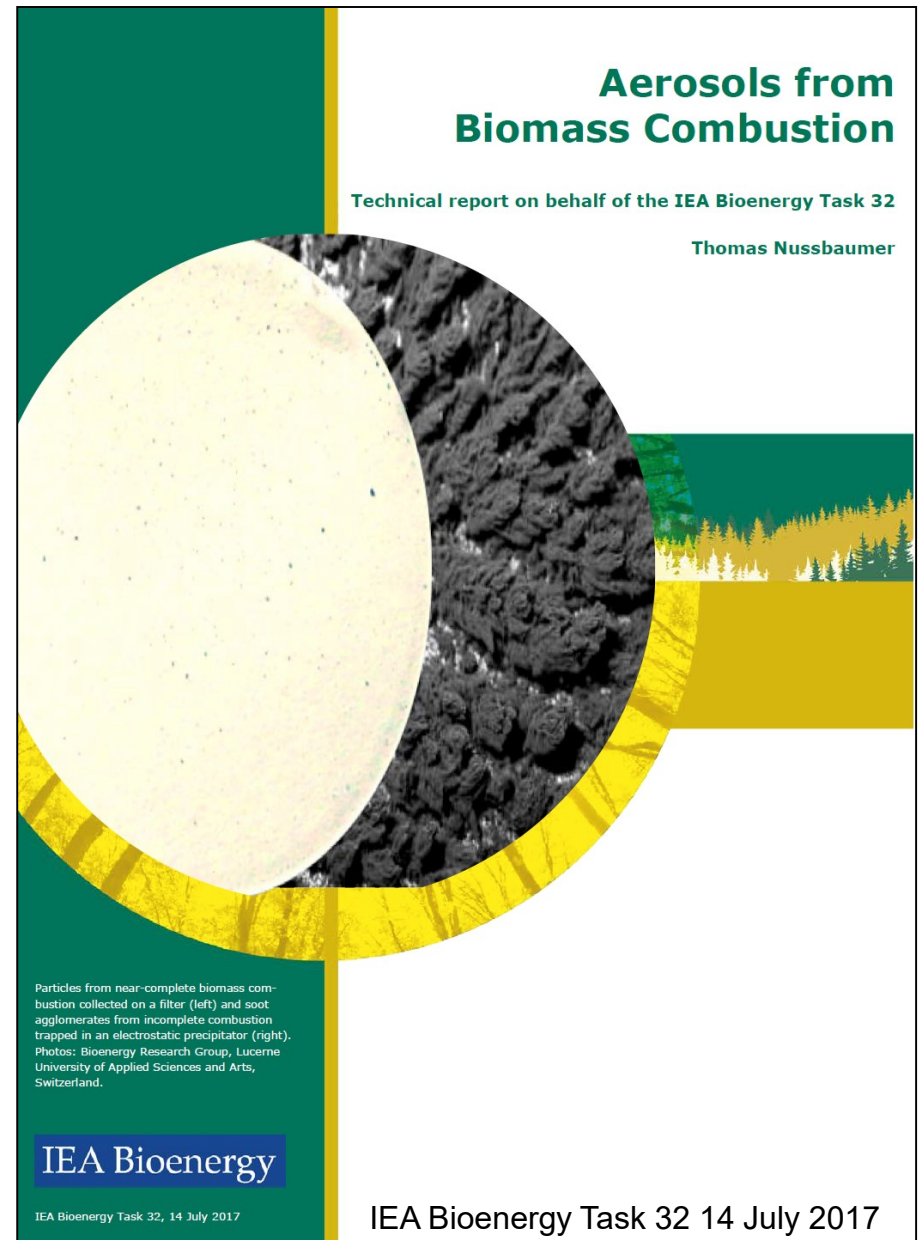


Thomas Nussbaumer

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IEA Bioenergy Task 32

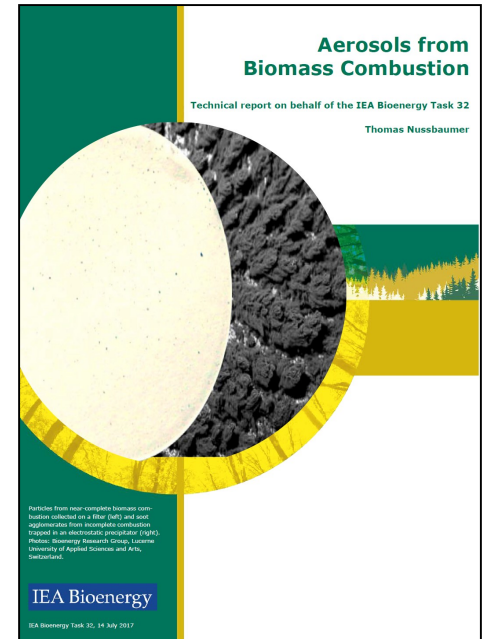


Part 1: Background

1.1 Suppositions, facts and figures

1.2 Measures to reduce or avoid PM

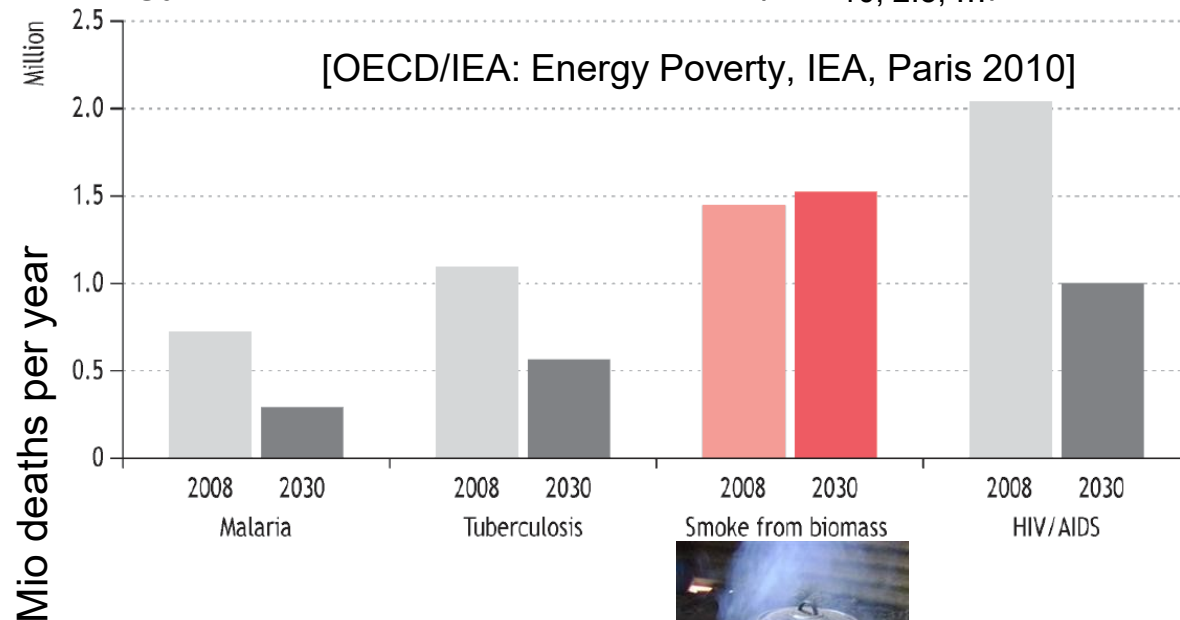
Part 2: Position of IEA Task 32



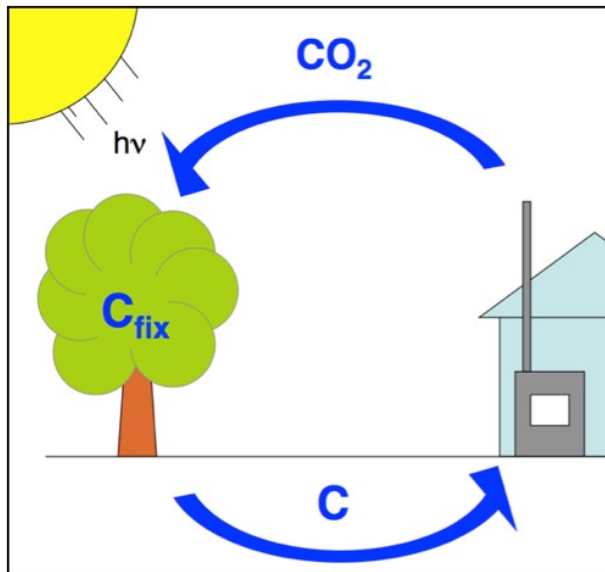
Part 1: Background

1.1 Suppositions, facts and figures

1. Priority 1 for IEA Bioenergy is to promote biomass as a renewable fuel, however, only for applications with low environmental impact
2. Good boilers cause low air pollution **if** they are properly operated
3. Non-ideal devices **or** operation cause **incomplete combustion** and **PIC**:
 - gases (CO, VOC) and
 - particulate matter (**PM**)
4. Epidemiology reveals that inhalable PM ($PM_{10, 2.5, \dots}$) is harmful to health



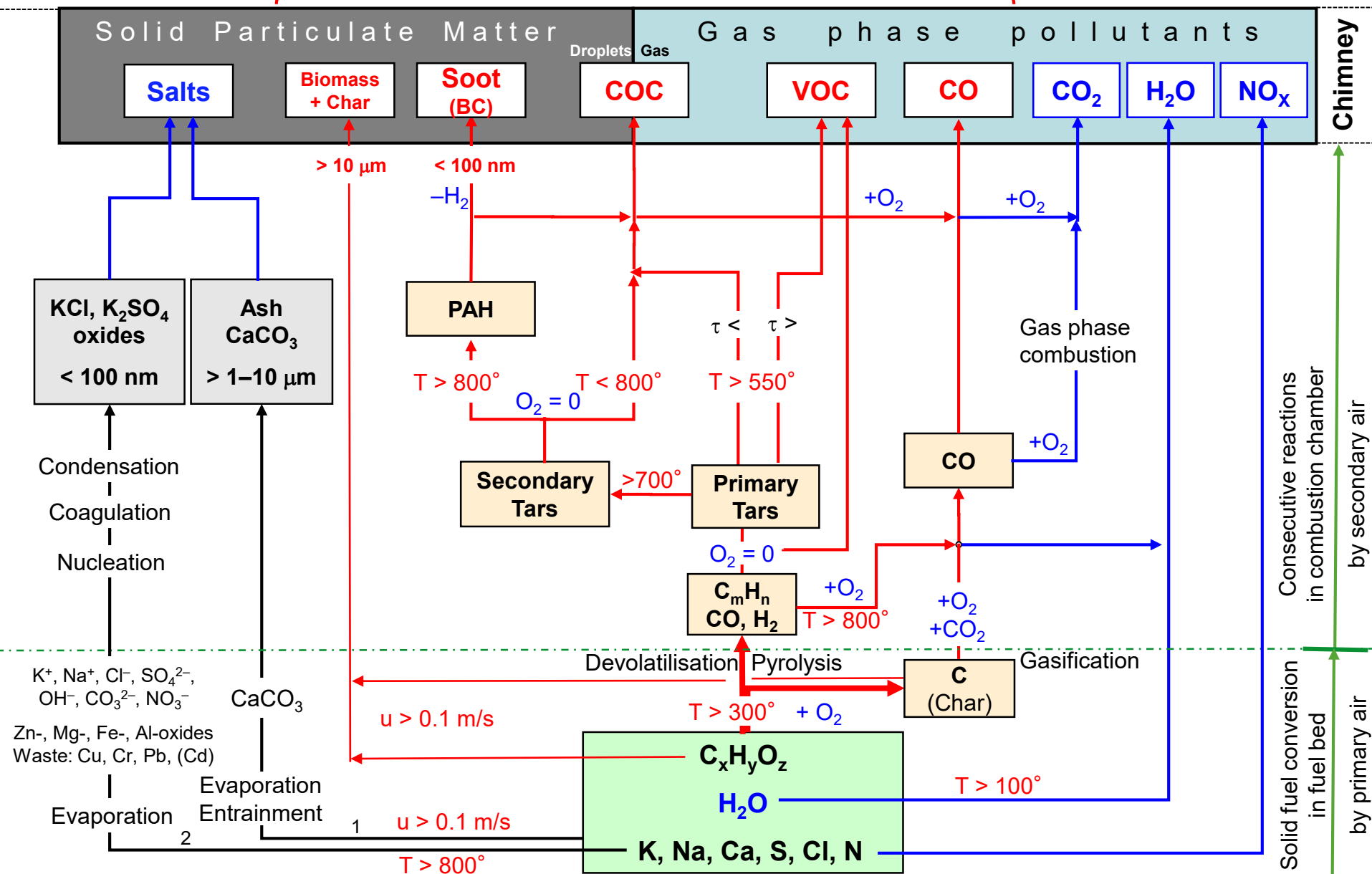
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1. Priority 1 for IEA Bioenergy is to promote biomass as a renewable fuel, however, only for applications with low environmental impact
2. Good boilers cause low air pollution **if** they are properly operated
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 - gases (CO, VOC) and
 - particulate matter (PM)
4. Epidemiology reveals that inhalable PM ($PM_{10, 2.5, \dots}$) is harmful to health
5. To assess combustion aerosols, two types of PM are distinguished

Type 1: Products from **incomplete combustion** (carbonaceous) causing a) primary PM as soot and POA (incl. COC (tar))
b) SOA formed from VOC

Type 2: Products also formed at near-complete combustion:
Primary inorganic aerosols from ash (K, Ca, Cl, ..)
Thanks to lack of OC, these “salts” can be precipitated



BC: Black Carbon

COC: Condensable Organic Compounds

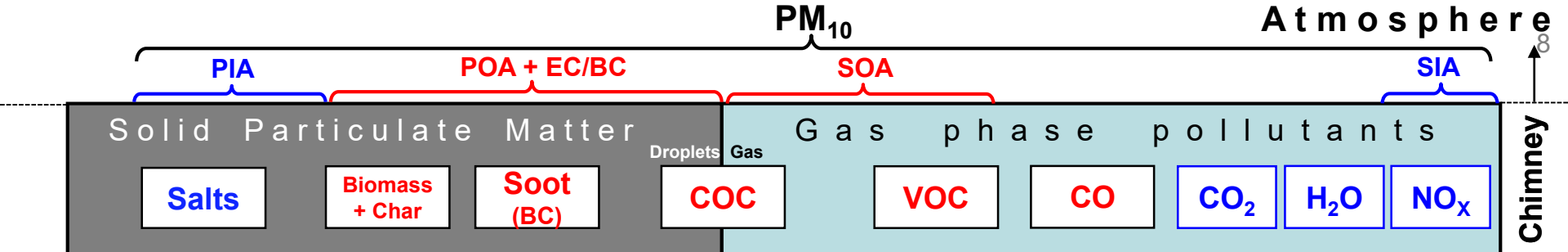
VOC: Volatile Organic Compounds

[Nussbaumer, T., IEA Report 2017]

Data on T: [Evans and Milne, 1987] on H₂: [Jess, 1996]

u Gas velocity, τ Residence time, \leq / \geq short/long

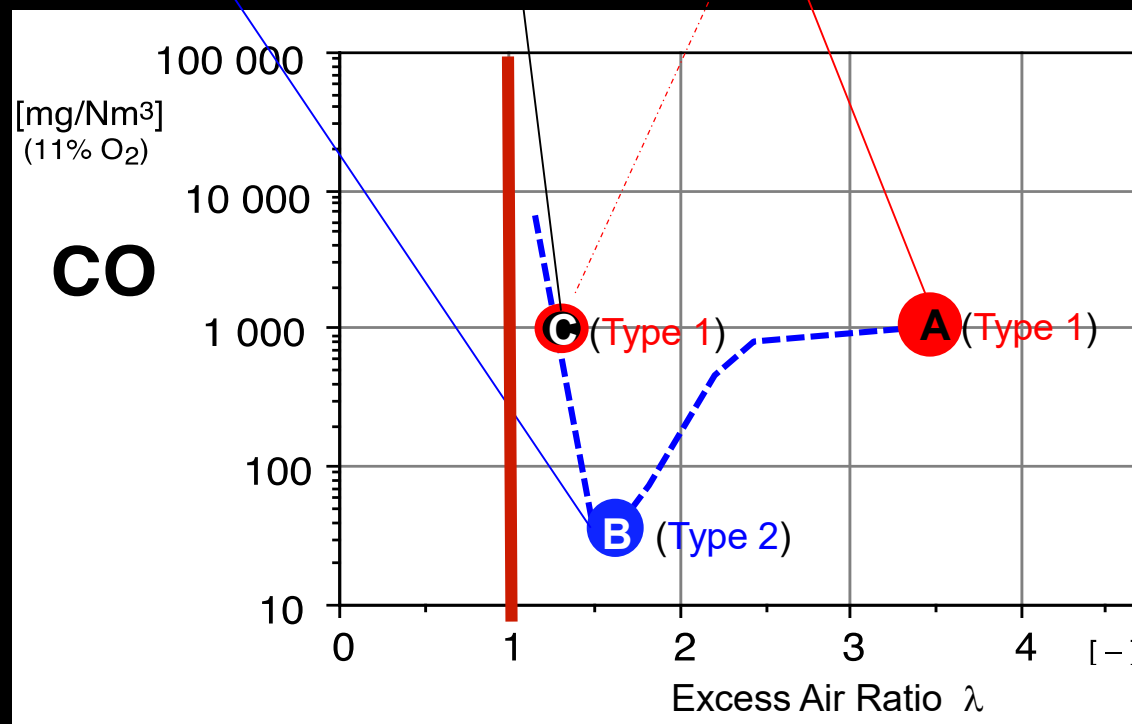
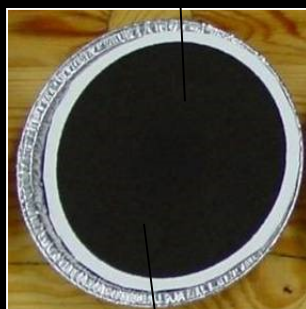
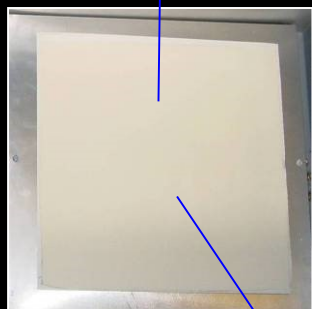
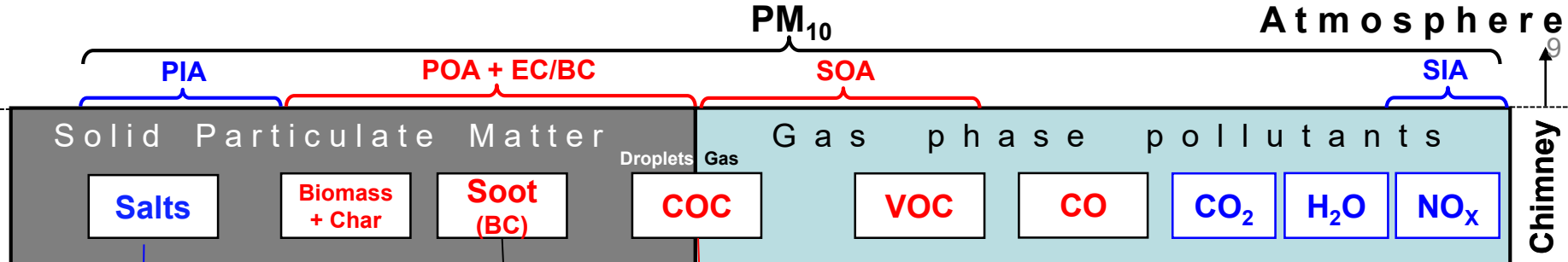
1 Solid-particle-path, 2 Solid-vapour-particle-path



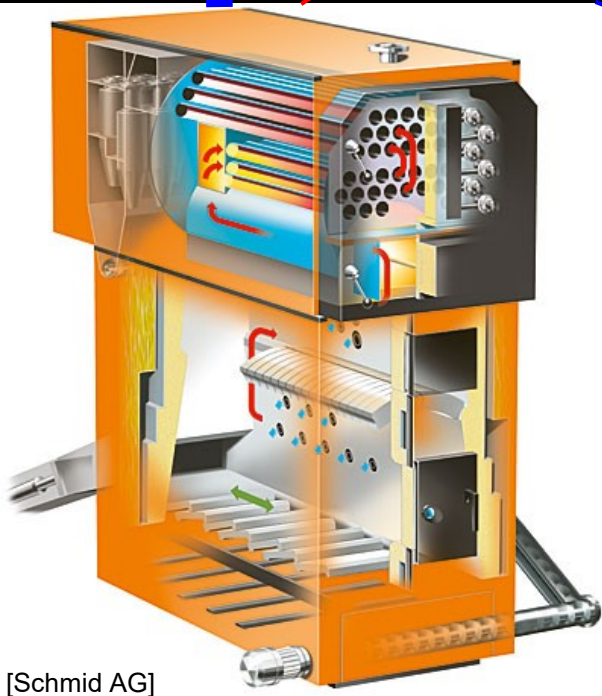
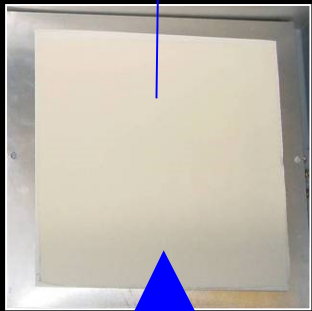
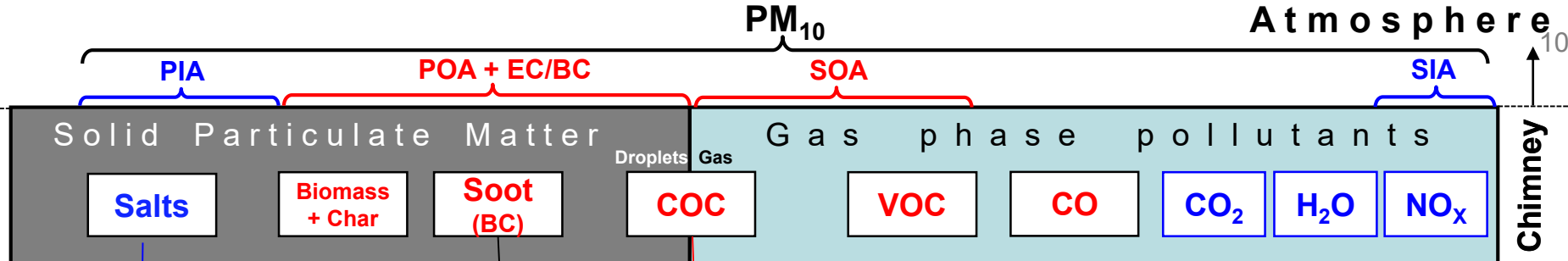
COC: Condensable Organic Compounds
VOC: Volatile Organic Compounds

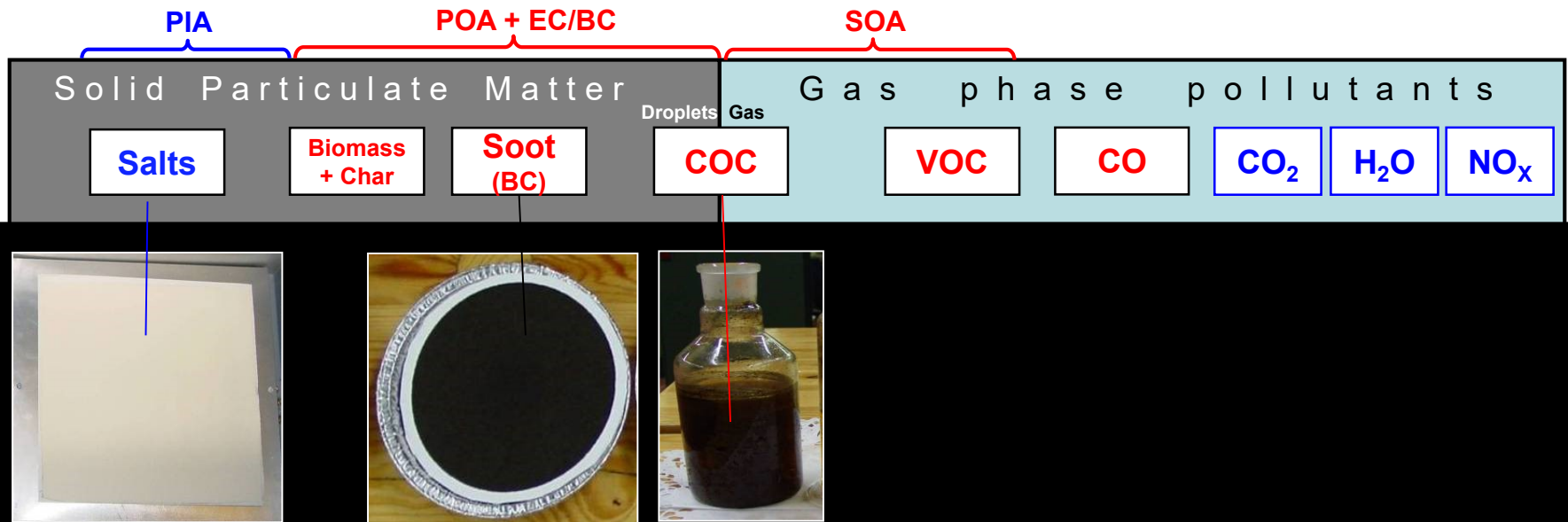
EC/BC: Elemental Carbon/Black Carbon
POA: Primary Organic Aerosol
SOA: Secondary Organic Aerosol

PIA: Primary Inorganic Aerosol
SIA: Secondary Inorganic Aerosol

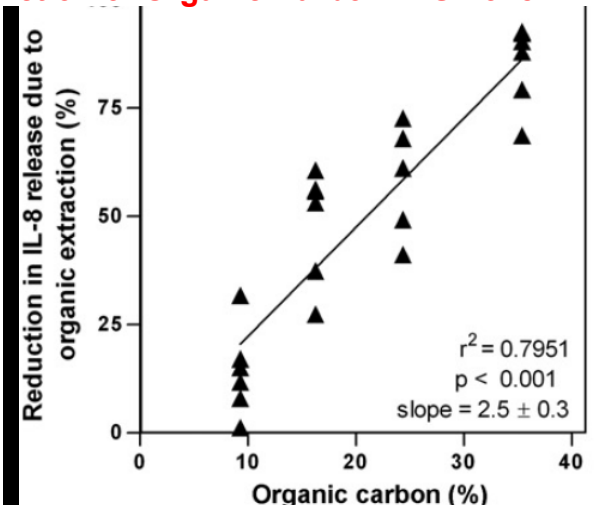
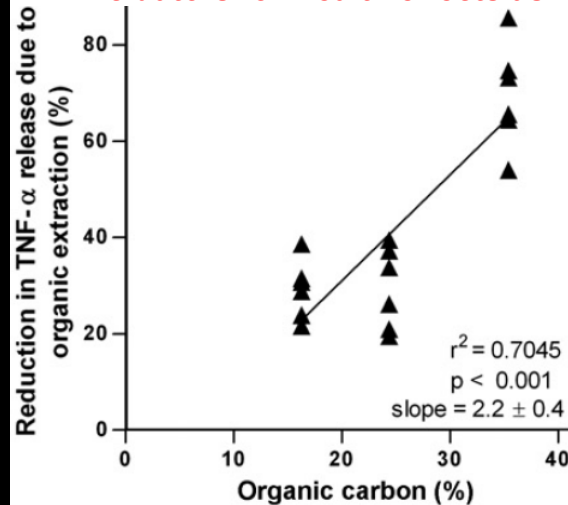


[Nussbaumer, T., Energy & Fuels, Vol. 17, No 6, 2003, 1510–1521, 17]
and
[Lauer, A., Nussbaumer, T., 13th ETH-Conf. on Comb. Gen. Nanop., June 22 – 24 2009, Zurich]

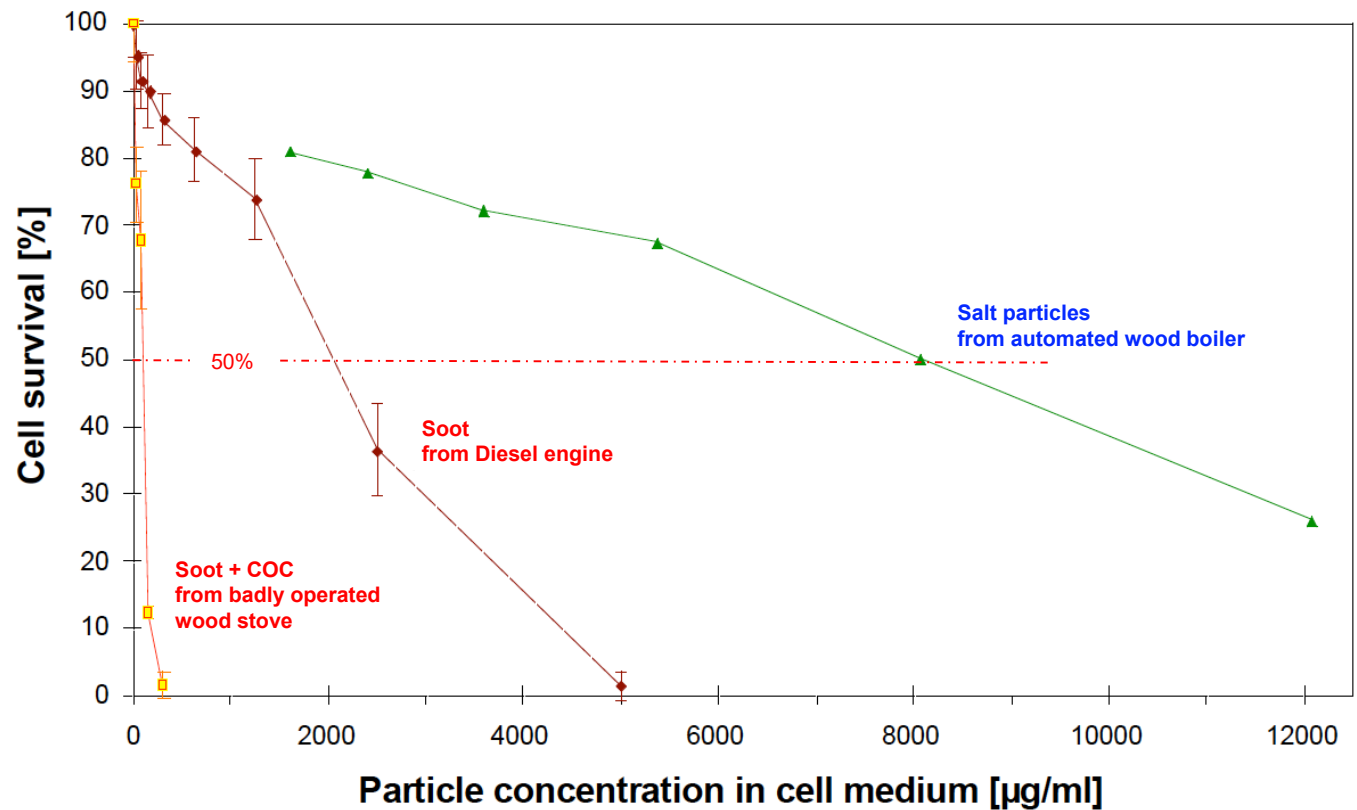
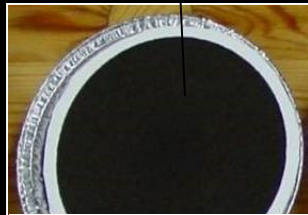
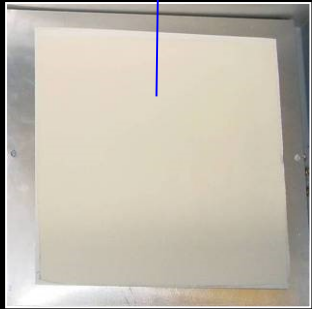
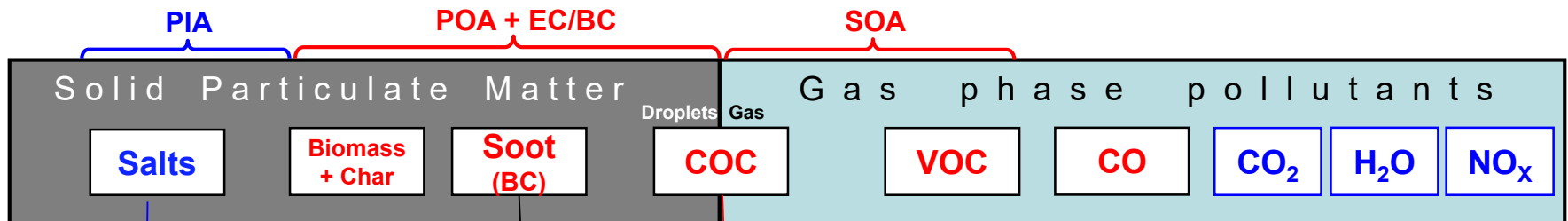


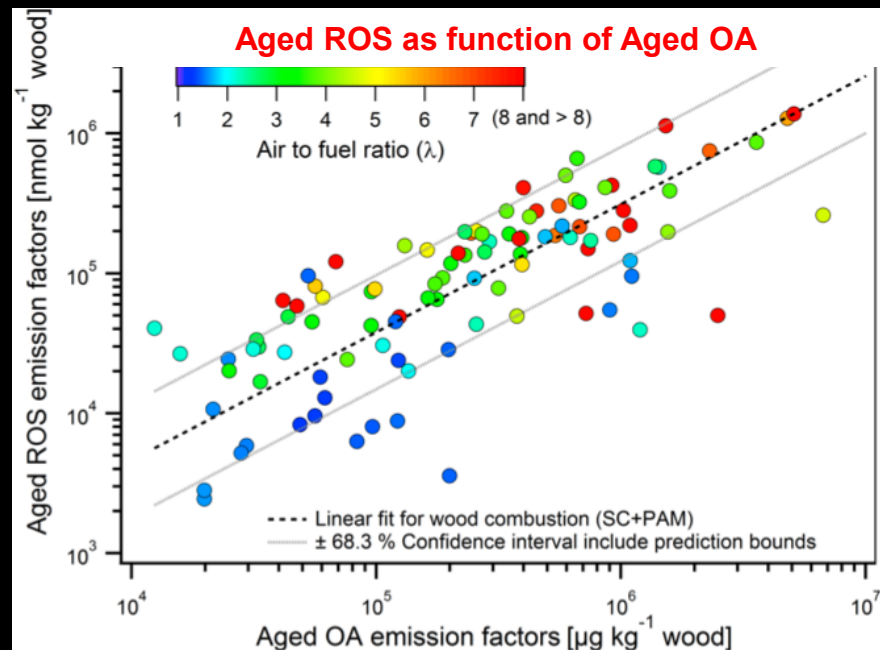
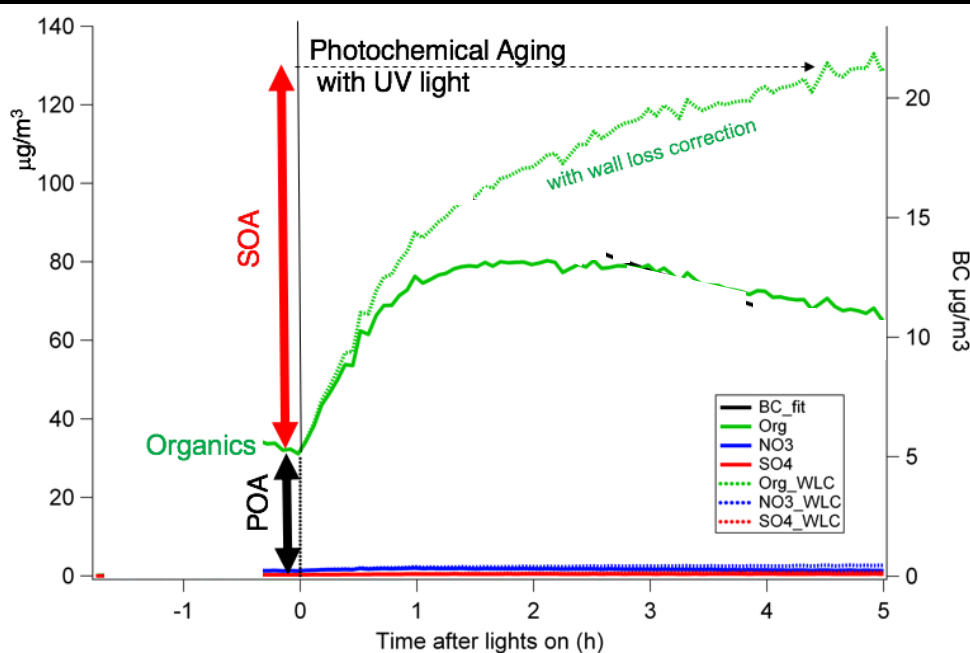
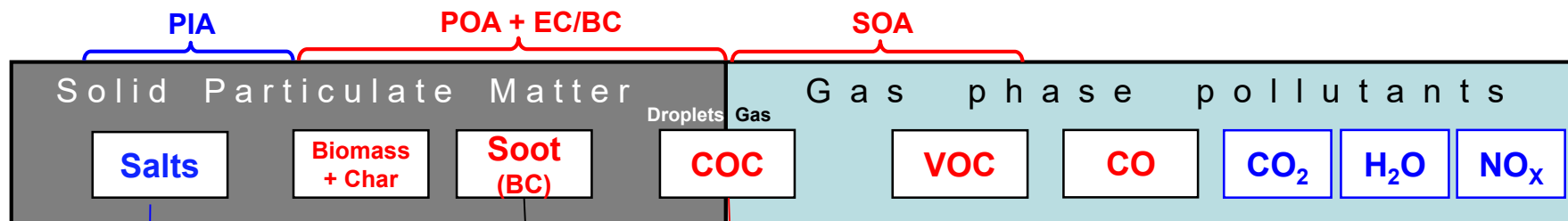


Incidentors for Health effects as function of Organic Carbon in Smoke



Pro-inflammatory cytokines TNF- α and interleukin 8 as a function of the organic content of smoke from tunnel, diesel and wood





LAC-PSI literature
(not in IEA report):

left [Baltensperger, U., 11. Holzen.-Symp., Zürich 2010, www.holzenenergie-symposium.ch]

right [Zhou, J. et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2017-1068>, 2017]

Part 1: Background

1.1 Suppositions, facts and figures

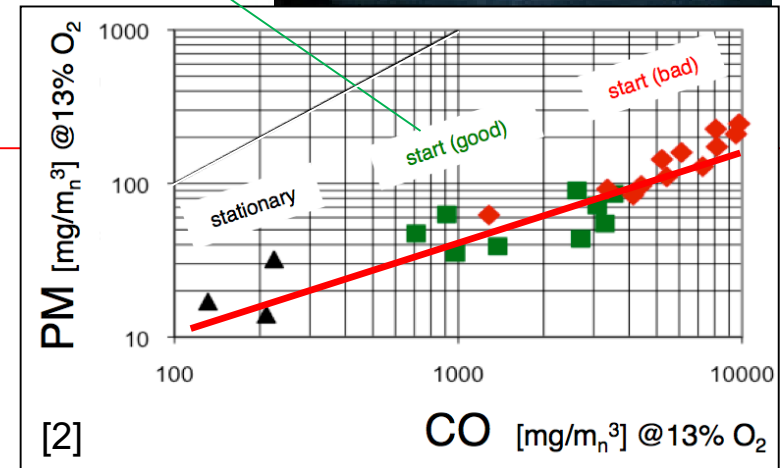
1.2 Measures to reduce or avoid PM

Measures to reduce PM or avoid increased PM

Primary Measures: Complete combustion

Type 1 (PIC)

1. Appropriate air-fuel ratio + T T T
2. Avoid non-ideal conditions:
 - ideal start-up
 - ...

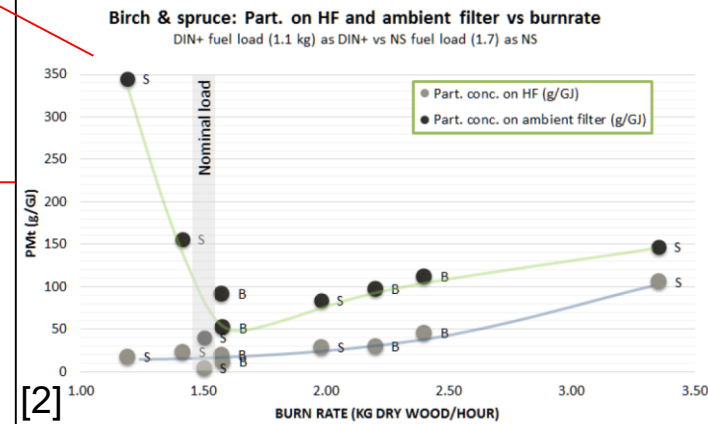
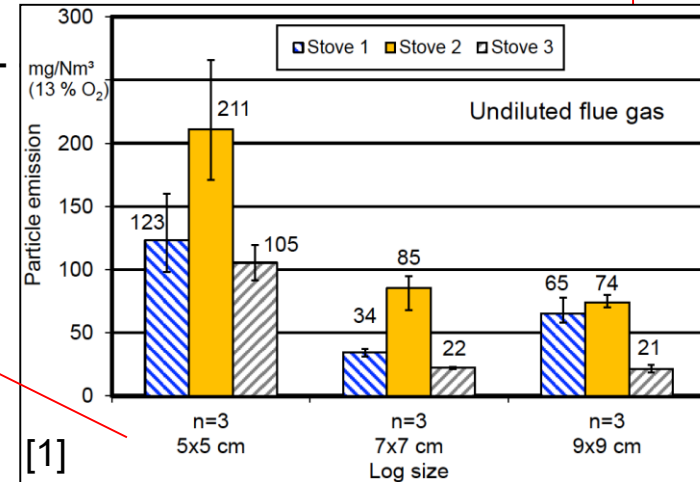


Measures to reduce PM or avoid increased PM

Primary Measures: Complete combustion

Type 1 (PIC)

1. Appropriate air-fuel ratio + T T
2. Avoid non-ideal conditions:
 - ideal start-up
 - fuel moisture and size
 - reasonable burn rate
 - no air throttling
 - ...



[1] Hartmann, H. et al., IEA T32 Session at ETH Conf. 2016

[2] Seljeskog, M. et al., IEA T32 Session at ETH Conf. 2016

Measures to reduce PM or avoid increased PM

Primary Measures: Complete combustion

Type 1 (PIC)

1. Appropriate air-fuel ratio plus T T T
2. Avoid non-ideal conditions:
 - ideal start-up
 - fuel moisture and size
 - reasonable burn rate
 - no air throttling

Secondary measures: catalytic oxidation & precipitation
only as add-on due to limited availability and drawbacks

Type 2 (salts) **Primary meas.:** Low ash fuels for small devices (harvest, sieving)
Secondary m.: Precipitation for autom. boilers (with low PIC)
 For RWC optionally, however critical for high PIC

Part 1: Background

Part 2: Position of IEA Task 32

7 statements agreed by 13 member countries

1. Mortality due to **cooking on open fires** shall be reduced by gasifier stoves or alternatives (gas, solar, el.)
2. For **manually** operated devices, an **appropriate operation** is crucial, secondary measures are only considered as an add-on
3. **Standardisation** of fuels, devices, and test methods can assist target-oriented development
4. **Automated plants** for heat and/or power with advanced design and control achieve
 - **very low organic pollutants** and
 - enable efficient precipitation of inorganic particles
5. Task 32 **supports automated boilers** with control and precipitation.
6. Future regulations should distinguish between organic and inorganic particles and take into account secondary organic aerosol
7. An **exchange** between research, industry, and authorities can assist advancements to promote biomass and prevent PM



Acknowledgments

IEA Bioenergy Task 32

Swiss Federal Office of Energy

Federal Office for the Environment

Swiss National Science Foundation

SCCER Biosweet and Innosuisse

The End