BEST
Bioenergy and Sustainable Technologies

Modern control strategies for biomass combustion systems in residential heating systems

6th Central European Biomass Conference

IEA-Workshop: TASK 32

Markus Gölles, Christopher Zemann

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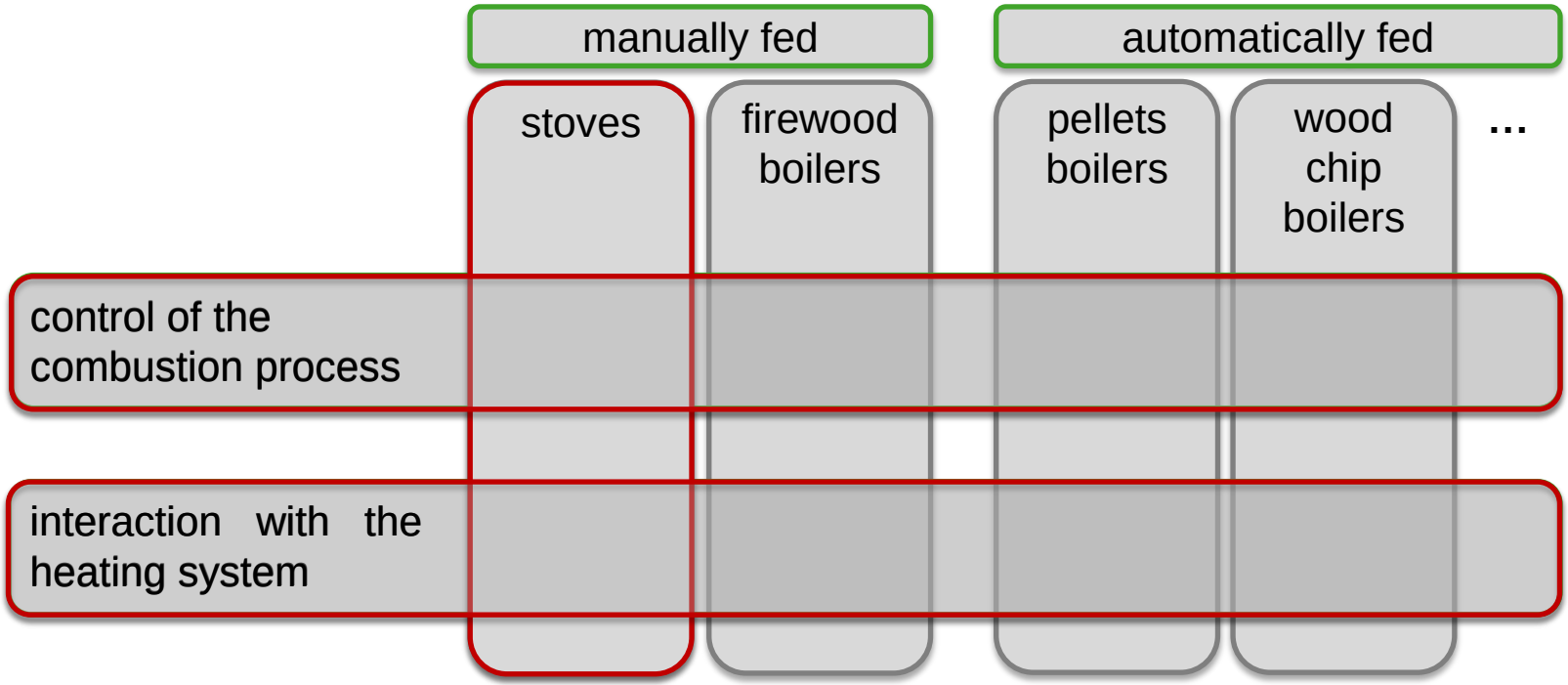
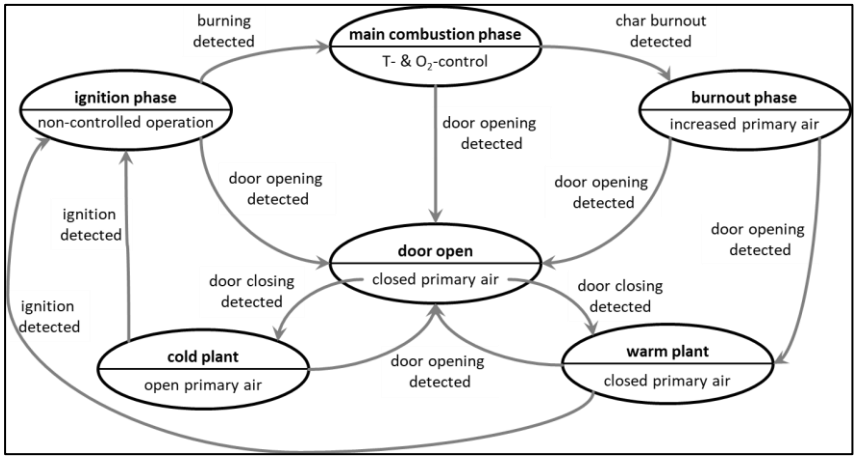
Overview


manually fed
automatically fed
stoves
firewood boilers
pellets boilers
wood chip boilers
...
control of the combustion process
interaction with the heating system

Control strategies for wood stoves

Control of the combustion process

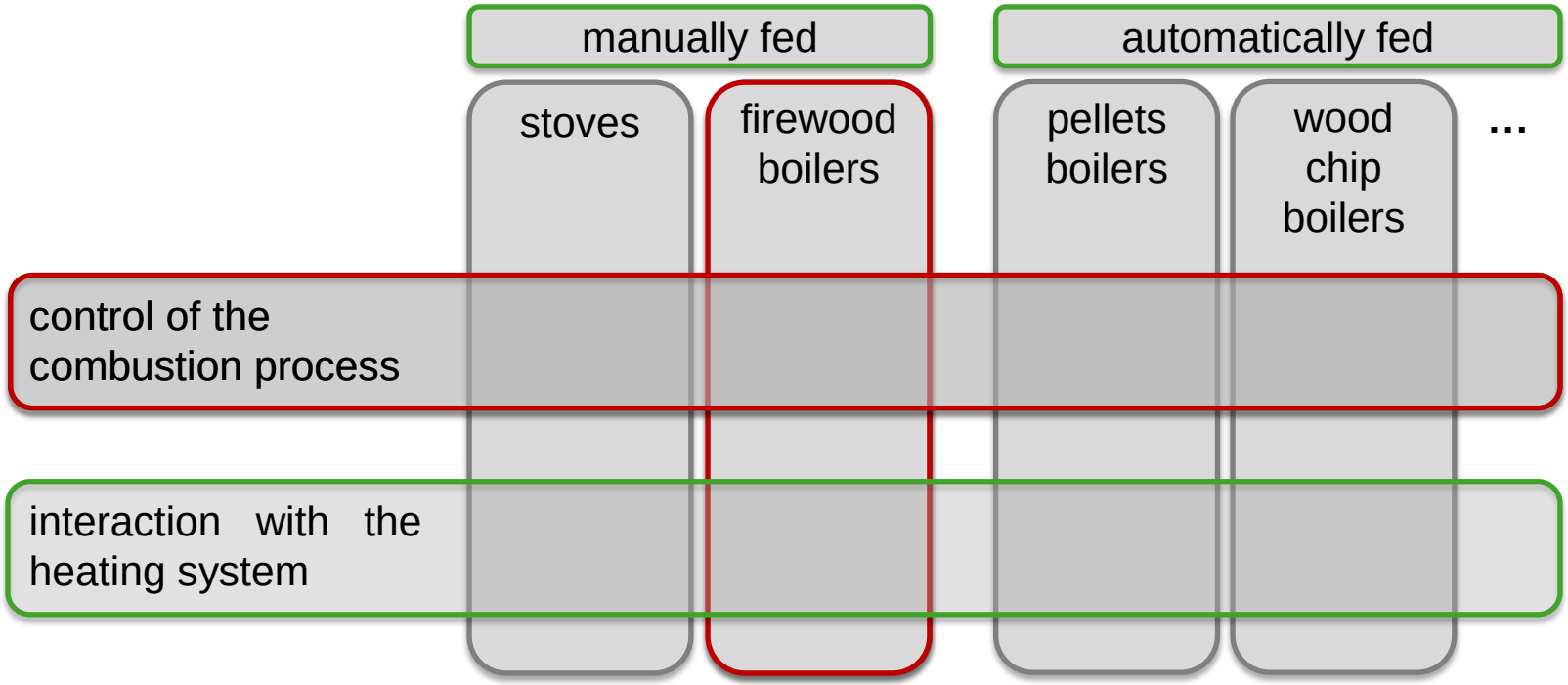
- utilization of finite-state machines



Interaction with the heating system

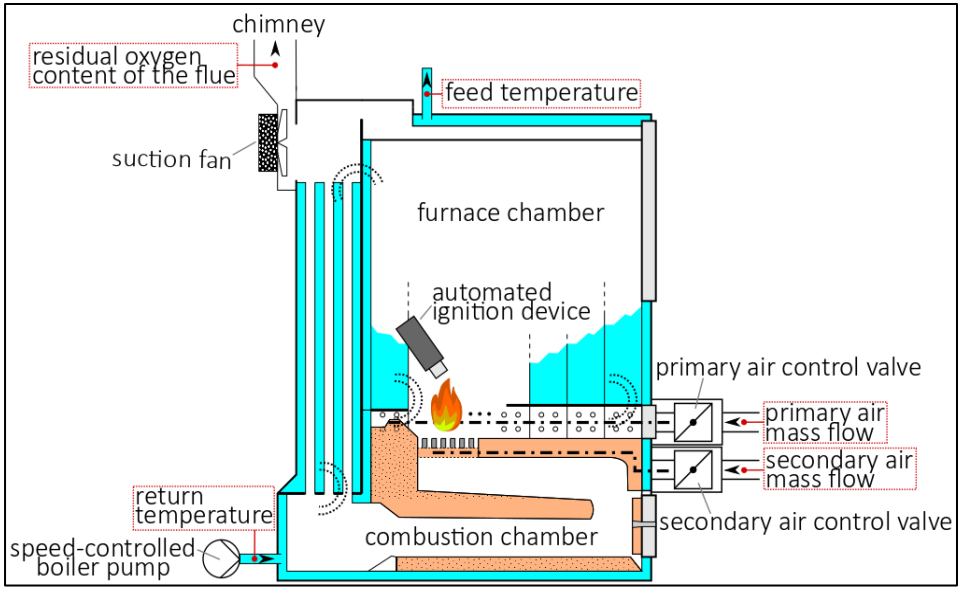
- very rare
- rule-based strategies
- manufacturer-specific

Control strategies for firewood boilers



Combustion control for firewood boilers – overview

Goal: control strategy which simultaneously guarantees good combustion conditions and ensures that the water temperature is kept at the desired value.



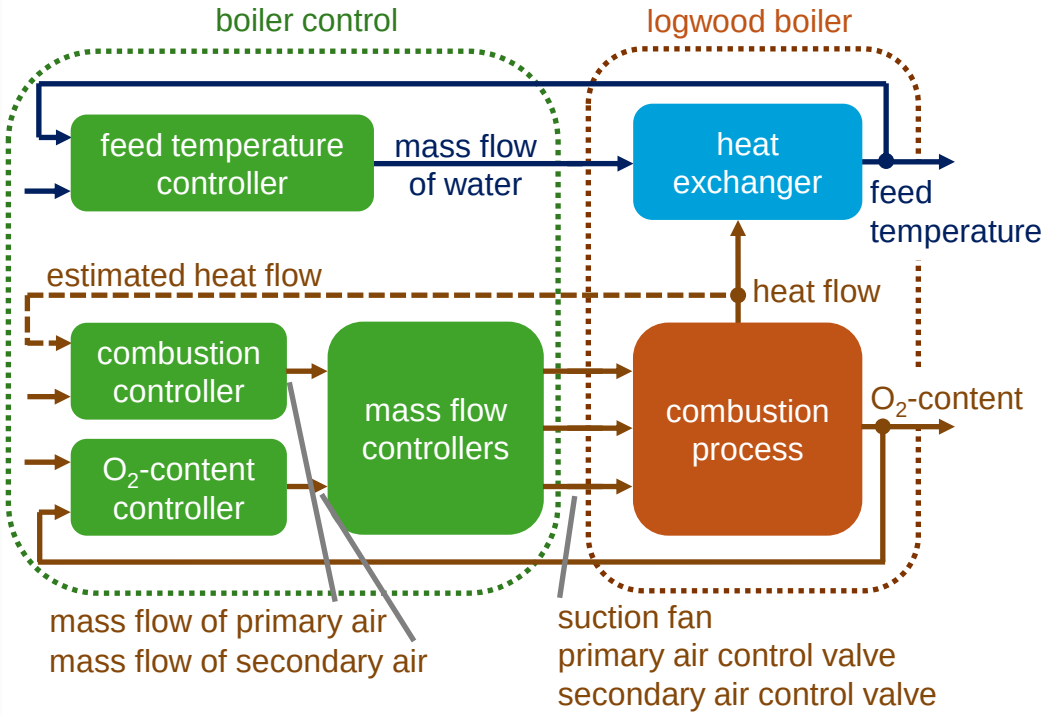
controlled variables

- feed temperature
- residual oxygen content of the flue gas

manipulated variables

- suction fan frequency
- primary air control valve
- secondary air control valve
- boiler pump frequency

Combustion control for firewood boilers – concept



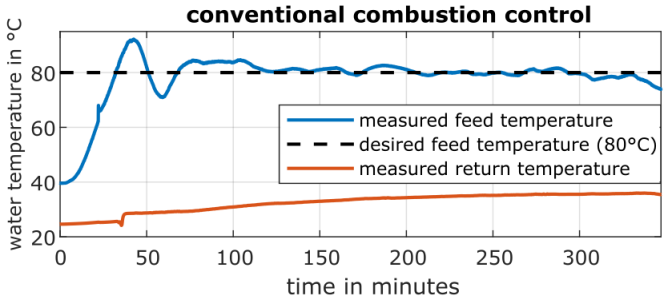
decoupling

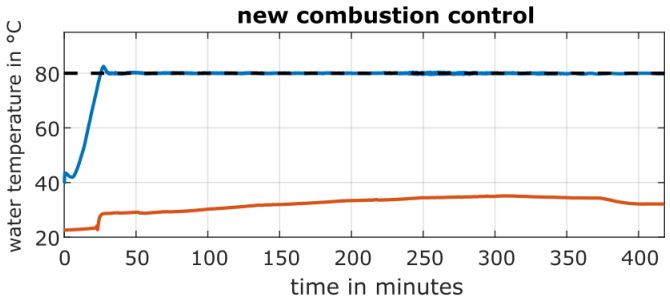
utilization of the mass flow of water to decouple the feed temperature from the combustion process

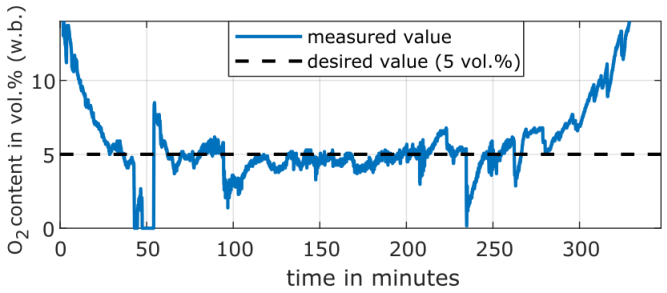
targeted combustion control

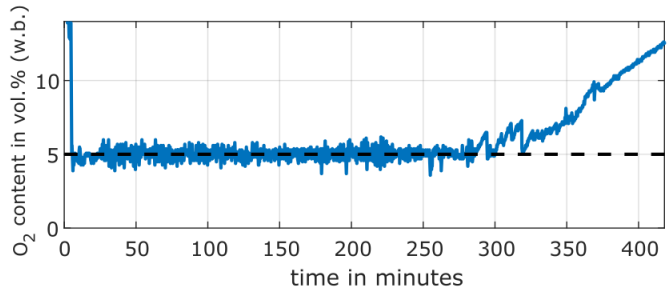
utilization of the mass flow controllers to ensure good combustion conditions

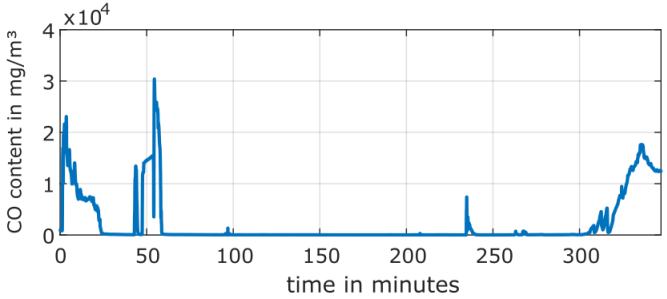
Combustion control for firewood boilers – results

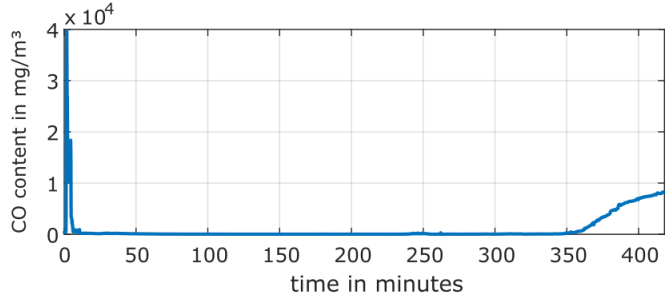




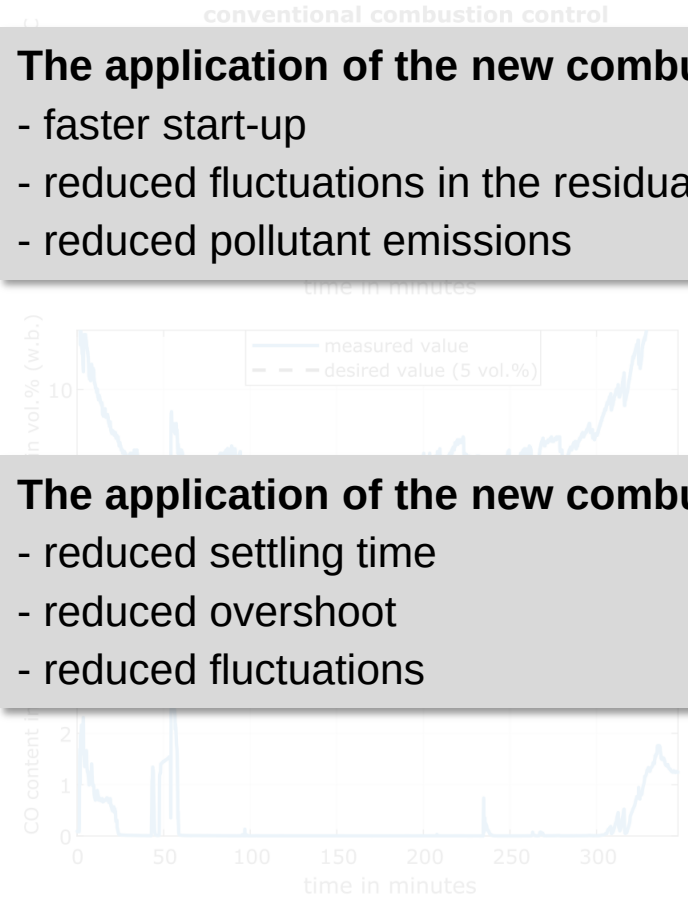


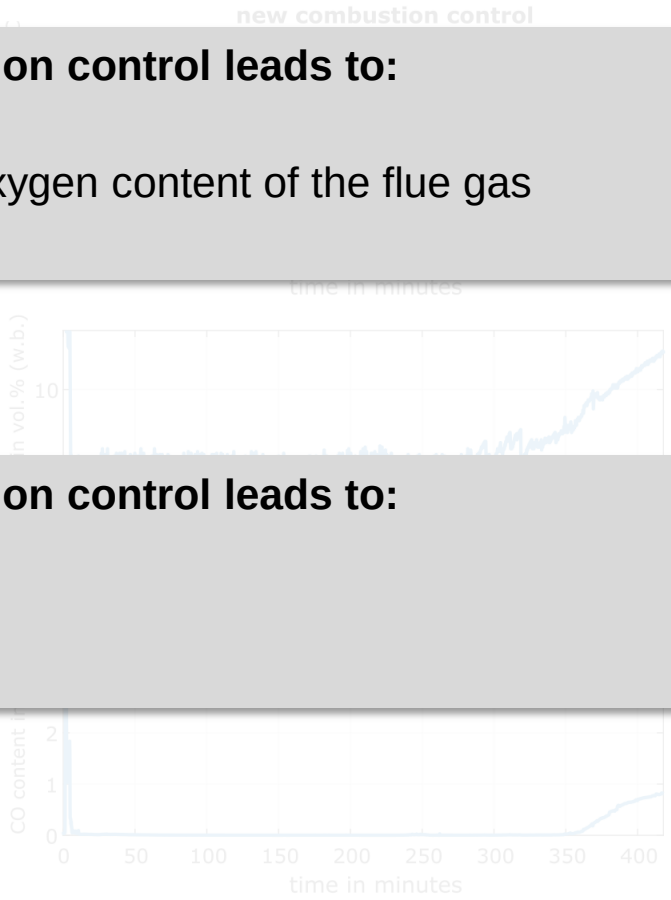






Combustion control for firewood boilers – results





The application of the new combustion control leads to:
- faster start-up
- reduced fluctuations in the residual oxygen content of the flue gas
- reduced pollutant emissions

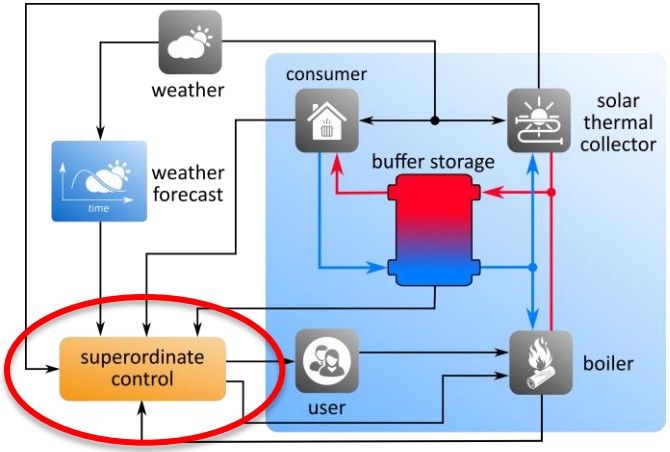
The application of the new combustion control leads to:
- reduced settling time
- reduced overshoot
- reduced fluctuations

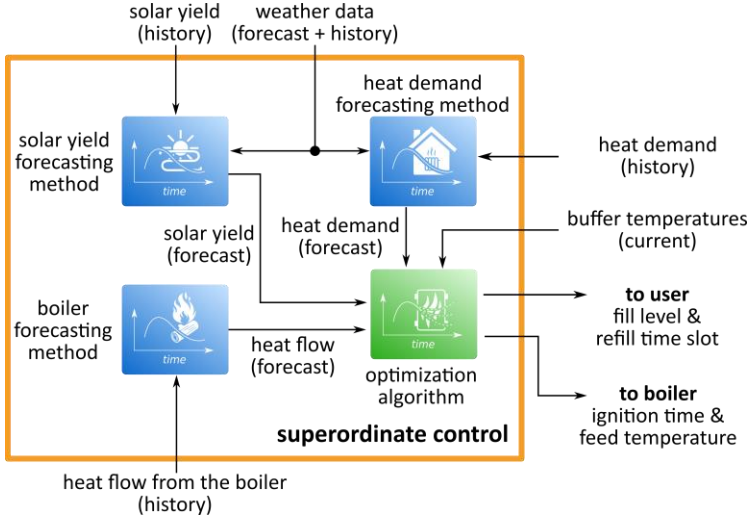
Control strategies for firewood boilers

Energy management system for firewood boilers

operation of manually fed boilers

- batch combustion → supply of heat depends on ignition time
- consideration refill windows defined by the user → user comfort





- utilization of forecasting methods using weather forecasts
- self-learning to adapt to the user behavior

Exemplary results from the application of an energy management system for firewood boilers

	Conventional operation	Superordinate control	
energy delivered to consumers	783 kWh	782 kWh	± 0 %
number of refills (total / within refill windows)	5 / 4	6 / 6	+1 / +2
utilized solar yield	117 kWh	126 kWh	+ 8 %
storage losses	122 kWh	105 kWh	- 14 %

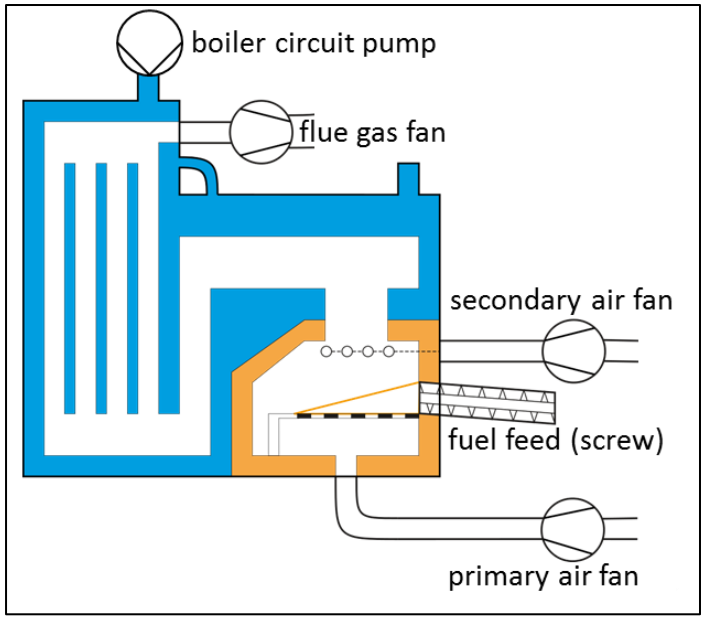
→ improved efficiency

→ improved user comfort due to no refills outside of defined refill windows

Control strategies for automatically fed boilers

Combustion control for wood chip boilers - overview

Goal: control strategy which simultaneously guarantees good combustion conditions and ensures that the water temperature is kept at the desired value.



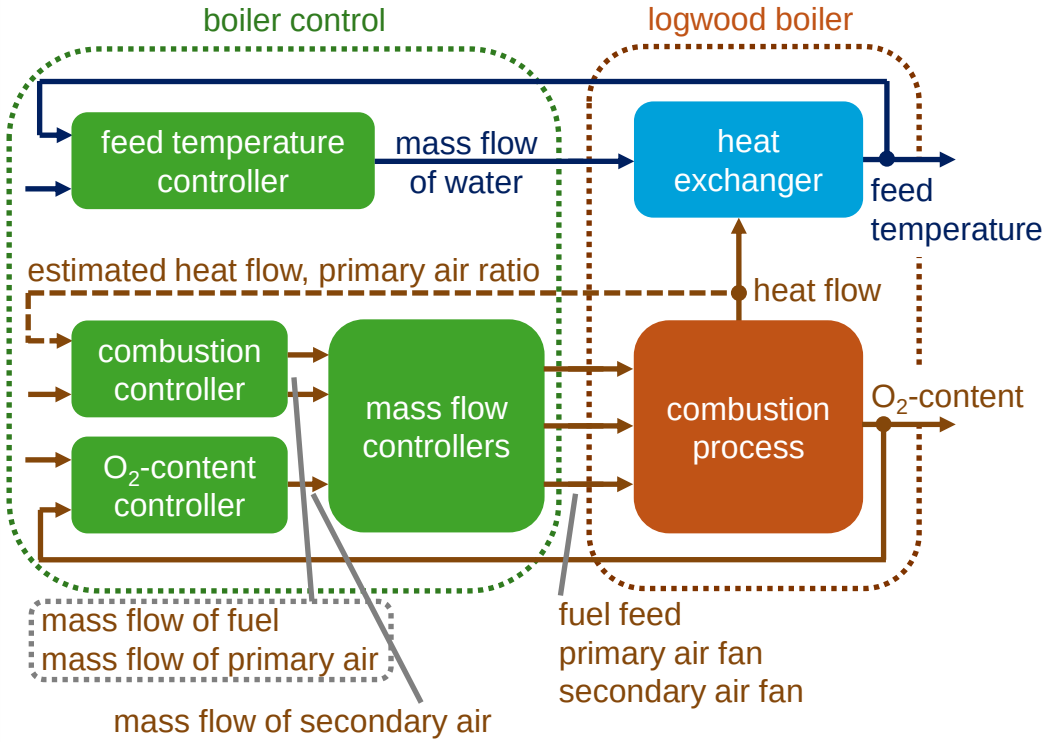
controlled variables

- feed temperature
- residual oxygen content of the flue gas
- primary air ratio

manipulated variables

- fuel feed
- primary air fan
- secondary air fan
- boiler circuit pump

Combustion control for wood chip boilers - concept



decoupling

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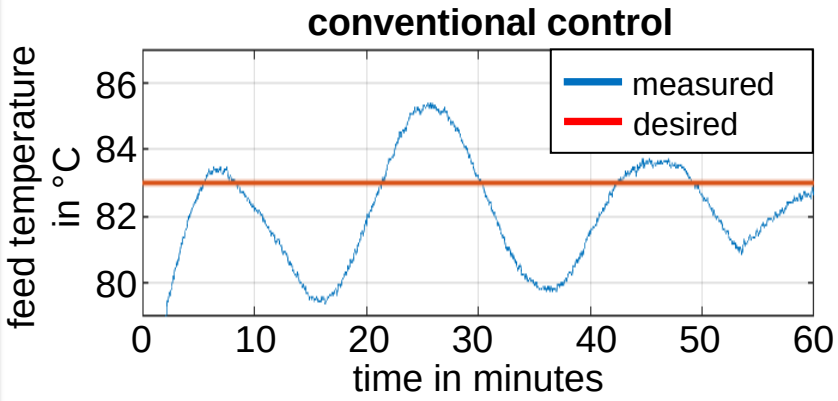
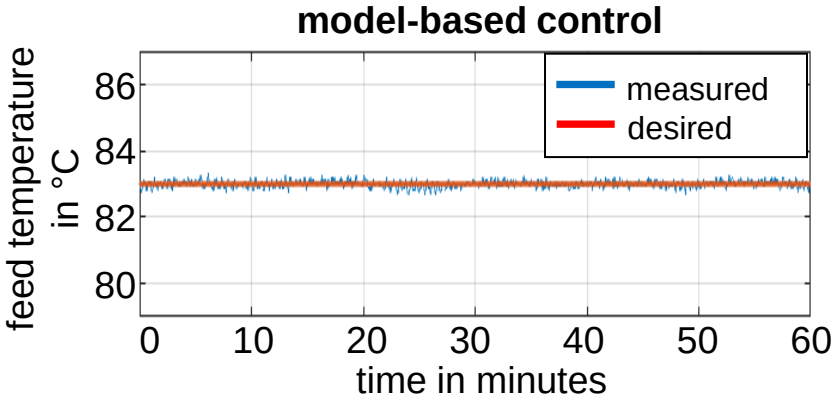
targeted combustion control

utilization of the mass flow controllers to ensure good combustion conditions

Combustion control for wood chip boilers – results (1)

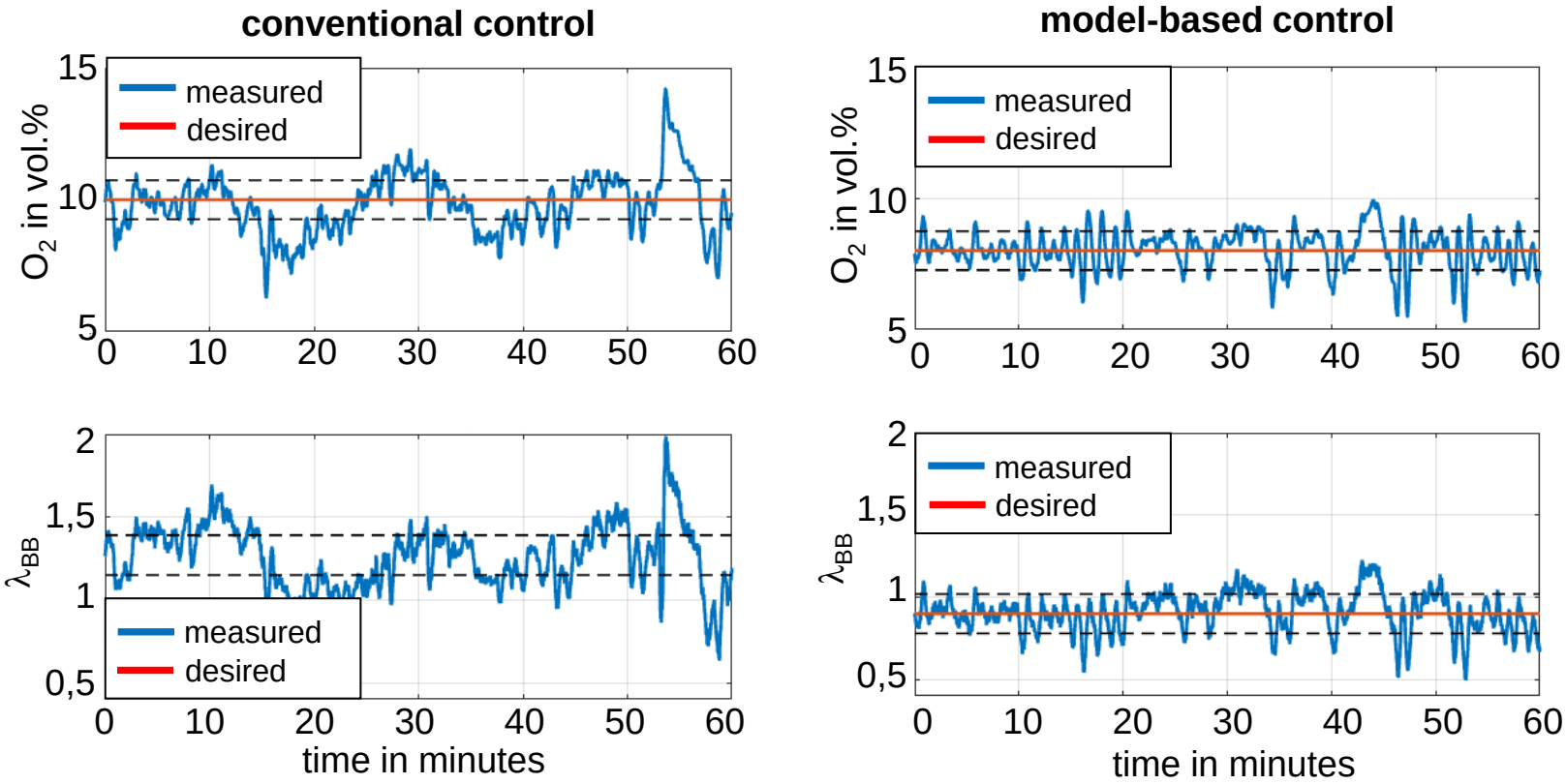




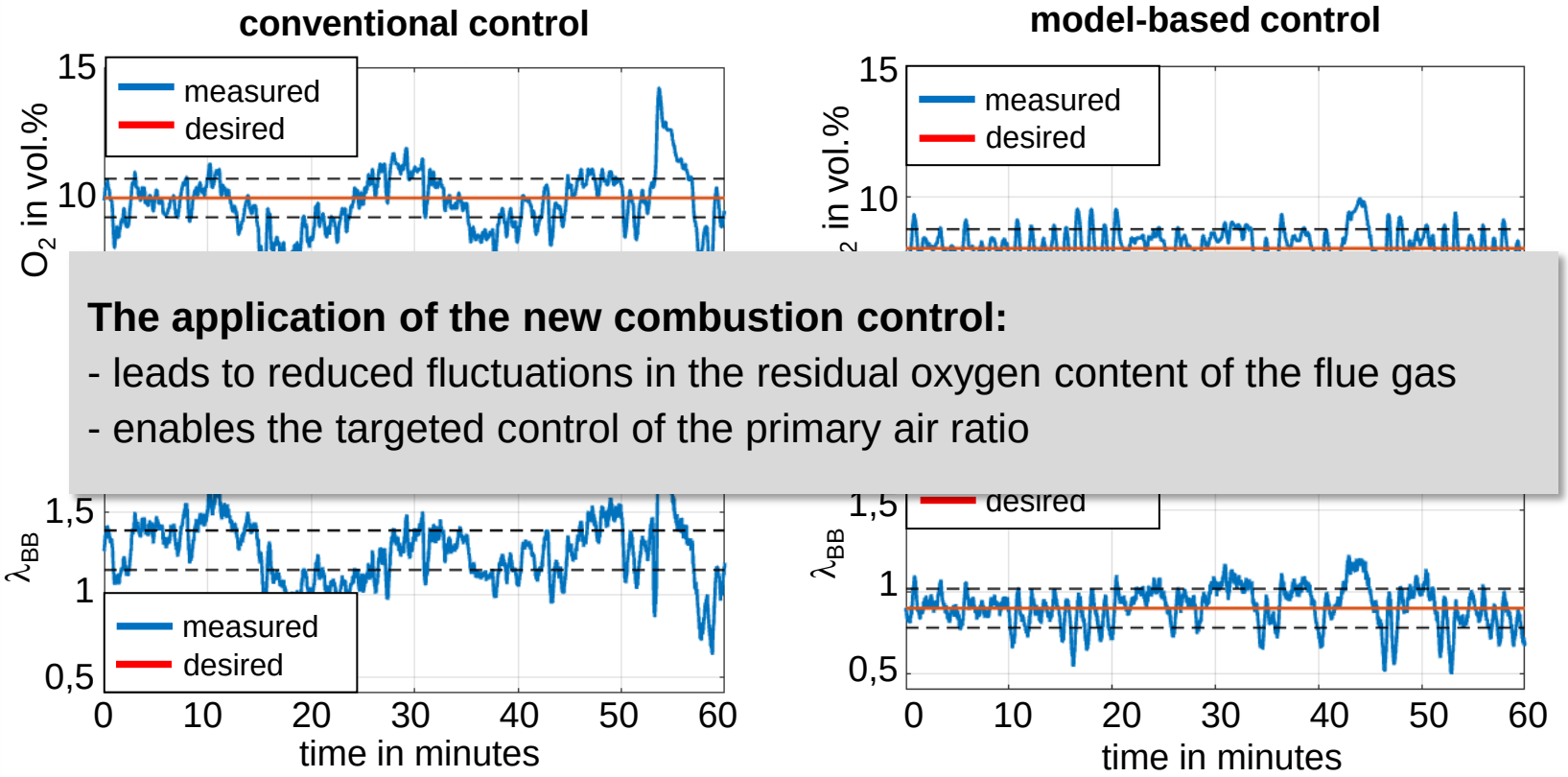
The application of the new combustion control:

- leads to reduced fluctuations in the feed temperature

Combustion control for wood chip boilers – results (2)



Combustion control for wood chip boilers – results (2)



The application of the new combustion control:

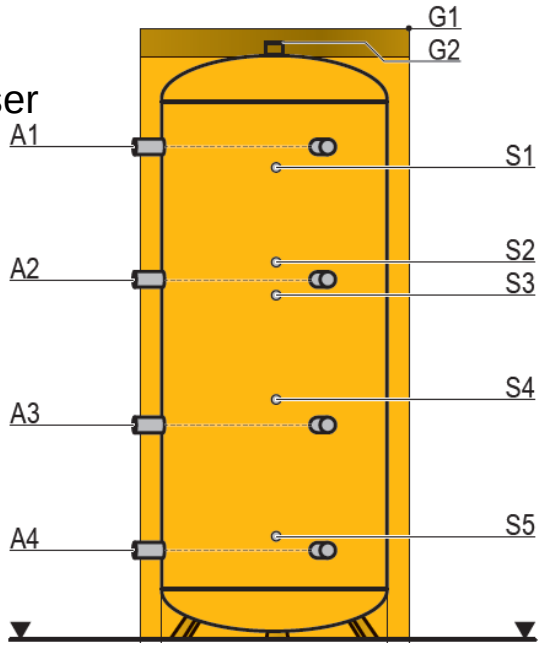
- leads to reduced fluctuations in the residual oxygen content of the flue gas
- enables the targeted control of the primary air ratio

Control strategies for automatically fed boilers

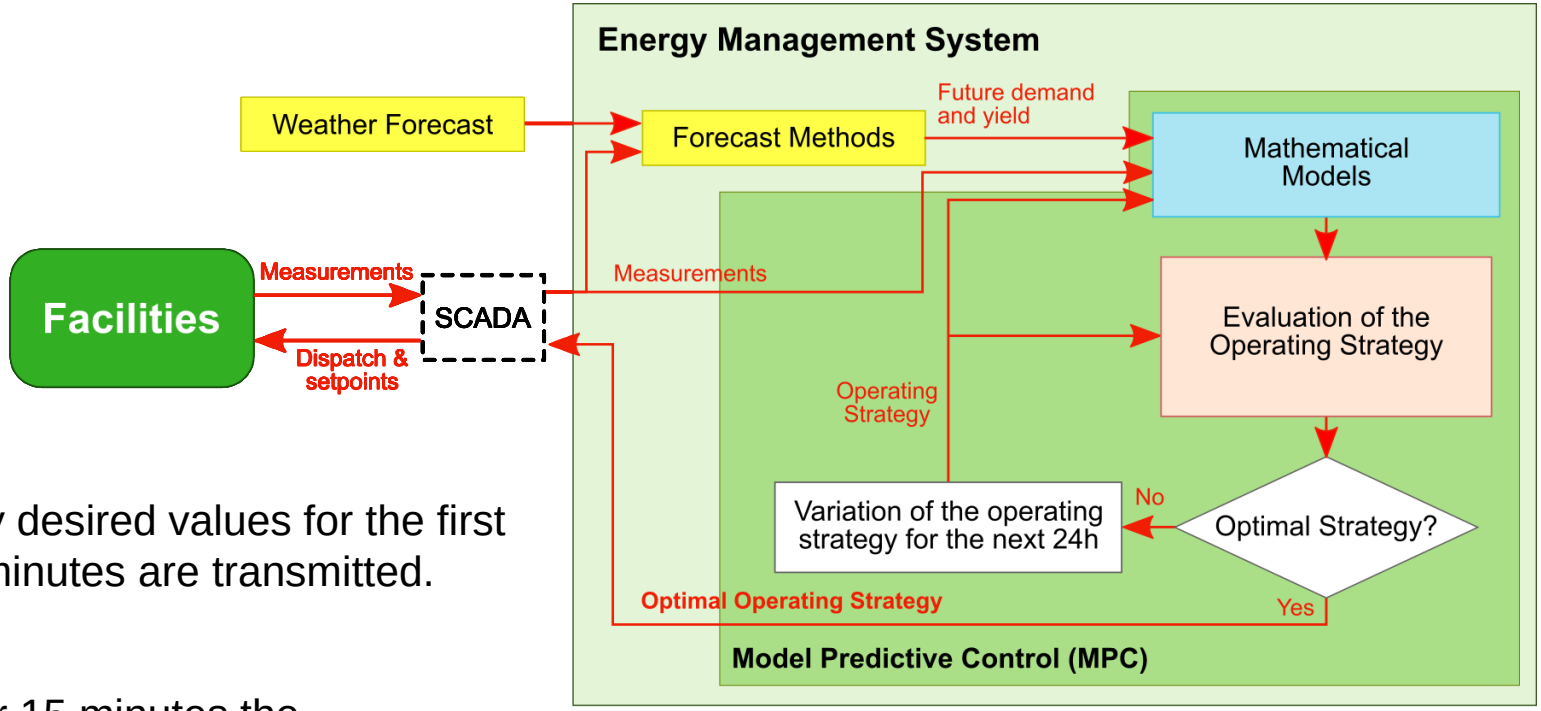
Simple rule-based load management for wood chip boilers

Definition of a desired thermal output of the boiler depending on the state of the buffer storage.

- **ignition**
  - start combustion process if S1 < T_1
  - start combustion process if ignition request from user
- **standard operation**
  - if S3 < T_2, increase thermal output
  - else: decrease thermal output
  - if S1 < T_1, maximum thermal output
- **shut-down**
  - if S5 > T_3, shut-down boiler



Optimization-based energy management system



Only desired values for the first 15 minutes are transmitted.

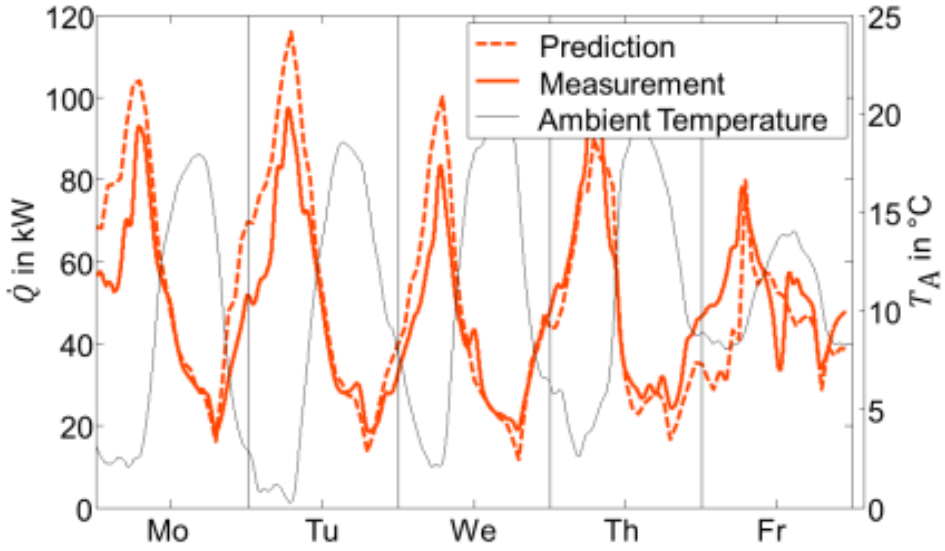
After 15 minutes the optimization is repeated with new measured variables.

Simple forecasting methods

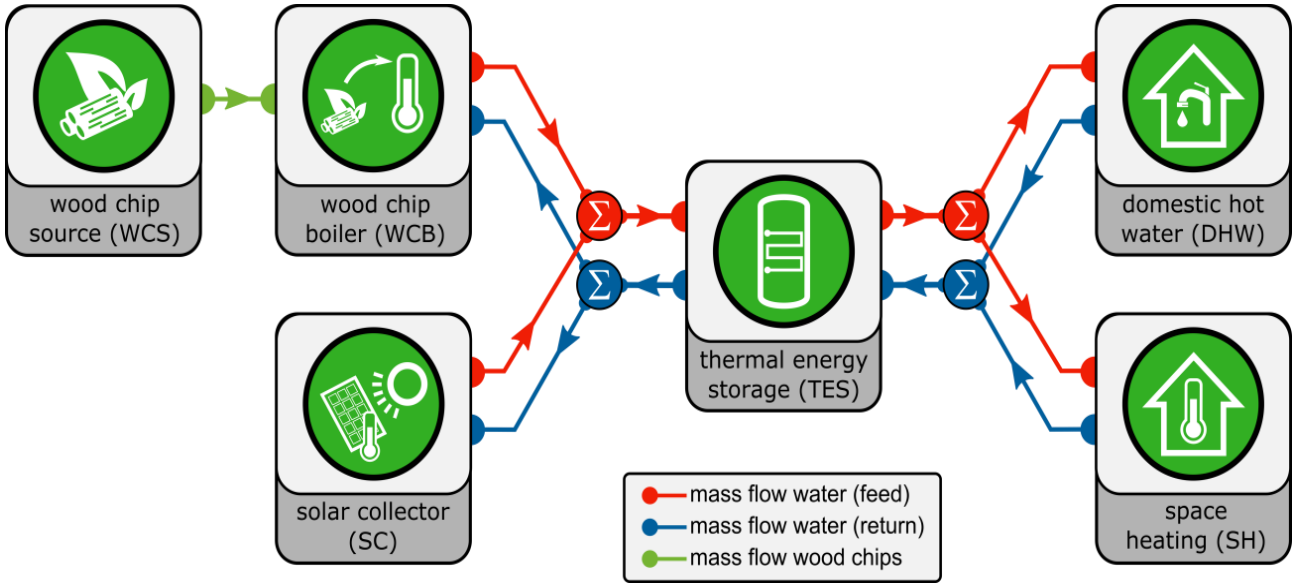
Forecasting method for the load demand in residential heating systems:

- simple to implement
- self-learning (based on measurement data from weather forecasts)

➢ no parametrization required



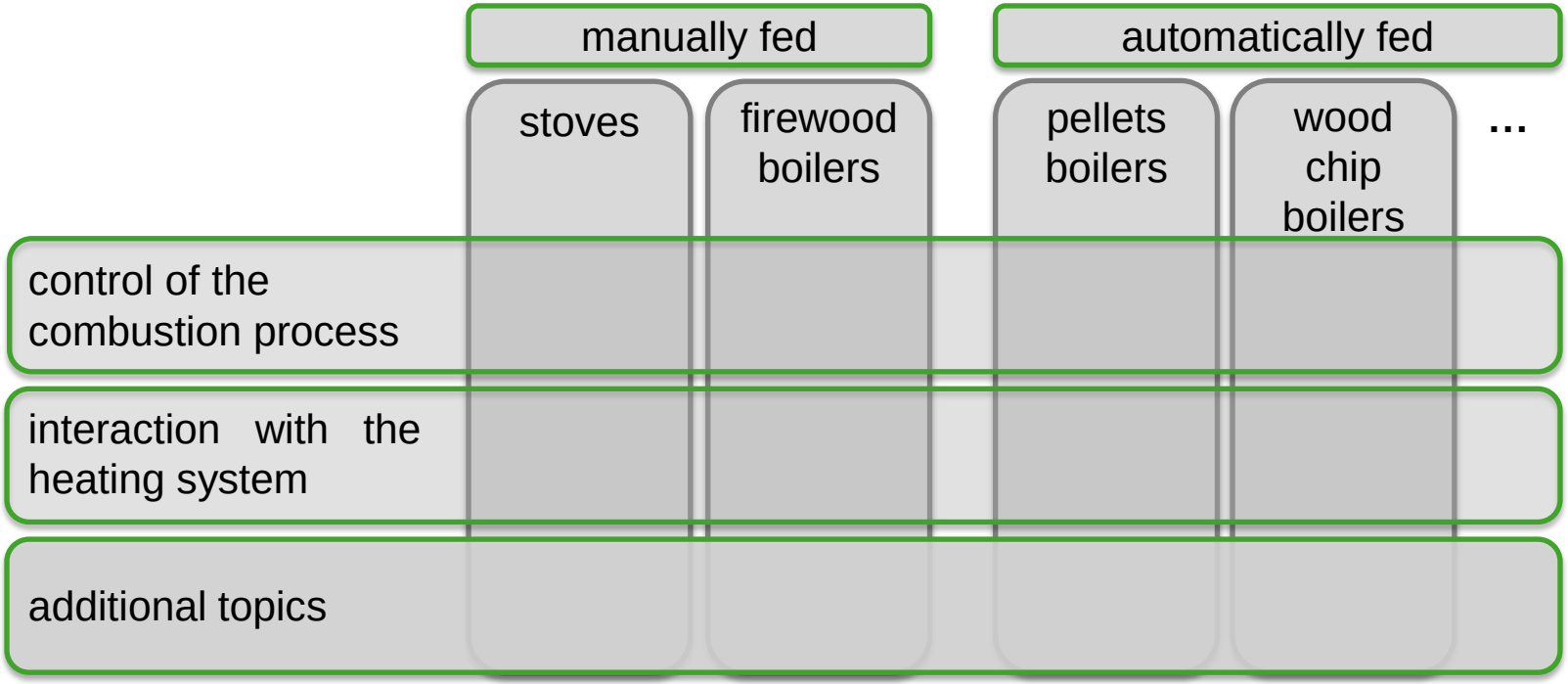
Modular energy management system



The system is modular: it allows a quick configuration from standard components.

Variable prices and availability of systems can be taken into account.

Conclusion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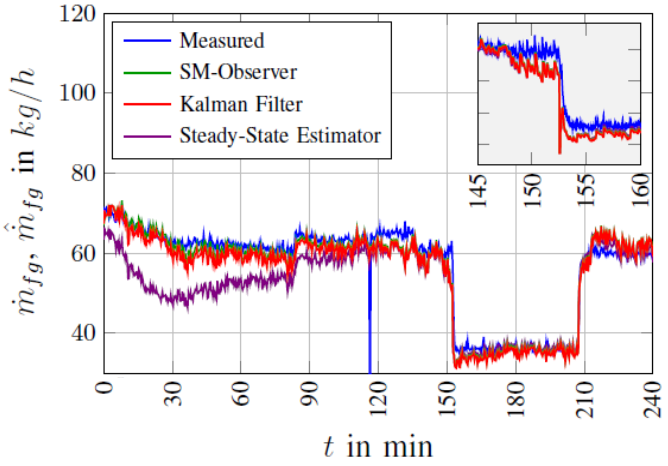
control of the combustion process
interaction with the heating system
additional topics

Estimation of non-measureable quantities

mass flow of flue gas

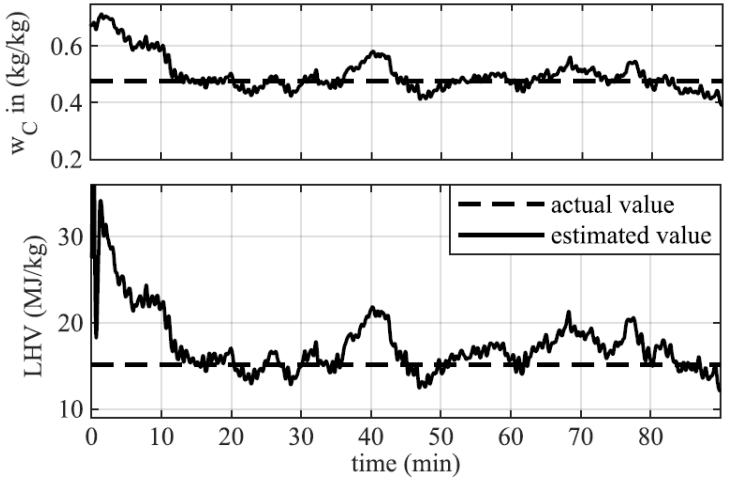
Knowledge about the mass flow of flue gas can be used in control strategies to ensure good the combustion conditions.

→ difficult to measure in biomass boilers

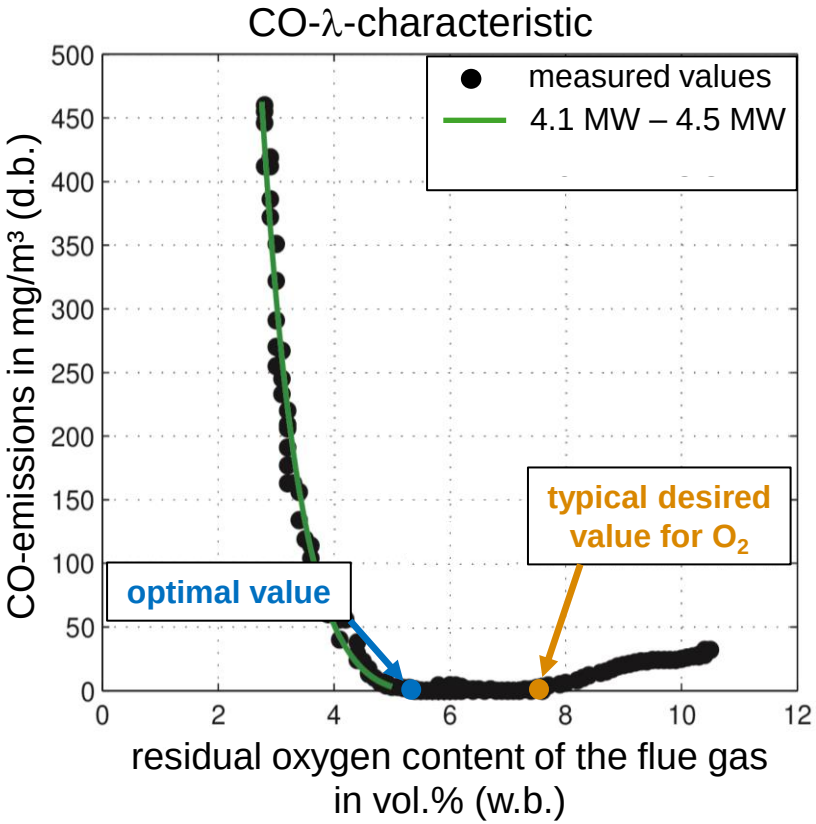


fuel properties

Estimation of fuel properties such as the carbon content (w_C) and lower heating value (LHV) during the operation of the biomass boiler.



CO-λ-optimization



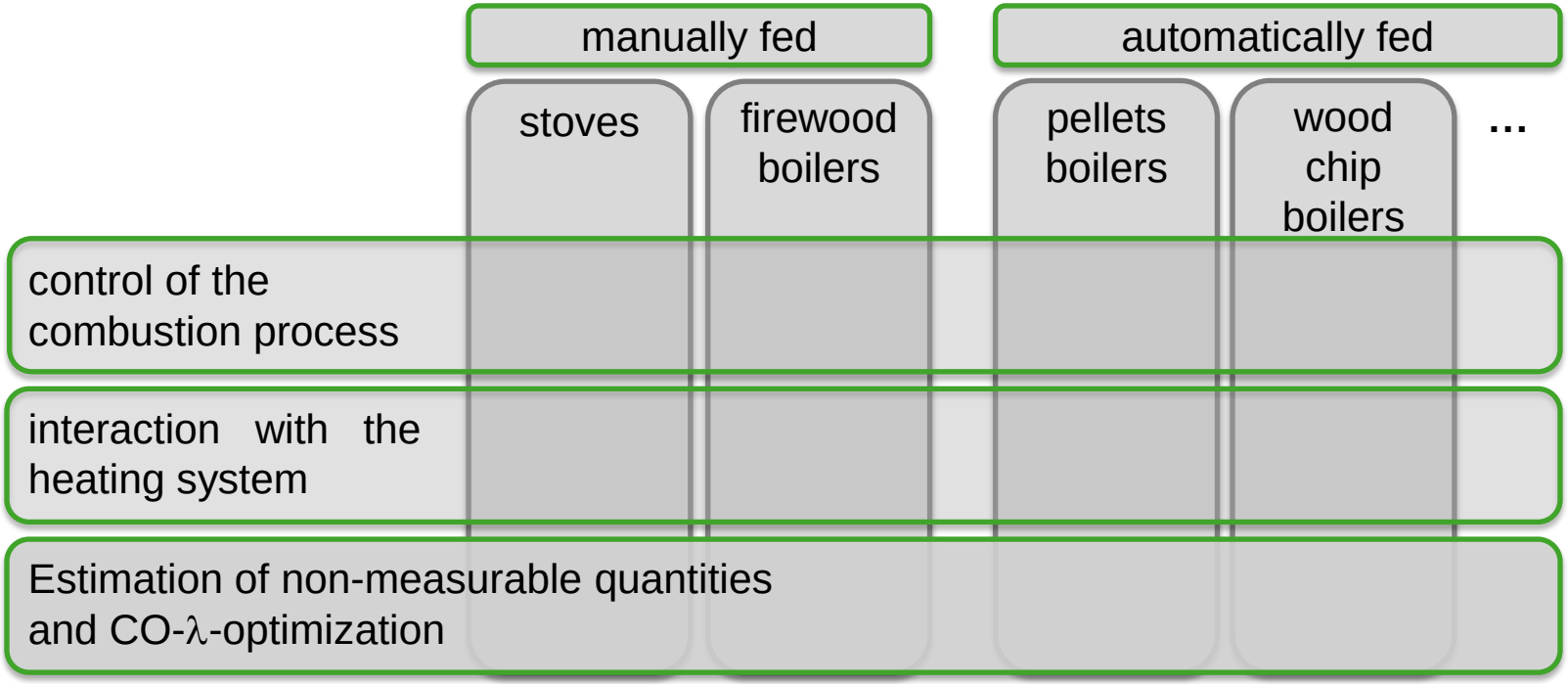
A long-term validation has been carried out at a biomass boiler in a district heating plant (nominal capacity of 2.5 MW_{th})

→ Nov. 2017 to Mar. 2019 (5 months)

During the long-term validation the modular CO-λ-optimization reduced the

- fuel consumption by -3,8%
- CO-emissions by -200 mg/m³
- total dust emissions by -19,5%

Conclusion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Estimation of non-measurable quantities and CO-λ-optimization

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BEST – Bioenergy and Sustainable Technologies GmbH

Markus Gölles
Automation and Control

E-Mail: markus.goelles@bioenergy2020.eu
Telefon: + 43 (0) 316 873-9208