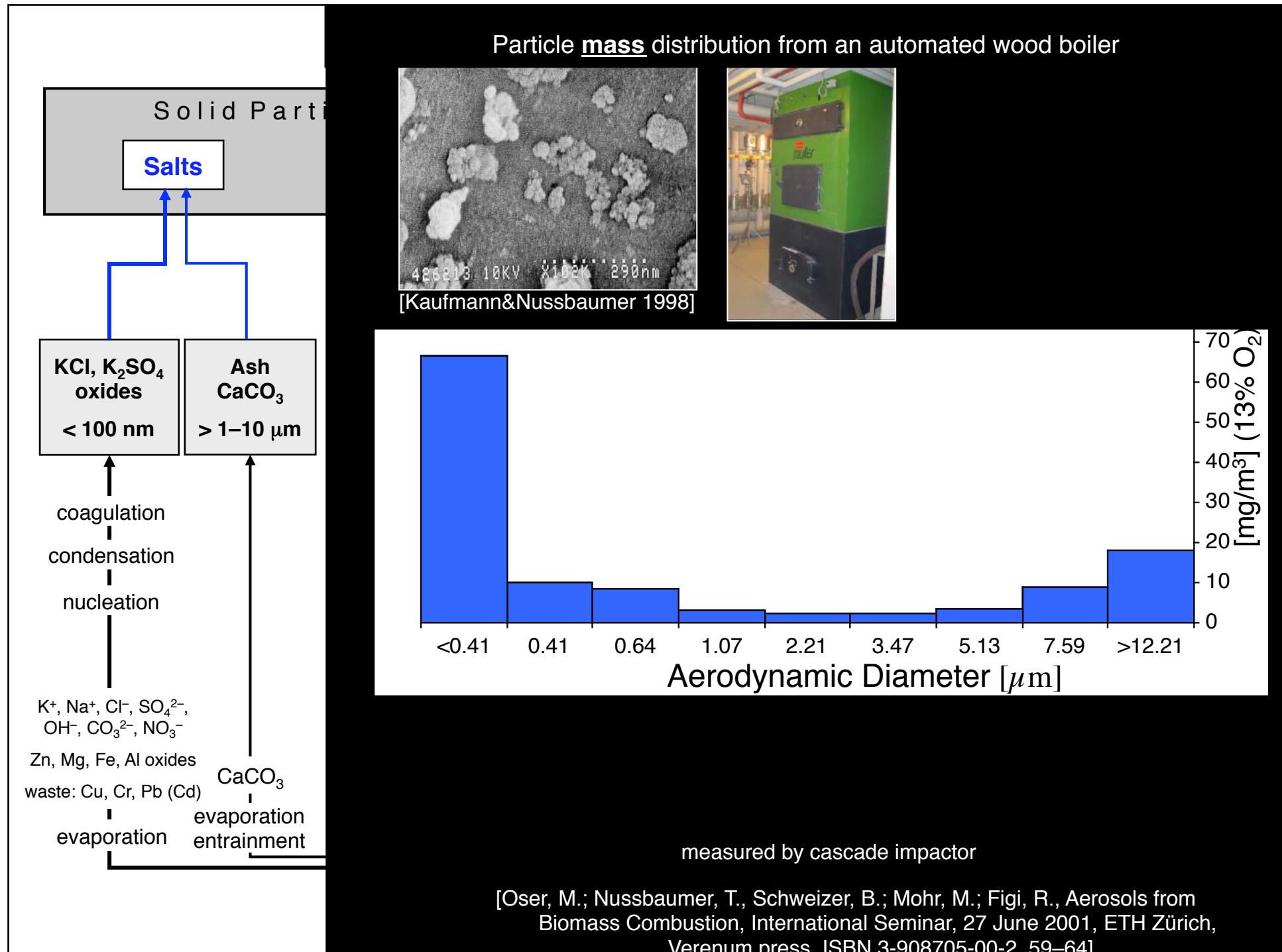


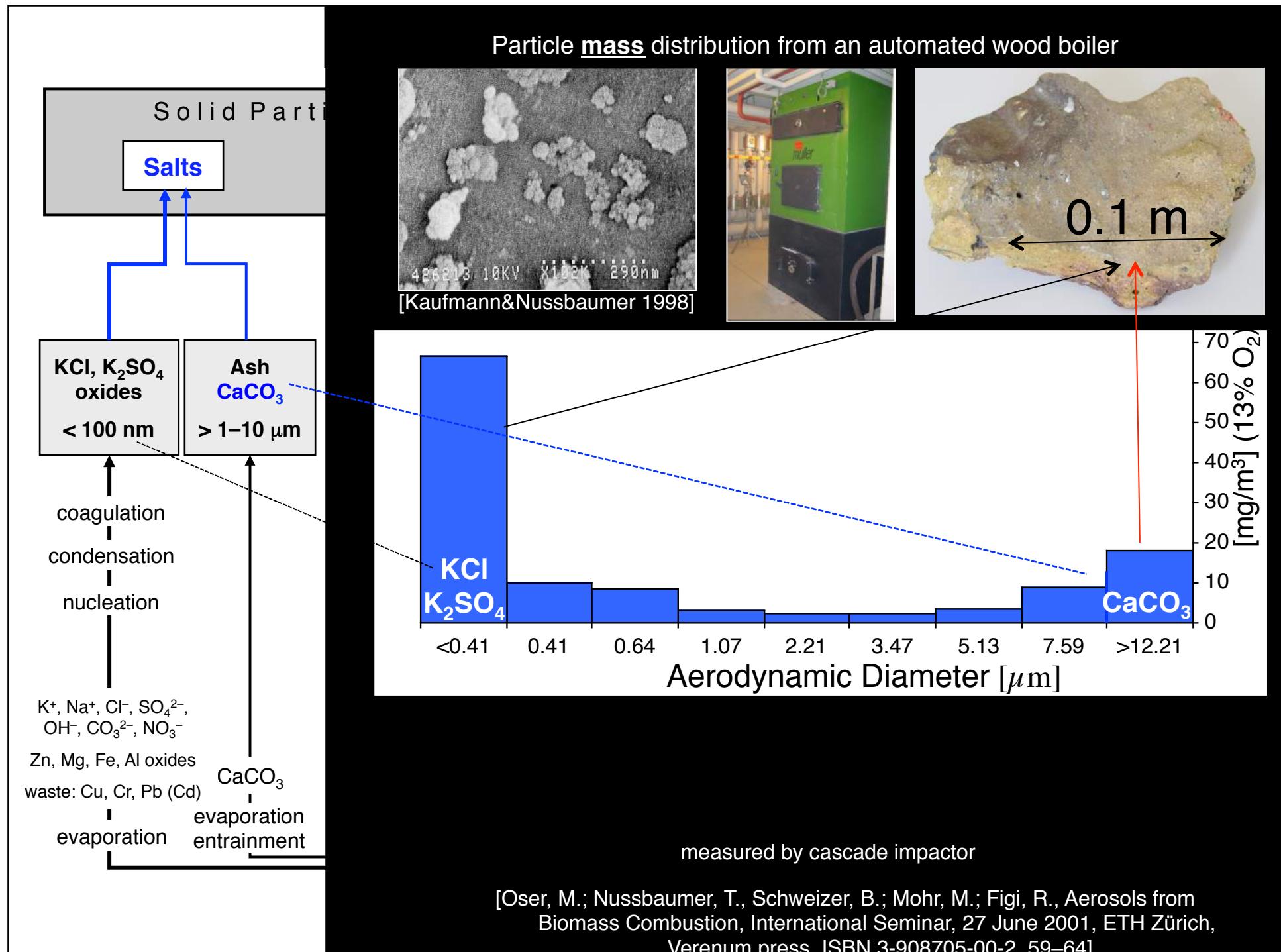


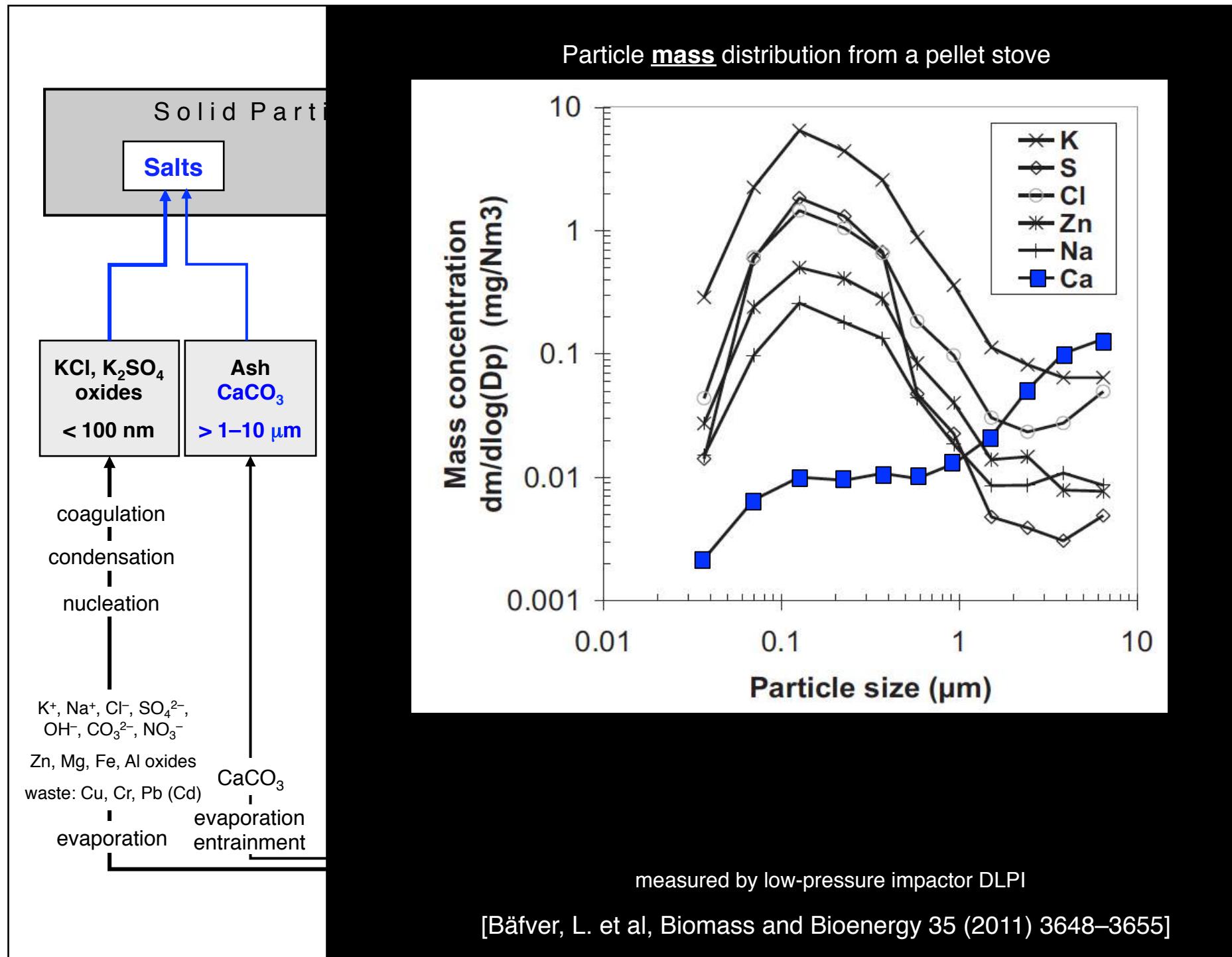




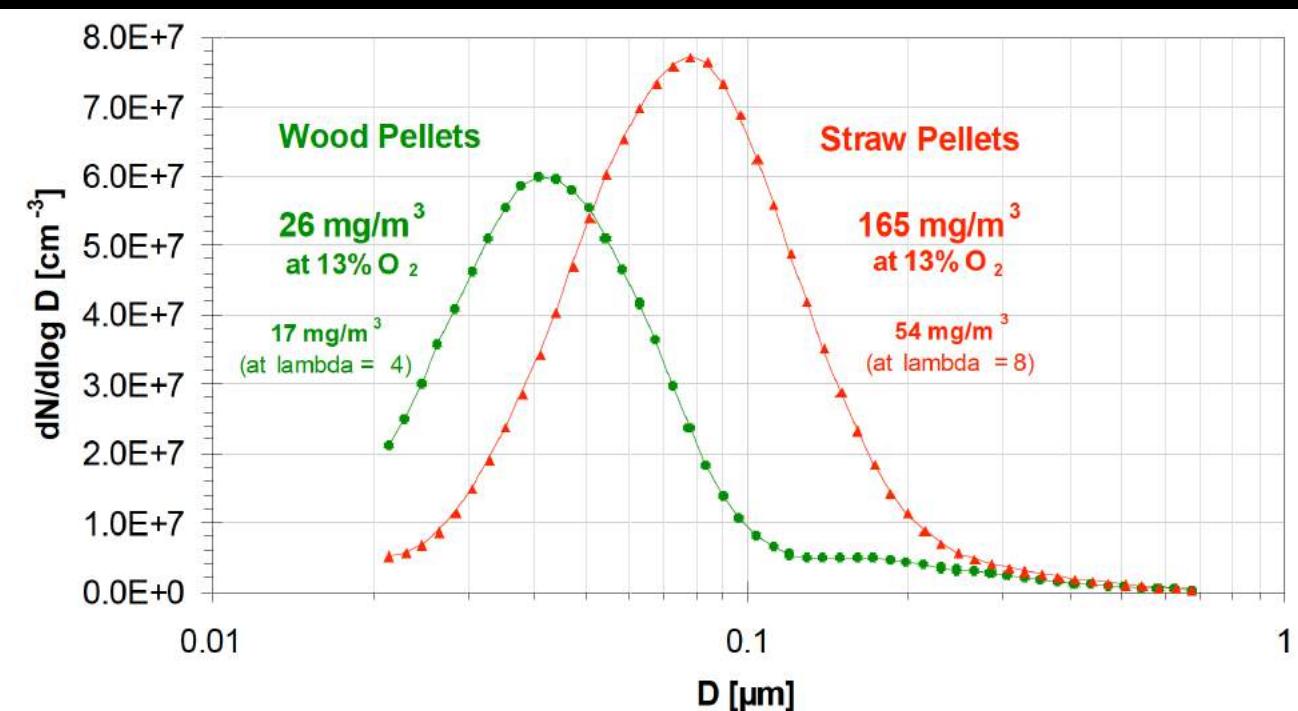
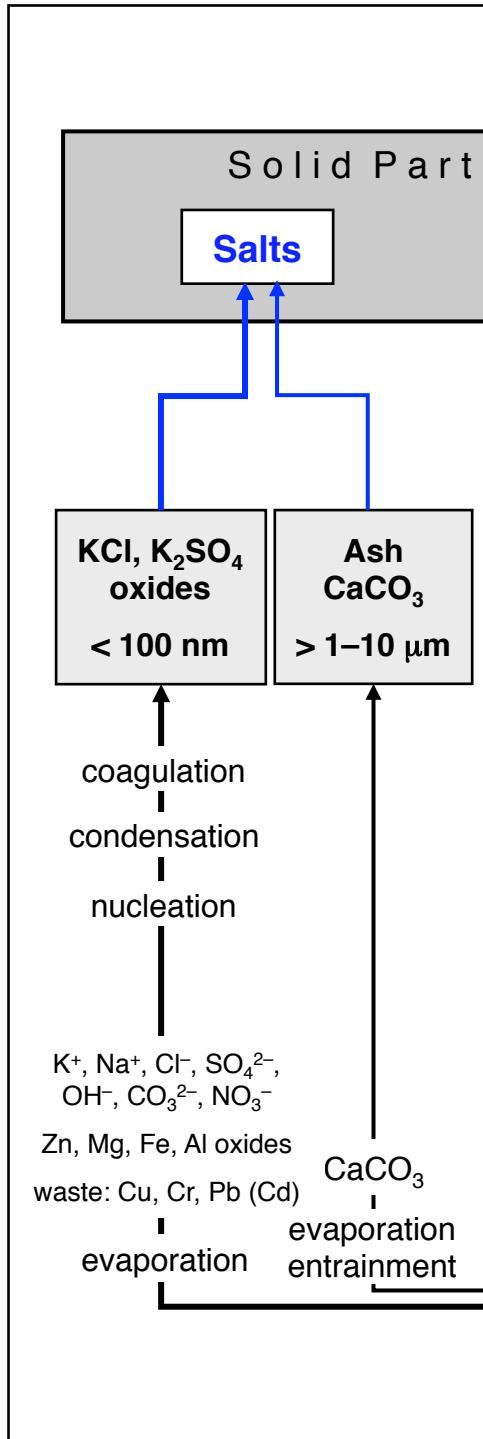






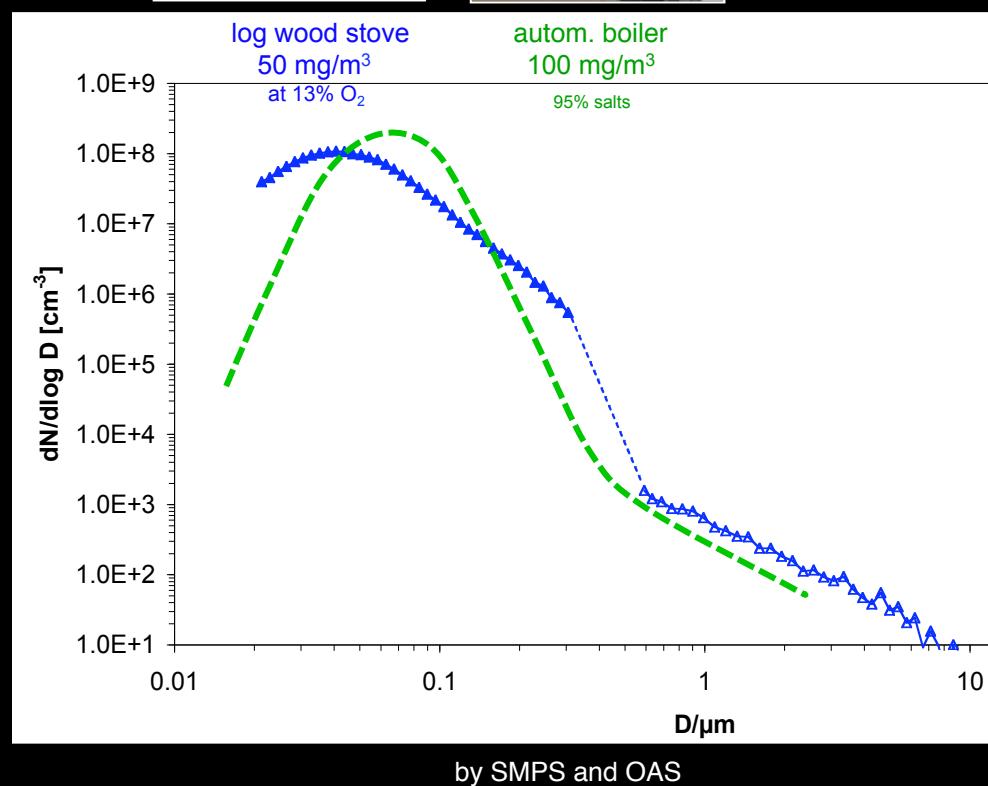
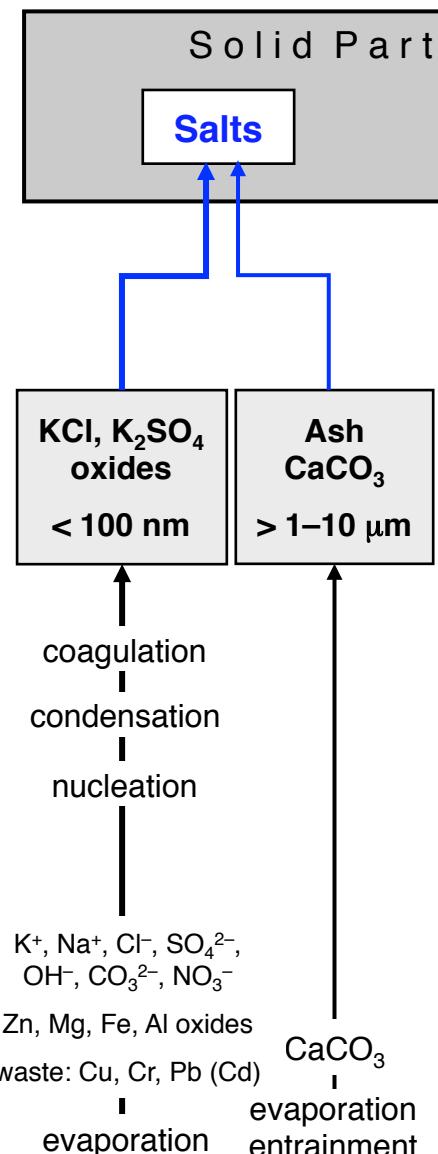


Particle number distribution: Influence of combustion type

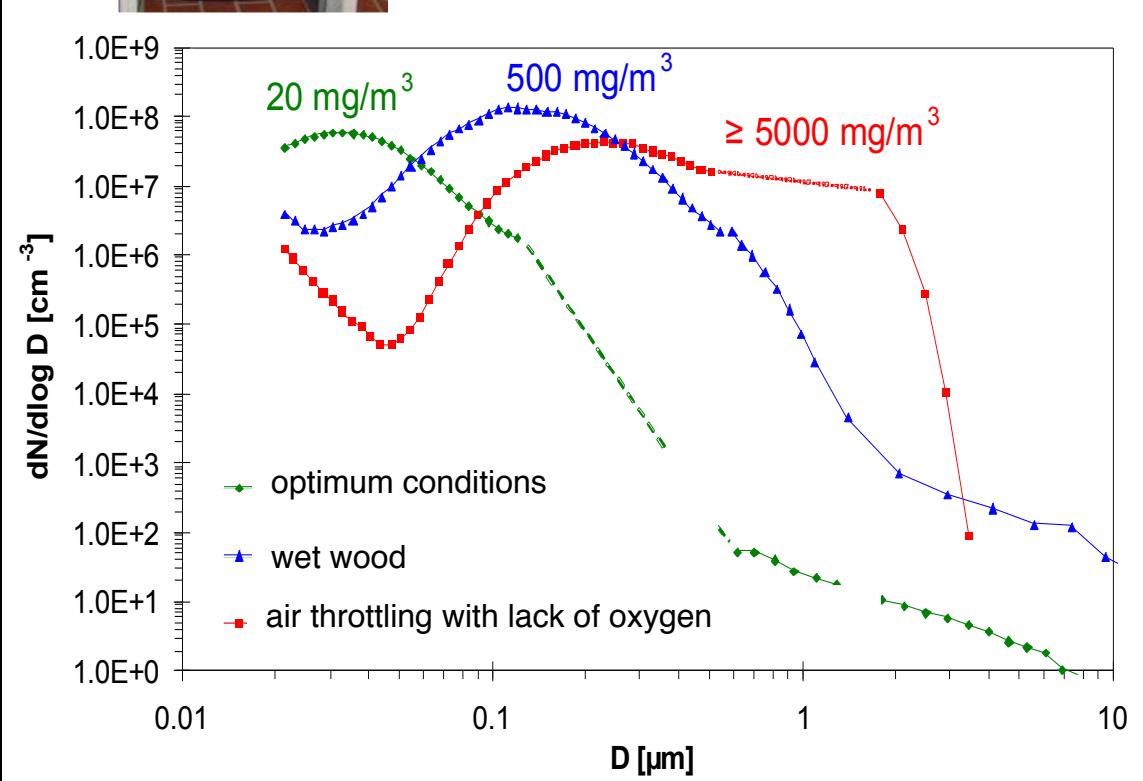
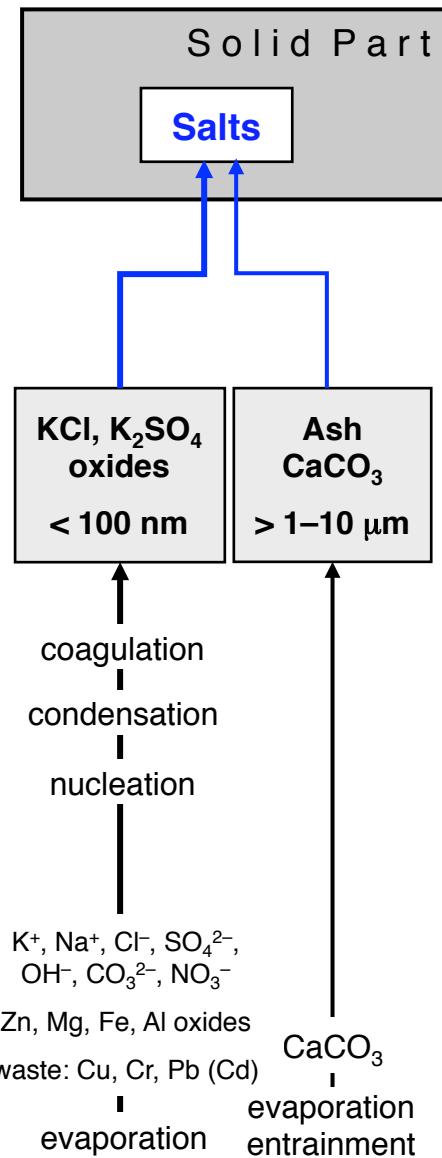


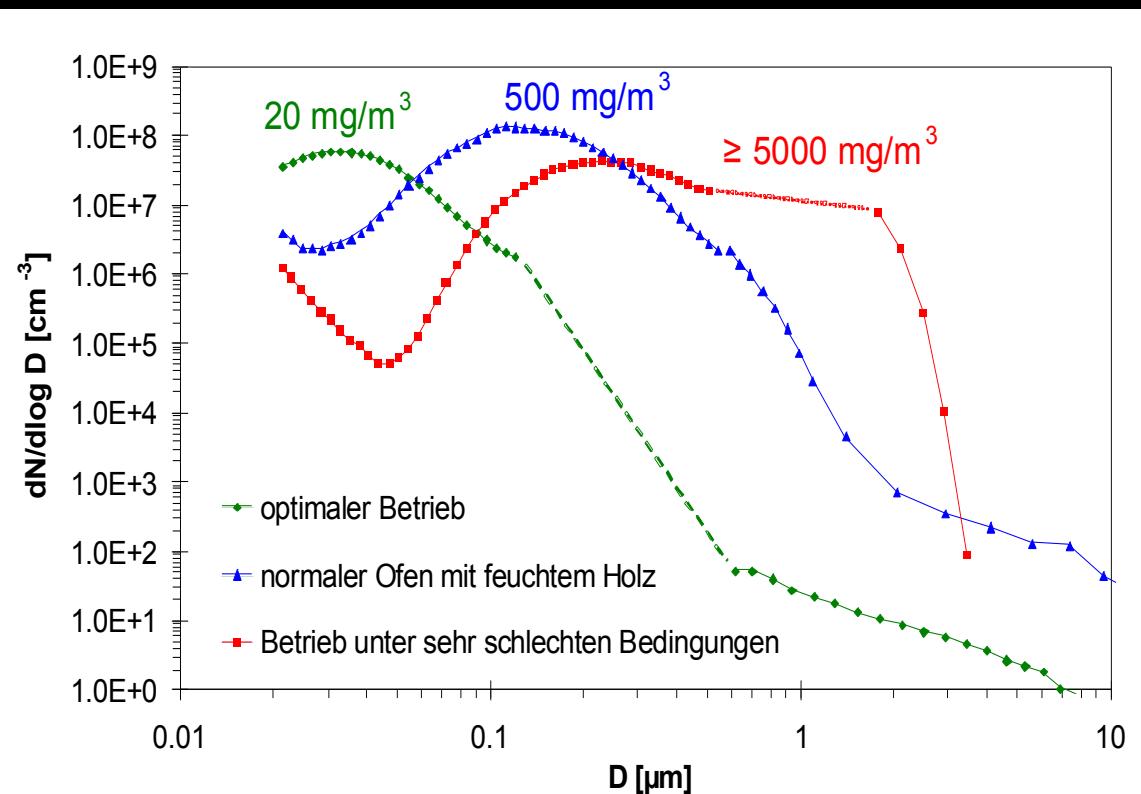
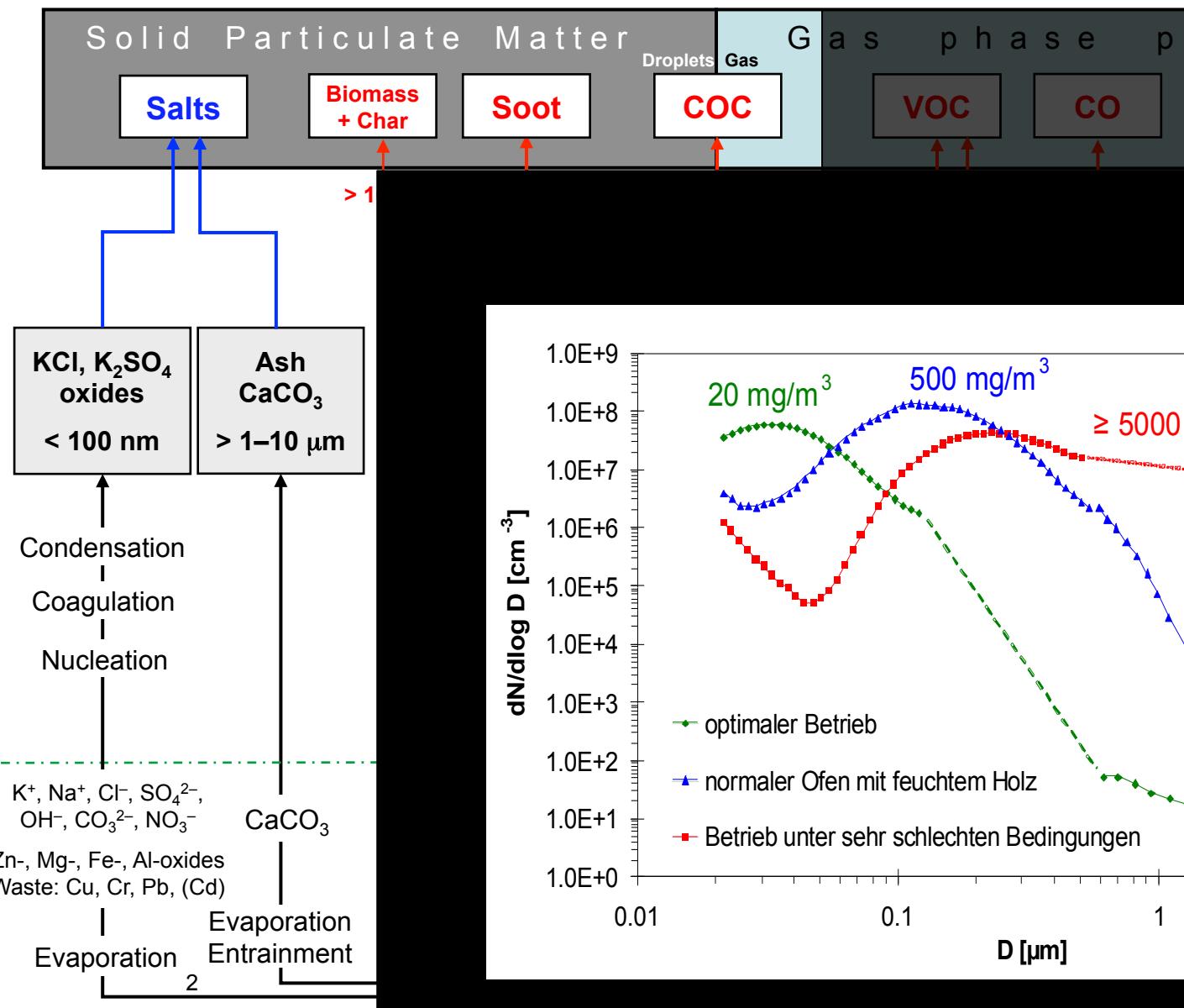
by SMPS

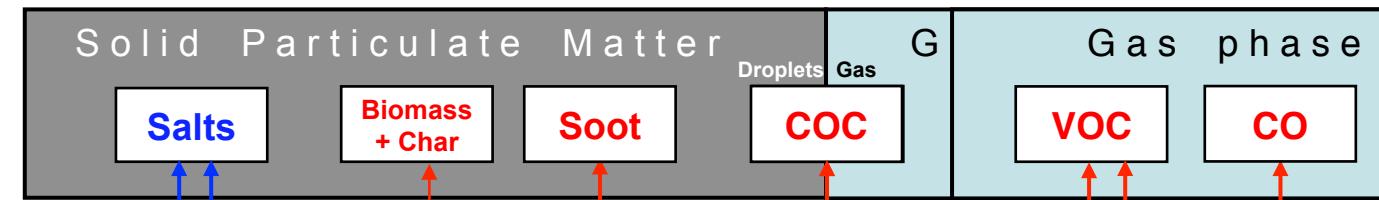
Particle number distribution: Influence of combustion type



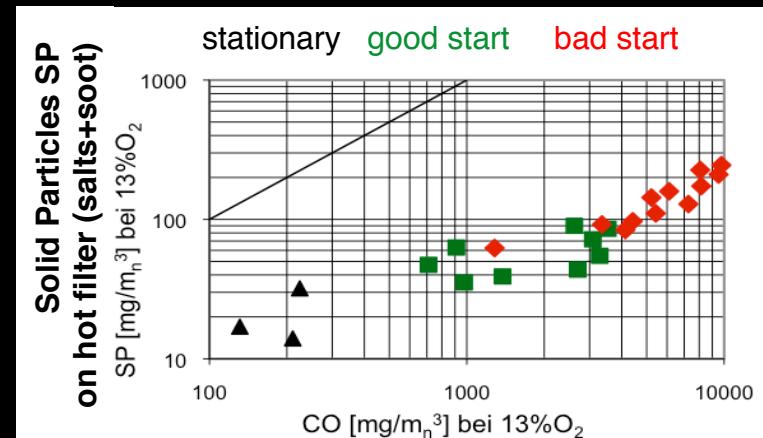
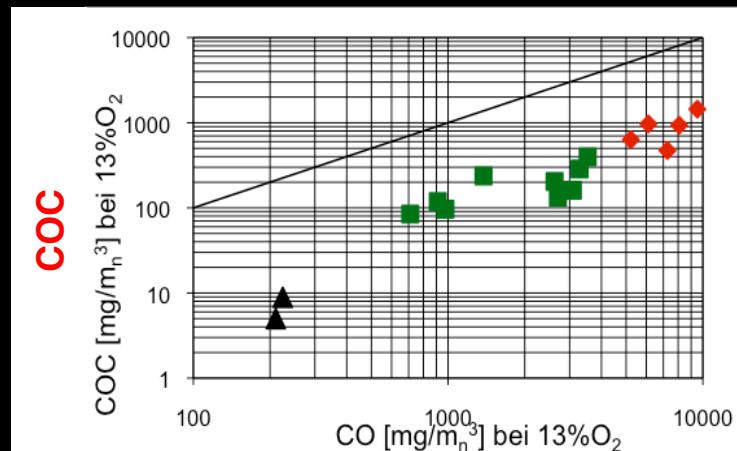
Particle number distribution: Influence of operation in wood stove





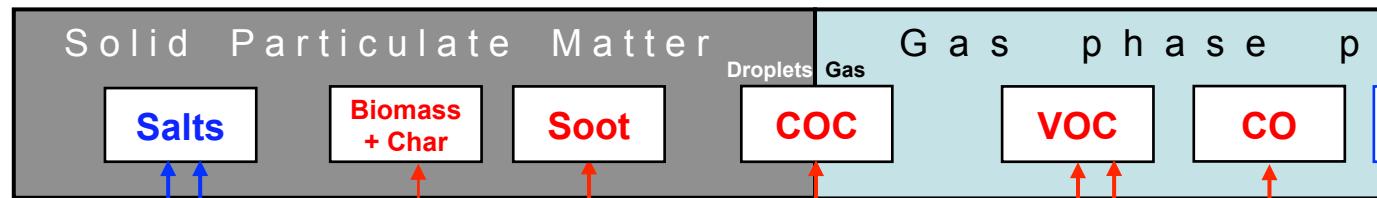


Log wood boiler: Influence of operation

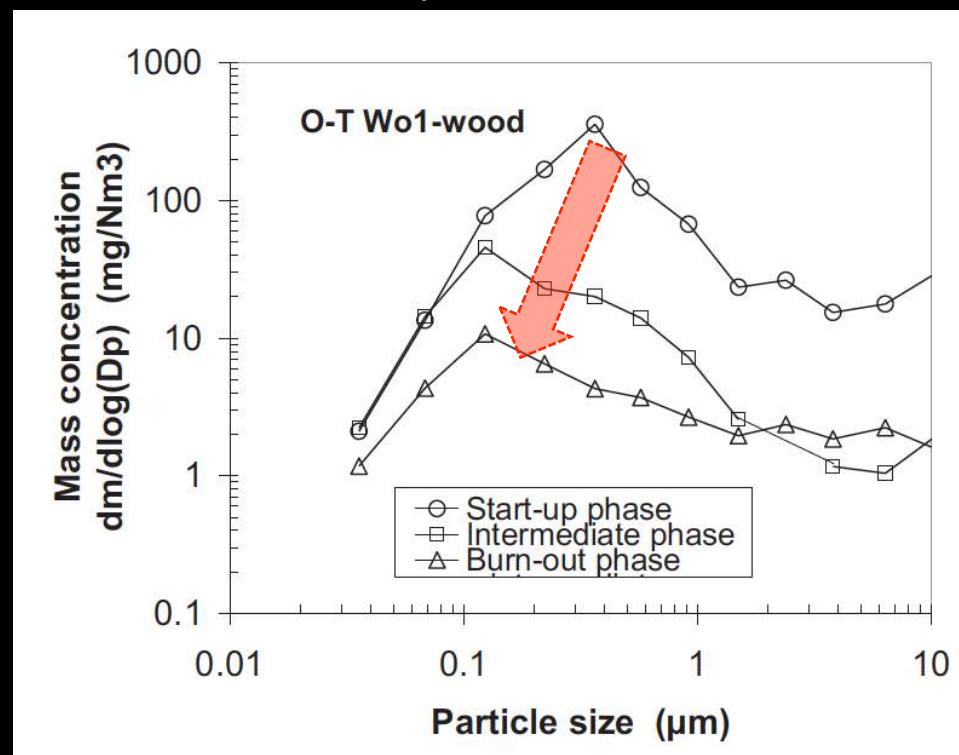


[Good, J., Obermayr, D., Nussbaumer, T., 11. Holzenergie-Symposium, ETH Zürich 2010]

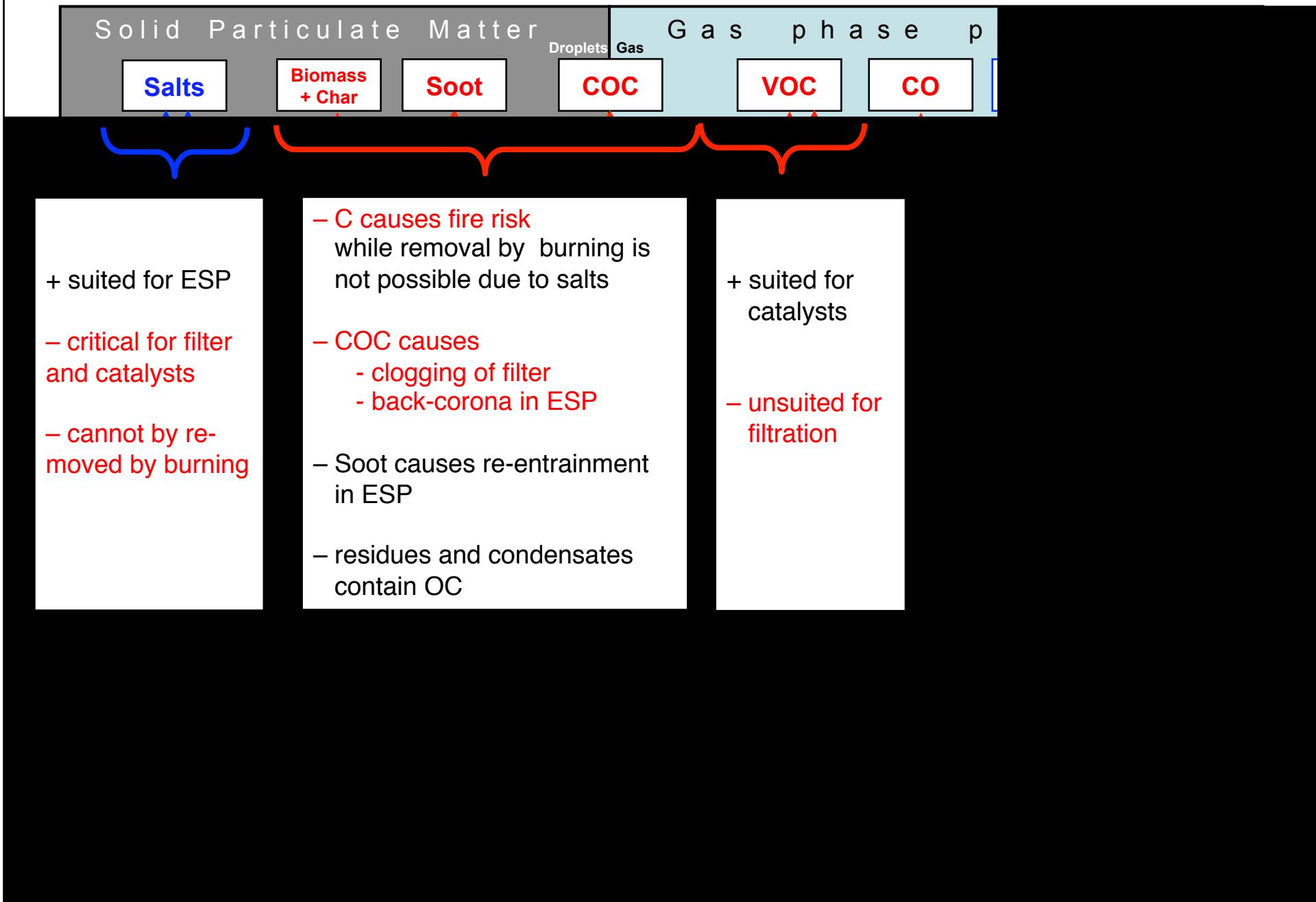
*[Johansson, L. et al., World Bioenergy 2008]

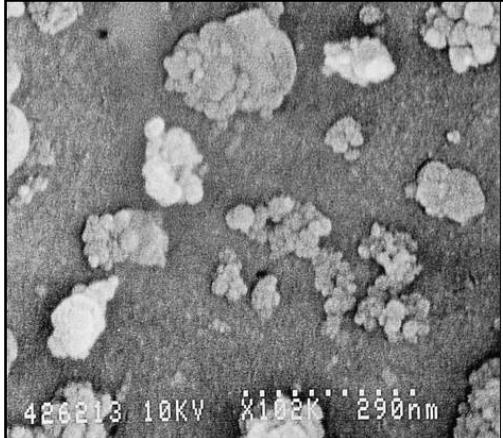


Influence of combustion phase in wood stove



Consequences for secondary measures: catalysts, filtration, electrostatic precipitation (ESP), wet cleaning





1. Biomass – what else ?
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Start-up of wood stoves: Ignition from the top



1-stage Combustion

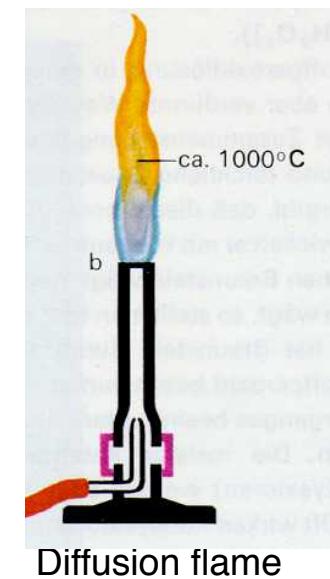
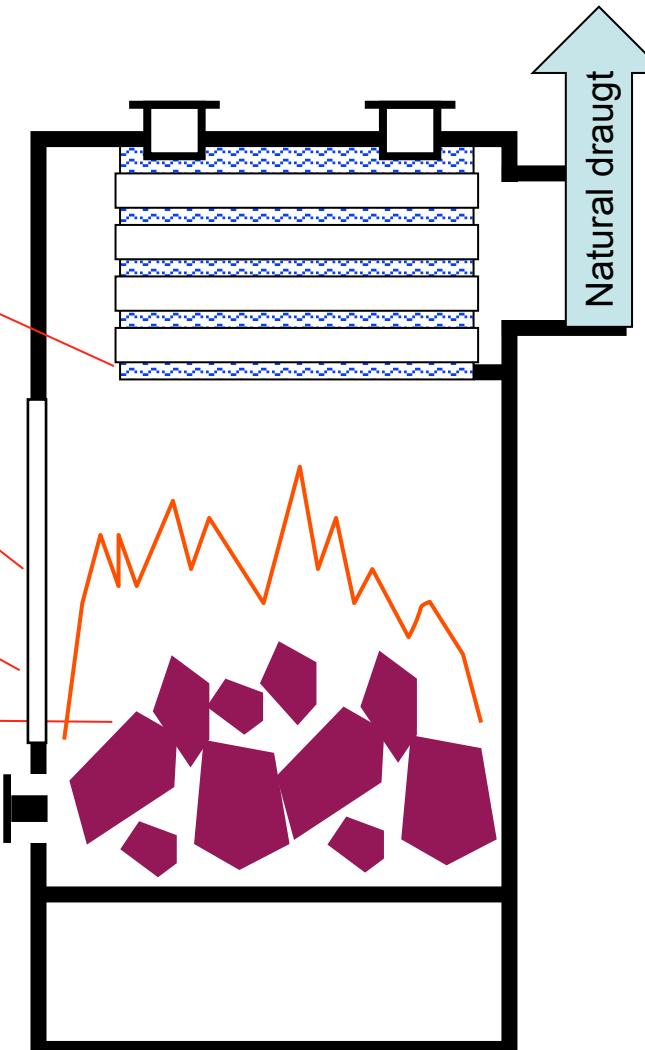
Problem 5:
Quenching

Problem 4:
Flame cooling

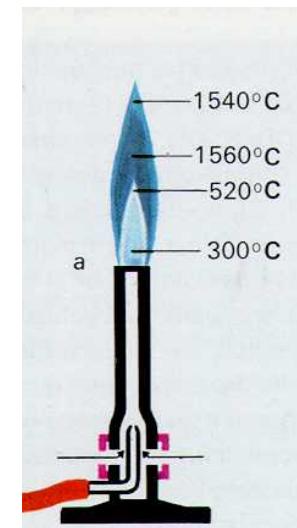
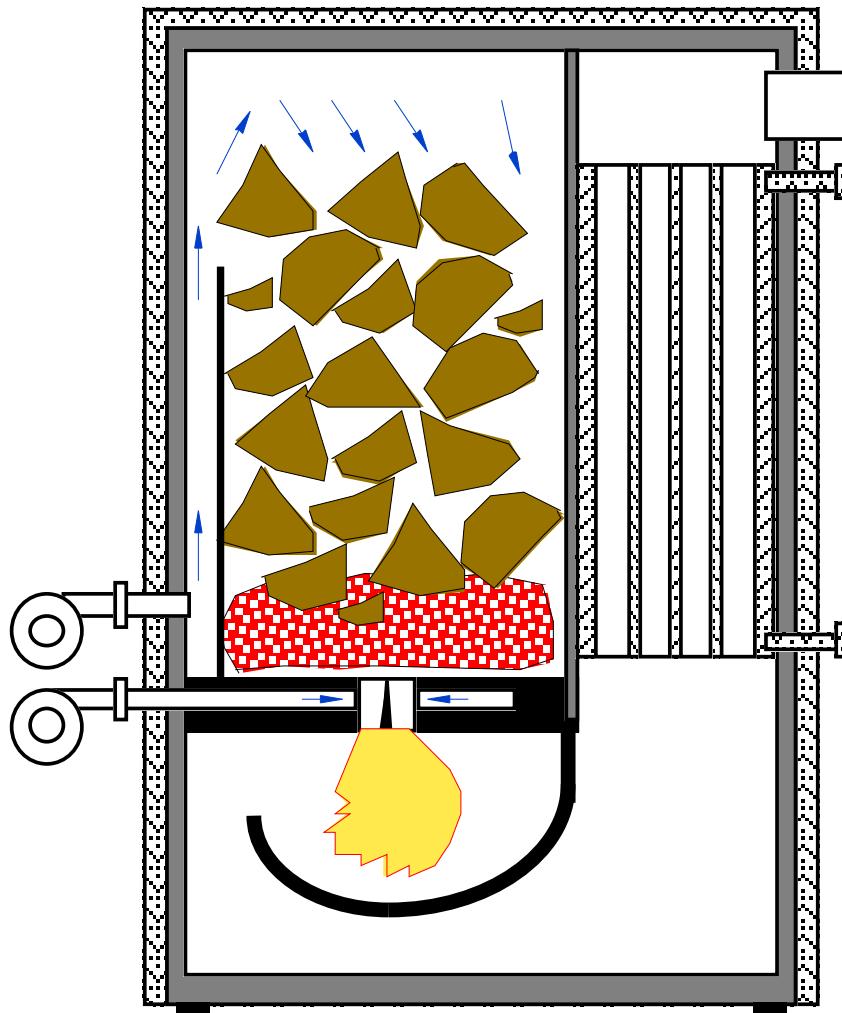
Problem 3:
Air leakage

Problem 2:
Mixing air + gas

Problem 1:
Air/fuel ratio

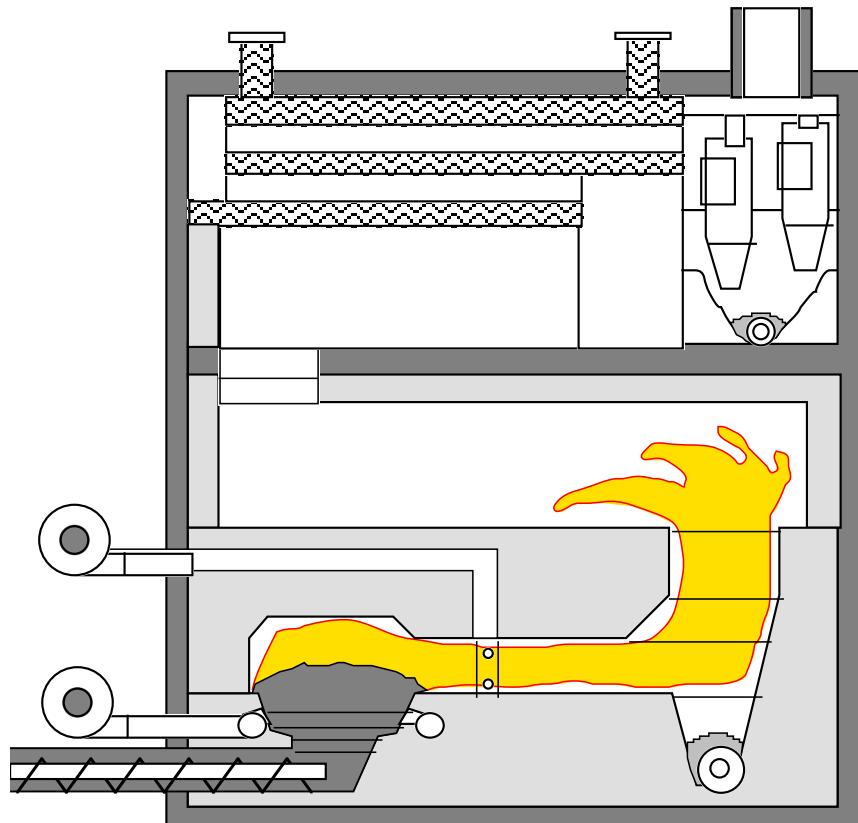


2-stage Combustion



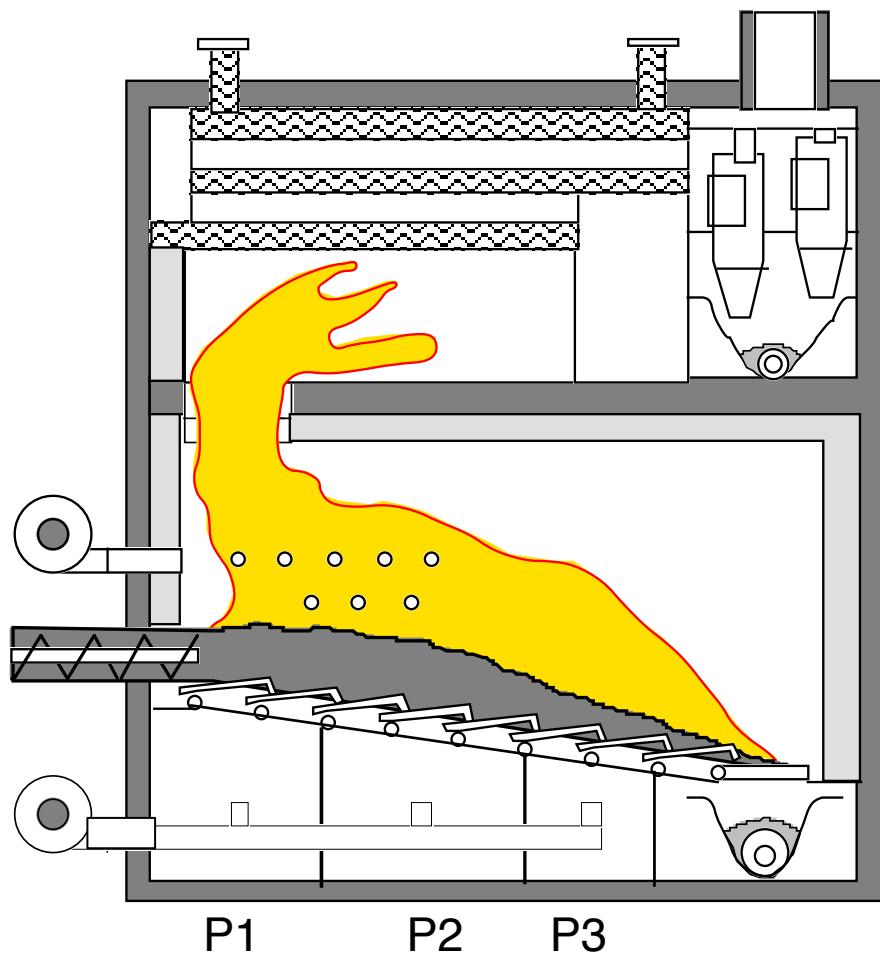
Premixed flame

Under Stoker Boiler



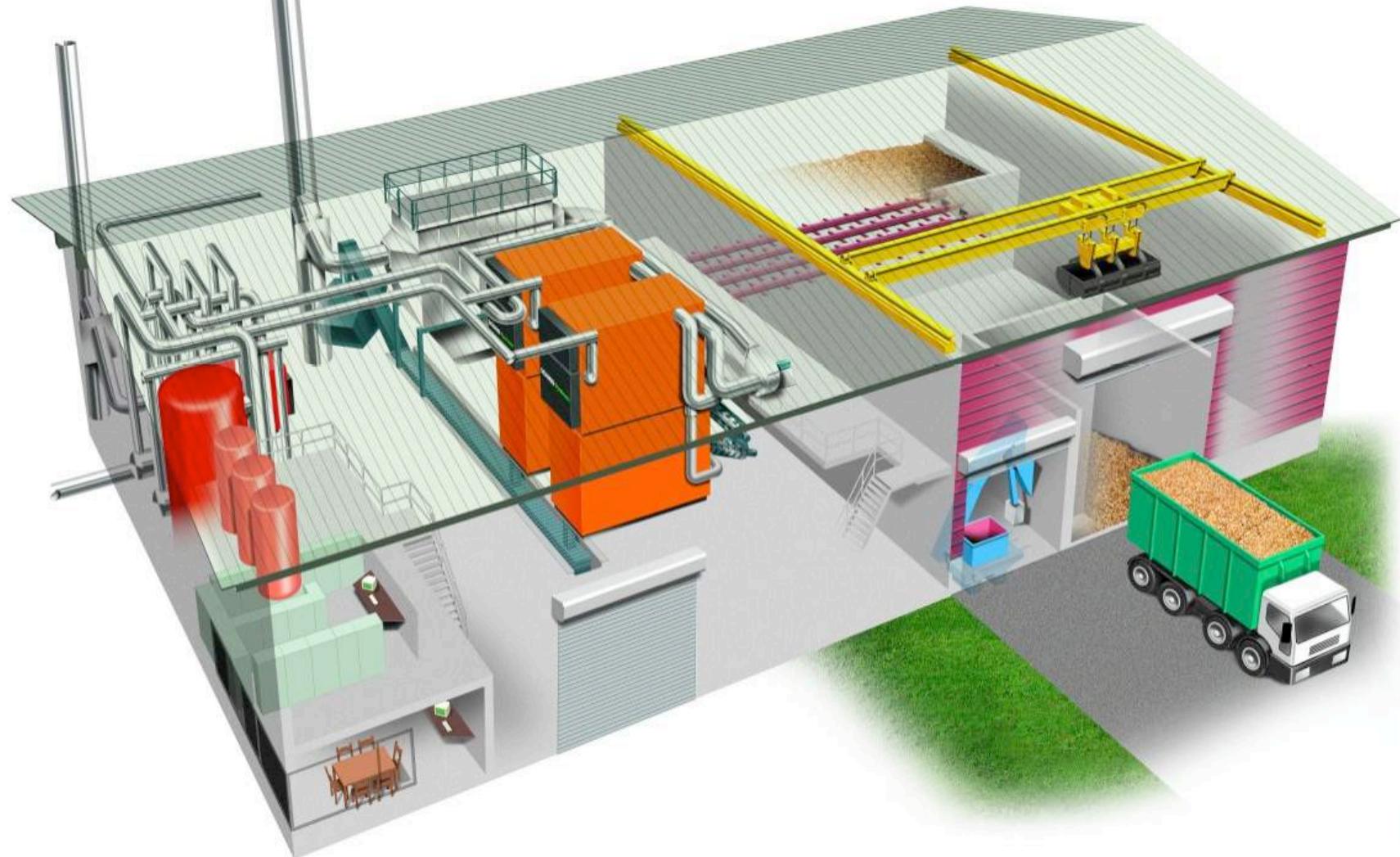
20 kW ... 2000 kW

Moving grate Furnace



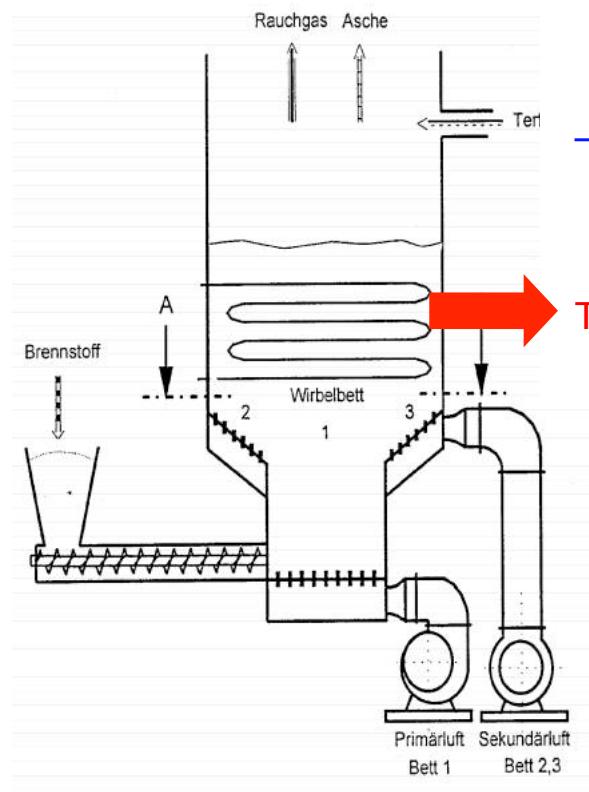
200 kW ... 10 MW

Example of 6.4 MW District heating plant



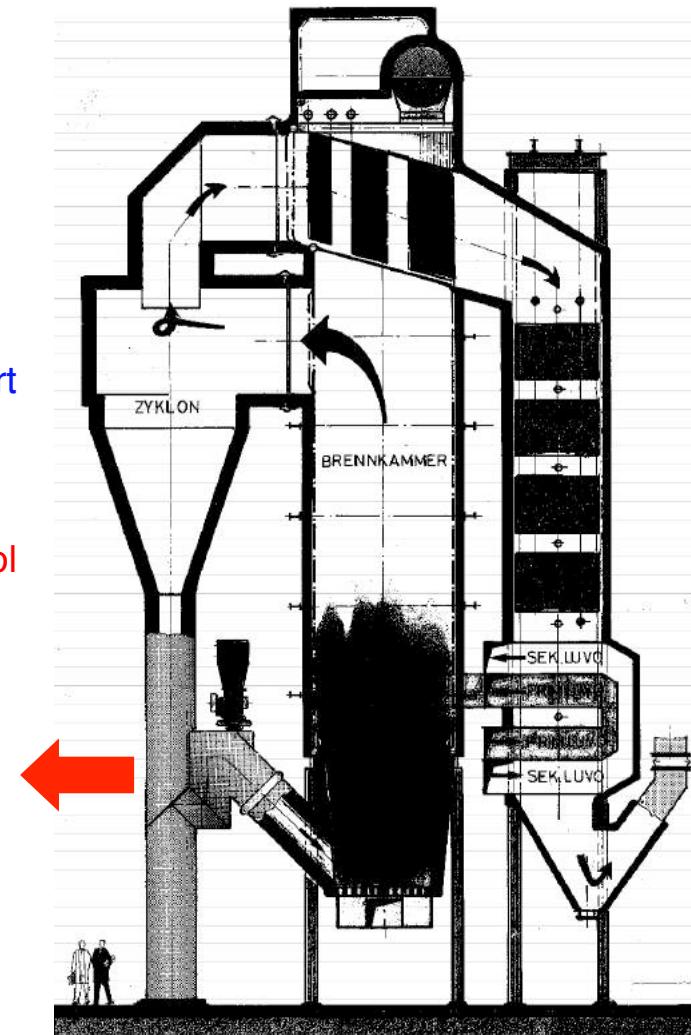
Fluidized Bed Combustion

stationary
5 – 100 MW

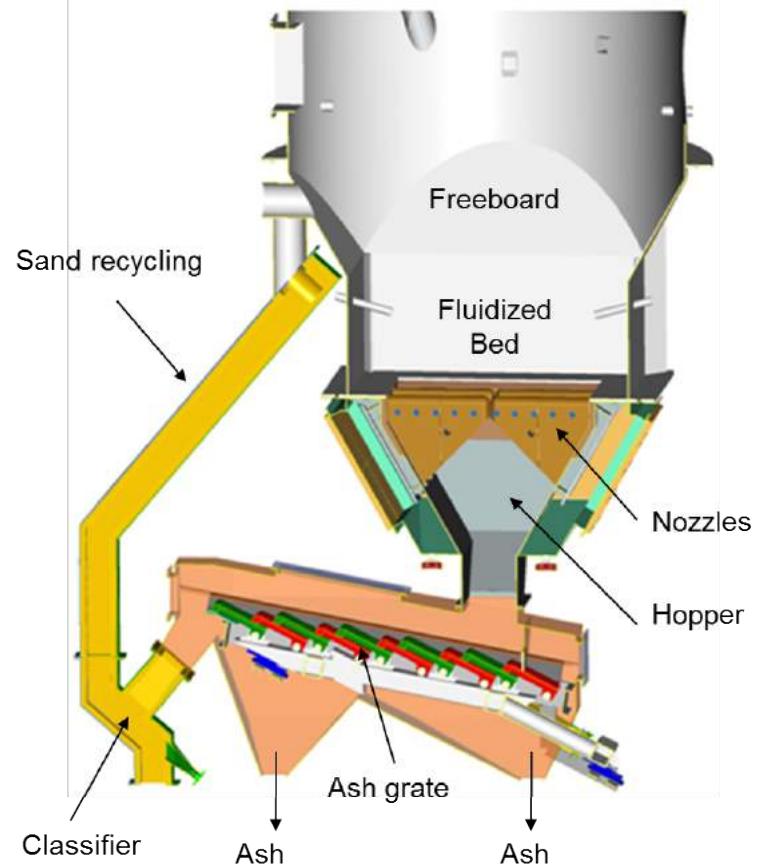


- High turbulence
 - Air staging
 - Circulation of inert bed material (sand, ash)
- Temperature control by heat extraction

circulating
20 – 100 MW



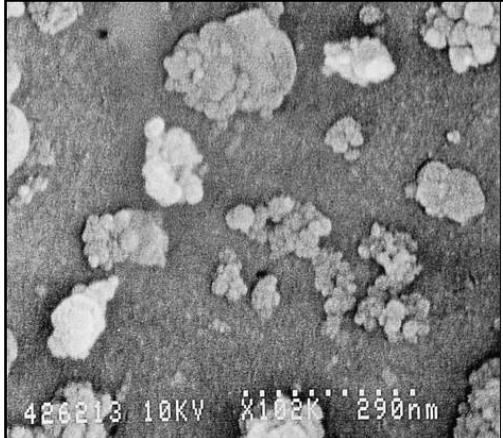
Example of 42 MW FB boiler heating ETH Zürich



[Bertsch]

[Kolbitsch, P., 13. Holzenergie-Symposium, ETH 2014]

HOCHSCHULE
LUZERN



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Conclusion 1: Biomass combustion causes **three types of atm. PM₁₀**:

1. **Inorganic particles** (salts) as primary PM from complete combustion
2. **Soot, COC (and C)** as primary PM from incomplete combustion
3. **SOA** from VOC

Conclusion 2: **Inorganic particles** are relevant for **automated boilers**

- salts can be effectively reduced by **precipitation incl. ESP**
- a limited decrease is possible by **reduction of temp. and gas velocity**

Conclusion 3: **PIC** are relevant for **manual combustion**

Type and concentration depend on **oxygen and temperature**:

- VOC and COC result from low temperature
- soot is formed at high temperature and local lack of oxygen,
- insufficient gas mixing increases all PIC

Conclusion 4: Improved design applies **two-stage combustion**:

- solid fuel conversion with primary air
- consecutive oxidation in a hot chamber with secondary air
- improved mixing assisted by forced ventilation

Conclusion 5: Appropriate **operation** is crucial, e.g.:

- stoves need be ignited **from top** and operated appropriately
- boilers need a **heat storage** tank to avoid throttling

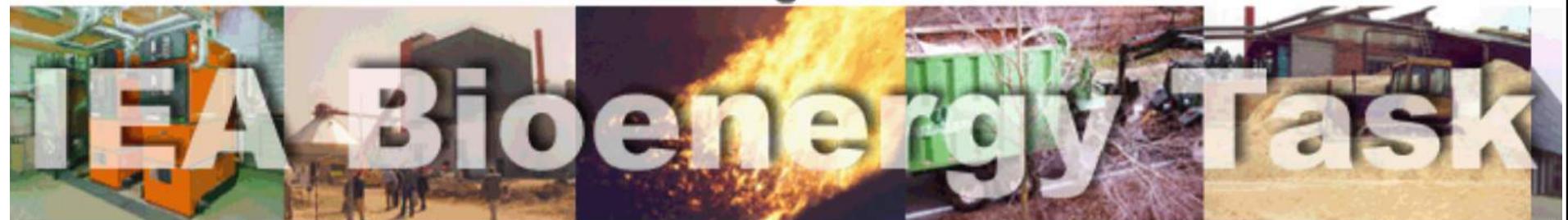


Acknowledgments

- Swiss Federal Office of Energy
- Federal Office for the Environment
- Swiss National Science Foundation
- Commission for Technology and Innovation

International Energy Agency IEA Bioenergy Task 32

Biomass Combustion and Cofiring



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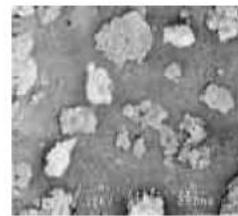
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2001



Aerosols from Biomass Combustion

Thomas Nussbaumer (Ed.)

International Seminar
at 27 June 2001 in Zurich (Switzerland)
organised on behalf of

International Energy Agency (IEA)
BioenergyTask 32: Biomass Combustion and Cofiring

and the

Swiss Federal Office of Energy



IEA Bioenergy

