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Load cycle test for biomass boilers

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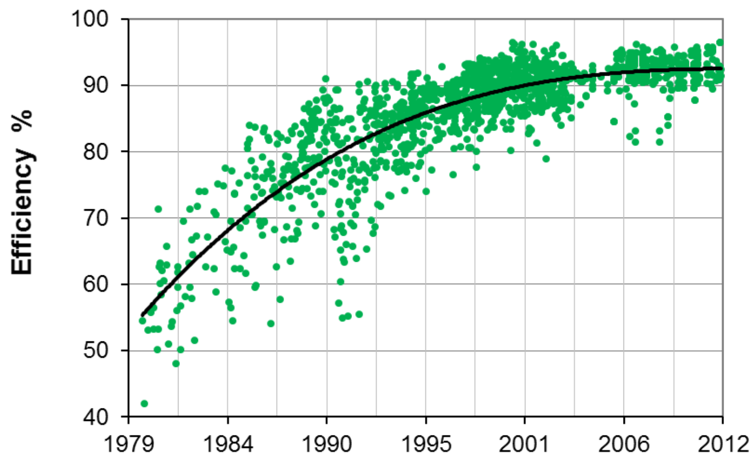
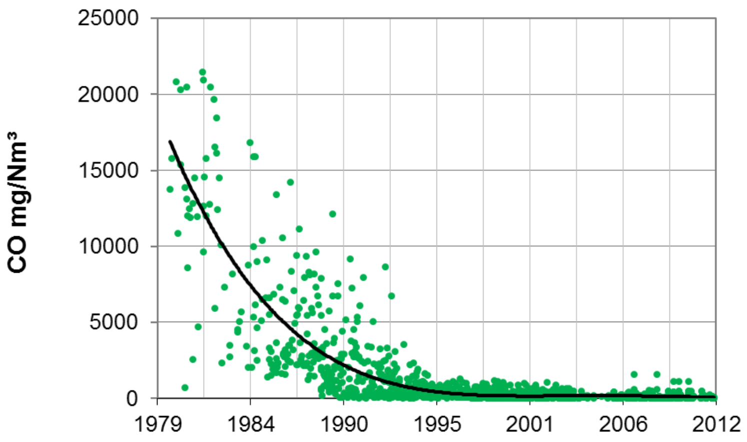
Current standard: EN 303-5

- Standard test method to certify efficiencies and emission factors of biomass boilers
  - Stationary operation: 6 hours at full load (100%) and 6 hours at part (30%) load
- Currently used to rate performance and compare different products





LIMITS OF EN 303-5

- Today majority of boilers in the market show efficiency above 90% and low emission factors → EN 303-5 cannot be used any more to compare products
- Test in stationary operation does not reflect real conditions (dynamic regime)

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Dynamic test methods

- Test methods to approach real life operating conditions:
  - *Bales et. al: 6-day test based on realistic climate sequence*
  - *Haberl et al: 12-day Concise Cycle Test for combined biomass-solar systems*

- Long duration →Relevant effort and resources
- Special equipment & Data post processing

→

Tests can be used for research purposes but cannot be widely adopted by industry

LOAD CYCLE TEST : new method to determine annual efficiency and emissions:

- Test is feasible in one working day with similar experimental set up as EN 303-5 tests → minimum expenses and effort in addition to EN 303-5
- All phases of boiler operation are included (ignition, different loads, stop, standby)
- Test results are representative of the boiler performance over the whole year

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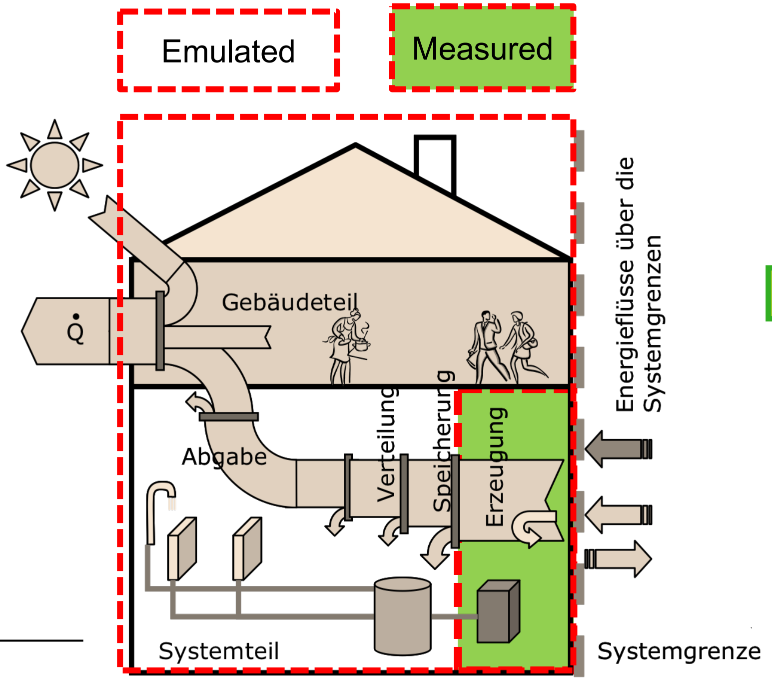
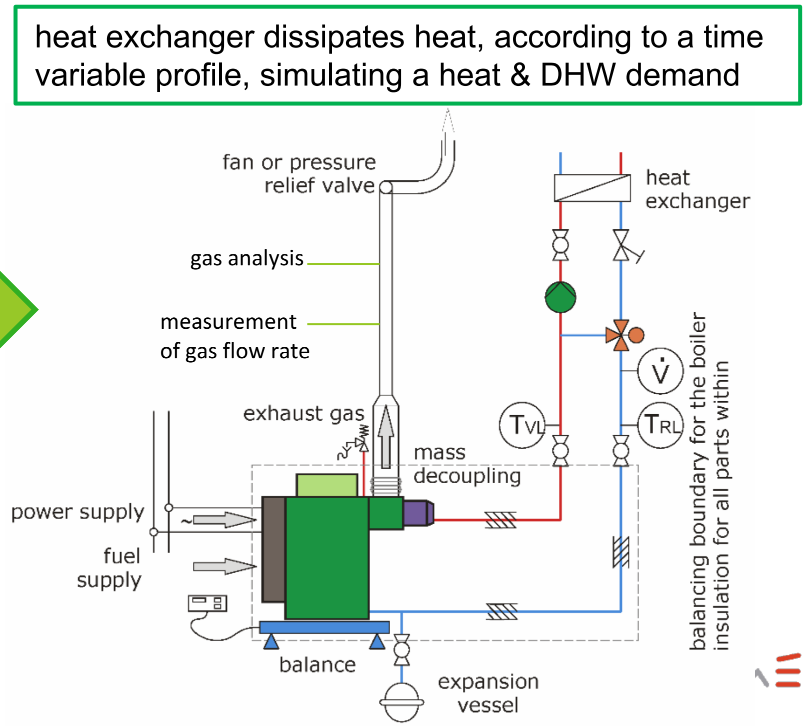
Case study and experimental setup in the laboratory

- The test emulates the operating conditions of boilers installed in **residential buildings** and **without a buffer storage tank**
- Boiler used to heat a “virtual house”, represented by a time variable demand profile





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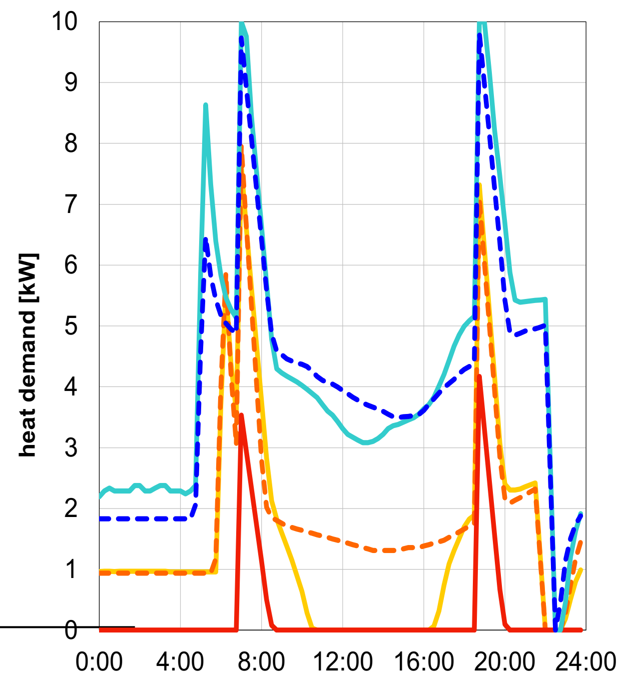
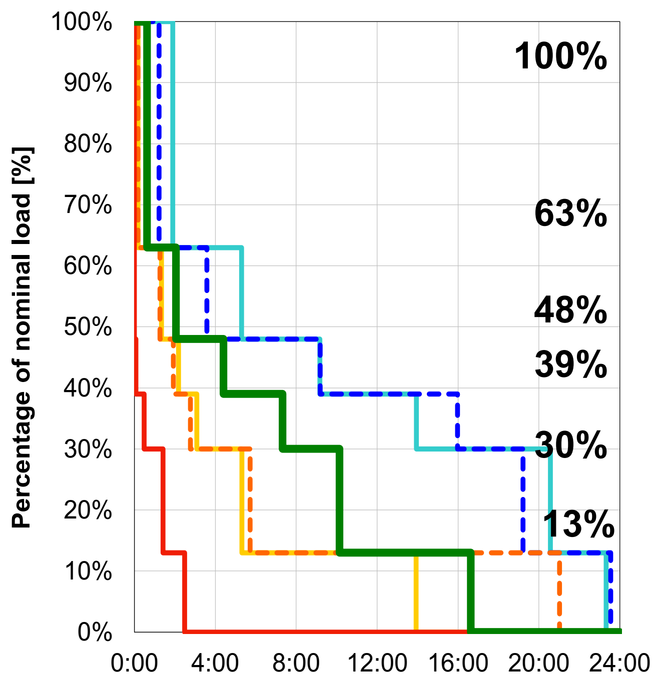
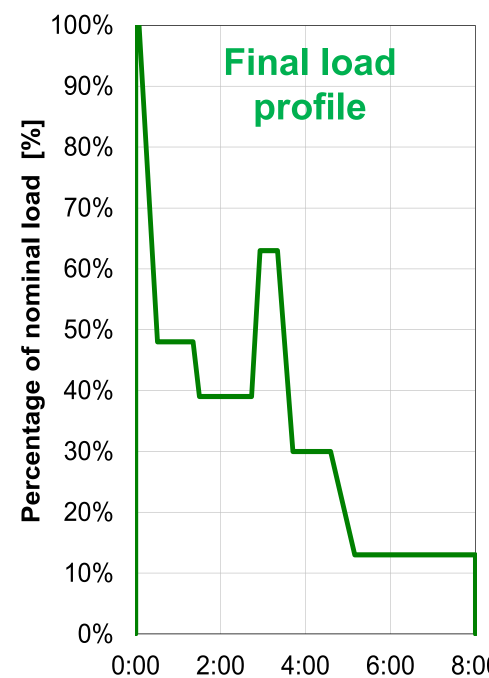
Load profile

- Literature review and field measurement to find typical daily profiles of heating and DHW demand in different seasons (winter, summer, spring/autumn)
- Reduction to load levels defined in DIN 4702-8 (referred to the boiler's nominal capacity)
- Weighted sum of the daily load levels to define an annual reference cycle
- Cycle is completed with load transitions and reduced from 24 to 8 hours







Boiler control during the test

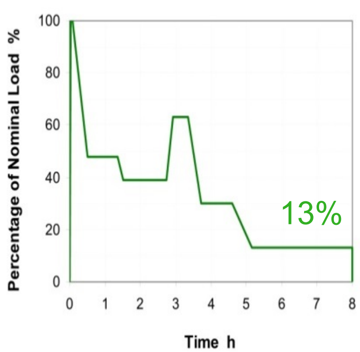
- Heat extracted by the heat exchanger, according to the load profile
- Constant set values of flow and return T
- Time variable water flow rate

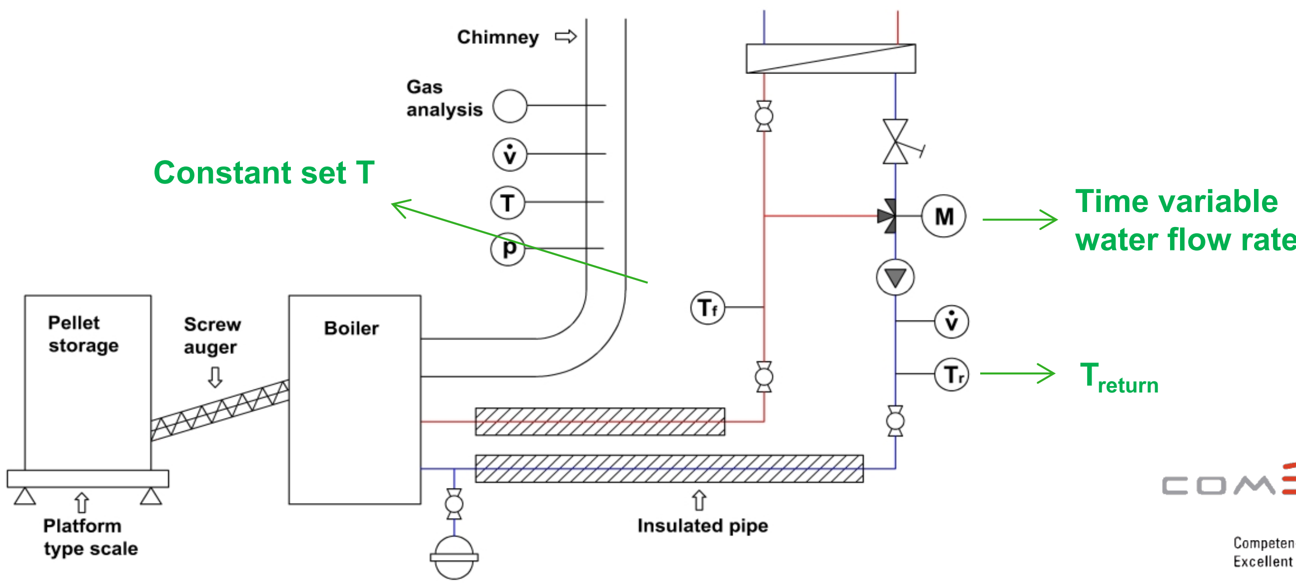
$Q = mc_p(T_{flow}-T_{ret})$

as hydronic heating systems in real life

- Last load step 13% → below lower limit of modulation range → boiler response to extremely low demands
  - Heat exchanger dissipates 13% of nominal load
  - No buffer storage

Increase of water temperature in the circuit until boiler stops





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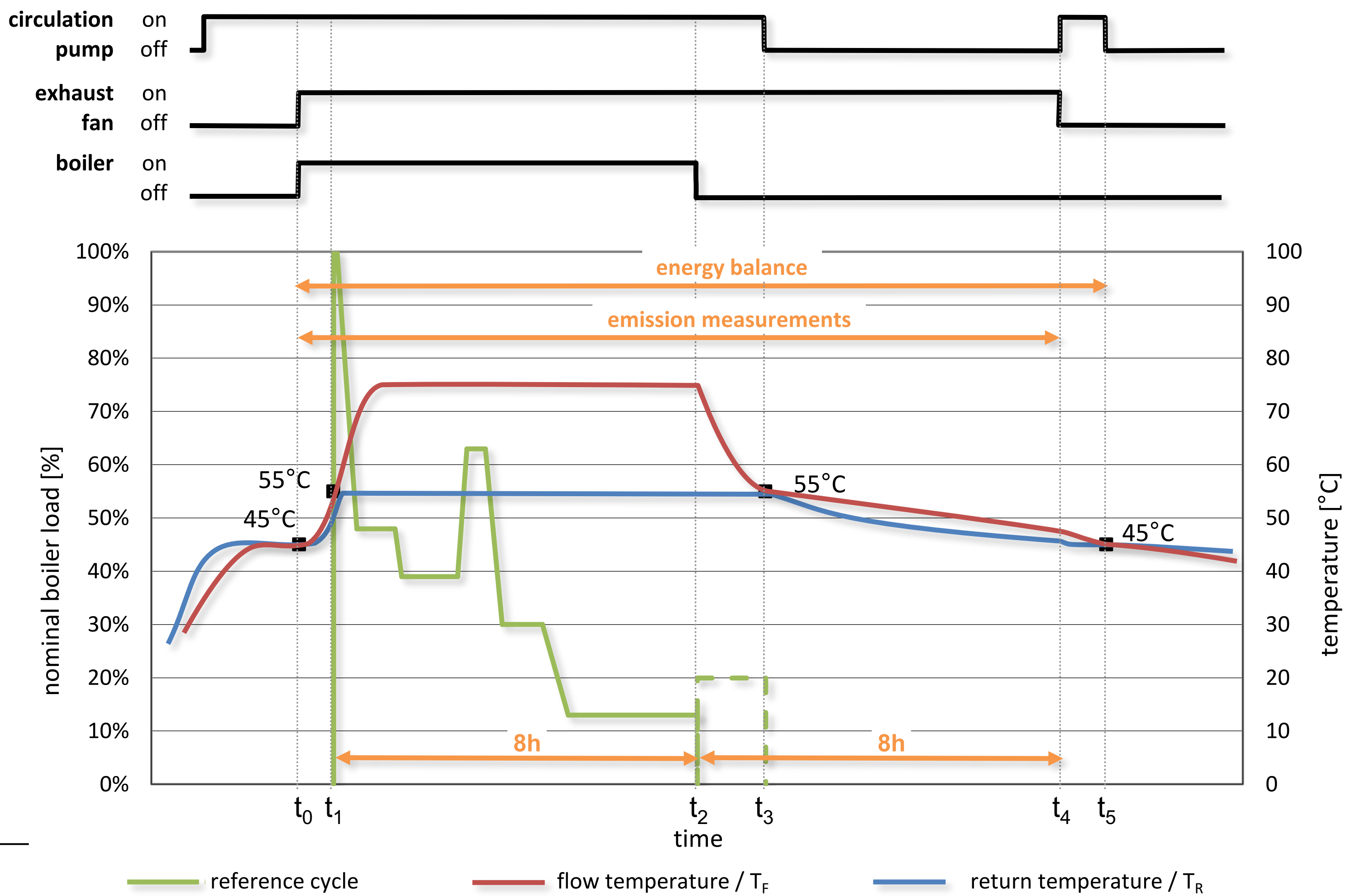
Complete test cycle



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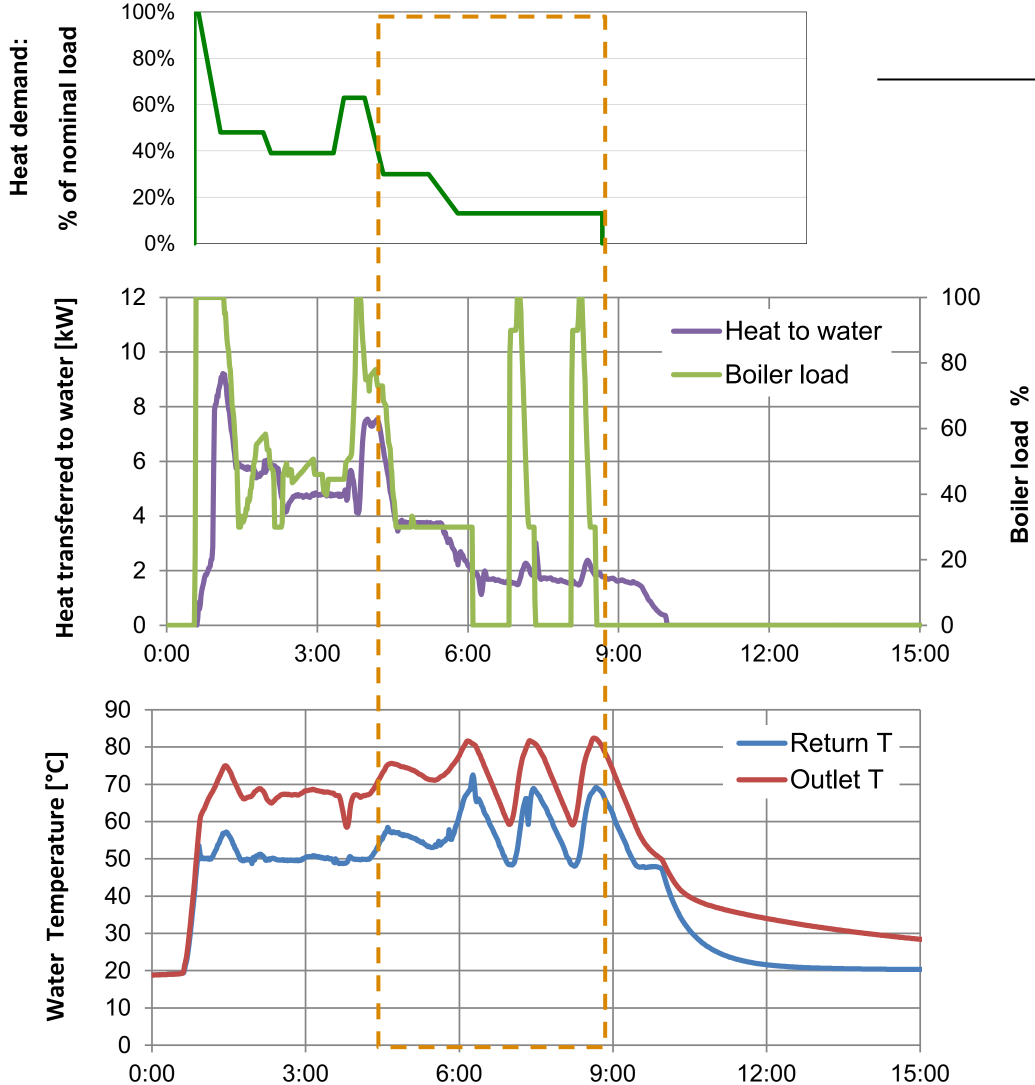
Example of test results: 12 kW boiler



→ Heat dissipated by heat exchanger, representing the DEMAND side

Heat supplied by the boiler to fulfill the heat demand

Boiler's load modulation range: 30-100%

Load levels equal and lower than 30% cause overheating in the water circuit

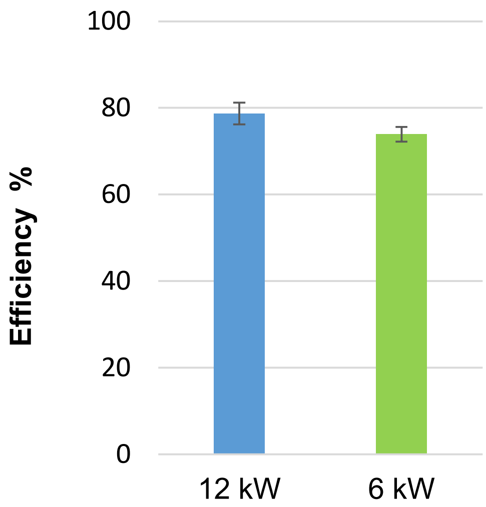
When T inside boiler reaches 85 °C ,the boiler stops for safety reasons → cycling operation in the final part of the load cycle

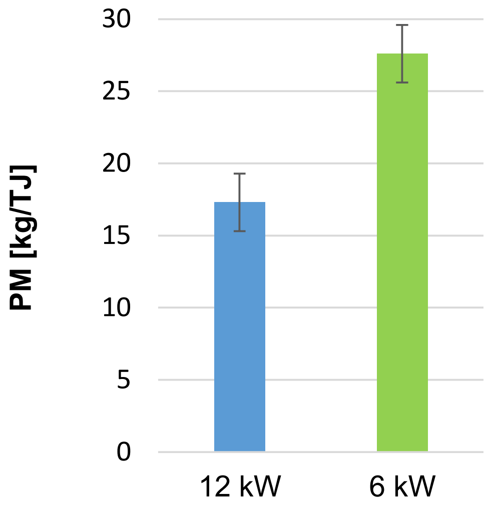
Reproducibility of test method

- Test repeated in different institutes in the EU (Austria, Germany, Spain, Greece)
  - 12 tests on 12 KW pellet boiler, 4 institutes
  - 5 tests on a 6 kw pellet boiler, 3 institutes
- Results shows reproducibility of test method

	12 kW Boiler	
	average	std deviation
efficiency [%]	78.7	2.1
CO [kg/TJ]	173.7	45.5
NOx [kg/TJ]	79.9	11.3
OGC [kg/TJ]	4.7	3.0
Dust [kg/TJ]	16.1	2.1

	6 kW Boiler	
	average	std deviation
efficiency [%]	73.9	1.7
CO [kg/TJ]	461.5	44.0
NOx [kg/TJ]	81.5	25.9
OGC [kg/TJ]	14.3	8.8
Dust [kg/TJ]	27.6	2.0





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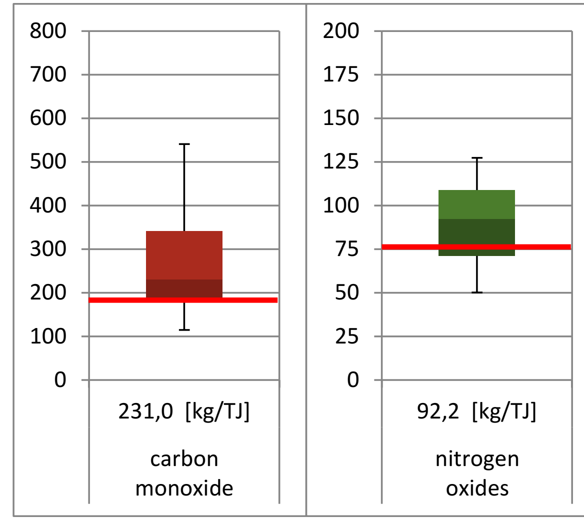
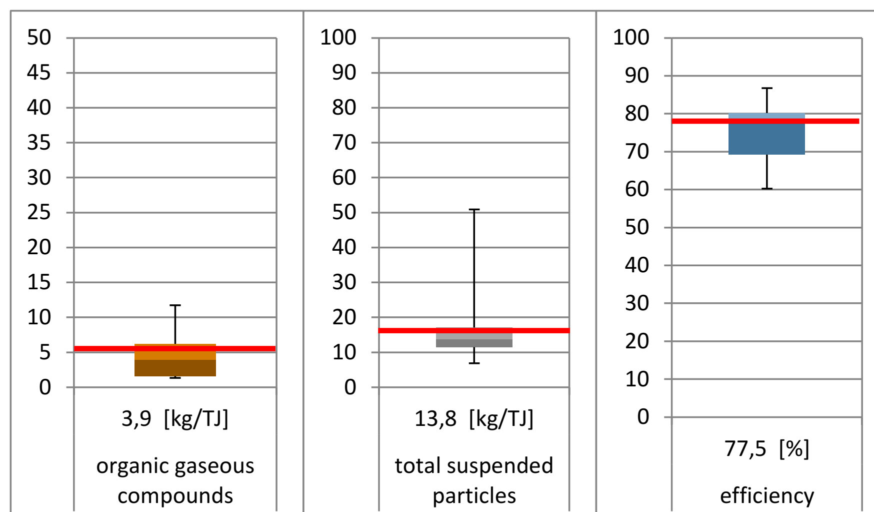
Comparision with real life operation

	12 kW Boiler		
	Type Test EN 303-5 (full load)	Load cycle test	Real life operation
CO kg/TJ	21	173.7	231.0
NOx kg/TJ	79	79.9	92.2
OGC kg/TJ	1	4.7	3.9
Dust kg/TJ	7	16.1	13.8
Efficiency %	91.4*	78.7	77.5

* based on fuel consumption

- Real life operation:
  - Emissions: 24 h field measurements
  - Median values of 17 measurements





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Results – 3: development of new product

- New version of a pellet boiler of an Austrian company
- EN 303-5 test results do not show improvements

	EN 303-5 (full load)		EN 303-5 (part load)	
	Old	New	Old	New
CO kg/TJ	27	25	88	94
OGC kg/TJ	1	1	1	3
Dust kg/TJ	6	6	13	9
Efficiency %	93.2	94.4	90.9	89.6

- LCT results show significant emission reduction (OGC) and + 6% efficiency

	Load cycle test	
	Old	New
CO kg/TJ	287	301
OGC kg/TJ	16	4
Dust kg/TJ	20	17
Efficiency %	75.2	80.7

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Conclusions

- Load Cycle Test method was developed, to estimate annual efficiency and emissions at the test stand
  - Repeatability of method was demonstrated
  - Method validated in comparison to field data

- The Load Cycle Test method:
  - is reliable tool to assess boiler performance under realistic operating conditions
  - can be used to evaluate the improvement of new products, in comparison to the current state of the art

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THANK YOU FOR YOUR KIND ATTENTION!

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