bioenergy2020+

IEA Bioenergy

Air pollution & modern boilers

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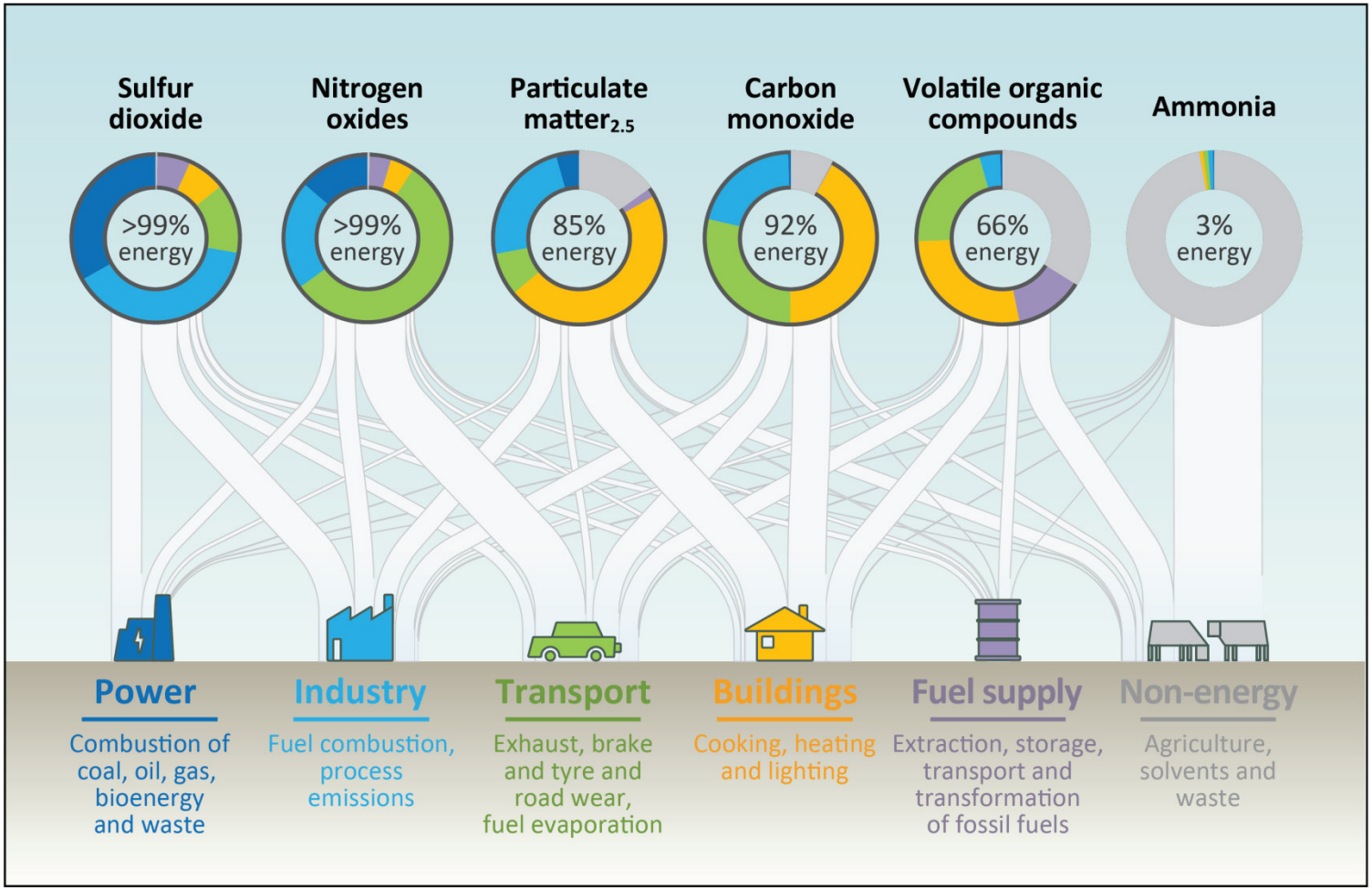
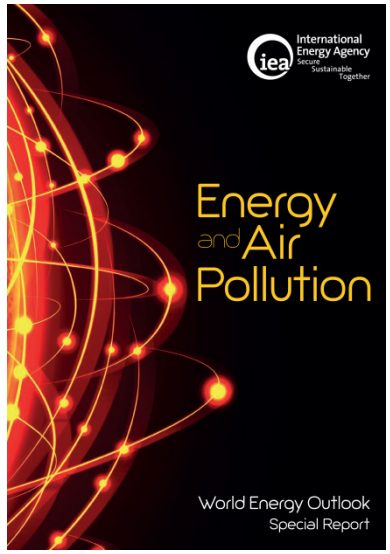
COMET

Competence Centers for Excellent Technologies

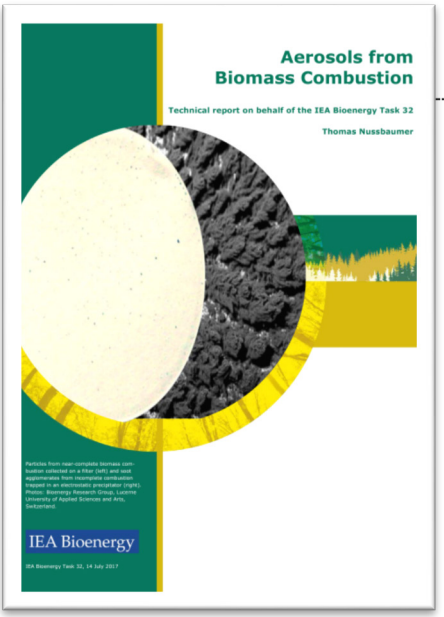
Setting the scene: Energy and air pollution





- Biomass burning is a major source of air pollution

How come? Emissions from biomass burning – quite a complex topic



Products from **Complete** Combustion

Products from **Incomplete** Combustion (PIC)

Products from **Complete** Combustion

Solid Particulate Matter | Gas phase pollutants

Droplets | Gas

Salts | Biomass + Char | Soot (BC) | COC | VOC | CO | CO_2 | H_2O | NO_X | Chimney

> 10 µm | < 100 nm

$-H_2$ | $+O_2$ | $+O_2$

KCl, K_2SO_4 oxides < 100 nm

Ash $CaCO_3$ > 1–10 µm

PAH

τ < | τ >

Gas phase combustion

T > 800° | T < 800° | T > 550°

$O_2 = 0$

CO | $+O_2$

Secondary Tars | >700° | Primary Tars

Condensation

Coagulation

Nucleation

$O_2 = 0$

C_mH_n CO, H_2 | $+O_2$ | T > 800° | $+O_2$ $+CO_2$

Consecutive reactions in combustion chamber by secondary air

Devolatilisation | Pyrolysis | Gasification

$K^+, Na^+, Cl^-, SO_4^{2-}, OH^-, CO_3^{2-}, NO_3^-$

$CaCO_3$

Zn-, Mg-, Fe-, Al-oxides
Waste: Cu, Cr, Pb, (Cd)

u > 0.1 m/s | T > 300° | + O_2

C (Char)

$C_xH_yO_z$

H_2O

T > 100°

Evaporation | Evaporation Entrainment

2 | 1 | u > 0.1 m/s

K, Na, Ca, S, Cl, N

T > 800°

Solid fuel conversion in fuel bed by primary air

u Gas velocity, τ Residence time, </> short/long
1 Solid-particle-path, 2 Solid-vapour-particle-path

BC: Black Carbon
COC: Condensable Organic Compounds
VOC: Volatile Organic Compounds

[Nussbaumer, T., IEA Report 2017]
Data on T: [Evans and Milne, 1987] on H_2: [Jess, 1996]

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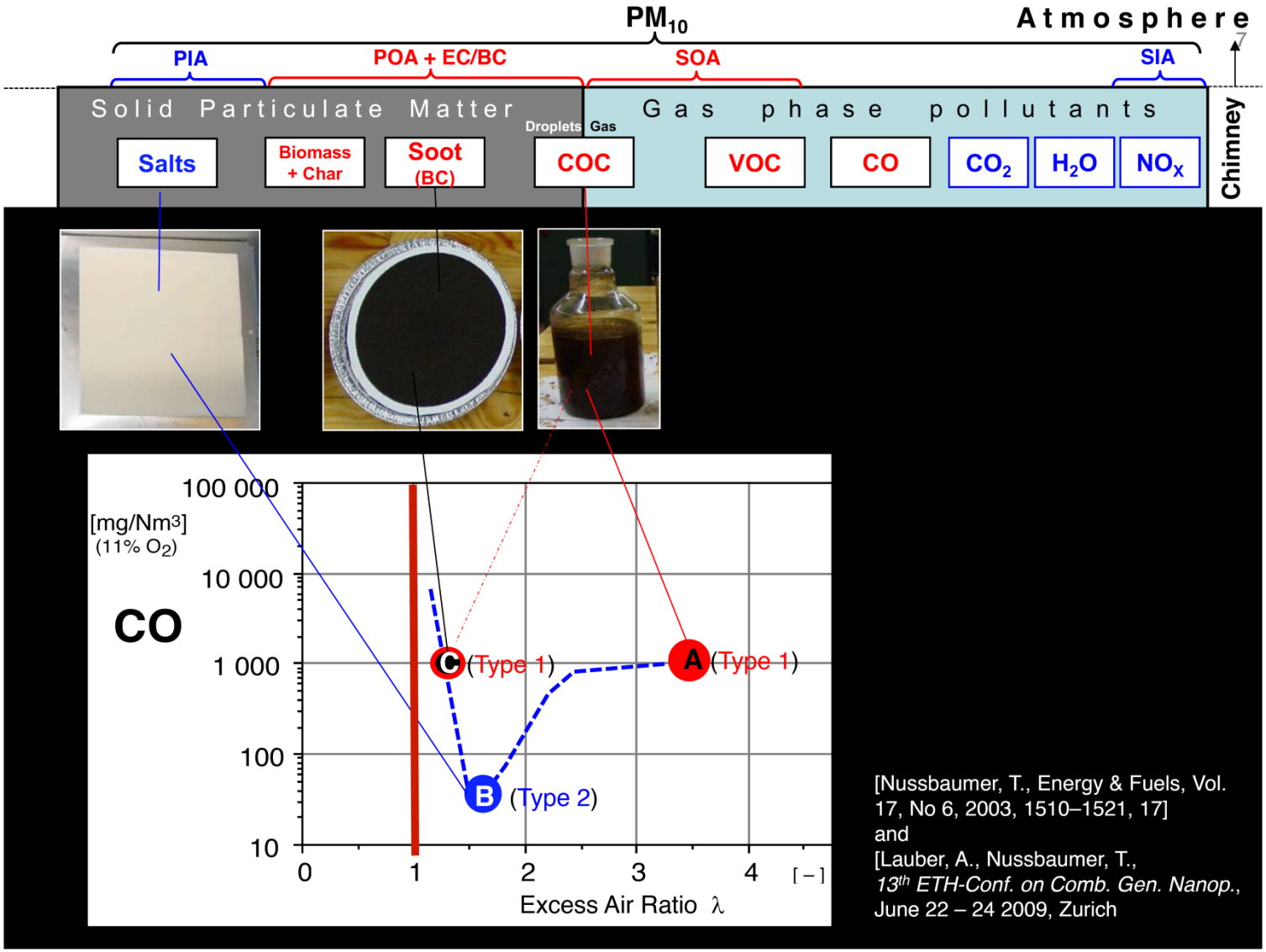
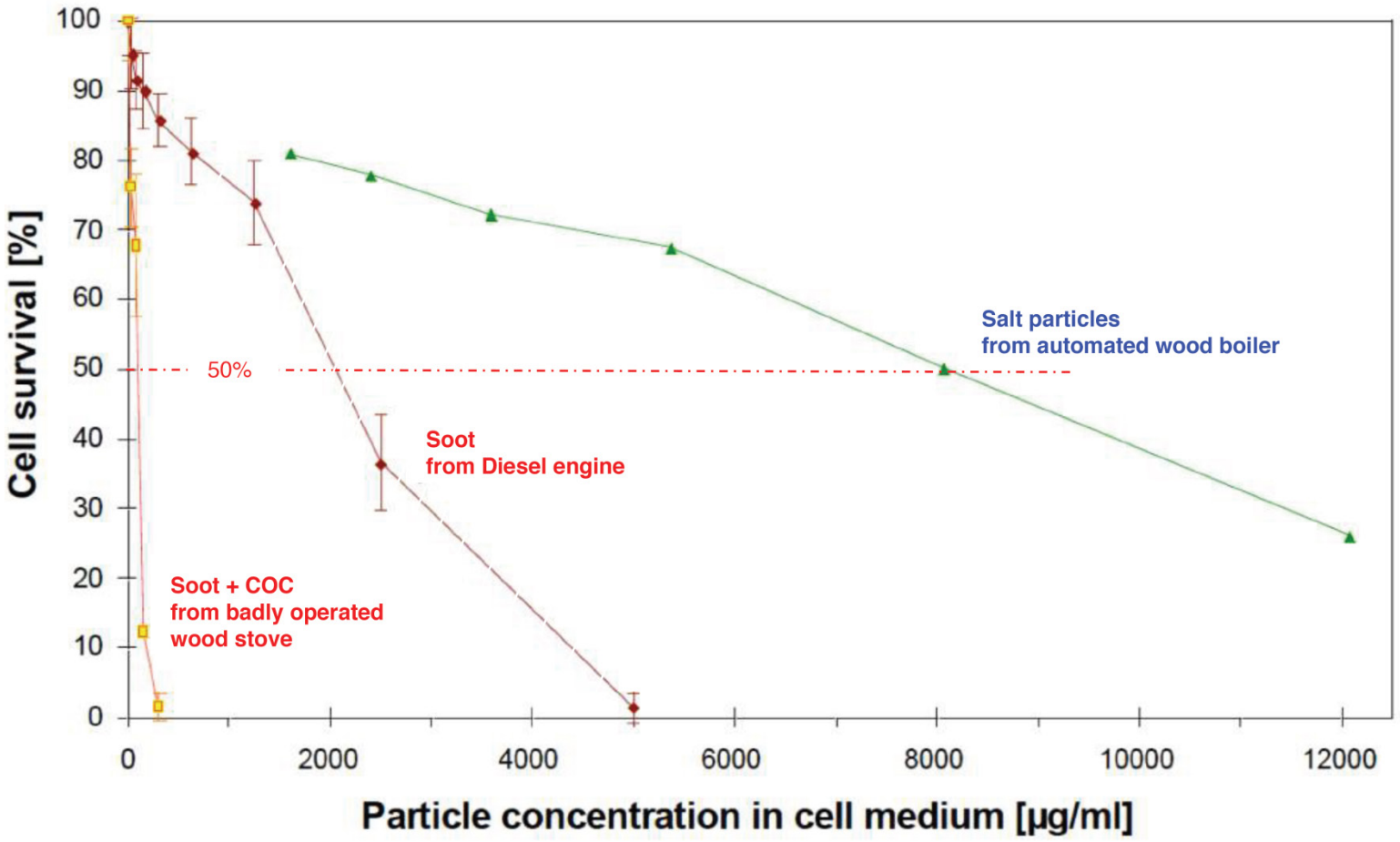


[Nussbaumer, T., Energy & Fuels, Vol. 17, No 6, 2003, 1510–1521, 17]
and
[Lauber, A., Nussbaumer, T., *13th ETH-Conf. on Comb. Gen. Nanop.*, June 22 – 24 2009, Zurich

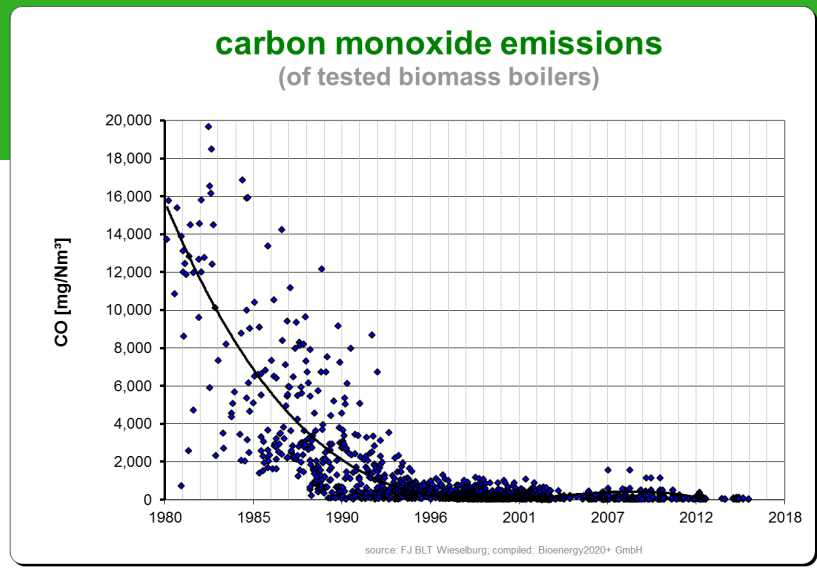
Health impact:
The type of aerosol makes the difference…

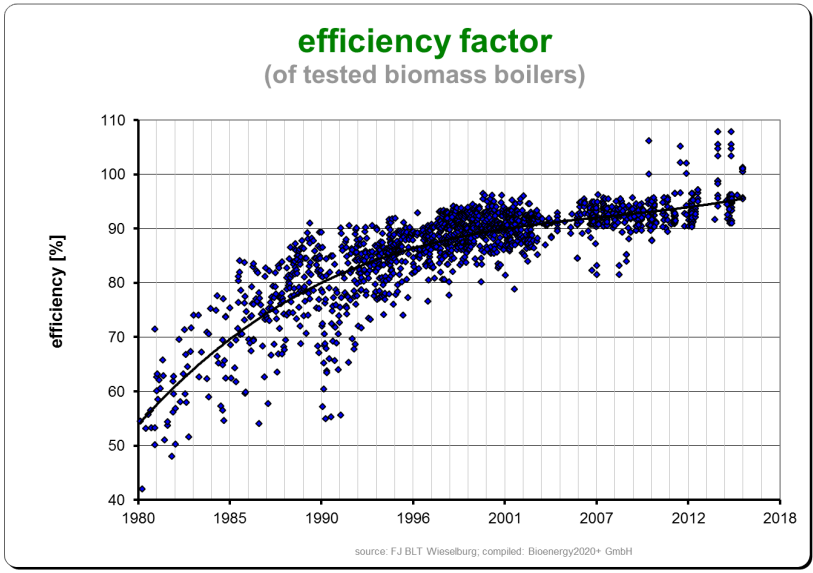


Kippel & Nussbaumer, European Biomass Conference, 2007. Berlin

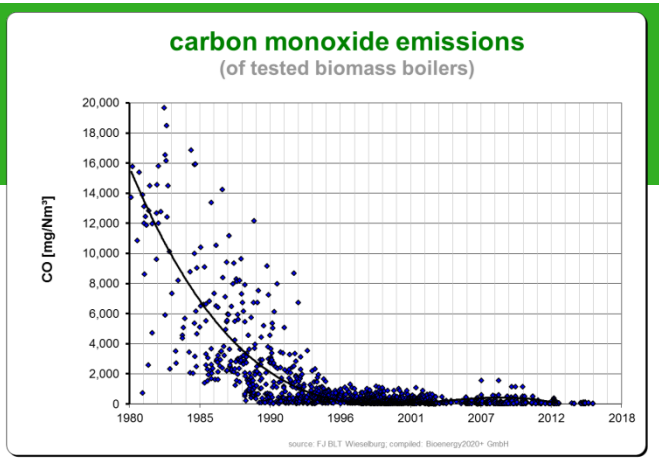
Modern biomass boilers

- Biomass Combustion Technology has improved tremendously:
- FJ-BLT Wieselburg Type Testing Averages 2015/16 (n=26):
  - Efficiency = **96%**
  - Carbon Monoxide = **5mg/MJ**
  - Organic gaseous Carbon < **1mg/MJ**
  - **Total suspended Particles = 7mg/MJ**
- Further Improvement Potential?
  - No, or very limited
  - Already complete Combustion
- EN303-5 testing at constant Load Conditions



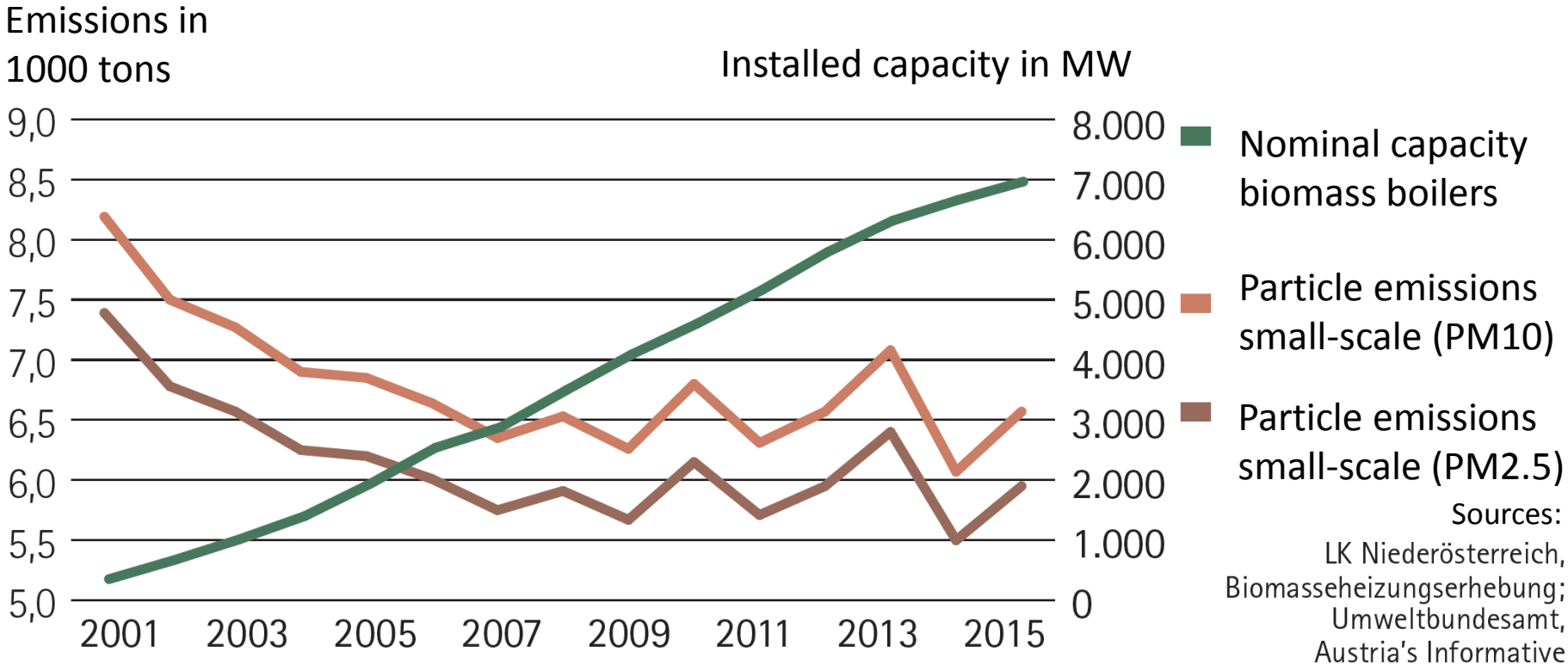


Keys to this success



- **Standardisation:**
  - Standardised testing of biomass boilers (going back to the 1970ies in Austria)
  - European/international standardisation (e.g. EN303-5)
- **Regulatory framework:**
  - Performance requirements for market implementation
    - Referring to standardised evaluation procedures
    - Based on state-of-the-art of technology
  - Ambitious but also reasonable (plannable) → EU Ecodesign
- **Big efforts in technology development**
  - e.g advanced control concepts (Lambda probe, model based control)

Also a success for air quality

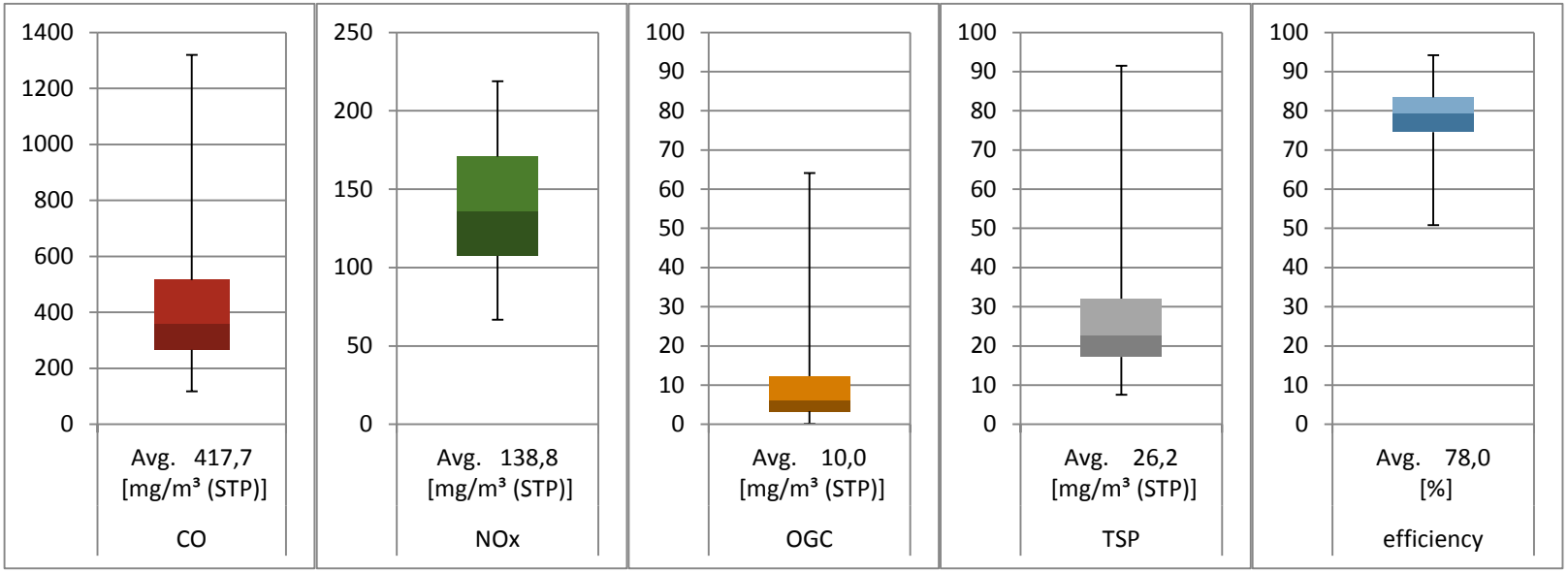


Sources:
LK Niederösterreich, Biomasseheizungserhebung; Umweltbundesamt, Austria's Informative Inventory Report 2017

Source Figure: Austrian Biomass Association

Everything fine?
Let us look into field performance…

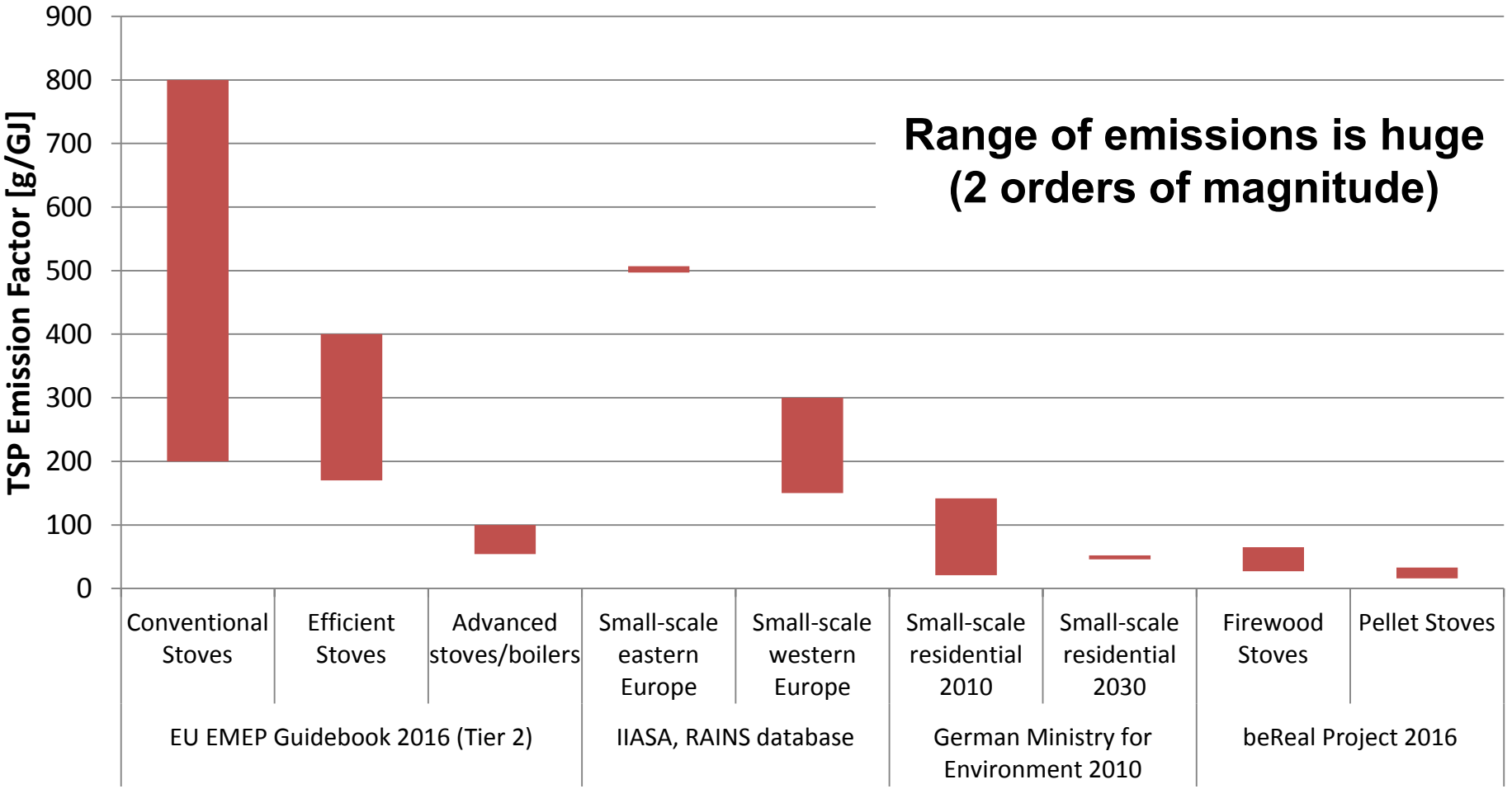
- Real-life (field) emission factors of pellet boiler in modulating operation:



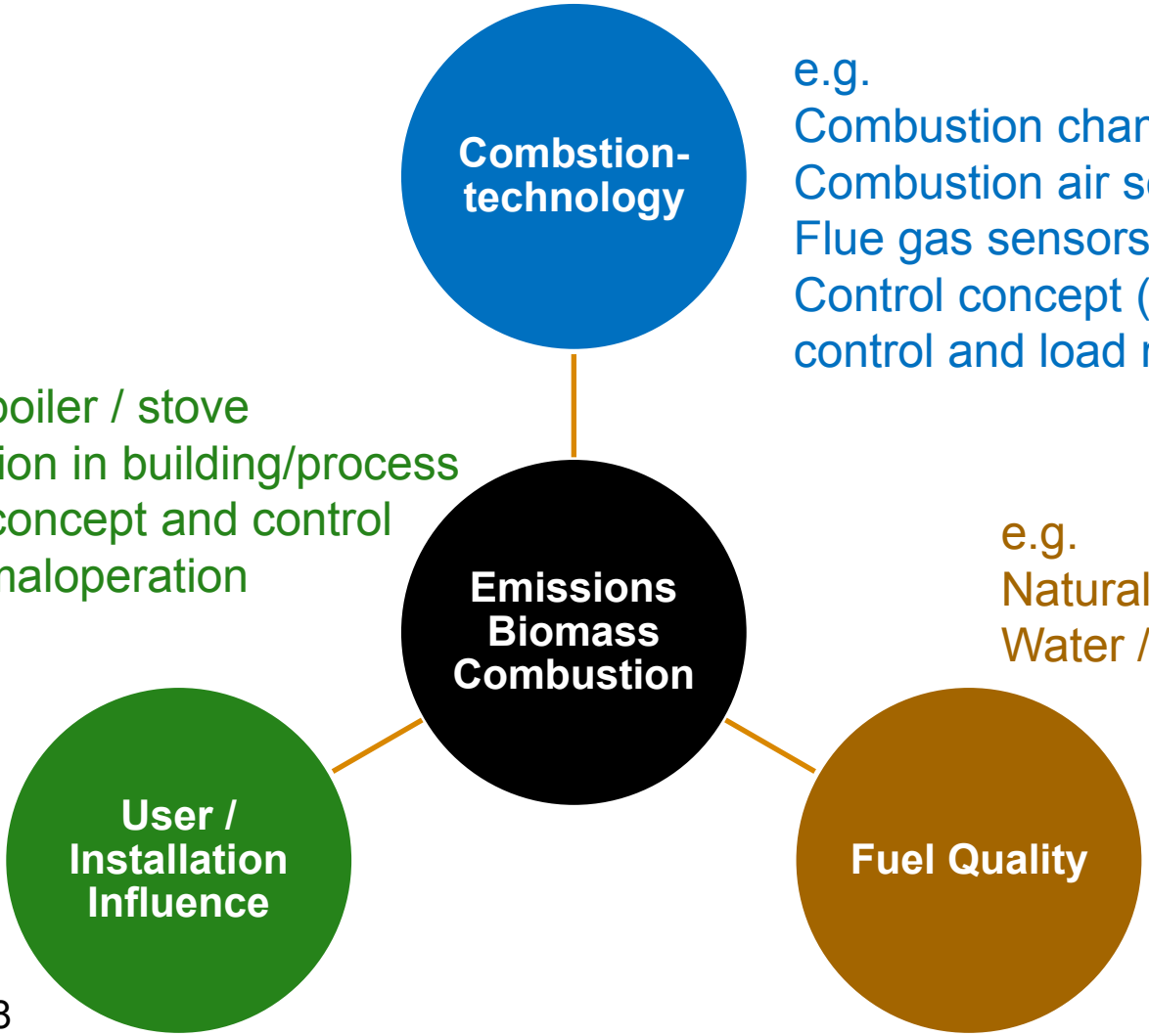
- Variable performance (extremely good – medium)

* Data from BioMaxEff project

TSP (Dust): Emission Factor Comparison



The three main influencing factors for real-life performance of biomass boilers…

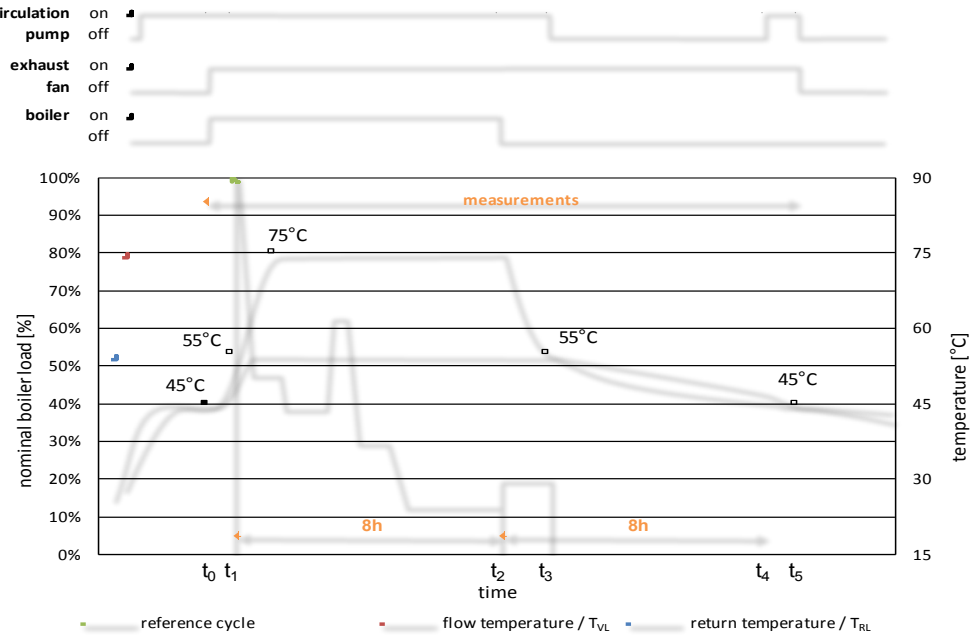


Further improvement (of real life performance) is ongoing…

- Intelligent Control Algorithms:
  - E.g. Model based Control Concepts (incl. weather prediction and self-learning systems)
- New combustion concepts
  - Extreme air staging (for boilers)
  - Candle burning principle (for stoves)
- Integration of secondary emission abatement systems (e.g. Electrostatic precipitators or catalysts)
- Real life optimisation and testing methods

Real-life oriented testing methods

- Testing methods strongly influence technological development
- Real-life oriented testing methods can support / force development into the right direction
- Proposals for such methods are available:
  - Load Cycle Testing of Boilers (www.biomaxeff.eu)
  - beReal Tests for Stoves (www.bereal-project.eu)



Key Messages 1

1. Modern biomass combustion technology has reached a **very high level of performance** under standardised testing conditions (~ complete combustion in boilers).
2. **Further sharpening of** already very low emission **thresholds** (in regulations or quality labels) will mainly increase the turnover of testing labs (for re-testing) but **will not improve the performance in real life**.
3. The **keys to better air quality** are
   a) **Replacement** of old appliances (factor: 10 – 100(0))
   b) **Focus on real-life performance** (supported by **suitable testing methods**)

Key Messages 2

4. Innovative solutions for further improvement of the performance of biomass appliances in the field are…
   a) **Advanced control strategies** such as model based control systems for combustion- and load-control (reducing starts and stops)
   b) **New combustion concepts** implementing advanced primary measures for emission reduction (e.g. extreme air staging, candle burning principle)
   c) **Secondary emission abatement** technologies for bigger size boilers (~ > 100kW)

Questions

- **Q1/Technology:** Which measures can support market penetration of state-of-the-art technology? What are the biggest barriers for these technologies (e.g. costs)?
- **Q2/Fuel:** How can we ensure that only suitable fuels are used?
- **Q3/User and Installation:** Which measures can ensure proper installation and operation of combustion appliances?

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ideas with a future

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