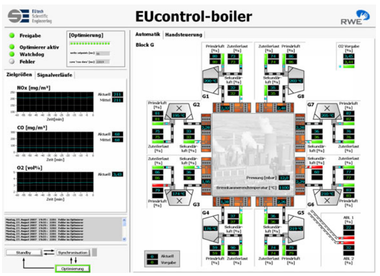
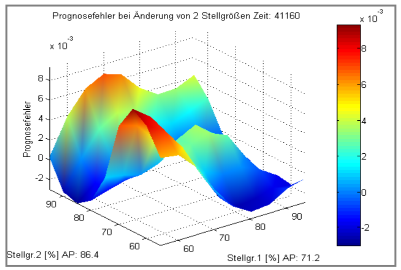
Ein modulares Messtechnik- und Prozess-steuerungssystem zur Optimierung der Betriebsführung von Großdampferzeugern

An advanced boiler monitoring and optimisation system

39. Dresdener Kraftwerkstechnisches Kolloquium
2007





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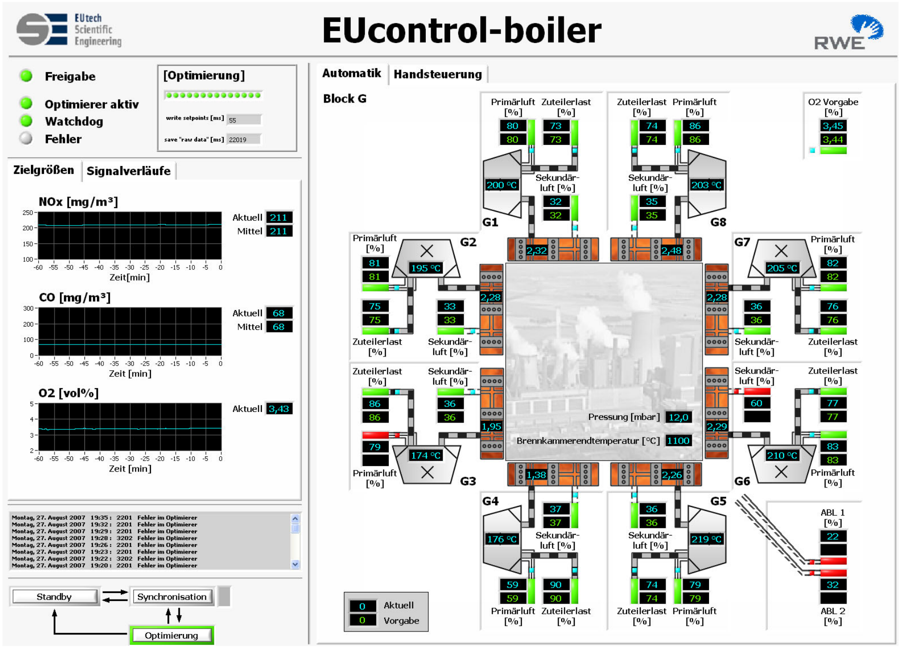
EUcontrol-boiler

Content

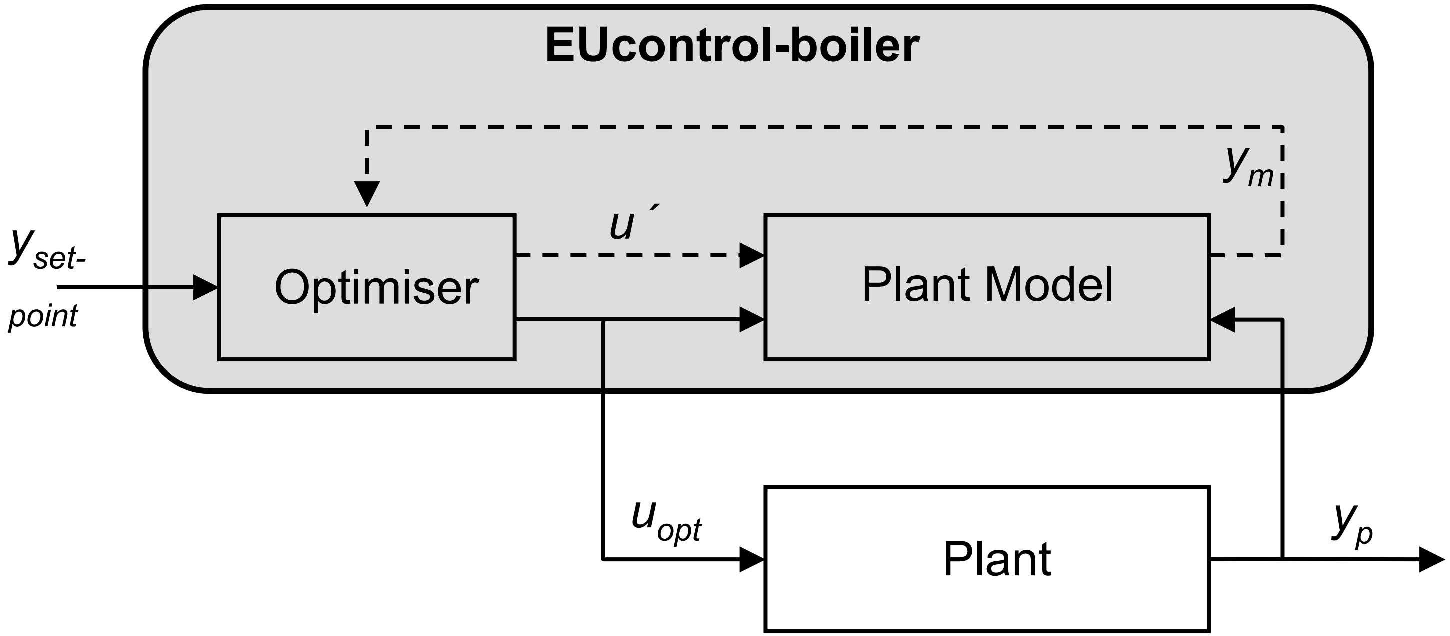
Modular, closed loop boiler optimisation



Content

- Which optimisation goals can be achieved with EUcontrol-boiler?
- What are the advantages of the modular approach?
- Which components can be integrated?

Structure of EUcontrol-boiler

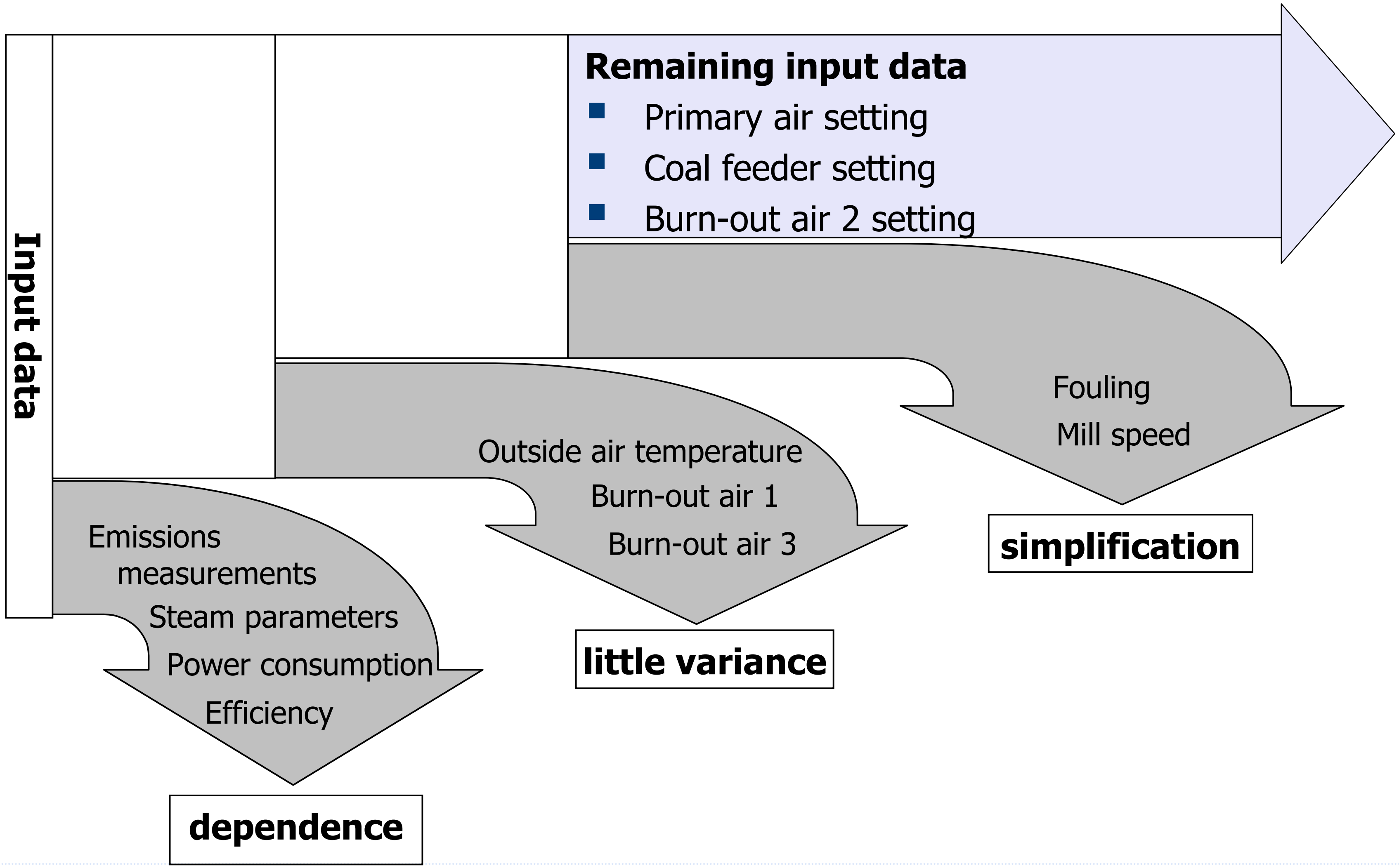


The plant behaviour is predicted with an (identified) process model. An optimiser calculates the best possible combination of inputs.

Hard and soft constraints can be equally considered. Preferential adjustment of set-points is possible if the degree of freedom is sufficient.

System identification

Systematic reduction of input data



Data structure

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Plant model

INPUT (u)

1. Manipulated variables

- Primary air (1...8)
- Coal hopper (1...8)
- Σ Secondary air
- OFA 1
- OFA 2
- O_2 Excess

2. Measured (dist.)

- Output power
- Sooth blowers

3. Unmeasured (dist.)

- Coal quality

Plant model (Boiler)

4. Constraints

- FD fan pressure drop
- Mill temperature
- Mill arrangement

OUTPUT (y)

- NO_x
- T_{BK}
- CO
- σ_T
- T_{Mill} (1...8)

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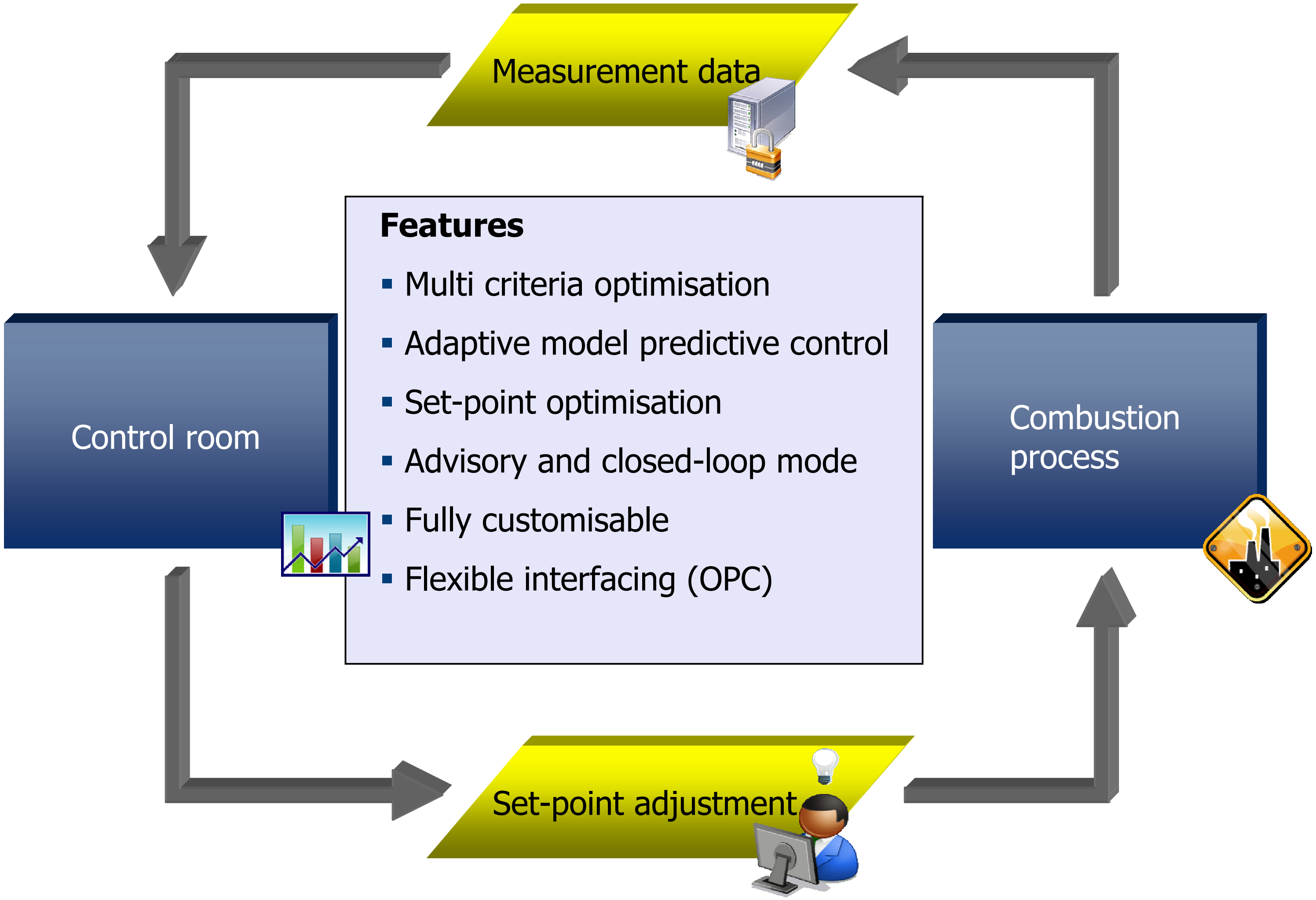
EUcontrol-boiler

Main features



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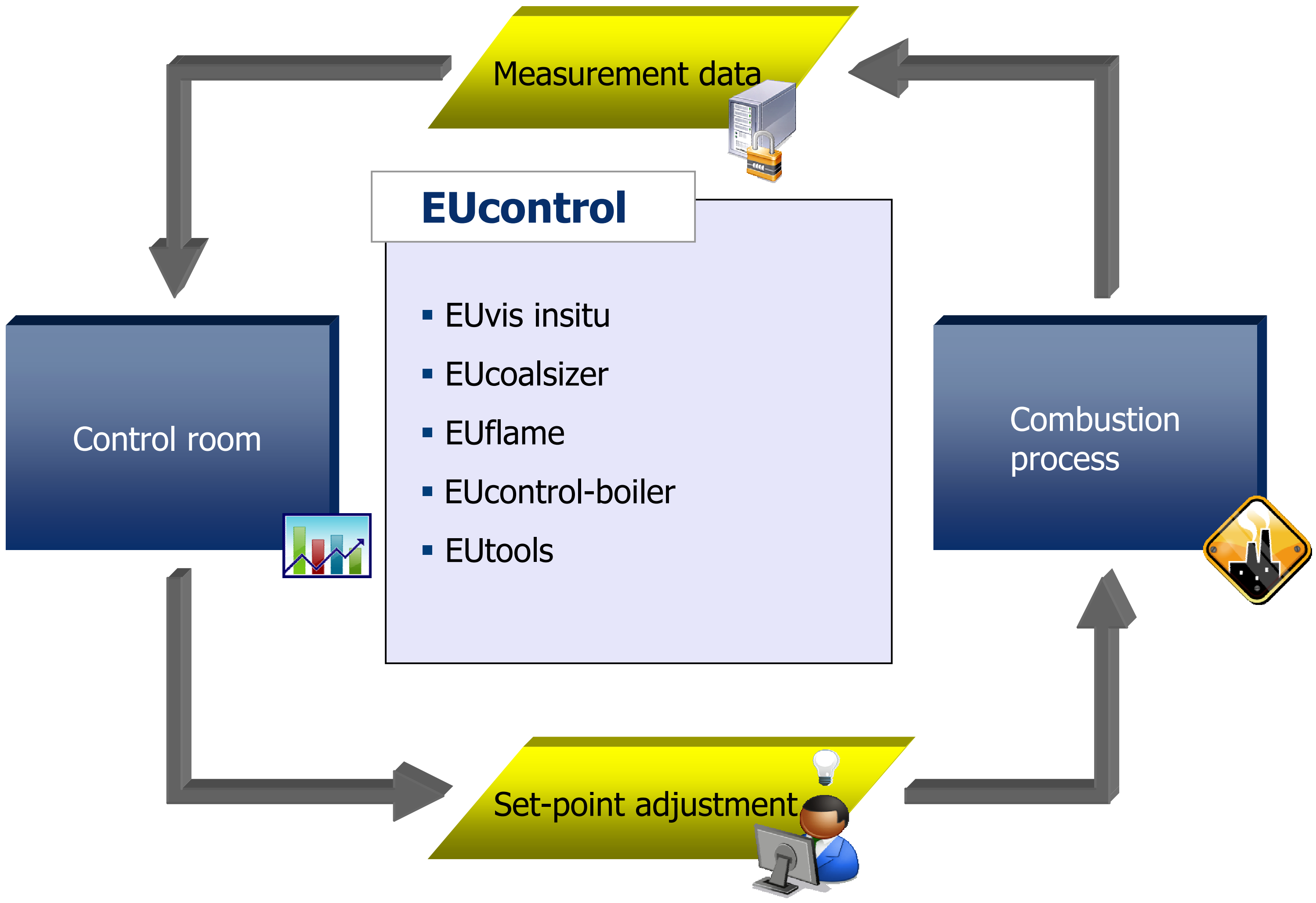
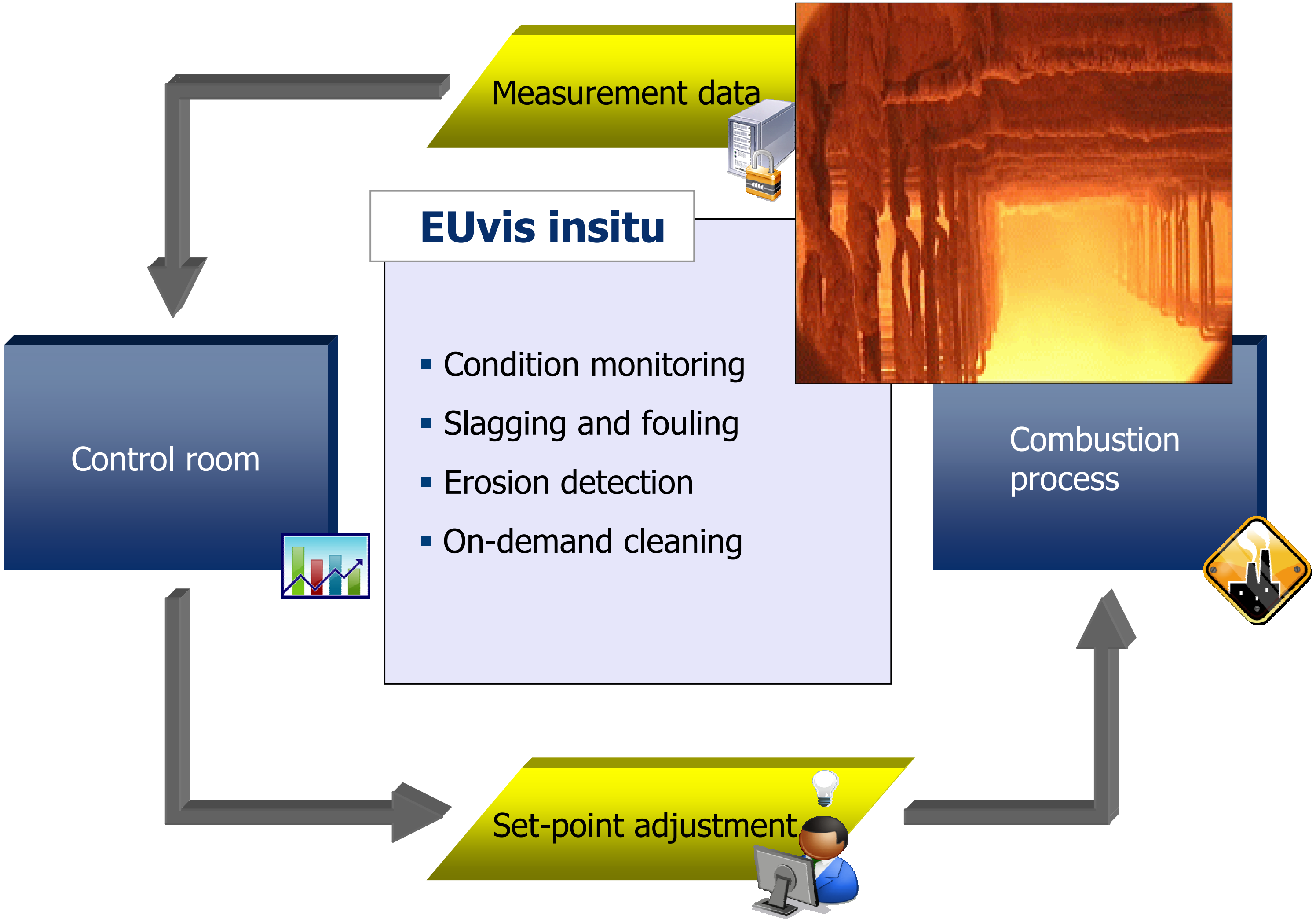
EUcontrol-boiler

Seamless integration of tools



EUcontrol-boiler

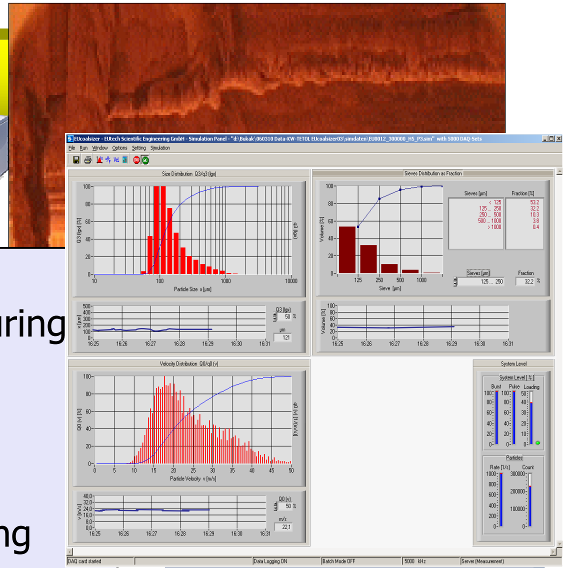
Seamless integration of tools



EUcontrol-boiler

Seamless integration of tools

Measurement data



Control room

EUcoalsizer

- Inline and online measuring
  - fineness (size)
  - velocity
  - mass density
- No by-passing, no sieving
- Mill and separator optimisation
- Control loop integration

Set-point adjustment

EUcontrol-boiler

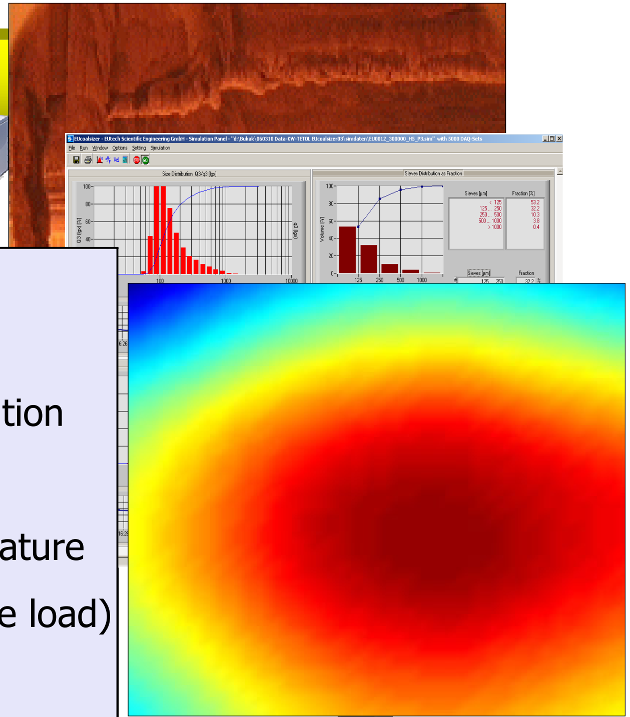
Seamless integration of tools

Measurement data

Control room

EUflame

- 2D temperature distribution
- Flame ball balancing
- Particle and gas temperature
- Flame thickness (particle load)



Set-point adjustment

EUcontrol-boiler

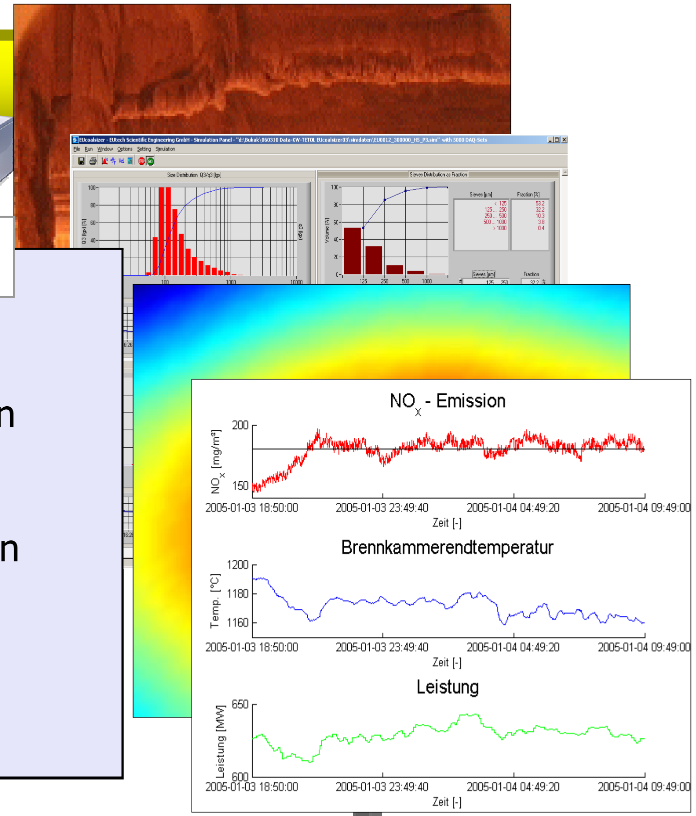
Seamless integration of tools

Measurement data

Control room

EUcontrol-boiler

- Closed loop optimisation
- Emissions control
- Combustion optimisation
- Efficiency improvement



Set-point adjustment

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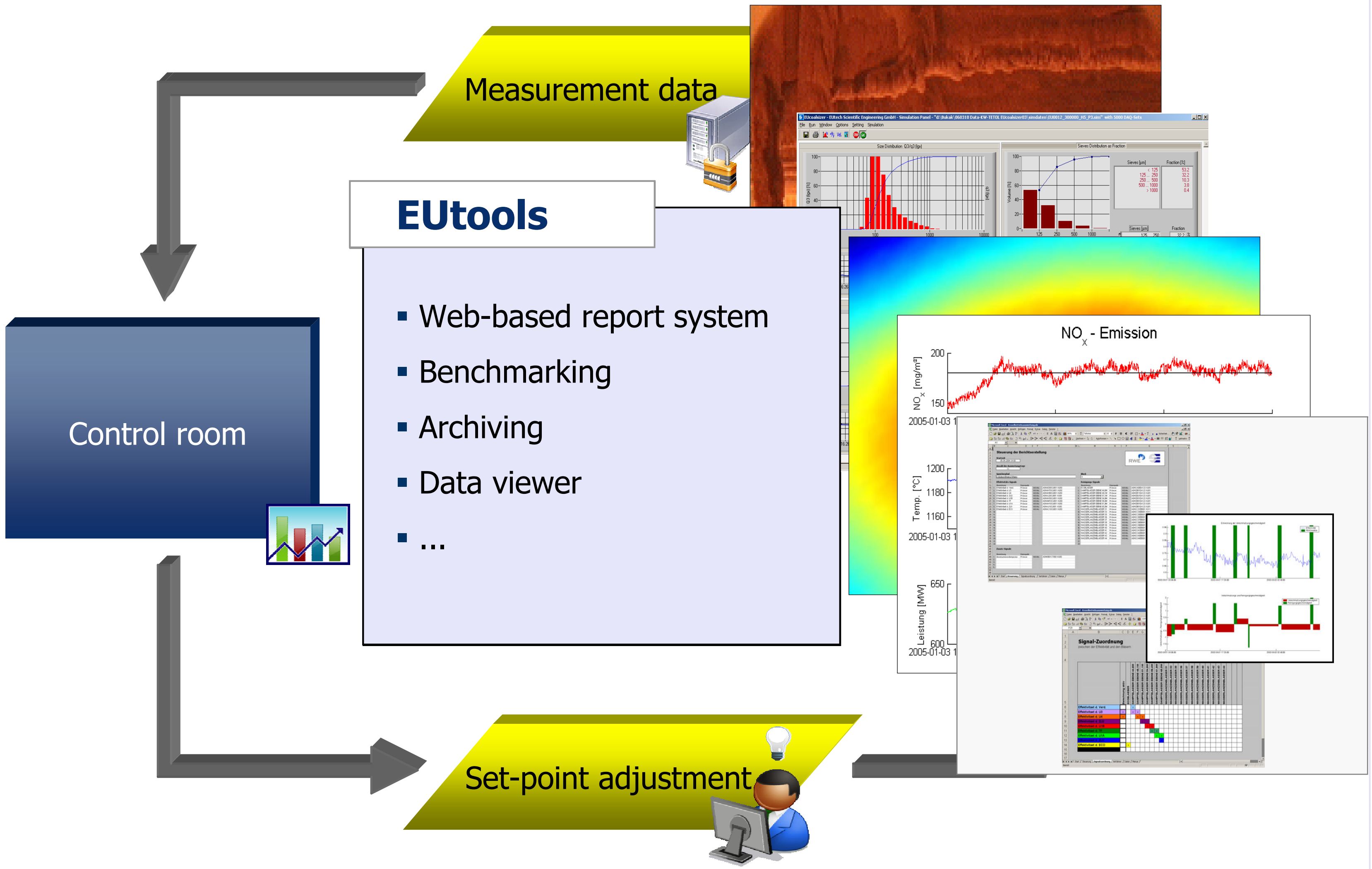
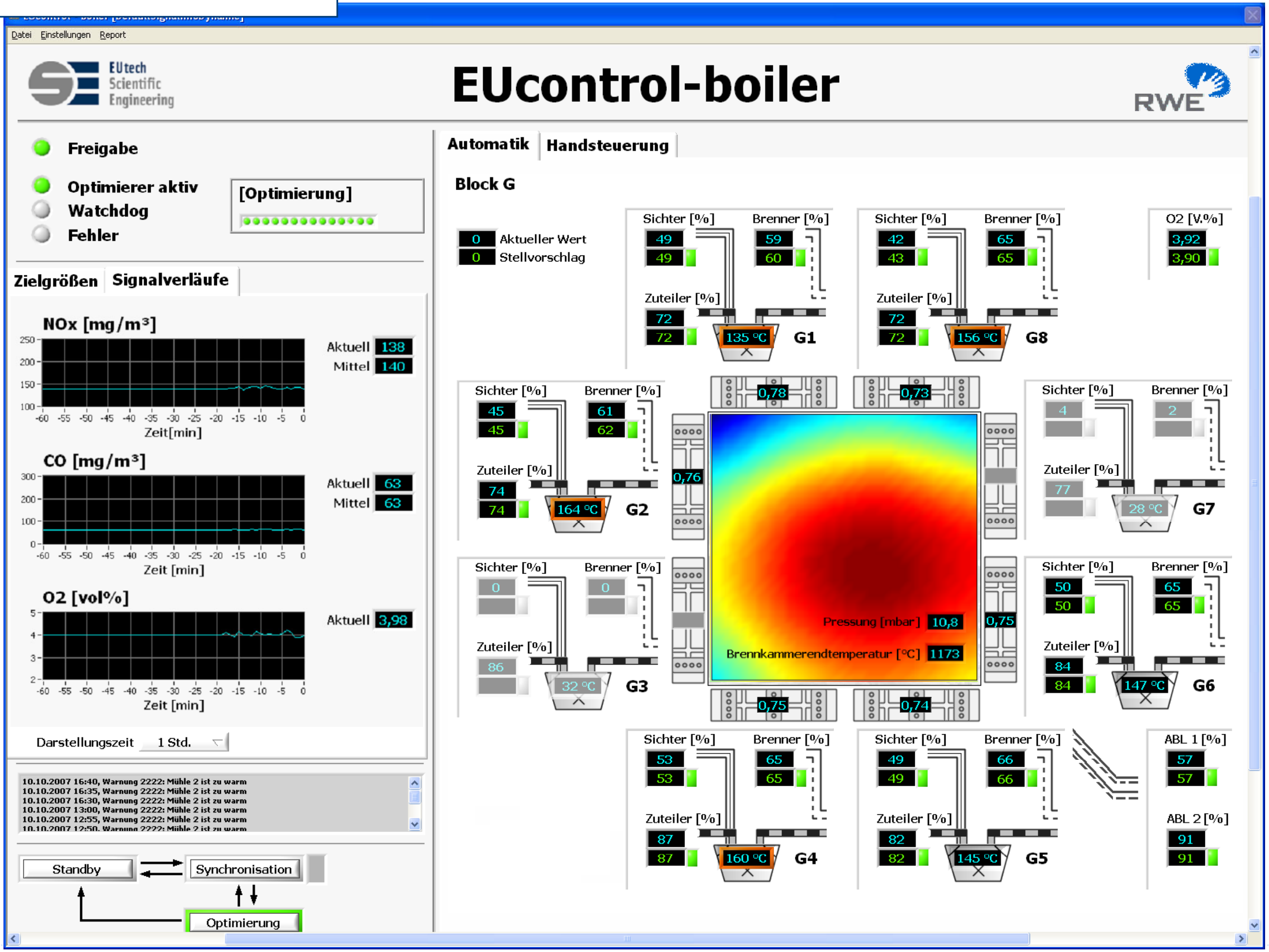
Seamless integration of tools



Snapshots ...

EUcontrol Boiler – Snapshots

Main user interface



EUcontrol Boiler – Snapshots

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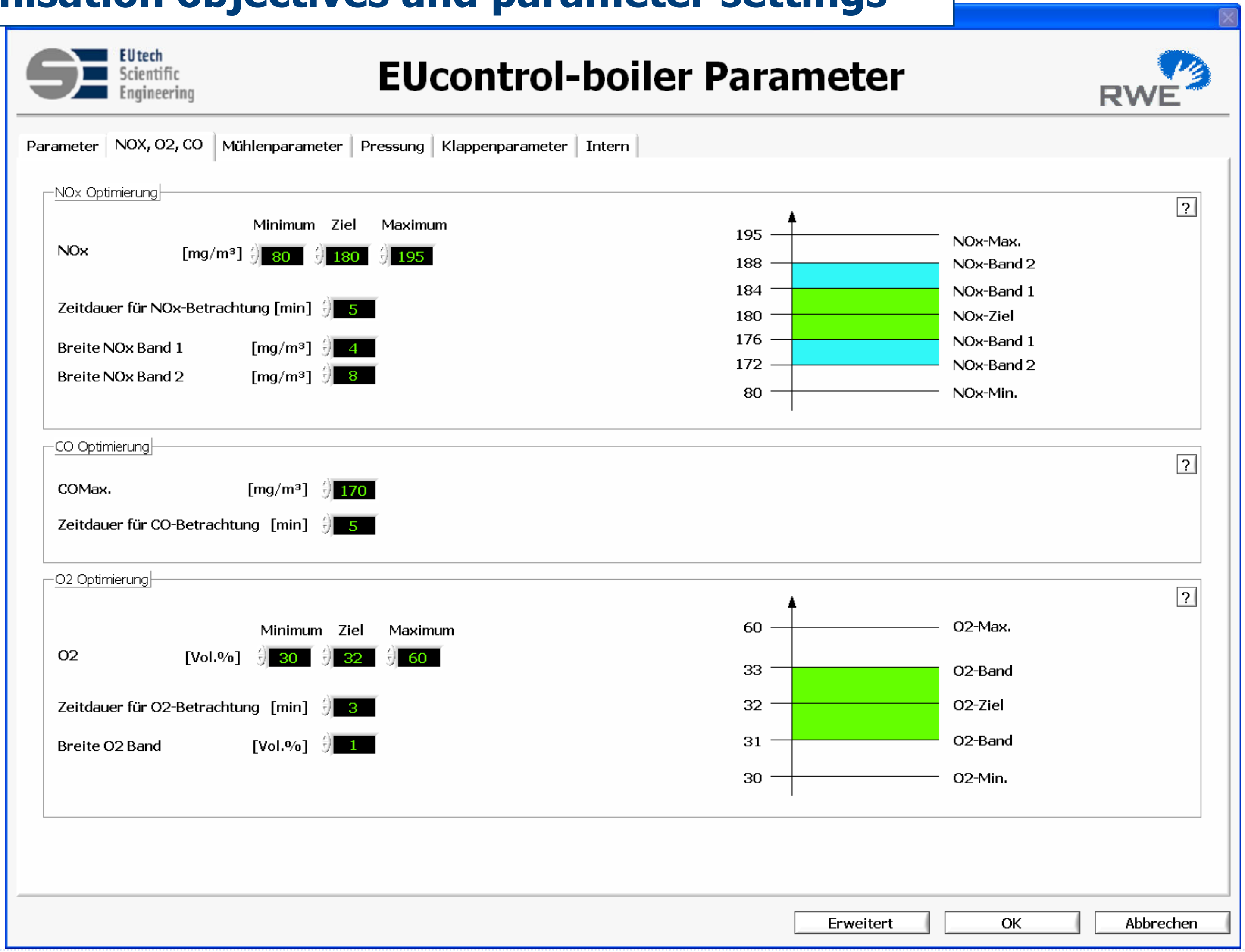
Optimisation objectives and parameter settings



EUcontrol Boiler – Snapshots

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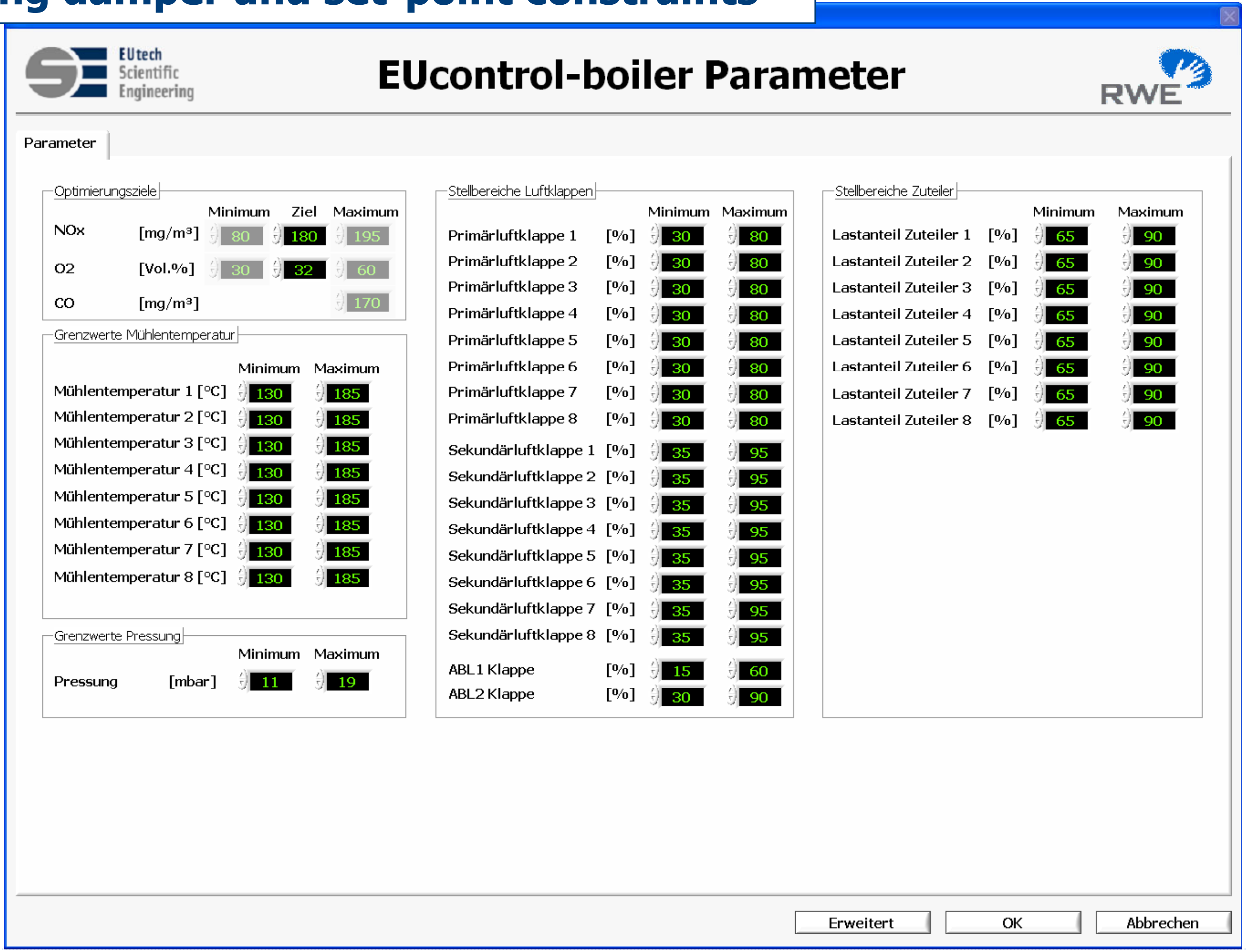
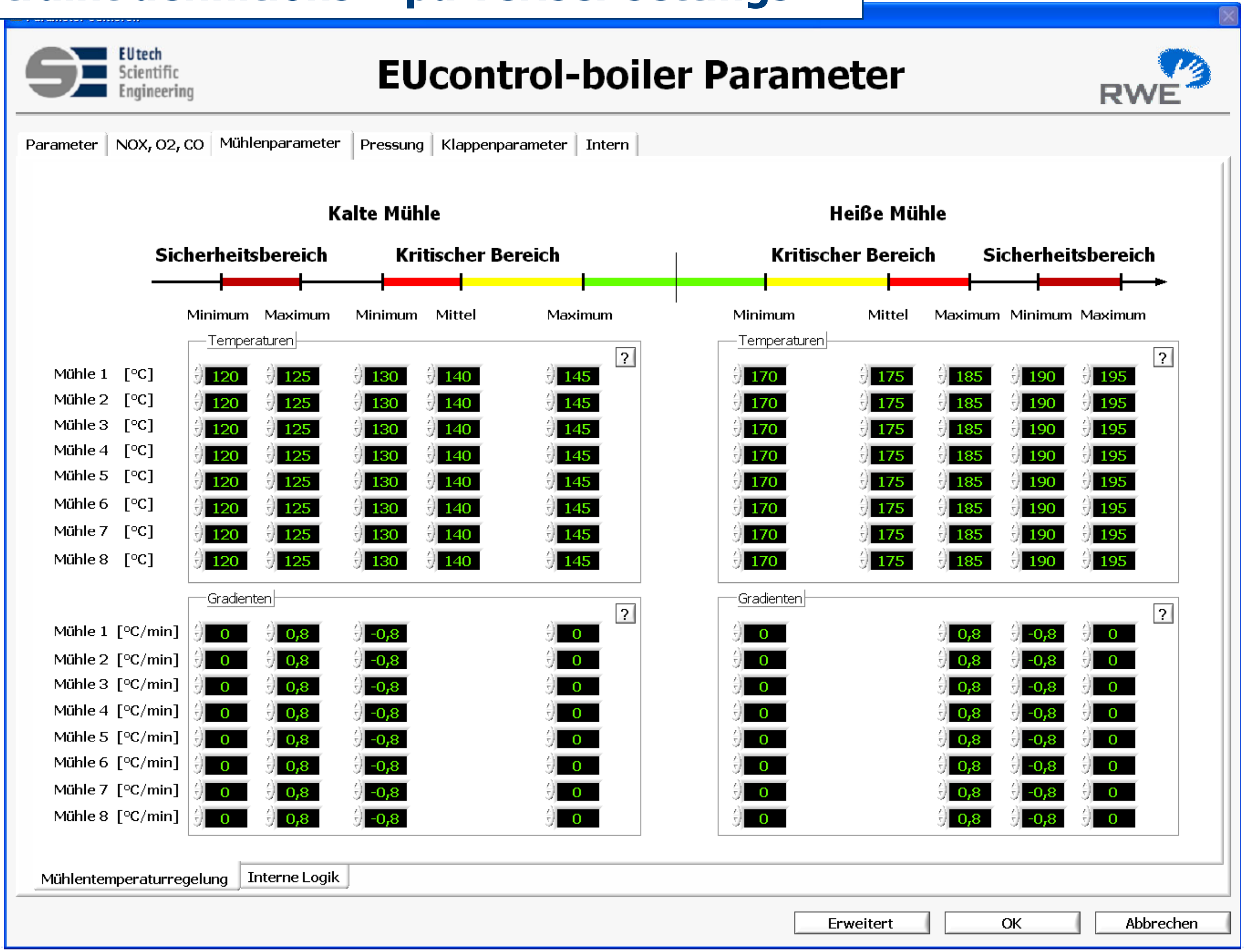
Defining damper and set-point constraints



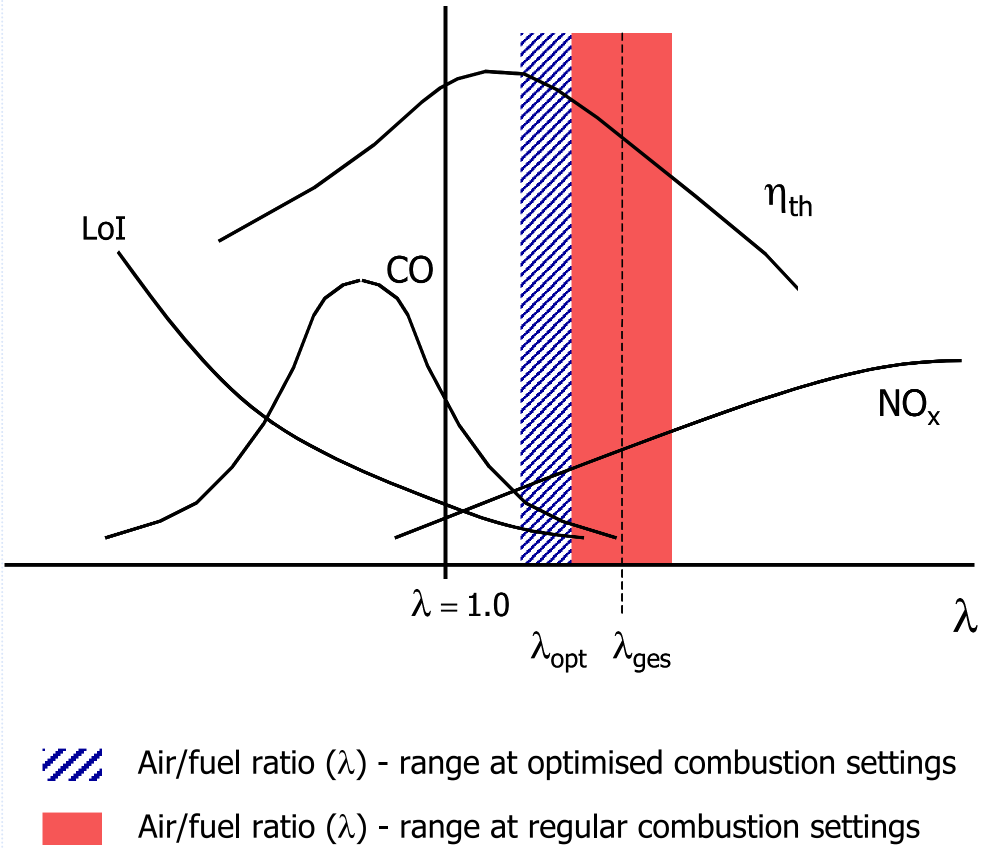
EUcontrol Boiler – Snapshots

Constraint definitions – pulveriser settings



Concept of combustion optimisation….

Optimising Combustion



- Combustion takes place at locally distributed microscopic scales
- Manipulated variables only adjust macroscopic parameters (e.g. overall excess air, mean temperature)
- Identify and utilise the intricate interplay of combustion parameters

Find the optimal trade-off for adjusting combustion parameters

Controlling NO_x, CO and fouling simultaneously

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Strategy

- Possibility to reduce NO_x but often with a negative impact on CO, carbon-in ash (CIA) or fouling – multiobjective optimisation
- Countless possible settings of mill combinations, fuel distribution, O_2 levels and damper settings – each with different NO_x, CO and fouling gradient
- Main objective is to identify the unit specific outcomes for different settings and advise on the optimal, overall set-up
- No major modification of plant DCS as only (independent) setpoints are adjusted
- Open loop operation provides advice for operation strategy, in closed loop biases are directly controlled
- Individual adaptation to a wide range of objective functions, plant types and constraints

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Case study I:
Avoiding slagging and increasing efficiency …

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Avoiding slagging and increasing efficiency

- Investigations show that an increase of surplus O2 at burner level reduces slagging
- Low temperatures at the end of the combustion chamber avoid melting of ash and glassification
- The homogenisation of combustion conditions (air-fuel ratio) at burner level improves burn-out and reduces slag formation
- Reducing excess O2 while simultaneously reducing CO improves efficiency

Simultaneous optimisation of a multitude of combustion objectives

(NOx,TBK, CO, O2) -> multi-criterial optimisation!

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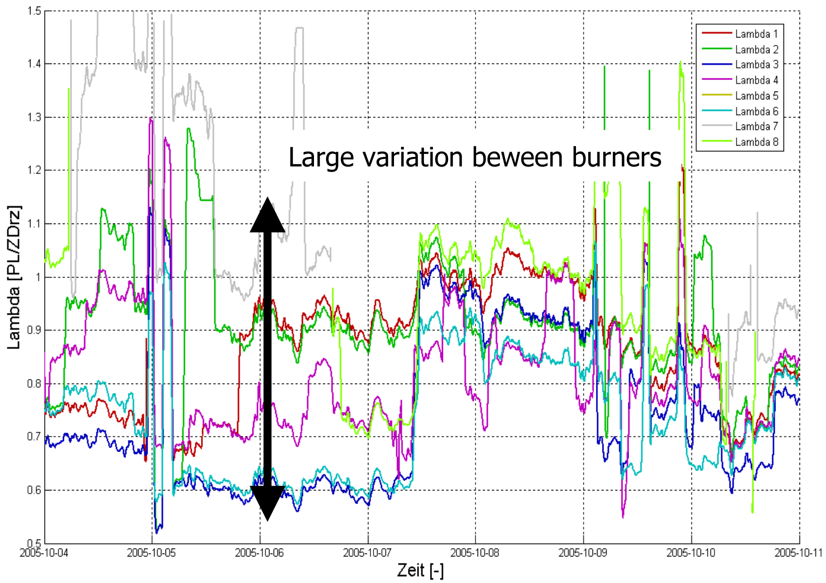
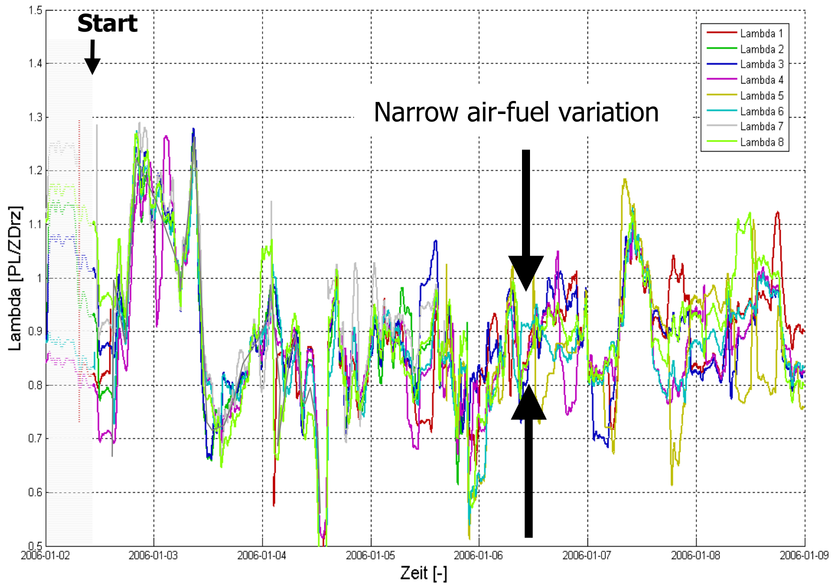
Air fuel balancing at individual burners

- The combustion is homogenised in the “horizontal” burner plane for every time step
- Primary air damper influences the mill temperatures and the air pressure drop
- Coal feeder RPM has an effect on mill temperatures, too
- Intelligent control required

Air-fuel ratio without EUcontrol-boiler



Air-fuel ratio with EUcontrol-boiler

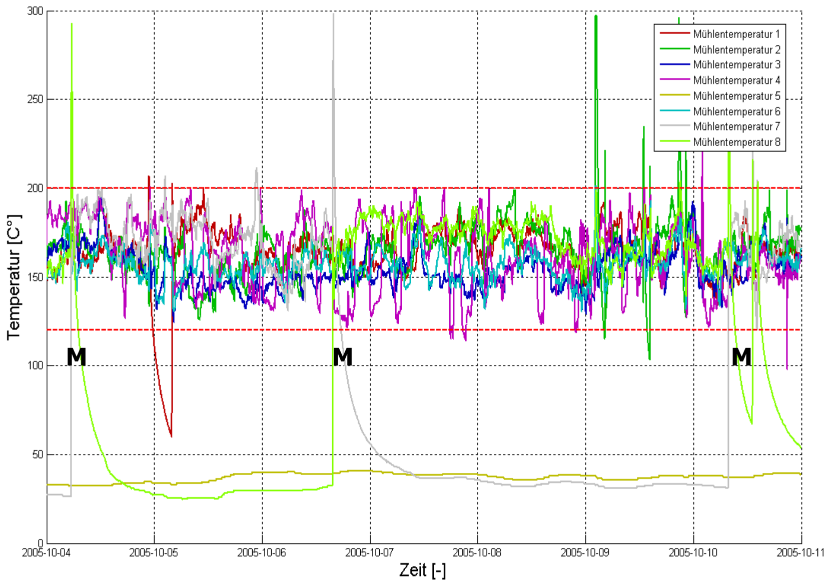


Optimising combustion

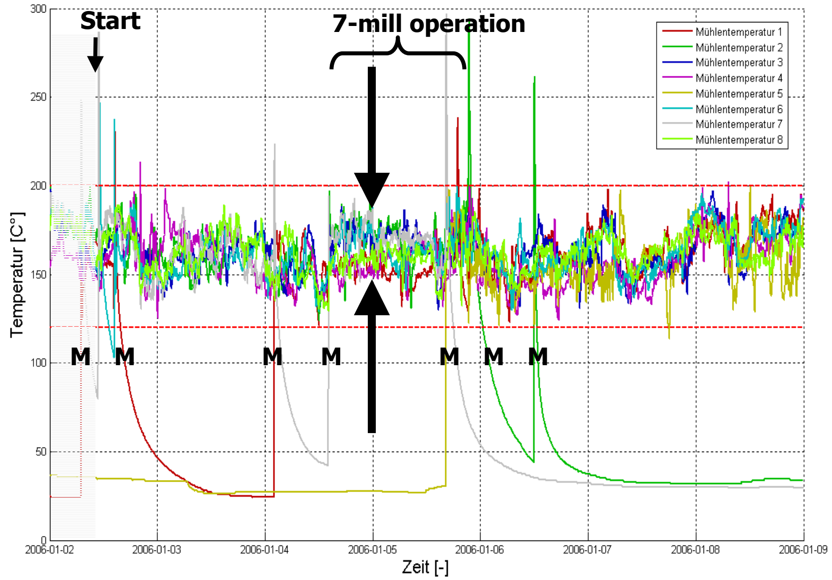
Mill temperature

- The mill temperature is controlled through primary air settings, coal feeder and mill speed. In this case it should be between 120°C - 200°C.
- Primary air affects the air-fuel ratio and the pressure distribution in the boiler
- The speed of the coal feeder affects the air-fuel ratio

Without EUcontrol-boiler



With EUcontrol-boiler



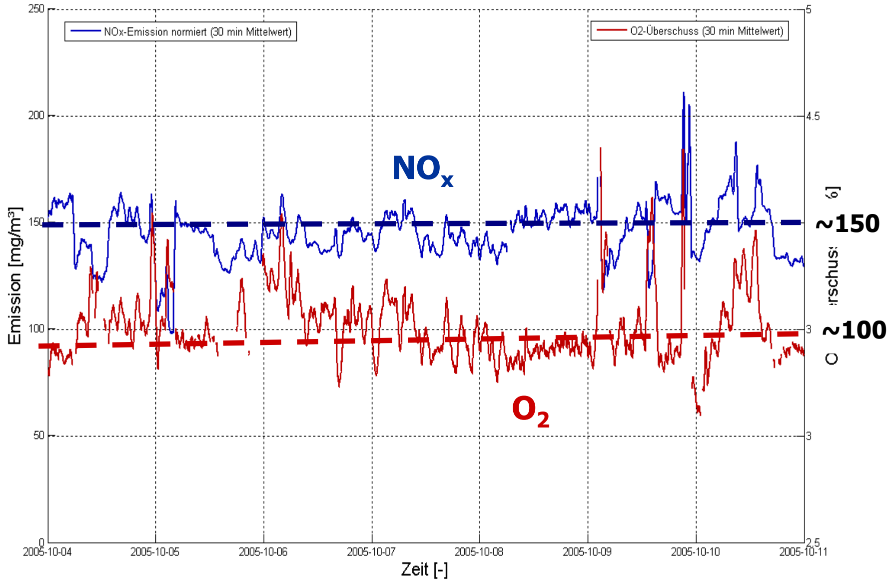
M = Change of mills, ramp up or down a mill

Optimising combustion

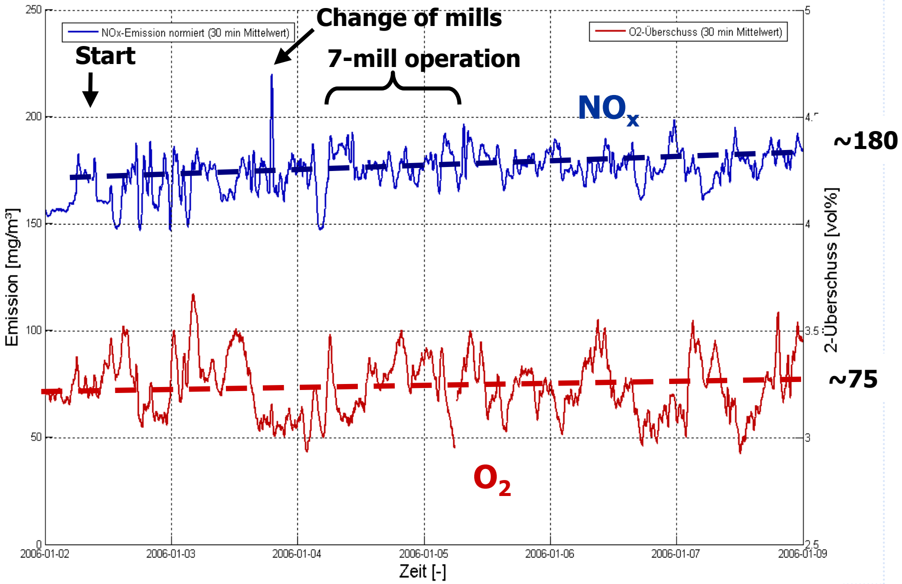
NO_x and O_2

- Combustion and burn-out are improved by opening primary and secondary dampers
- As more oxygen enters at the burner level NOX is increased to an adaptive set-point well below the emission allowance (200 mg/m³) –> NOx level becomes an indicator for good burn-out
- Simultaneously the excess air was reduced !

Without EUcontrol-boiler



With EUcontrol-boiler



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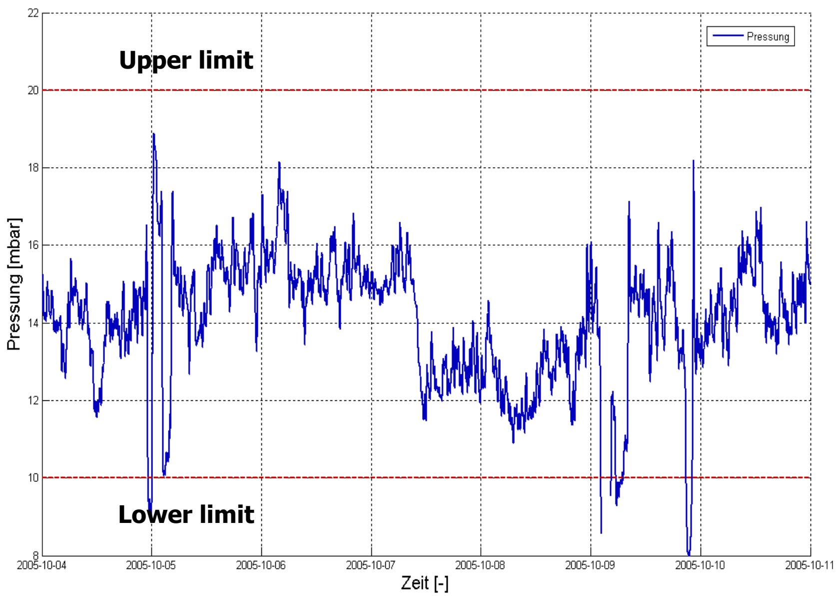
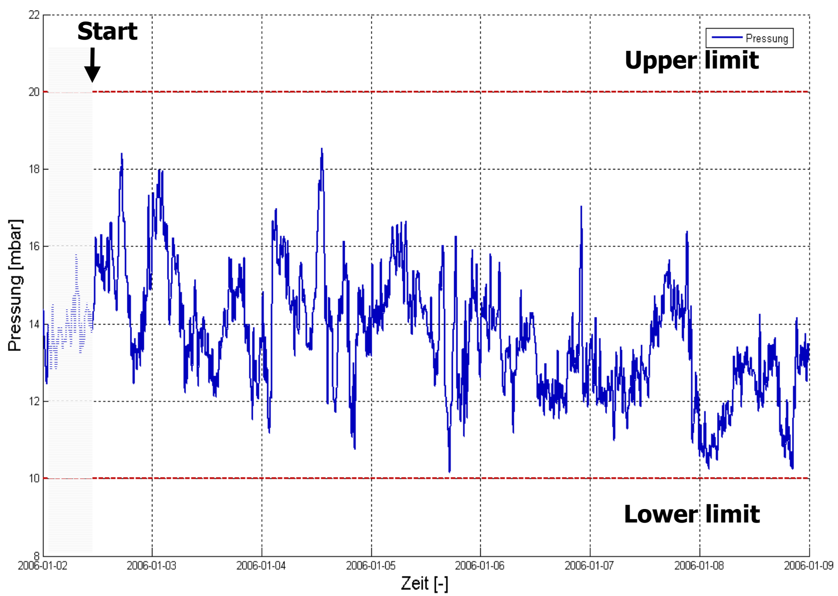
Pressure drop ID fan

- Many operational constraints must be considered while optimising combustion
- The air pressure drop is influenced by damper interaction: primary, secondary and over- fire air and ID fan setting
- The pressure limits can be parameterised

Beispiel KW40/2005: Pressung ohne EUcontrol-boiler



Beispiel KW01/2006: Pressung mit EUcontrol-boiler



Optimising Combustion

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Result

- Slagging and fouling of boiler walls significantly reduced
- Forced outages due to excessive on-load cleaning are at a minimum
- CO emissions reduced indicating improved burn-out
- NOx level reliably below allowance level
- Mills operated close to optimal conditions
- Balanced temperature profile reducing material stress
- Reduced level of excess O2 improves efficiency
- Operator can select combustion strategy according to situation

Case study II:
Minimising furnace temperature imbalances

Situation/Problem

Minimising furnace temperature imbalances

- Asymmetric mill or burner arrangement, unequal burner loads or damper settings may bias temperature profile at furnace exit
- Non-centred flame ball leads to material stress and can cause slagging problem
- Asymmetric temperature profile at furnace exit leads to steam temperature differences in boiler sections that have to be compensated by spray water
- Spray water reduces boiler thermodynamic efficiency

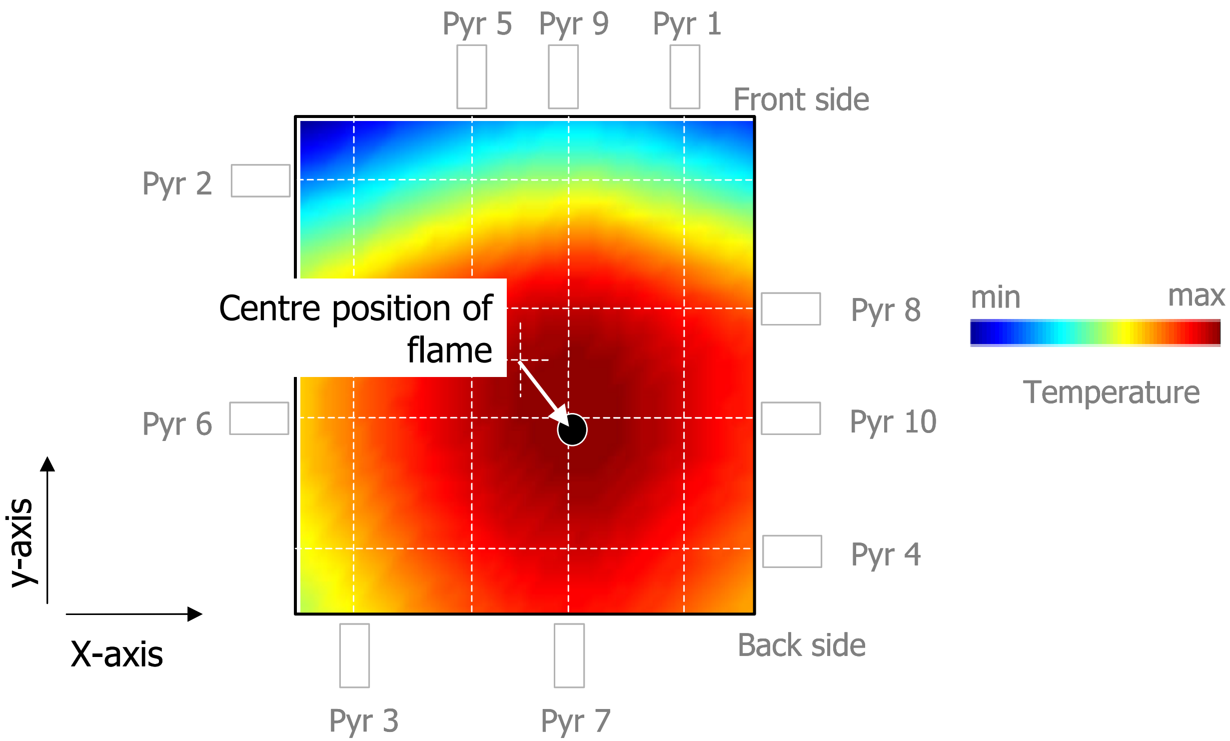
Definition of task

- Reduction of the temperature difference of four given temperature measurements (4 „AGAM zones “) in a large scale utility boiler (> 900 Mwel)
- Additional optimisation tasks (partly correlated):
  - CO (minimise)
  - Average O2-level at at the end of boiler (minimise)
  - O2- deviation at the end of boiler (minimise)
  - Overall boiler efficiency (maximise)

Solution – Measuring temperature distribution

EUflame-2D

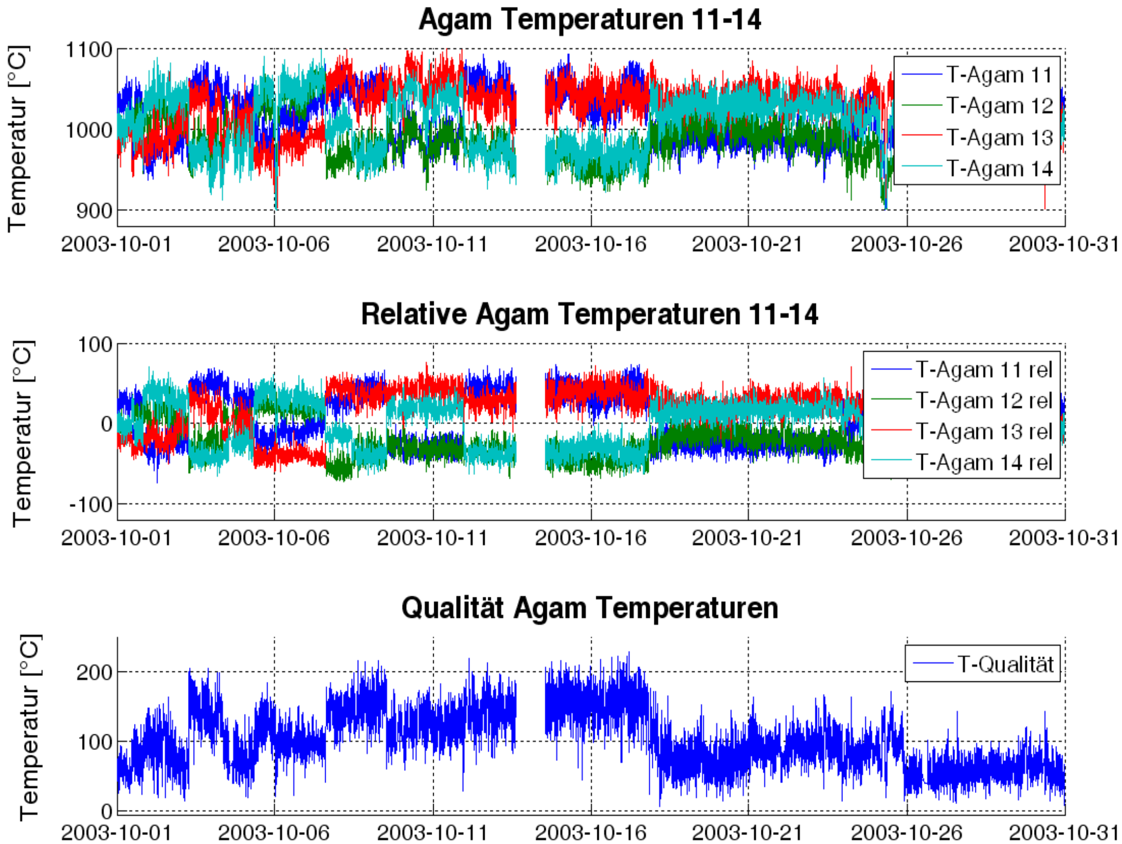
- Direct measurement of furnace exit gas temperature (FEGT) distribution
- Flame characterisation via mean value and standard deviation (max/min) of temperature and flame ball position (centre of flame)



Minimising temperature variation

Primary optimisation goal

Minimisation of FEGT temperature variation ("Agam" zones)



Relative temperatures

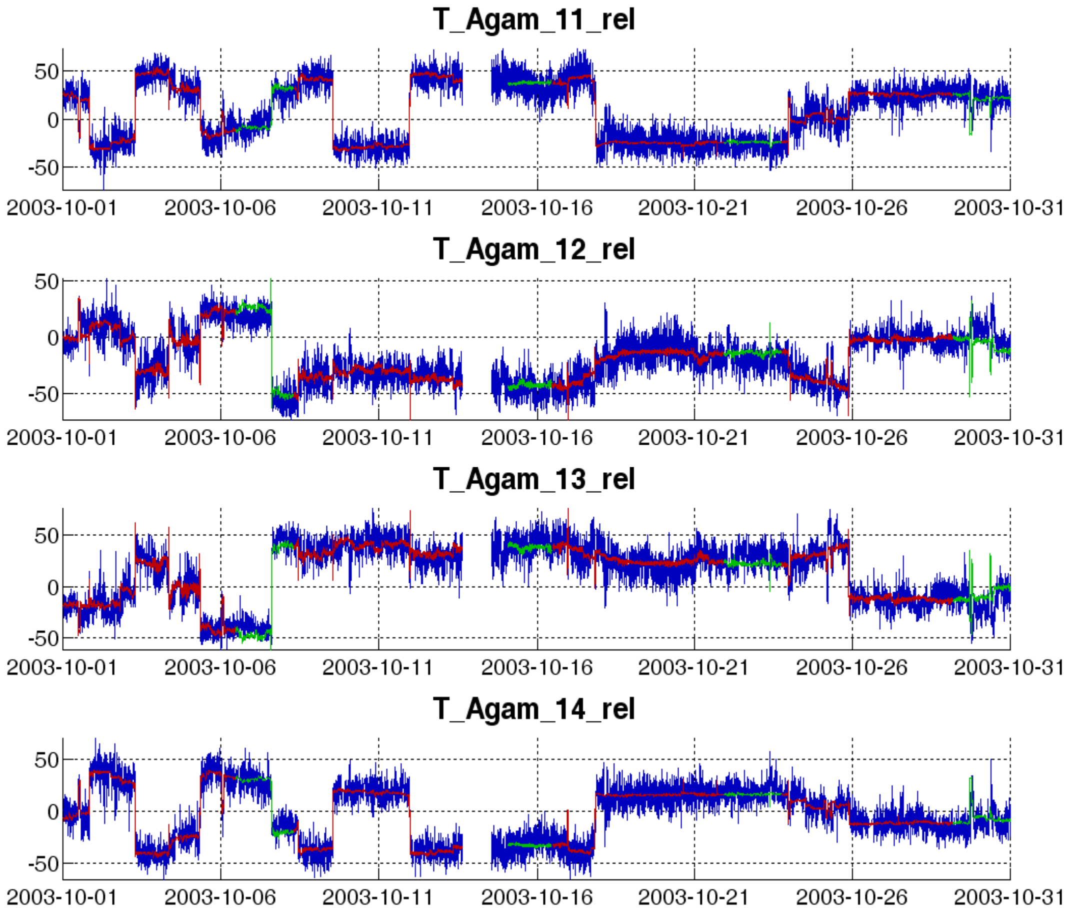
$$T_{AGAM\ rel,i} = T_{AGAM,i} - \overline{T_{AGAM}}$$

Temperature „quality"

$$T_{AGAM\ qual} = \Sigma\ |T_{AGAM\ rel,i}|$$

System identification – direct parameters

Model of temperature variation



- Input data: Relative inputs
- Output data: Relative temp.
- Properties: Prognosis model of all available data sets
- Conclusion: Good model quality. Model can be directly use for optimisation.
- Quality: 92 %

Blue line	Original temperature
Red line	Temperature during model generat.
Green line	Temperature during model validation

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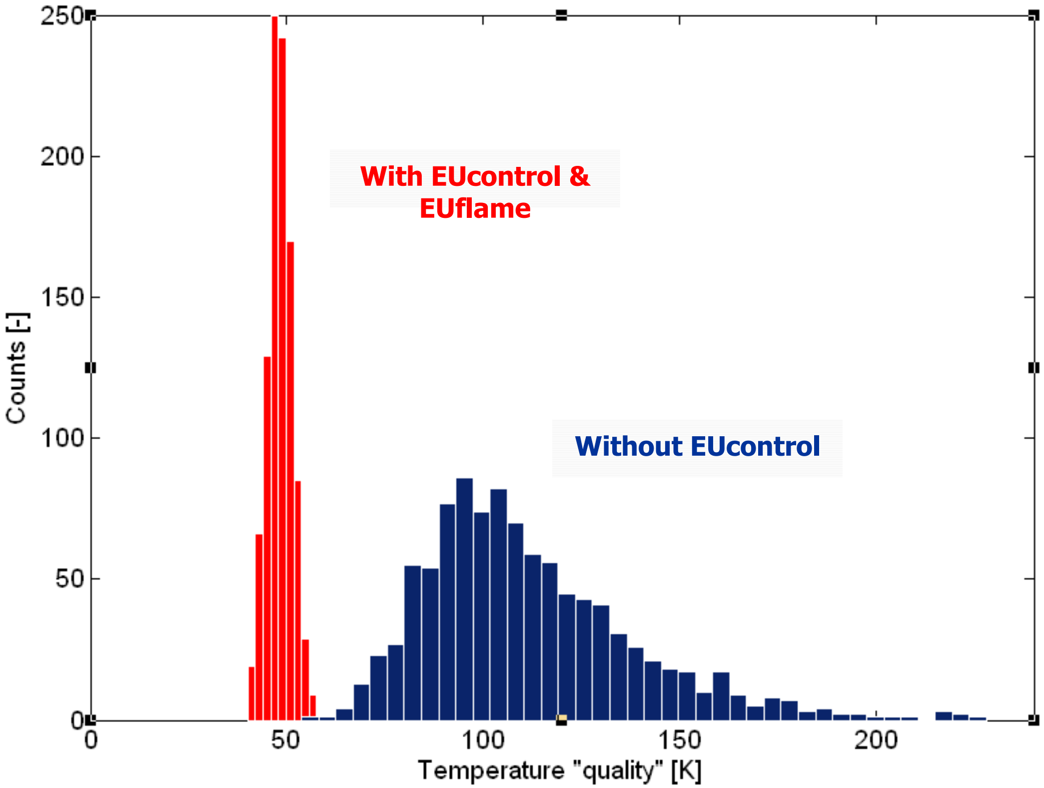
Optimisation - results

Result of optimised settings (optimisation goal)



- Temperature quality = $\Sigma \, |T_{AGAM\ rel,i}|$
- Significant improvement of temperature quality through optimisation

Summary....

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Benefits and deliverables

Benefits ...

- EUcontrol-boiler is an optimal cost-value ratio option for producing sustained boiler operation under desired conditions (low NOx, reduced slagging, high efficiency)
- No modification of plant DCS system required
- Highly adaptive, automatically adjusting to changing situations
- Multivariate target optimisation (low NOx AND low fouling AND high efficiency)
- Customisable to individual plant requirements

... leading to a new value proposition

- Consideration of different operational objectives (technical, commercial, environmental)
- Offering an attractive means to upgrade older boilers at low cost
- Straightforward implementation at lowest risk (model based)