

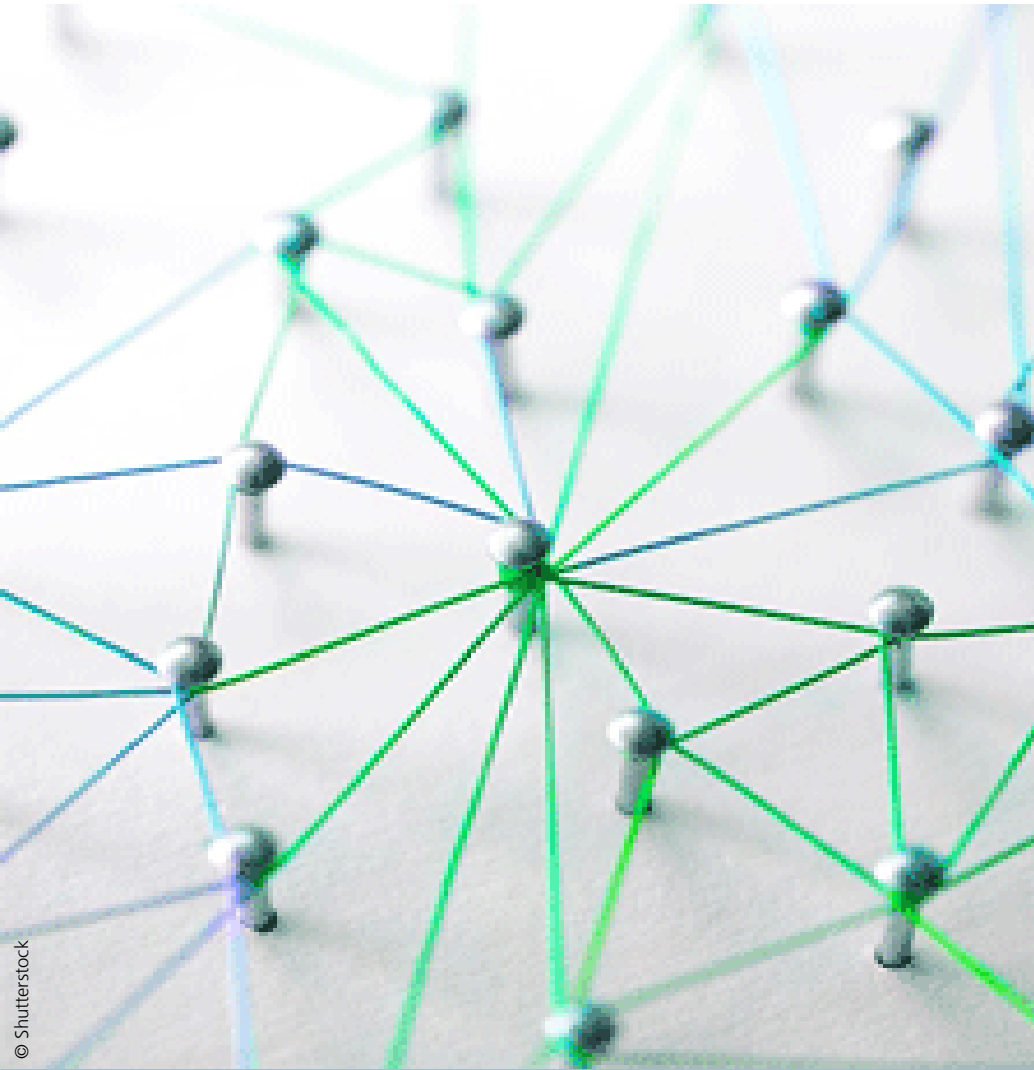
The Combined Integrated Combustion Technology for the Simultaneous Reduction of NO_x and Combustible Gaseous Compounds in Biomass Boilers

Souha Meriee / Dr. Mohammad Aleysa
Research Project / Doctoral thesis

10.10.2024



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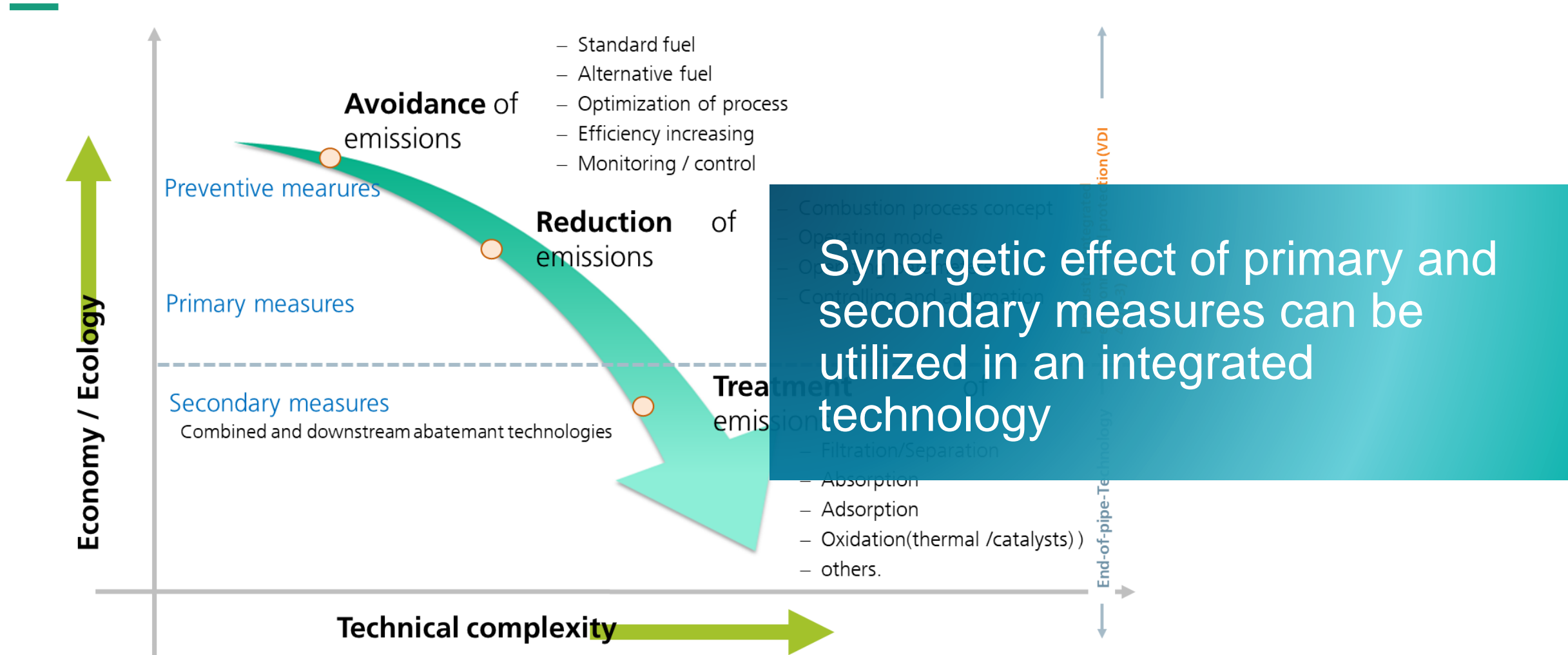
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Process concept and technical technology

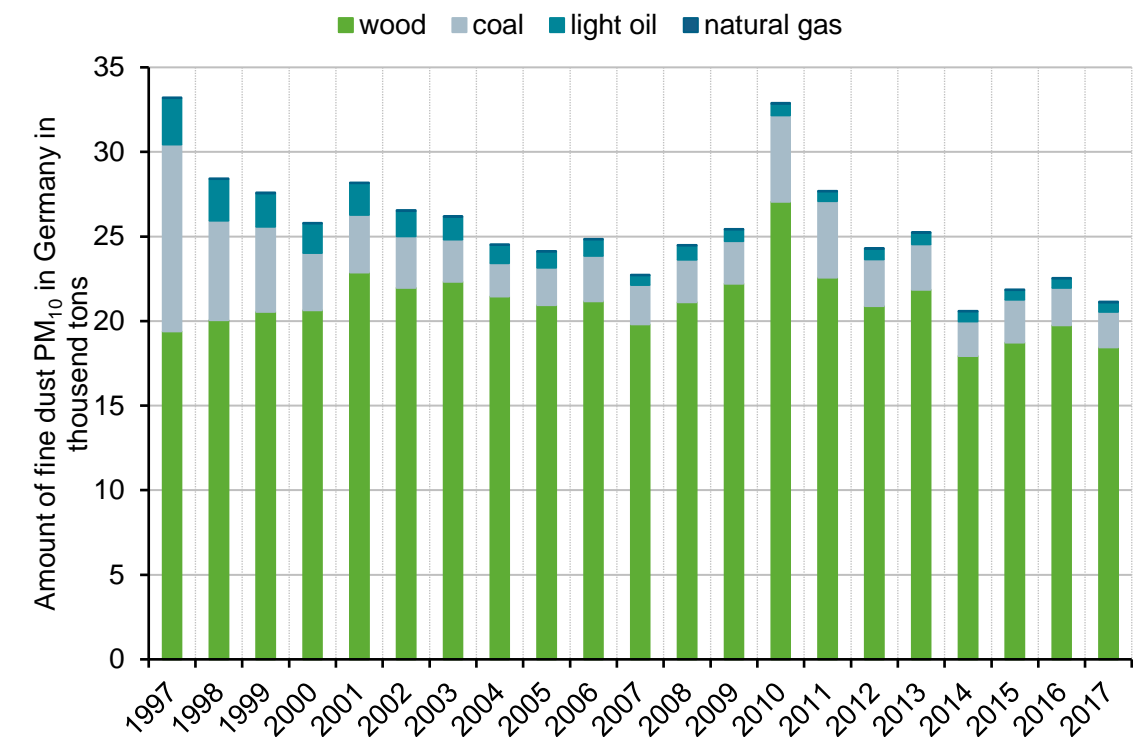
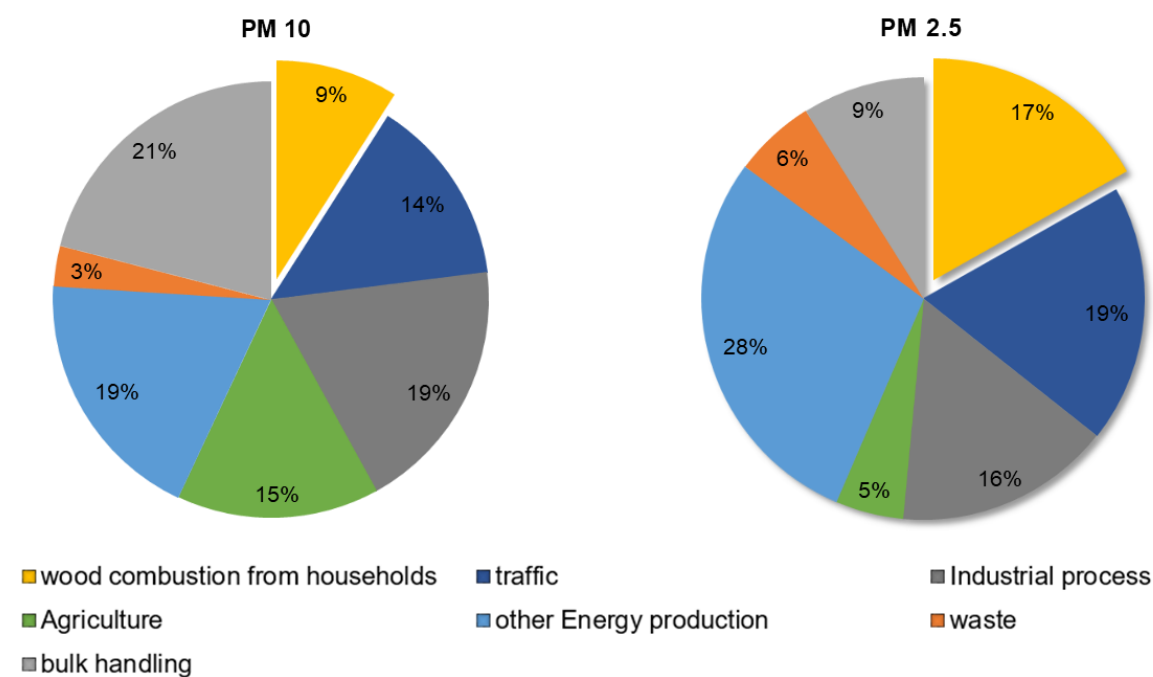
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Experimental study and results

Hierarchy for pollution reduction in biomass combustion



The contribution of sectoral sources to fine dust emissions

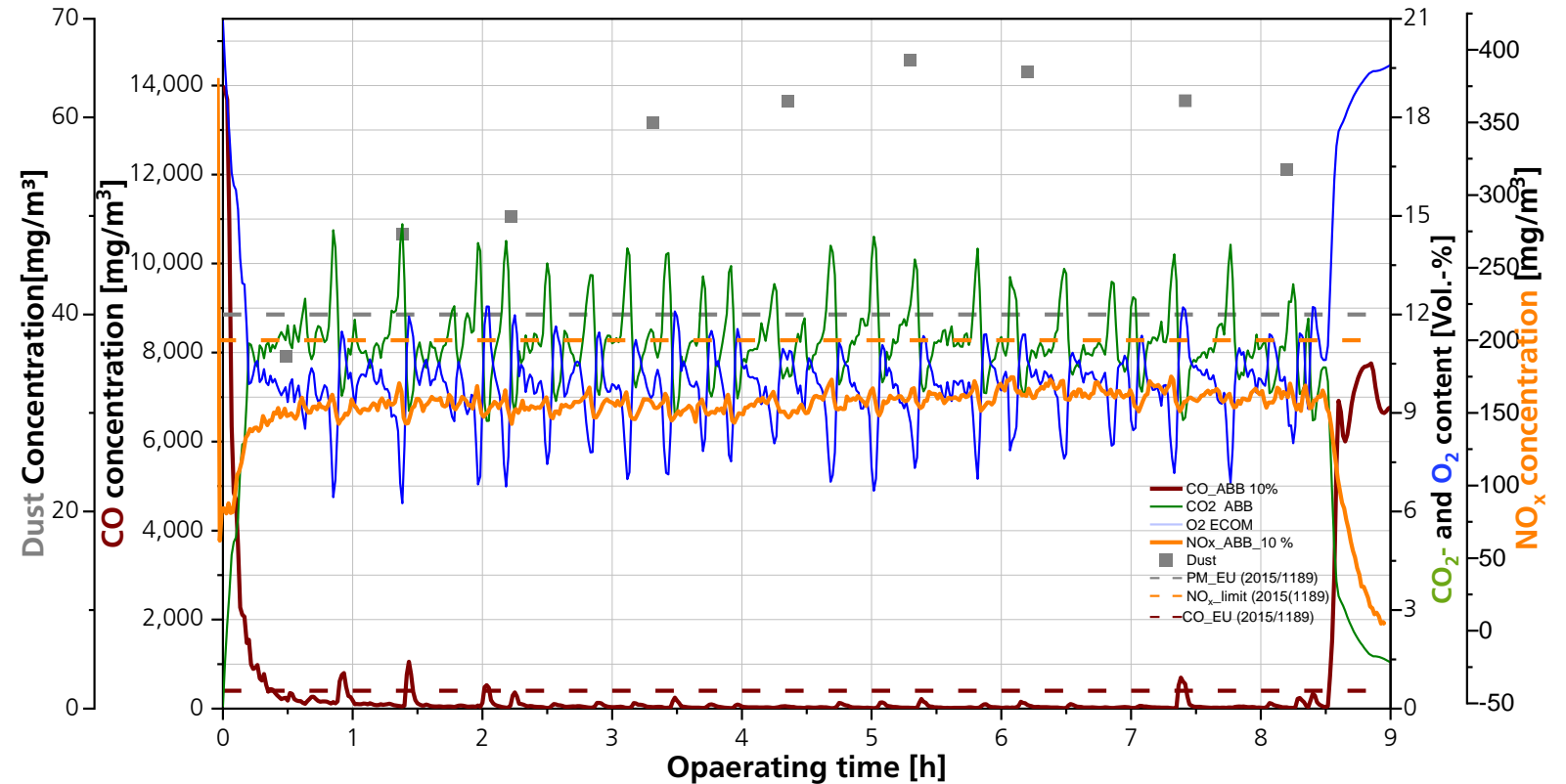


German Federal Environment Agency (2019)

Problematic issues

Combustion behaviour of conventional **automatically** charged biomass boilers
— using commercial wood chips

- High concentrations of fine dust 40-60 [mg/m³] > limit value = 40 [mg/m³]
- and NO_x up to 550 [mg/m³] when low quality fuel is used
- Many downstream technologies have been developed recently for reducing particulate matter emissions .
- Adequate technical solutions for reducing NO_x still have been lacking for the use in households.

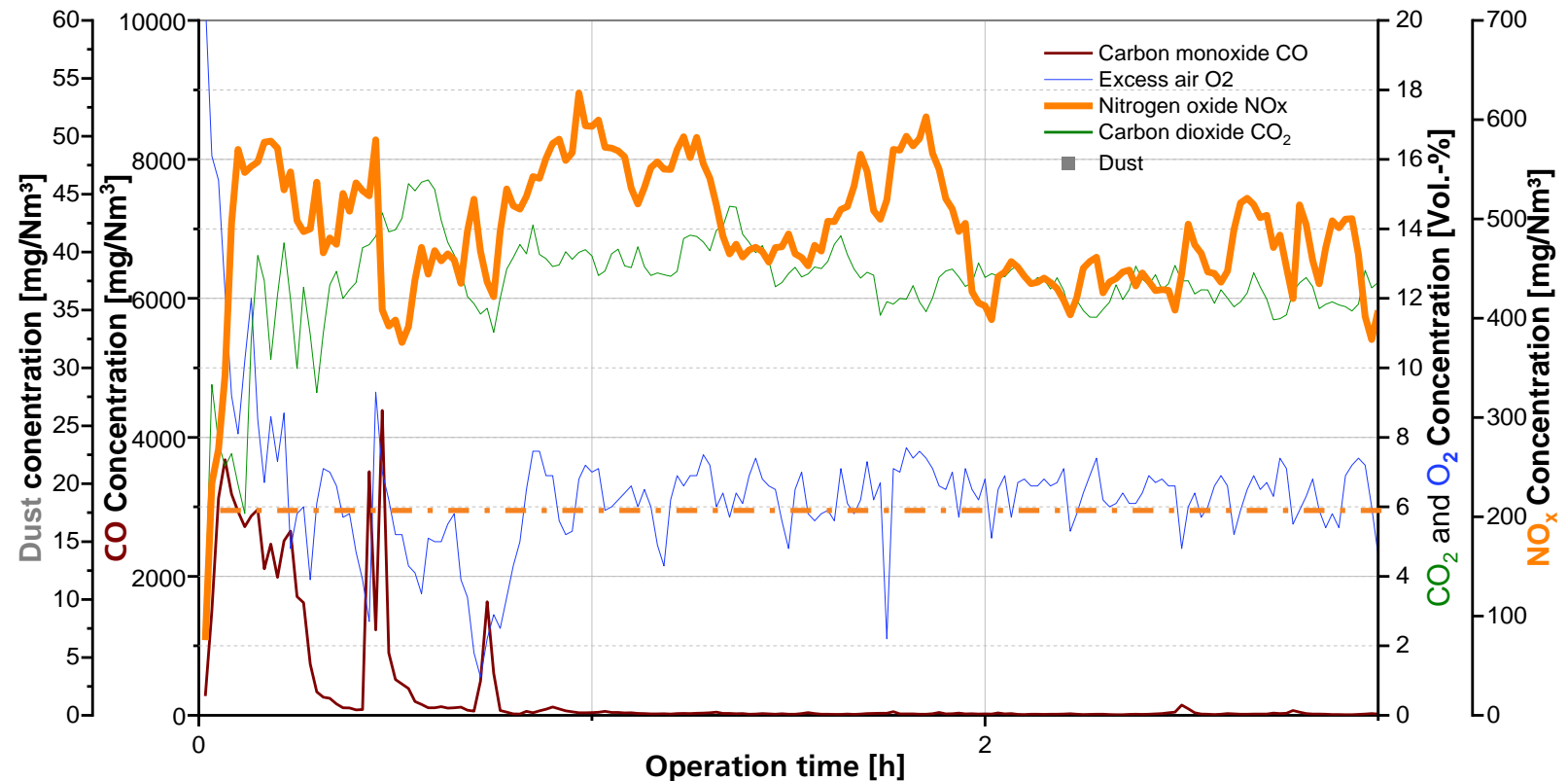


Problematic issues

Combustion behaviour of automatically charged conventional biomass boilers

— using commercial wood chips -low quality

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Main target

Combined Integrated Combustion Technology

The compliance with:

- The national standards of 1.BImSchV and European commission regulation **(EU) 2015/1189** of Eco-design Directive, so that (CO, OGC, NO_x and total fine dusts) will be reduced,

and

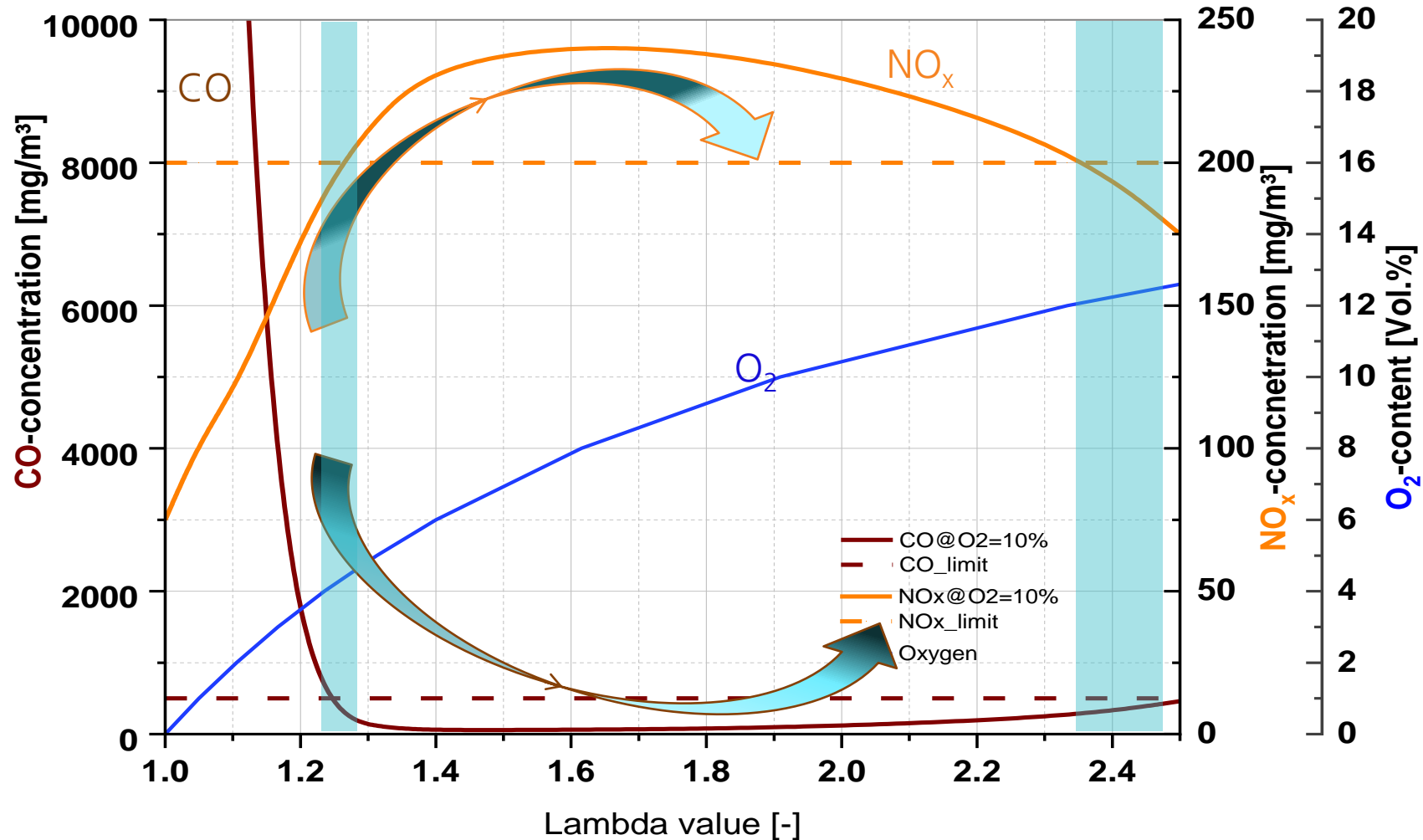
- The national air pollution control commitments in 2030 in accordance with the European Directive **(EU) 2016 / 2284, namely for NO_x**, and PM_{2.5} will be reduced

without the use of **further secondary abatement technologies**

Main target

Key to solution

Contrary behaviour of CO and NO_x

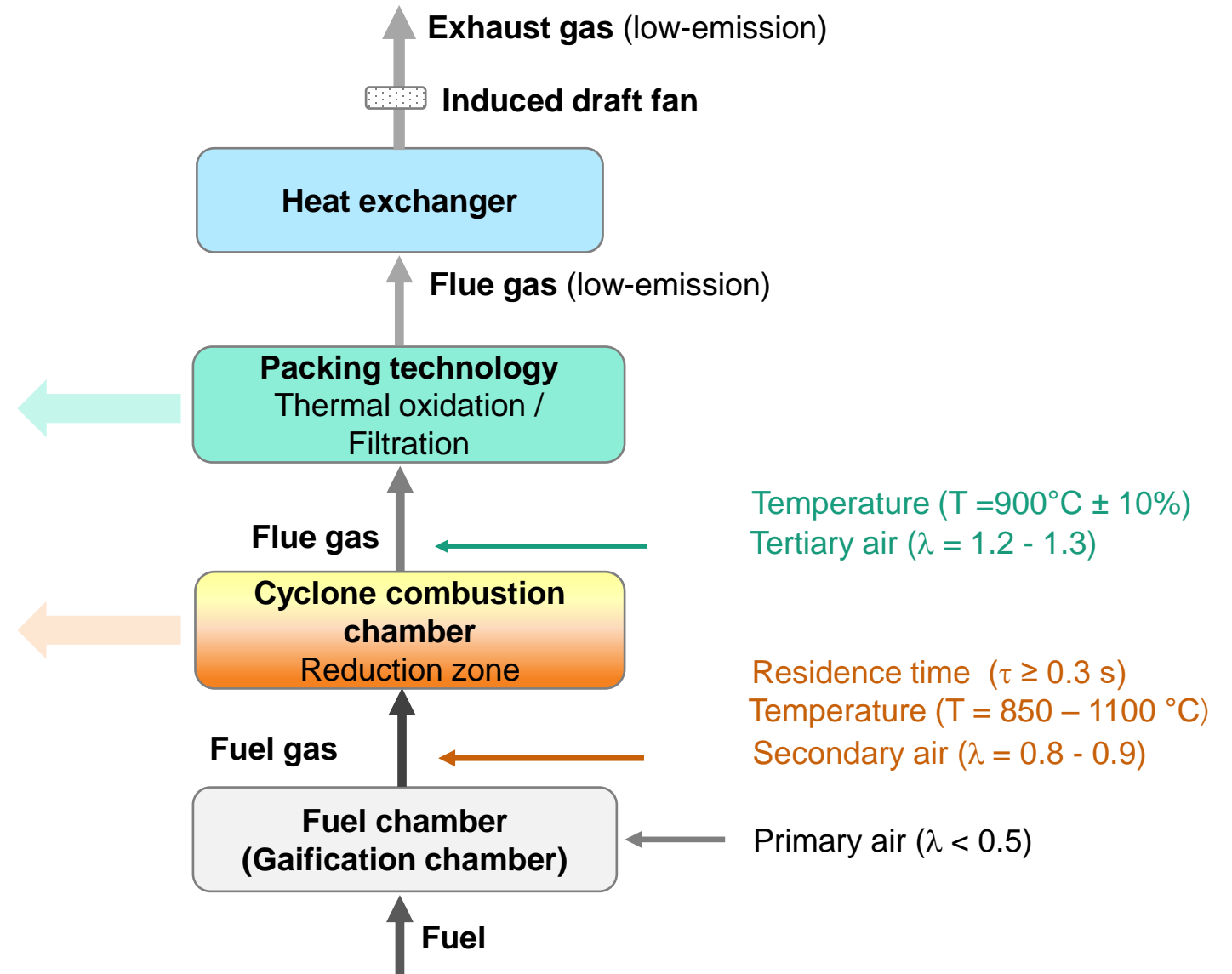


CIC-Technology

Process concept

- Oxidation of combustible gas components
- Filtration of fine dust (organic and inorganic)

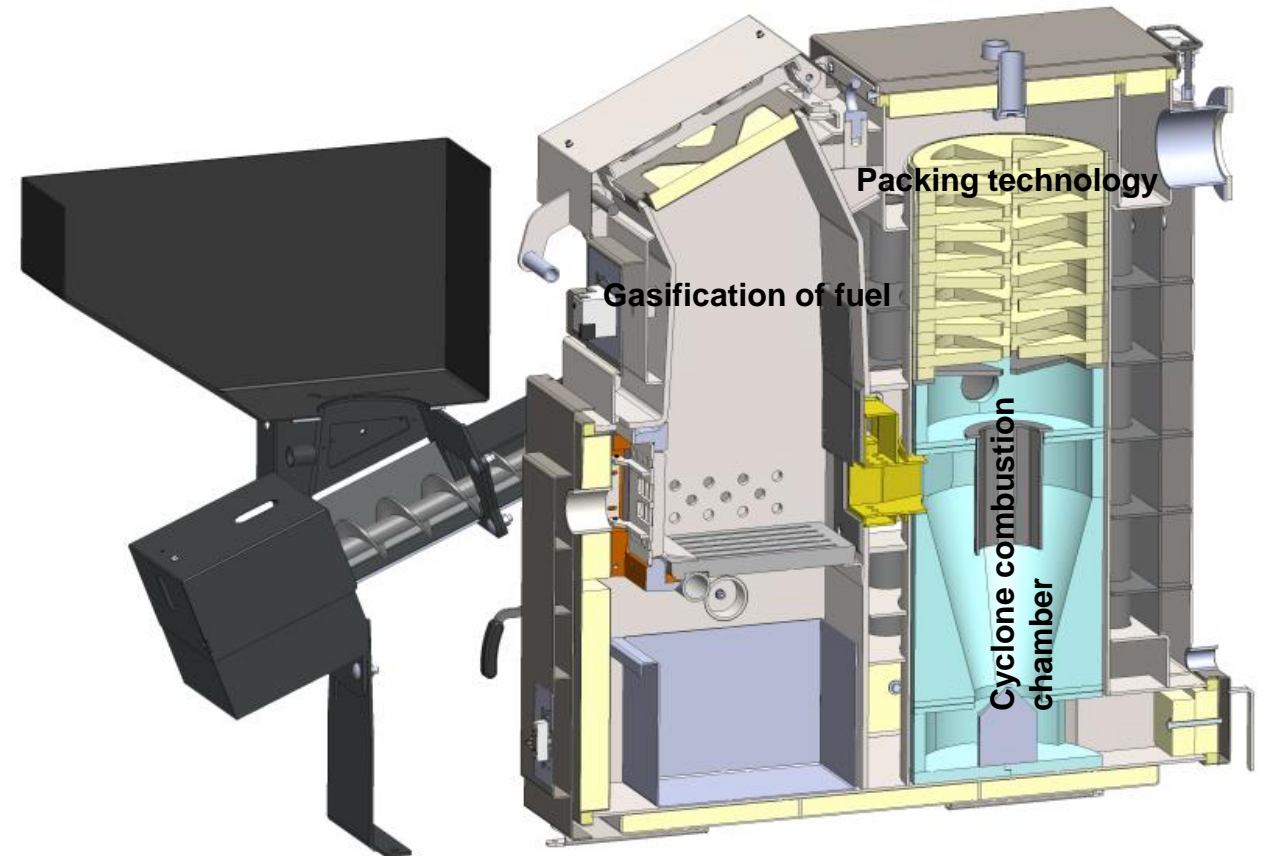
- Oxidation of combustible gas components
- NO_x -reduction (into N_2)
- Separation of coarse dust



Combined Integrated Combustion Technology

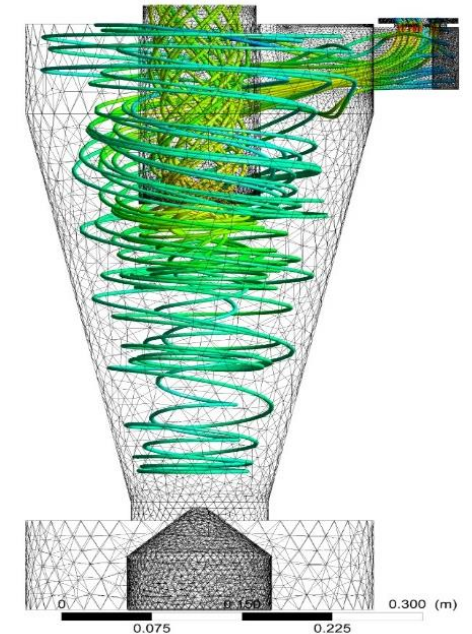
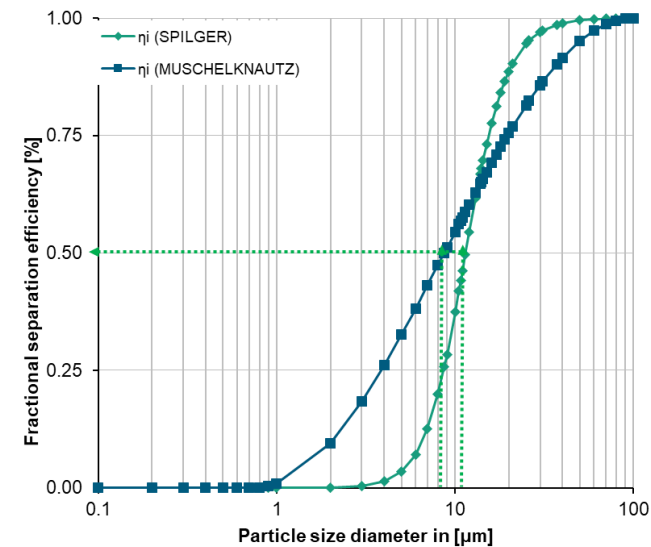
Technical realization

- **The CIC-technology is designed for the use:**
 - In household and enterprises
 - Standard and commercial wood chips
 - Fuel number 8 and 13 of 1.BImSchV (residual forest)
 - manually charged biomass boiler with a lateral automatic fuel feeding
- **Three stage of combustion:**
 - Gasification chamber
 - Cyclone combustion chamber
 - Ceramic packing technology
- Two stage combustion is also possible



Cyclone Combustion chamber

- A combination of combustion chamber and dust separator in one unit
 - A reduction zone for NO_x -emissions
 - Spiral flow of flue gas
 - enhances the 3-T rules
 - Filtration of coarse to fine dusts
 - Centrifugal forces and mechanical separation mechanisms ($>10 \text{ mm}$)
 - adhesion and agglomeration mechanisms ($<10 \text{ mm}$)
- Three-stage combustion: NO_x -reduction zone
- Two-stage combustion: Main combustion chamber



Packing technology: Reactor and filtration unit

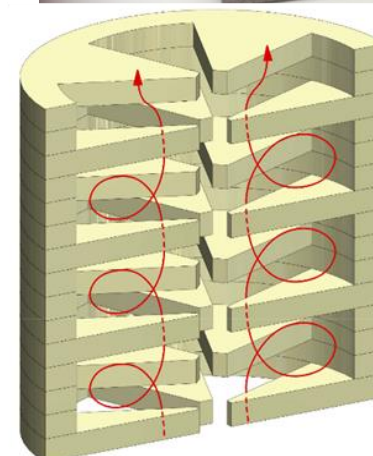
- **Ceramic modules**

- positioned next to the combustion chamber and before the heat exchanger
- Already used in small room heaters
- Thermal oxidation of CO, OGC and soot
 - regardless of the fuel used
- A pre-condition: $T > 550\text{ °C}$
- Filtration of the adhesive fine dusts and aerosols

- **Advantageous:**

- Low acquisition and construction costs
- No regulation or external energy for regeneration

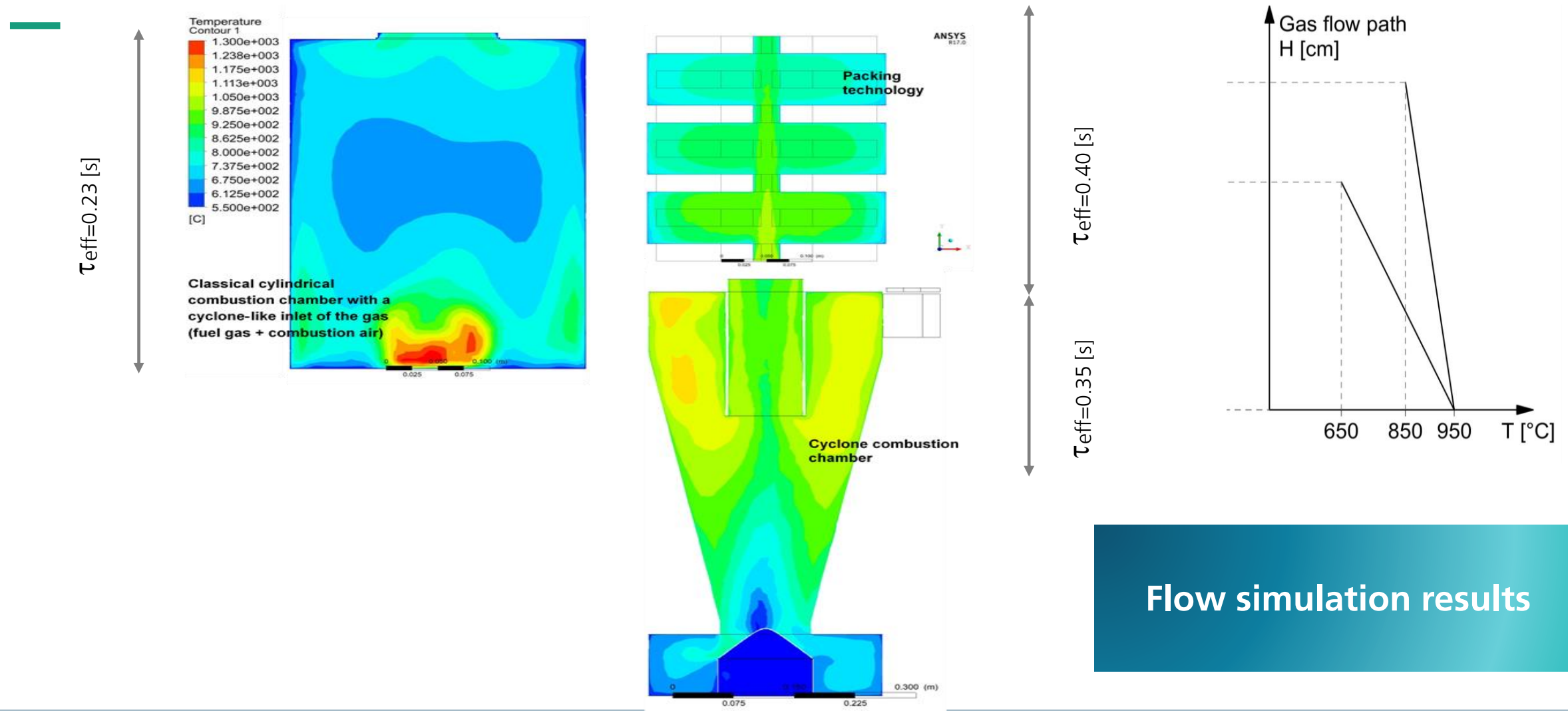
- **Necessity:** discontinuous mode of operation and different fuel properties



TONA Tonewerk GmbH

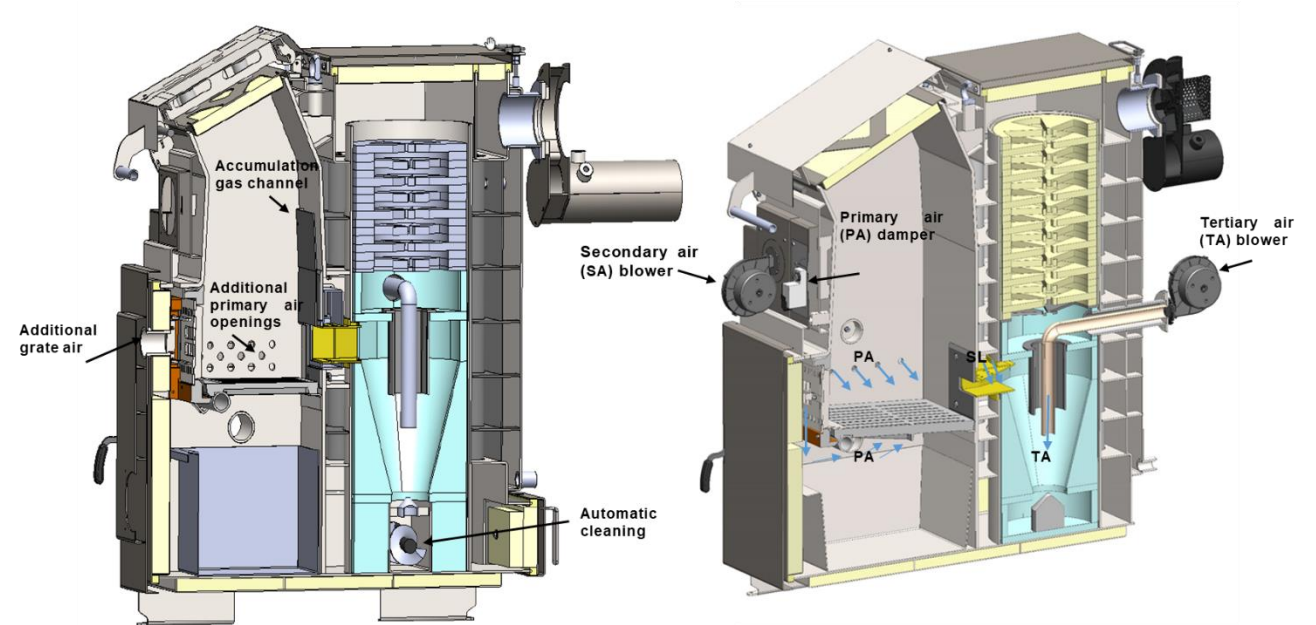
Combined Integrated Combustion Technology

Improvement of temperature profile along the combustion gas flow path



Air Supply System

- Combined combustion air supply system:
 - Motor-controlled dampers (flaps) for primary air
 - Pressure blowers for secondary and tertiary air
- Induced draft air fan
- Ratios of the secondary- and tertiary air :
 - Tertiary air with I-Value= 1.2 - 1.3
 - Secondary air = 20 % of tertiary air
 - lowest CO and NO_x are emitted



Experimental study

Test boiler



Type

Central gasification boiler system

Manufacturer

Company HDG Bavaria / Tonewerk GmbH

Combustion principle

downdraft with lateral burnout.

Thermal output

23 kW to 75 kW

Exhaust gas delivery system

Air draft fan of an electrical power of 225 Watt

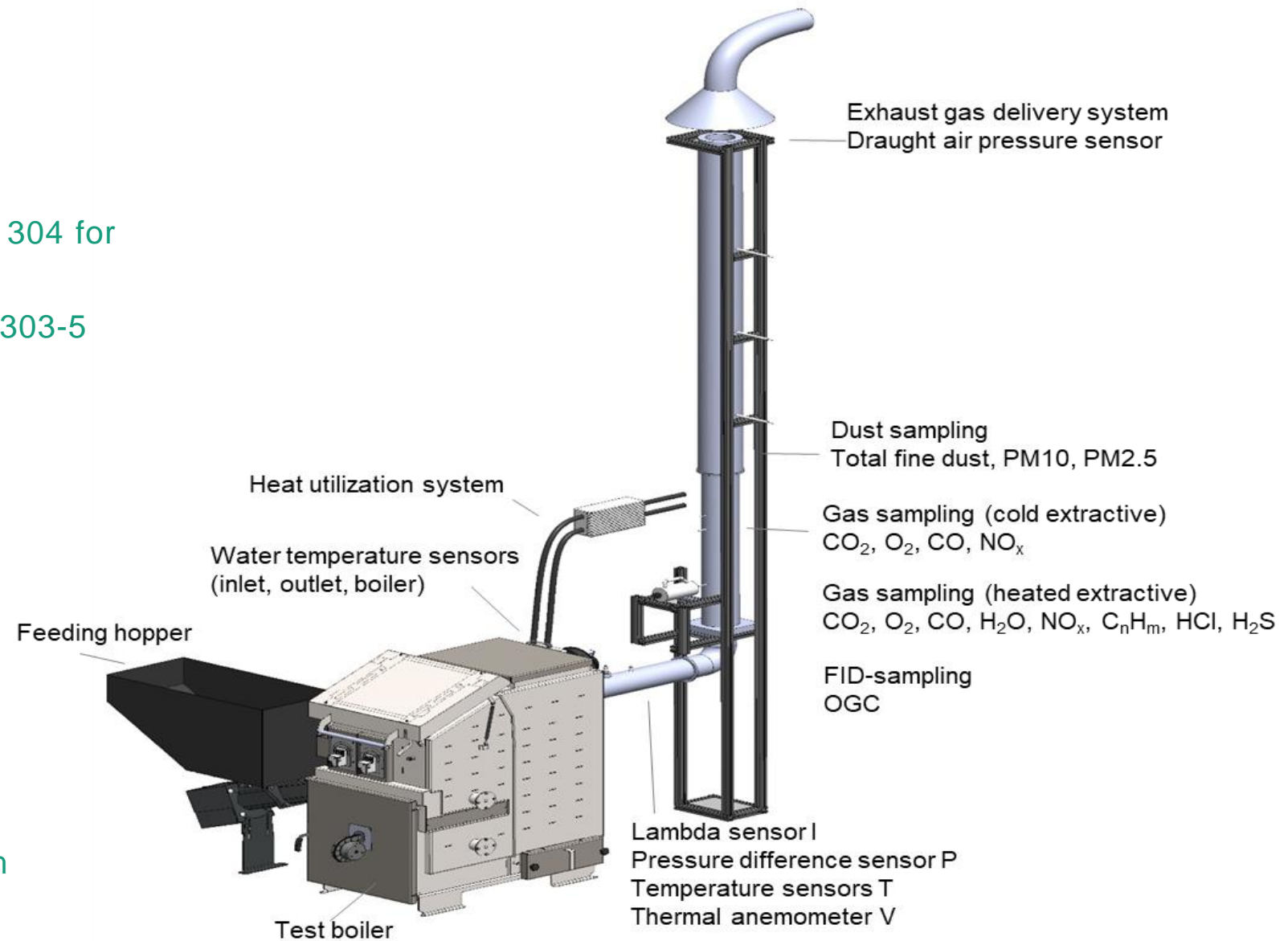
Air supply system

Combined air supply system

Experimental study

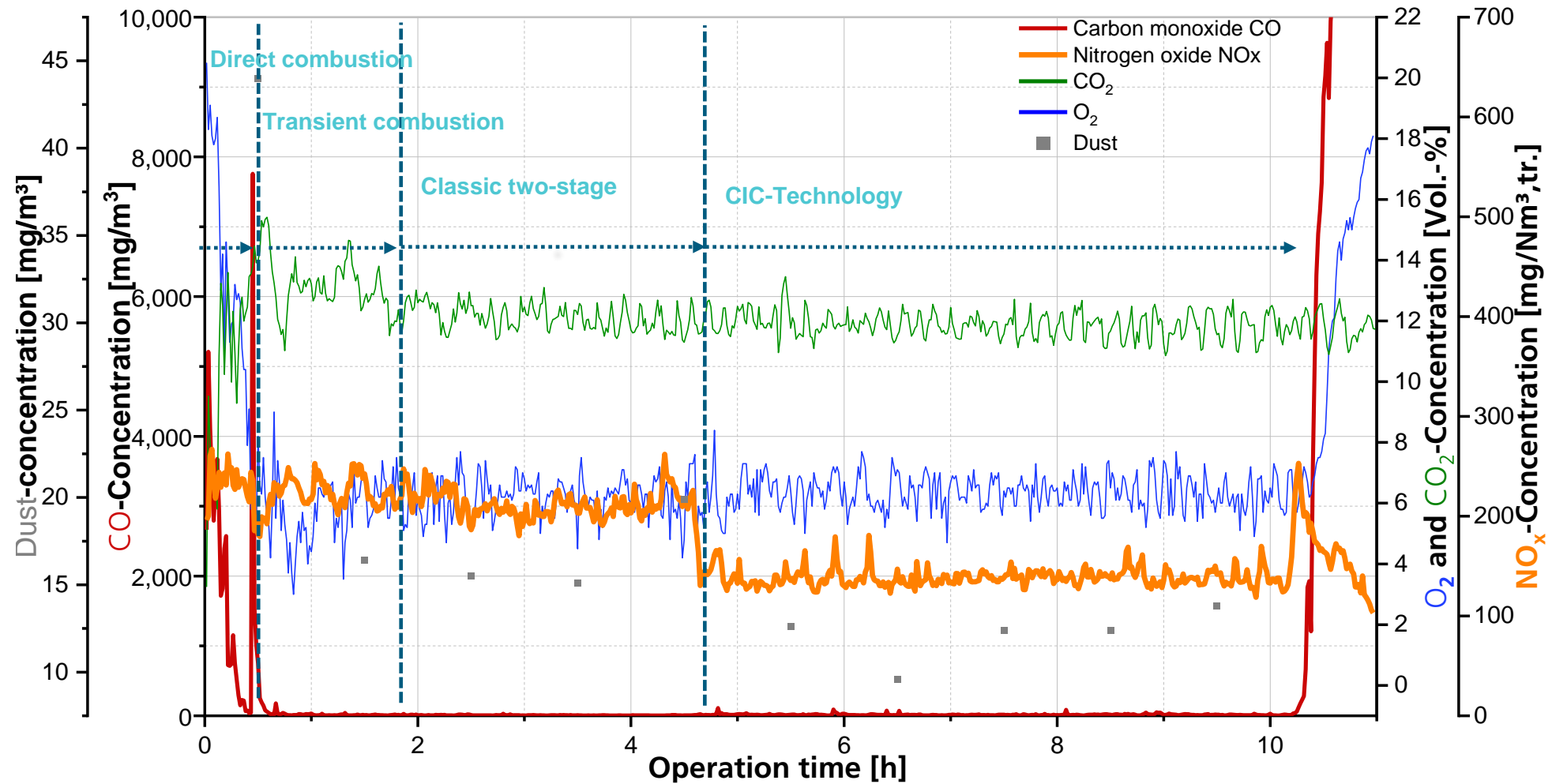
Test facility

- Test stand in accordance with DIN EN 304 for heating boilers
- Test boiler in accordance with DIN EN 303-5
- Flue gas measuring section:
 - Exhaust gas parameters
 - Ex-situ emissions measurement
 - In-situ emissions measurement
- Emission measurement systems
- sensors
- Exhaust gas draft system
- Controlled heat utilization system
- Programmable logic controller (PLC)
- Data acquisition and evaluation system



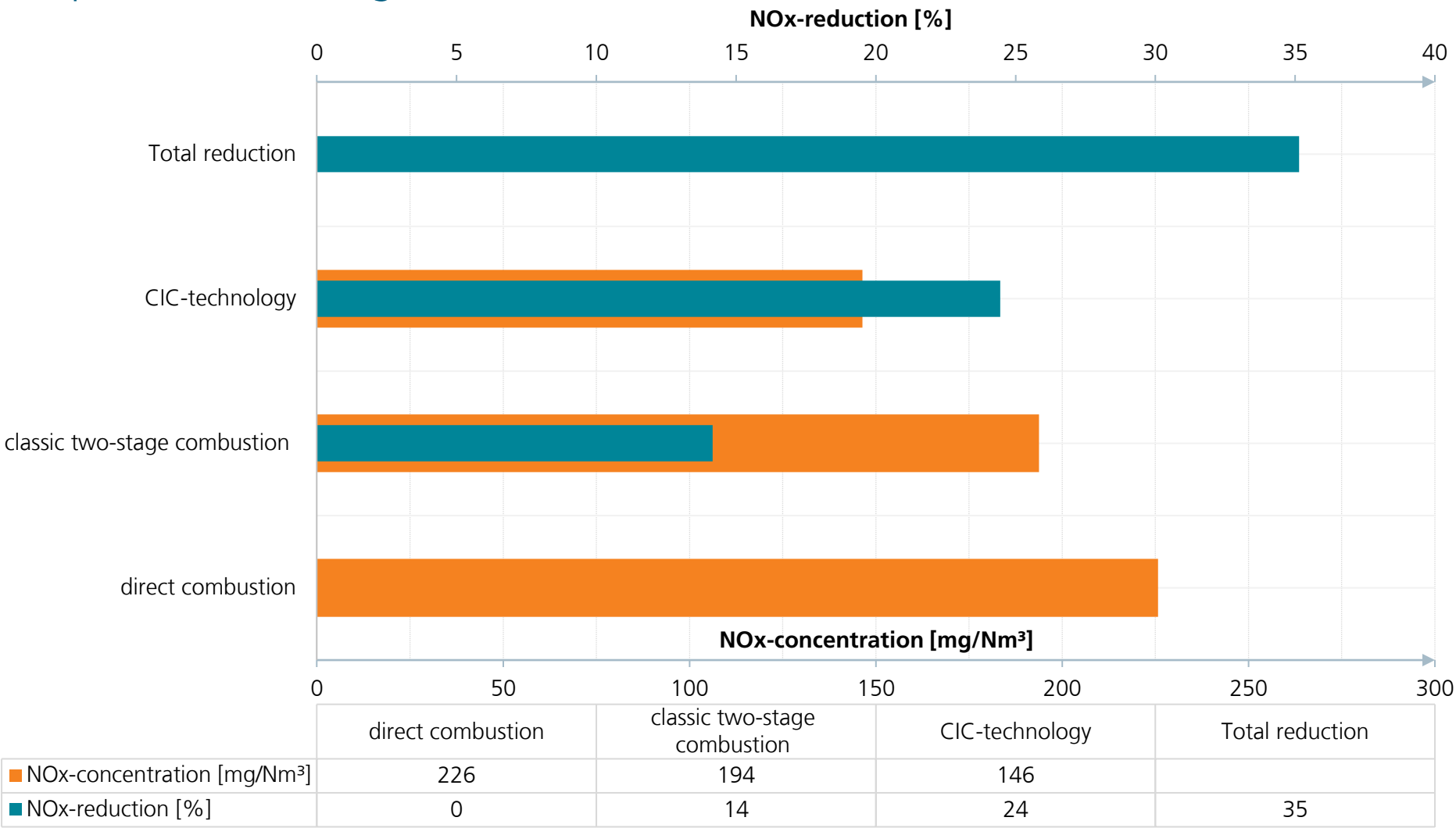
NO_x-reduction

Use of wood chips with low nitrogen content



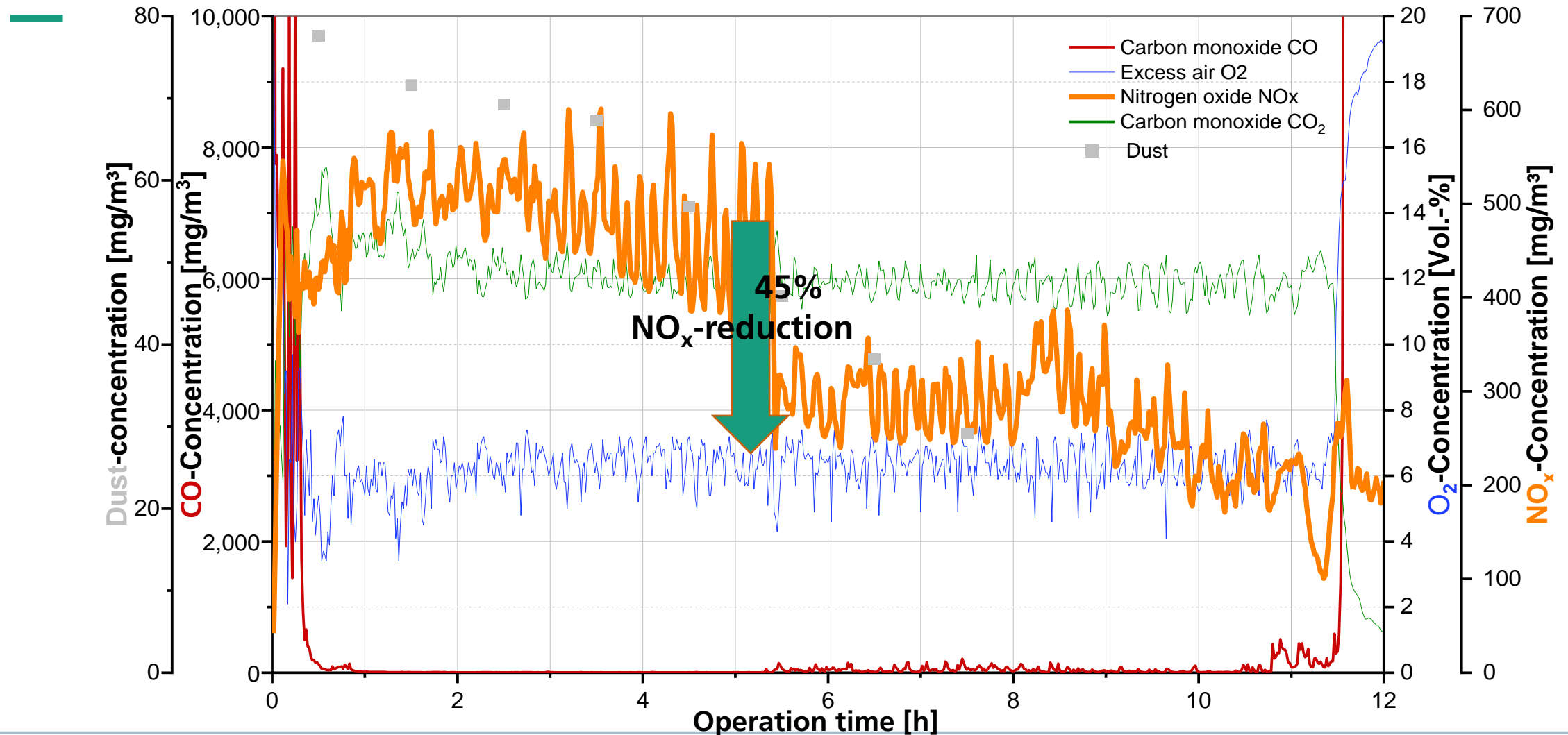
NO_x-reduction

Use of wood chips with low nitrogen content



NO_x-reduction


Use of wood chips with higher nitrogen content



Overview of emission results

for the use of different kinds of fuel in the test boiler and different combustion principles

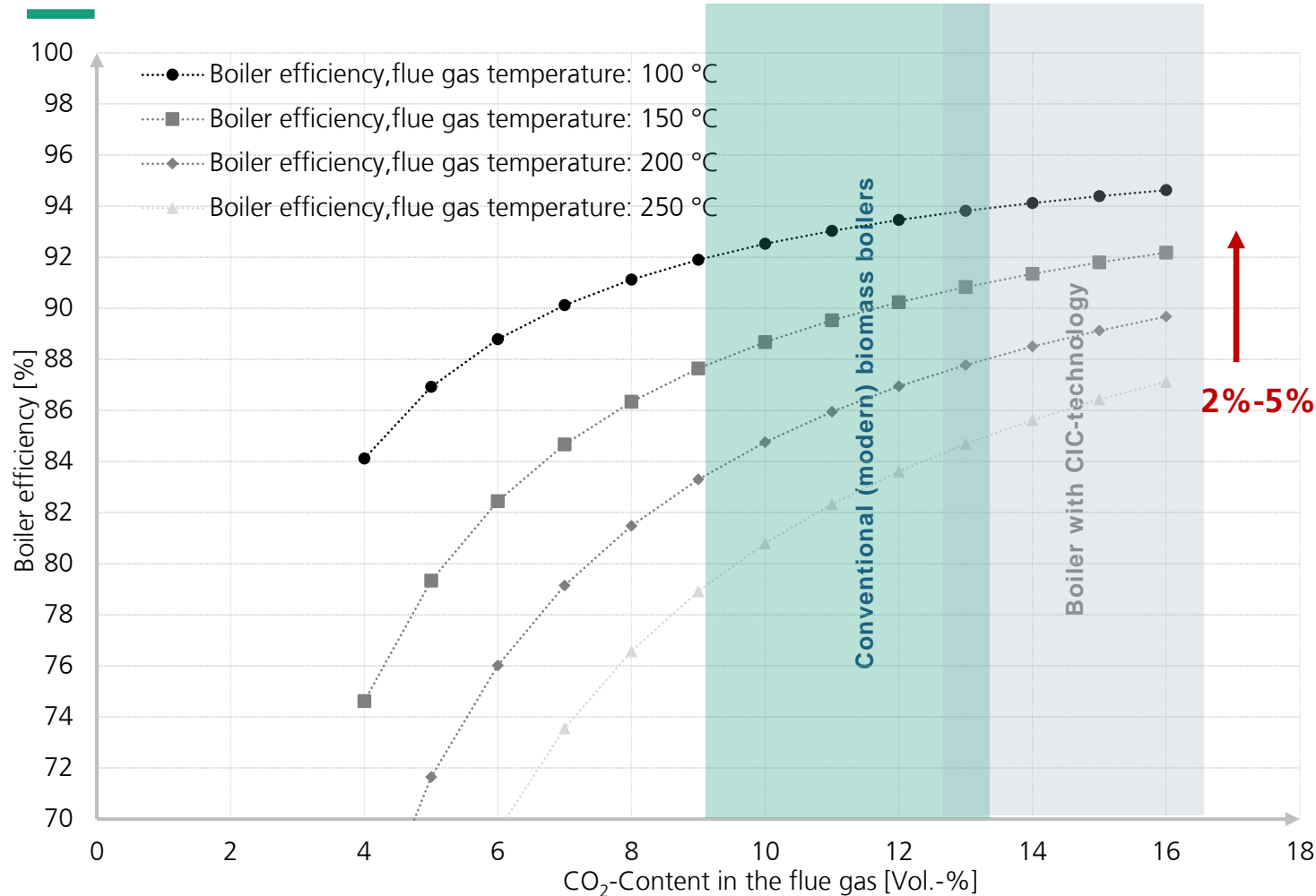


		Operating Mode	Averaged emissions and gaseous products according to (EU) 2015/1189						
			O ₂	CO ₂	CO	OGC	NO _x	Total fine dust	
			--	[Vol.-%]		[mg/Nm³]			
			--	--	--	500/250 ⁽¹⁾	20	200/500 ⁽²⁾	40.0
Fuel type	Wood chips	2-stage	6.4	14.0	16	< 5	200	10.0	
	Commercial wood chips	2-stage	7.9	13.1	8	< 5	215	15.4	
		3-stage	8.0	13.0	16	< 5	138		
	Commercial wood chips + green cuttings	2-stage	7.8	13.2	39 ⁽¹⁾	< 5	454 ⁽²⁾	32.7	
		3-stage	8.1	12.9	83 ⁽¹⁾	< 5	269 ⁽²⁾		
	Commercial wood chips + straw pellets	2-stage	8.7	12.3	7 ⁽¹⁾	< 5	491 ⁽²⁾	36.0	
		3-stage	9.2	11.8	54 ⁽¹⁾	< 5	271 ⁽²⁾		

(1) The threshold of CO-emissions for fuel number 8 and 13 according to 1.BImSchV/ §3 is 250 [mg/Nm³].
(2) The threshold of NO_x-emissions for fuel number 8 and 13 according to 1.BImSchV/ §3 is 500 [mg/Nm³] for 2014 appliances and 600 [mg/ Nm³] for 2010 appliances.
All emissions are calculated for dry exhaust gas and an oxygen content of 10 % in the flue gas

Boiler efficiency

in the test boiler of a thermal output of 75 kW for the use of low-quality fuel



Minimization of heat losses

- Minimization of energy-containing exhaust gas volume
- Complete combustion results in higher CO₂ contents
- Constantly clean surfaces of heat exchanger systems
- Operating at very low excess air
- The targeted optimizing of the air supply in the burnout operating phase

Thanks For Your Attention

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