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Technological Progress and Innovation of small scale combustion appliances: Impact on PM and Benzo(a)pyren emission reduction

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Verona, 21 February 2018

COMET

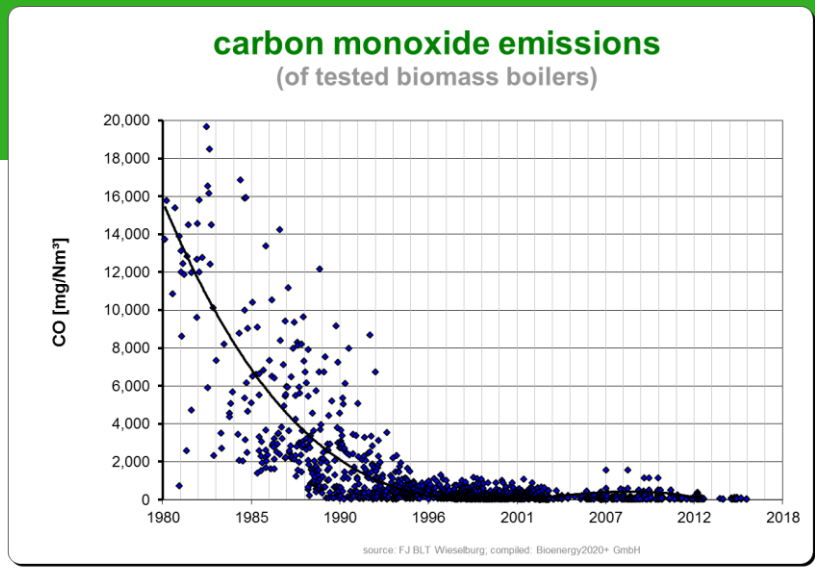
Competence Centers for Excellent Technologies

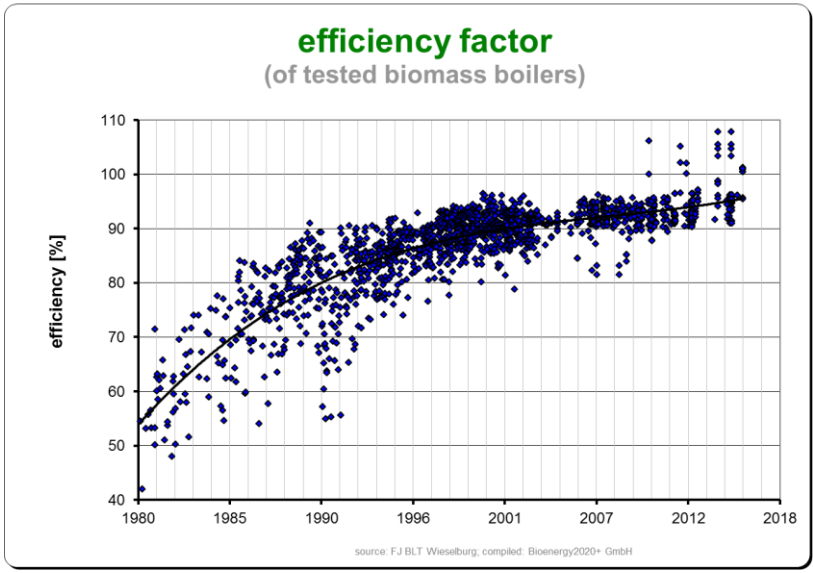
Outline

- Introduction
- Situation in real life
- PM/TSP and BaP emissions of boilers and stoves
- Comparison with emission factors from inventories
- Current technological progress
- Key (Take-Home) Messages

Introduction: General

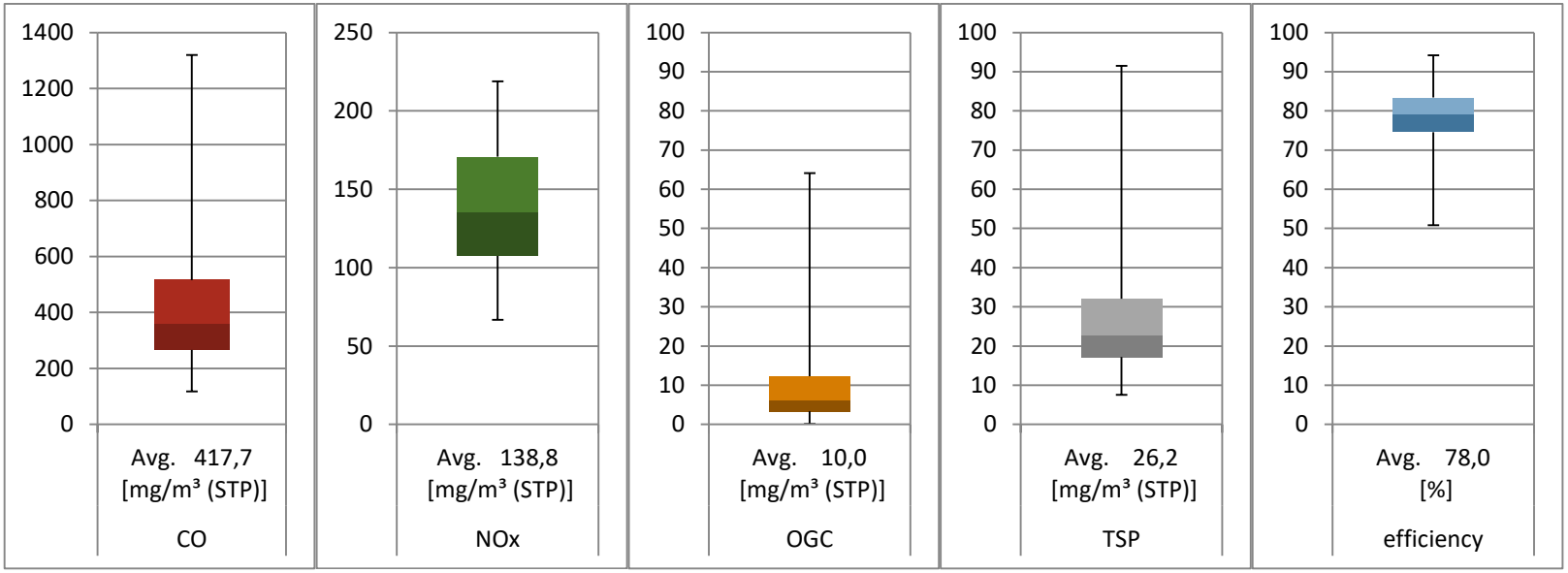
- Biomass Combustion Technology has improved tremendously:
- FJ-BLT Wieselburg Type Testing Averages 2015/16 (n=26):
  - Efficiency = **96%**
  - Carbon Monoxide = **5mg/MJ**
  - Organic gaseous Carbon < **1mg/MJ**
  - **Total suspended Particles = 7mg/MJ**
- Further Improvement Potential?
  - No, or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





What is the situation in the field?

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

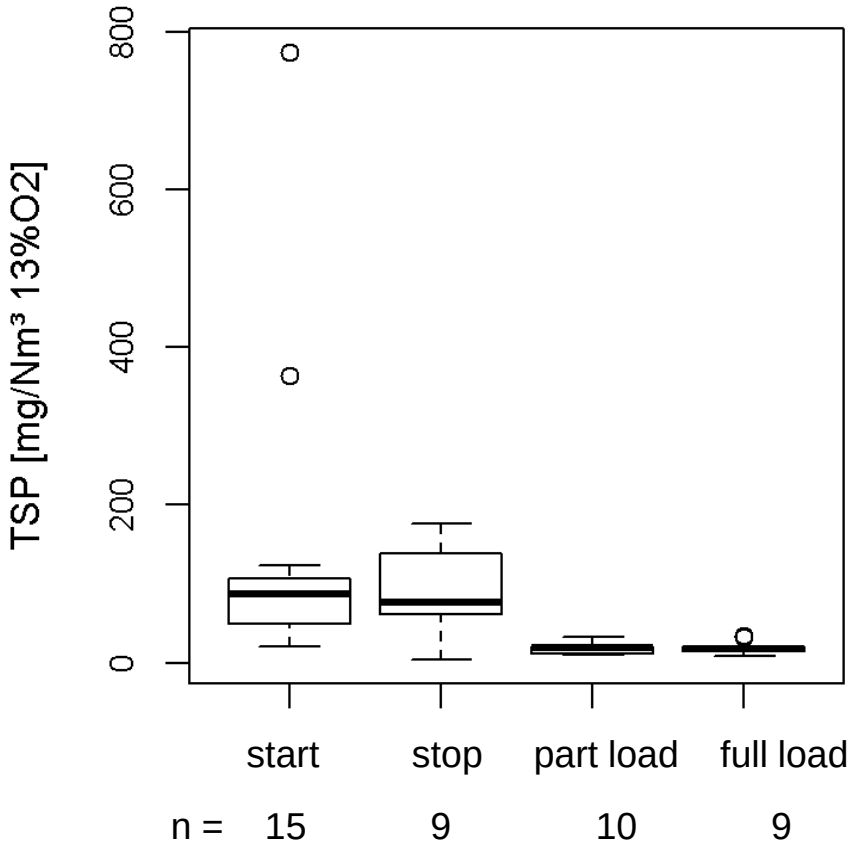


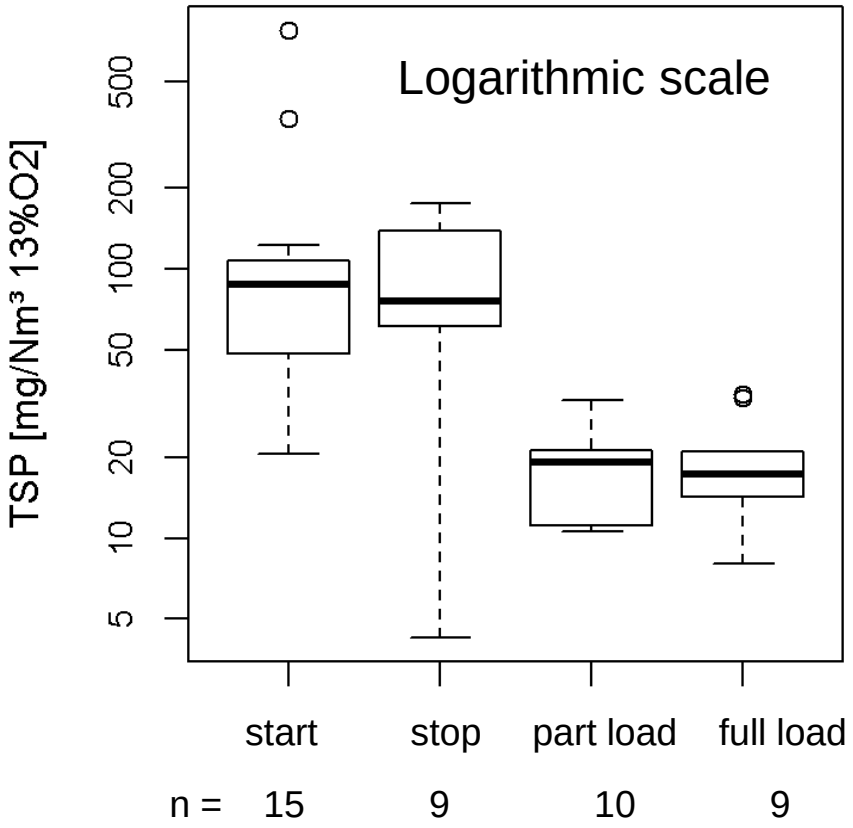
- Variable performance (extremely good – medium)

* Data from BioMaxEff project

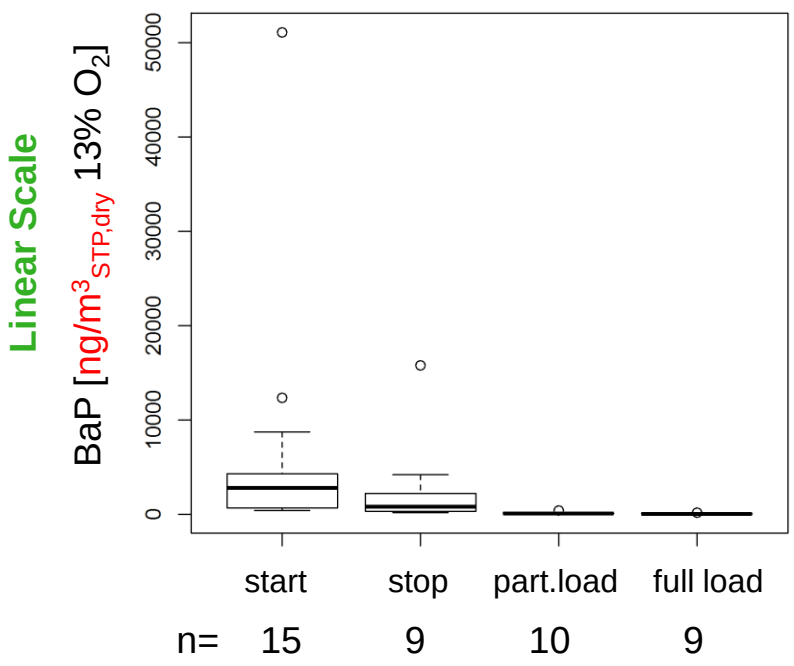
Main Reason: not only stationary combustion phases in real-life

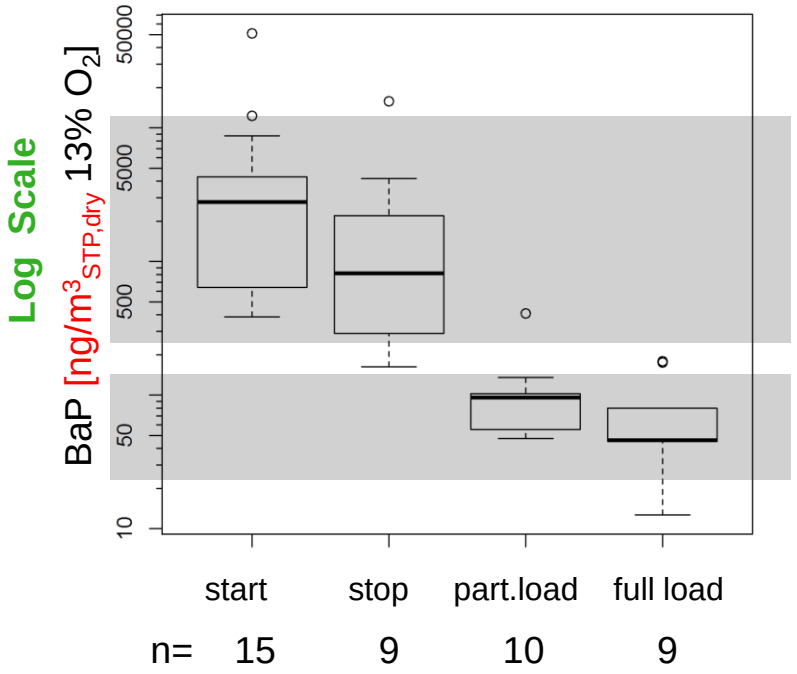
Particle emission concentrations from different biomass boilers





BaP Emissions – Operation Phases Boilers

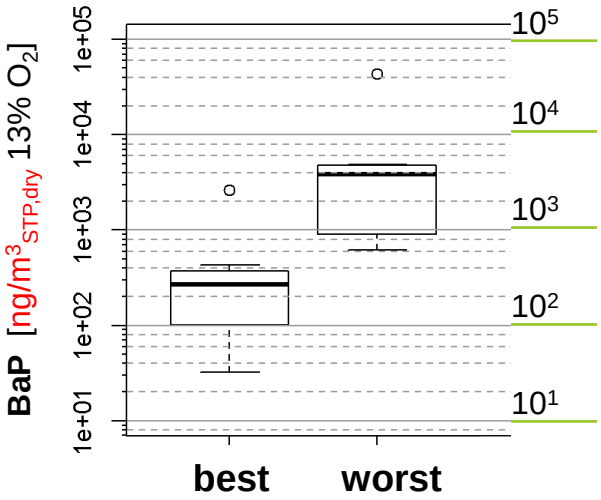




The emissions during start and stop are **1 to 2 orders of magnitude** higher than during continuous operation!

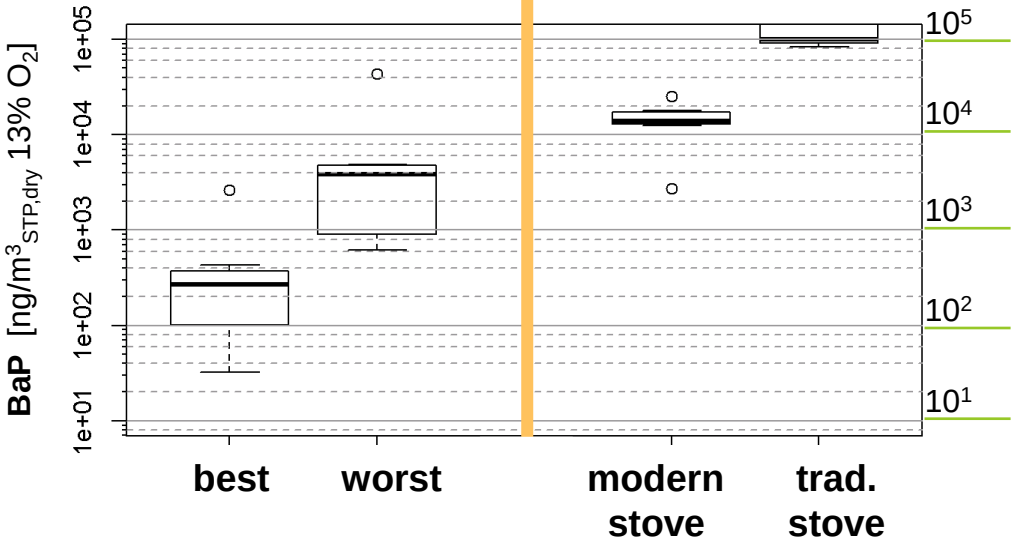
Comparison with Literature

Best Case operation	Worst Case operation
Automatic boilers	
1x Start and Stop, 8 h full load	Start-Stop-operation

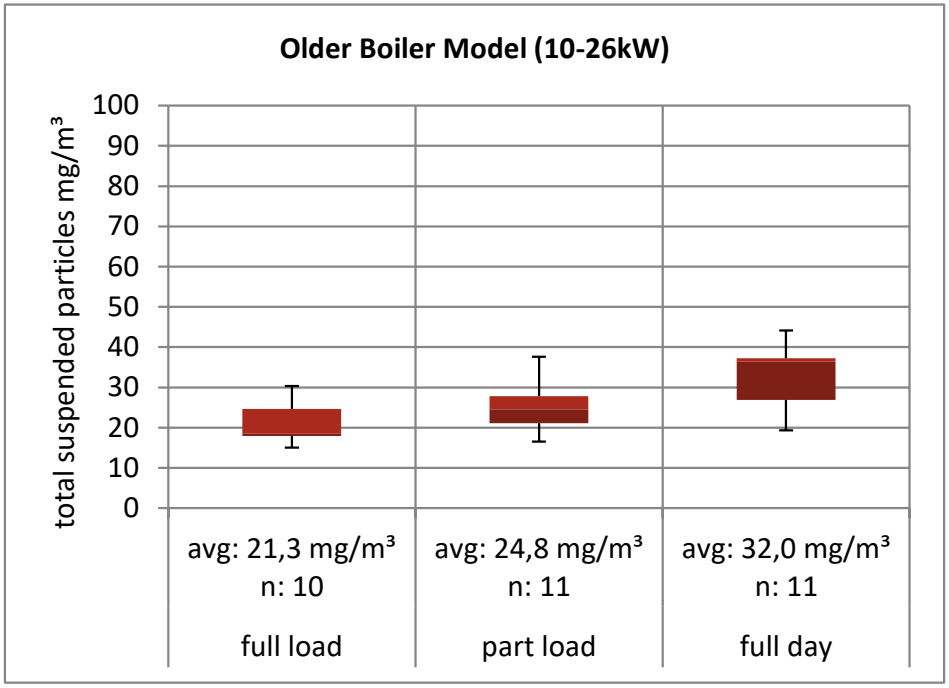


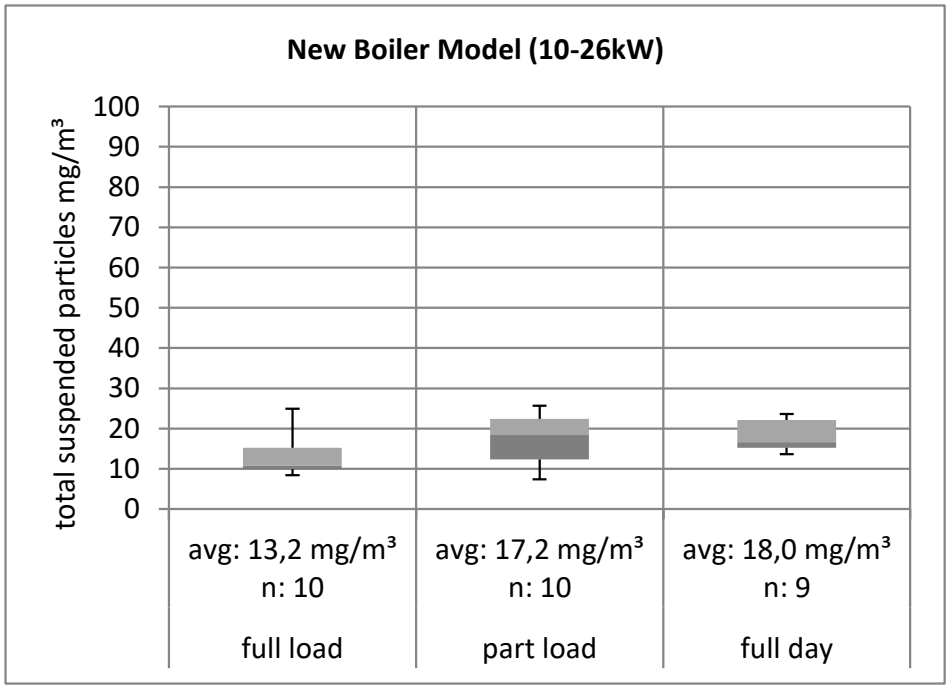
Comparison with Literature

Best Case operation	Worst Case operation	modern	„traditional“
Automatic boilers		Logwood stoves	
1x Start and Stop, 8 h full load	Start-Stop-operation	Primary and secondary air supply (Ozgen et al., 2014) (Kelz et al., 2012)	(Kelz et al., 2012) (Orasche et al., 2012)



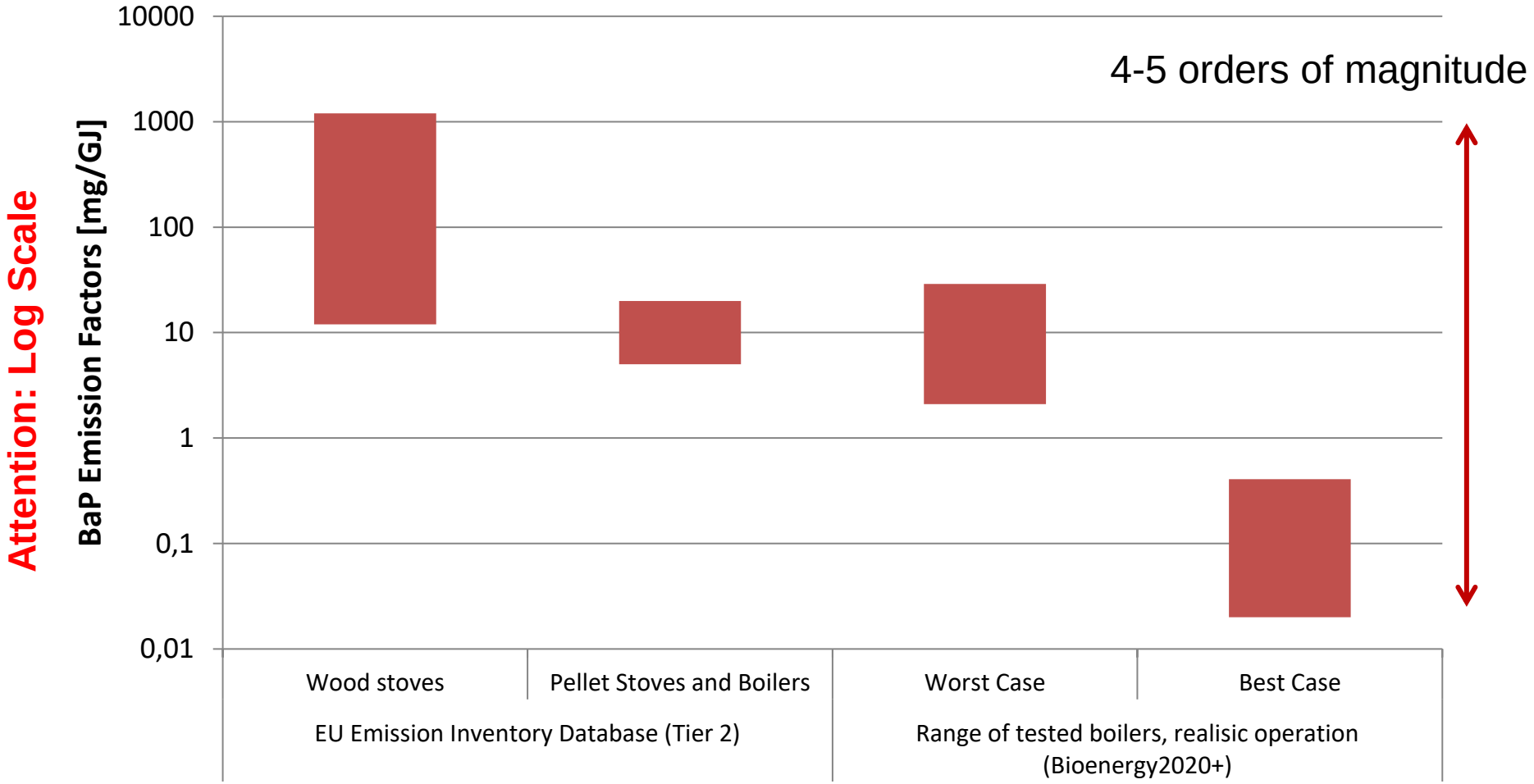
Best practice in field performance: Pellet Boilers 10-26kW



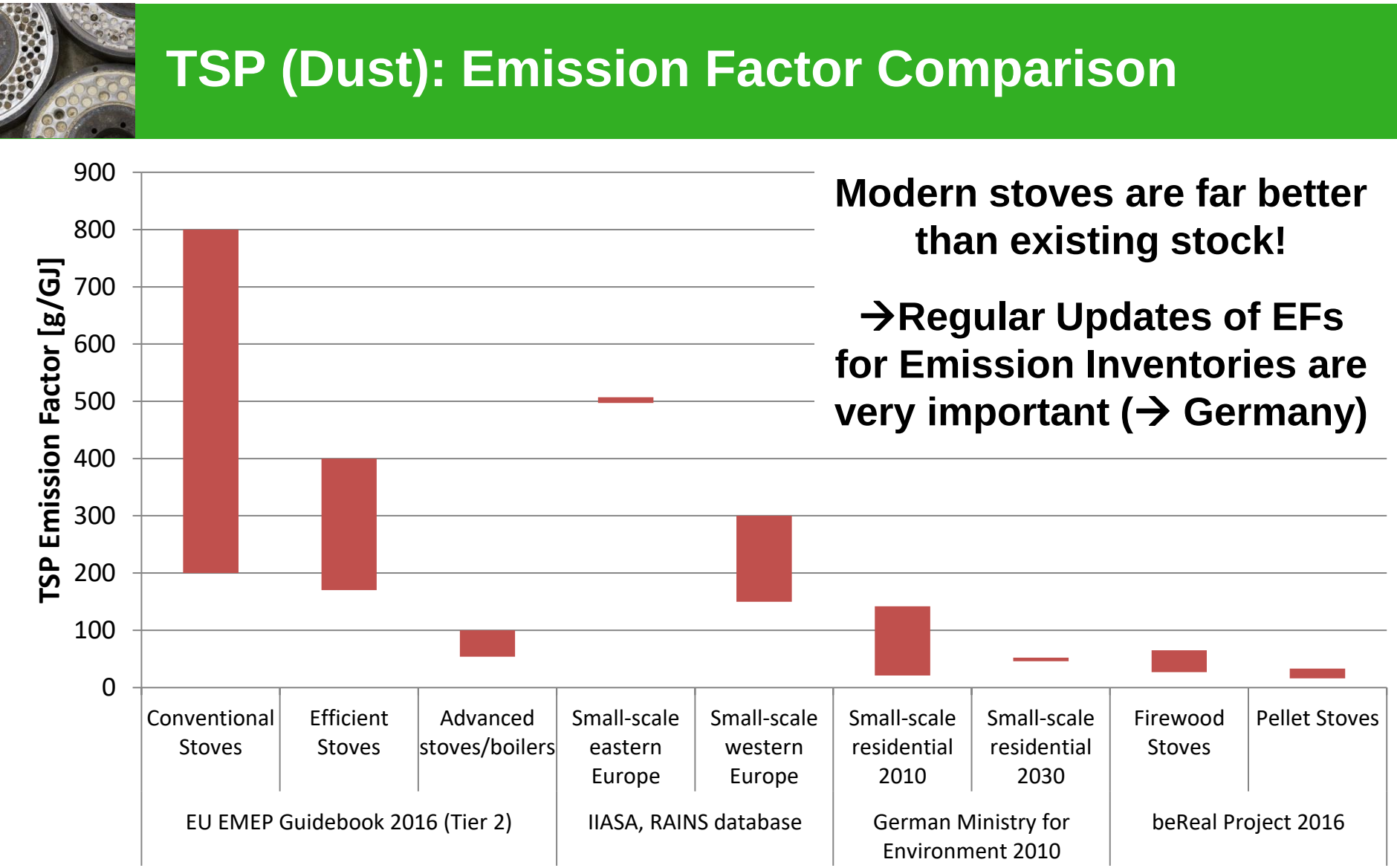


- Improvement of boiler technology is evident
- Narrow distributions → very stable performance even in full day measurements

Boilers/Pellet Stoves: BaP Emission Factor Comparison



TSP (Dust): Emission Factor Comparison



Modern stoves are far better than existing stock!

→Regular Updates of EFs for Emission Inventories are very important (→ Germany)

Current technological Progress (Examples)

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

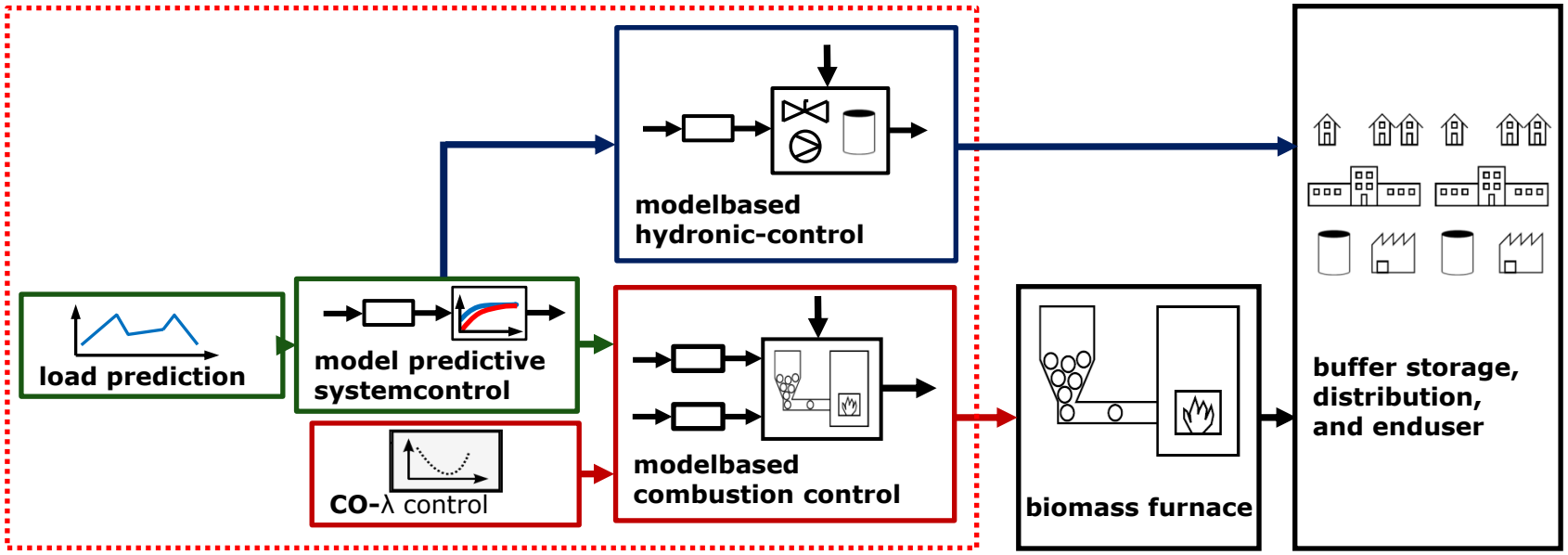
Innovative Control concepts: Model-based control

- **Automatic adjustment** of control strategy to changing fuel properties (water content, density)
- **Stable load conditions**
  - Faster response to load changes
- **Stable trend of oxygen concentration in all load ranges**
  - Potential for the reduction of O_2-concentration → improvement of efficiency
- **Reduced emissions (CO and particulate matter)**

Intelligent control algorithms

Optimisation of the operation by model based control – modular approach

independent of range of capacity



Source: Bioenergy2020+ GmbH

Extreme air staging – Motivation and Concept

- Particle reduction without any additional precipitators
- Additional costs are expected to be lower than standard technologies + filter (suited for lower power levels)
- Synergy effects with NO_x reduction
- Results show - depending on fuel quality – similar or even lower emission values as for (economically feasible) electrostatic precipitators
- Technology is interesting for small- and medium scale starting at around 20kW (to 2 MW)

Extreme staged combustion – Concepts and Development Challenges

Secondary and tertiary air

Gas ignition

Fuel bed

$\lambda_{primary} < 0,5$

- Load modulating operation more difficult
- Material lifetimes
- Secure flame formation (i.p. during start-up
- Emissions during start/stop
- Stable fuel bed (homogeneous flow)
- Tight ash removal system to maintain reducing conditions (avoiding false air)

➢ finding suitable system configuration and control concept

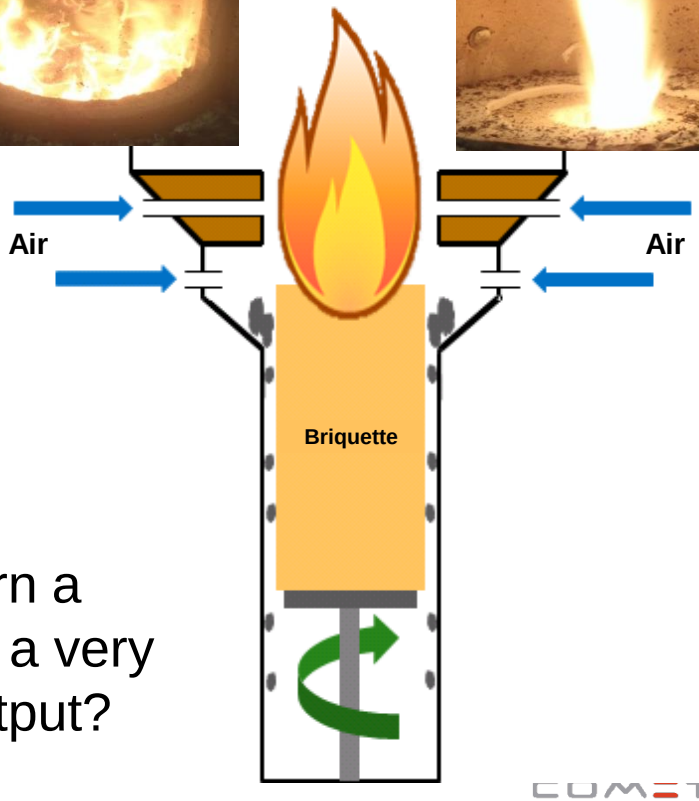
Source: Windhager Zentralheizung Technik GmbH

New combustion concepts for stoves

Briquette Candle Burner
PCT Patented

≈

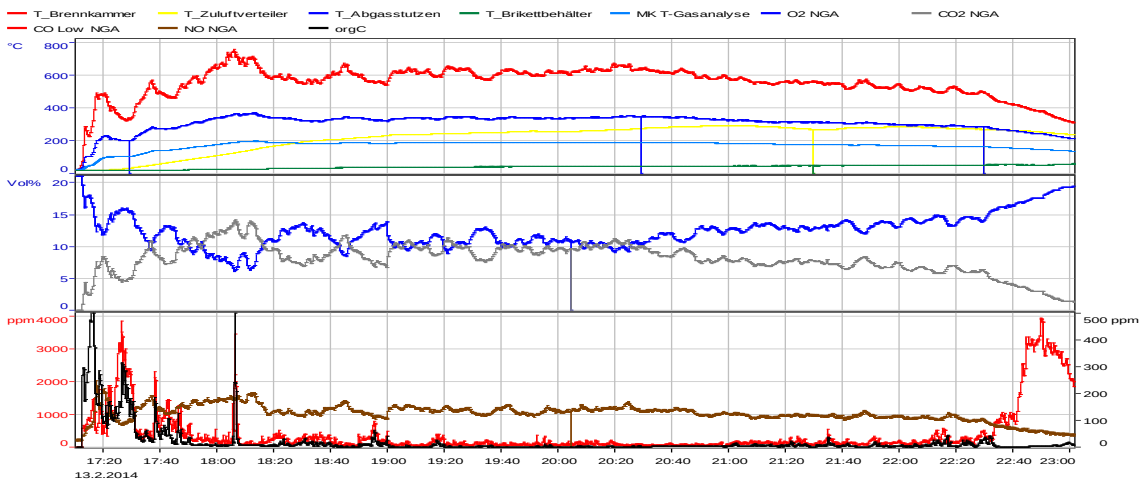
Combustion Chamber



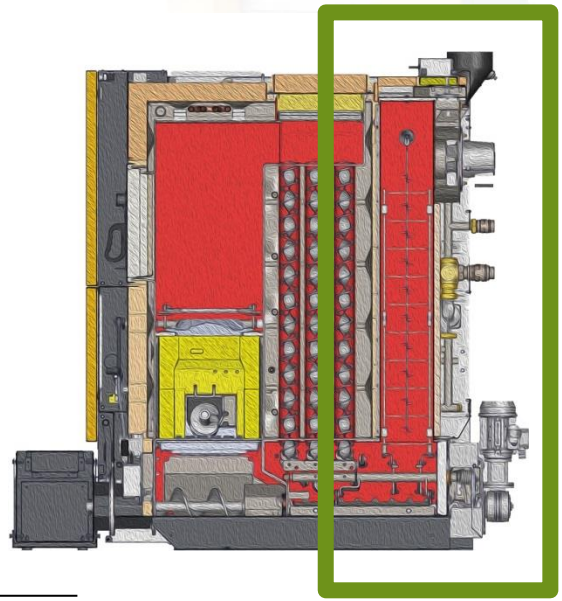
How to burn a briquette with a very low heat output?

Candle burning principle – Motivation / Advantages

- Semiautomatic operation with a flame design comparable to a log wood stove
- Comfort: Long burning periods (e.g. 8 hours for 2 briquettes)
- Low loads: Well suited for low energy buildings
- Low emissions also for low loads (1-2 kW)



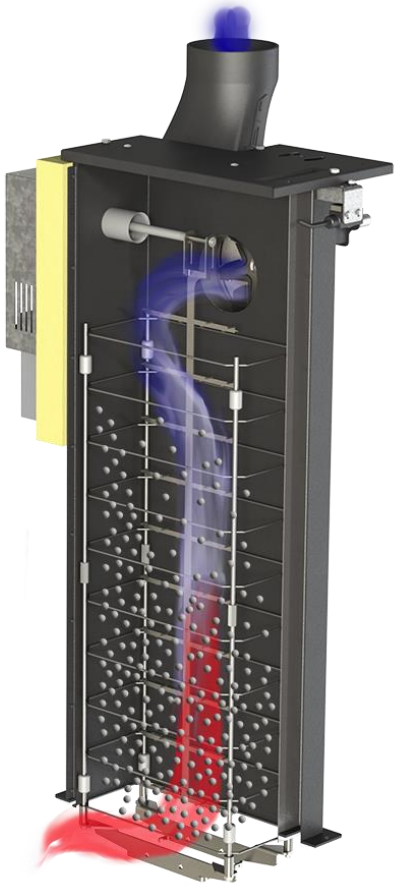
Integrated Particle Precipitators



- Conformity and security to stay significantly below limit values
- Compact design provides advantages in space demand and during start up.
- Coupling with cleaning system of heat exchanger effects efficiency
- Combined ash removal and control systems allow a reduction of production costs compared to stand alone solutions.
- Power range > 100 kW

Sources: Eta Heiztechnik GmbH,
KWB Kraft und Wärme aus Biomasse GmbH

Integrated precipitators - success criteria

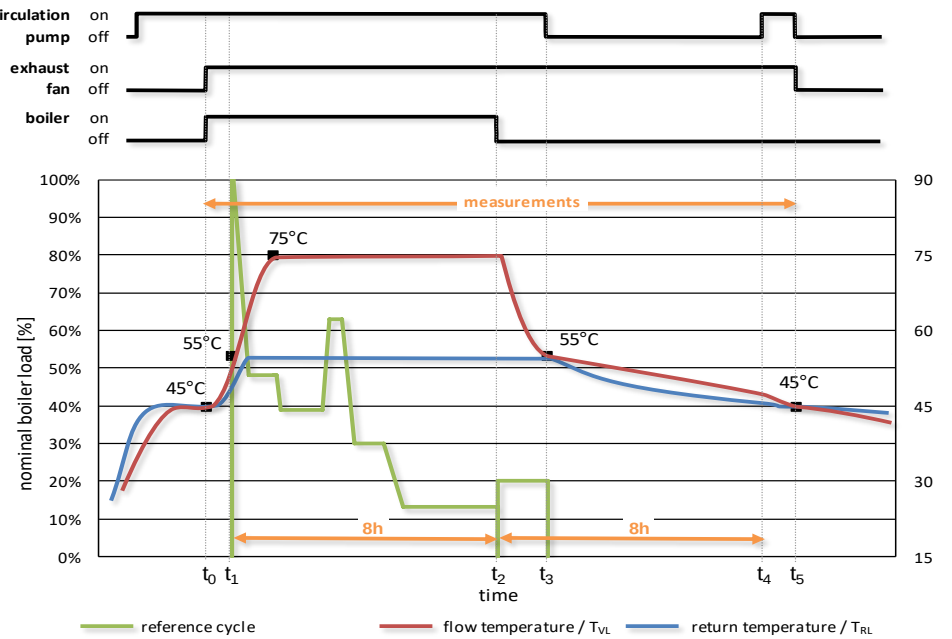


Source: Eta Heiztechnik GmbH

- Modular compact design
- Long-term stability of electrostatic field for sufficient precipitation efficiency
- Cleaning efficiency of electrode and deposit surfaces
- Cost reduction compared to standard boiler + standard filter

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
  - beReal Tests for Stoves (see separate presentation)



Key (Take-Home) 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) **Development-focus on real-life performance** (supported by **suitable testing methods**)

Key (Take-Home) 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)

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