Direct and indirect control of process plants with a neural network

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NEURONALNETWORKS!

NeuronalNetWorks! GmbH – Overview

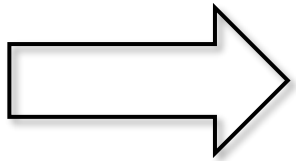
30+	14	~ 3 Mio.€	3
Years of experience	**Projects****	**Development**	**Products**
Plant-Engineering:	Germany*	~ 20,000 man-hours of development work	AI-Prediction*
- Electrical and I&C technology	Netherlands*	with originally approx. 9 team members	AI-Assistant
- Thermal process engineering	Austria	Spin-off of Uniper SE 2023	AI-Operator
- Renewable energies	Netherlands		
	England		

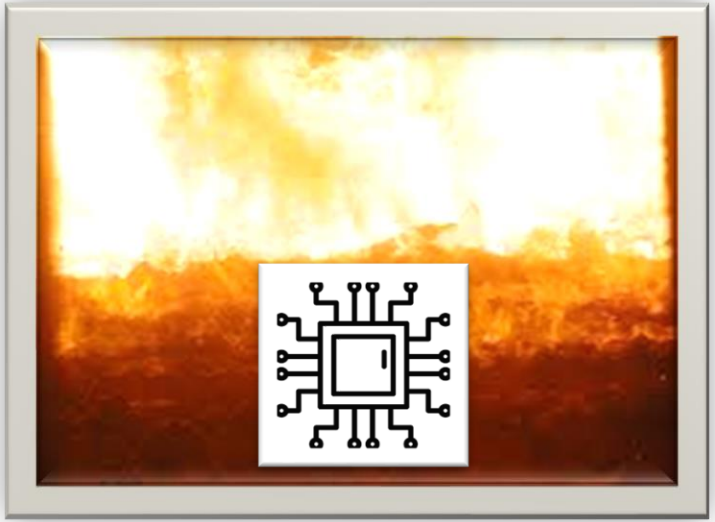
* Focus NNW
** with predecessor companies

Content of today's lecture

- **AI can improve process engineering operations**
- **Presentation of implemented improvements** through the implementation and operation in a pilot plant
- **Presentation of the AI implementation**
  - Examples of AI Operator
  - Examples of AI Prediction

That's what it's about





- **AI**
  - **trustworthy**
  - **deterministic**

- Process engineering plants
  → here especially **waste incineration plants**
  - with conventional control

The AI-Solution can improve waste incineration plant operations

Development of AI applications with the following challenges:

- **Volatile incineration process** (e.g. fresh, damp waste versus high-calorie waste)
- **Long dead times**, e.g. in connection with CO generation, are challenges for plant operators and automation
- **Optimization** of several key figures (e.g. waste throughput, energy efficiency, flue gas reduction, reduction of emissions and consumables, etc.)
- **Human plant** operators often control several blocks / lines in parallel
- **High requirements** with regard to plant and data security
- **Limited budget** for additional equipment

The pilot: 27 months of operation in an MVA (2019-2021)

The pilot project

waste2energy

>17.000
Hours

First
of its kind

KINRW

First results

+10% ↗
Power Generation & Wastethroughput

-30% ↘
O2-Level

Reduction ↘
Consumables (e.g. oil)

Reduction ↘
Emissions (e.g. CO)

Safety First

TÜV NORD

- ✓ Human operator sits in the control room – No replacement
- ✓ AI operator can be stopped at any time
- ✓ Strict separation from boiler protection
- ✓ No external access possible

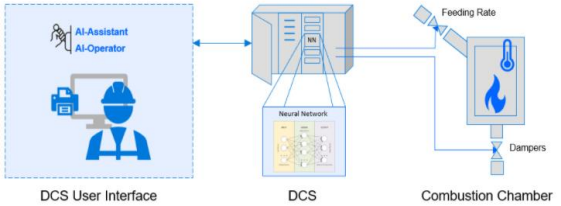
NNW AI solution differs from other AI tools in the energy sector

Focus below

Analyse AI-Tools

- Centralized data analysis
- Mostly cloud-based
- Tools belong to Condition Monitoring, Predictive Maintenance, Combustion Modelling

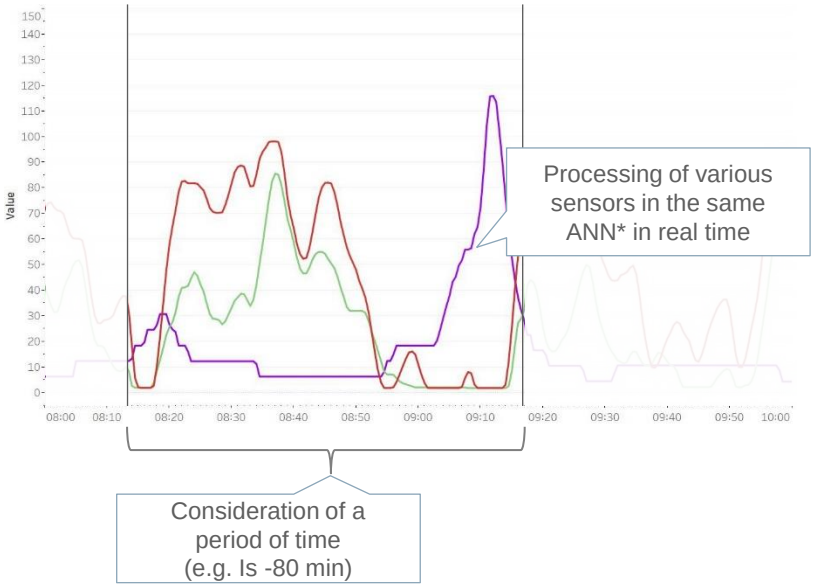
NNW AI-Tools



- The aim is to operate/automate the system
- Directly embedded in the DCS
- No cloud connection due to the local control system in the plant

Use of artificial intelligence to analyze process data

Analysis of process data with artificial intelligence (ANN*)



Strengths ANN*

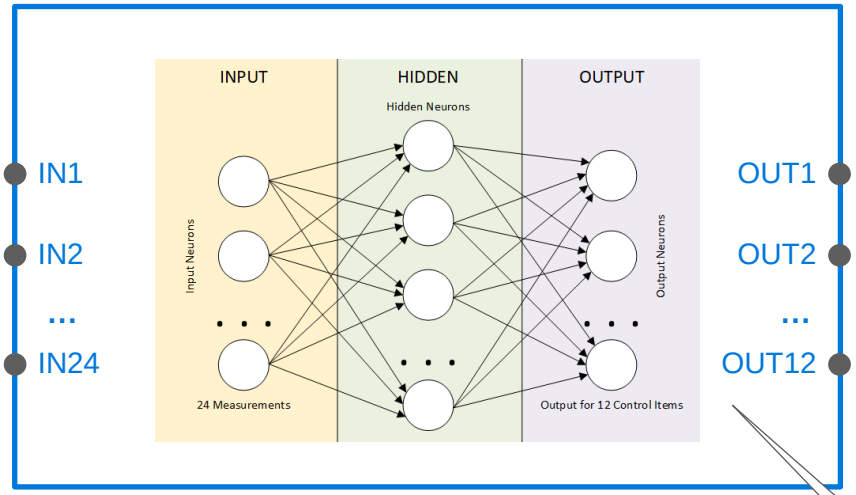
- **Detecting correlations**
- **Pattern recognition**
- **Recognition of dead times (time-shifted relationships)**

* Artificial Neural Network

AI processes complex relationships

The neural network learns the process image

- Result of the correlation analysis
- 24 measured values
  Use of relevant sensor data
- History
- Includes values derived from measured values, e.g. gradient, curvature and dead times



Implemented as a **function block** in the DCS

Plant **safety system** is not changed

No cloud – high **data security**

Predictions or Control by AI

- 12 learned control outputs
- Several time **predictions** possible: e.g. 5 min to 30 min into the future
- Continuous **control** without delays
- AI can operate the system in 24/7 mode
- AI can handle dead times

CUDA C/C++

Different operating modes are possible

AI-Prediction

AI anticipates the process

Operator controls the system

AI-Assistant

AI recommends actions

Operator controls the system

AI-Operator

AI controls the system

Works like an autopilot

Operator monitors AI

Example: AI-Assistant/ AI-Operator - 1

Project Setup

Type	**Waste incineration plant**
Fuel	waste (350,000 t/a)
Automation	Manual operation
Location GER,	Lower Saxony

Challenges & goals of the pilot project:

- Older boiler with low automation
- Old sensors (tw. over 25 years old)
- Older boiler design leads to suboptimal air distribution
- Long dead times
- Higher waste throughput possible if steam production is equalized

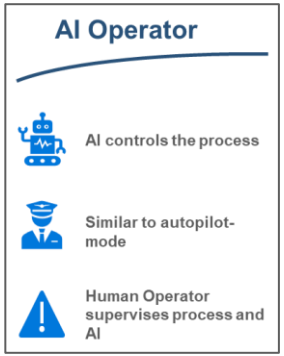
Solution

Step 1: AI-Assistant

- Recommendations for the air flaps; Optimization of air distribution
- Recommendations for the setpoint of the load
- Operator control

Step 2: AI-Operator

- Automation of air flaps and automation of the oad setpoint
- Operator can switch the AI operator on/off at any time
- Positive feedback from the AI Operator by the Operators



Example: AI-Assistant/ AI-Operator - 2

Project Setup

Type	**Circulating fluidized bed**
Fuel	Sewage sludge (200,000 t/a) dewatered, coal
Automation	Manual operation
Location	GER, NRW

Challenges & Goals:

- Keep the temperature in the combustion chamber of the CFB furnace constant at about 890°C
- Increase in sewage sludge throughput and steam production
- Avoidance of:
  - Support burner insert
  - Unavailability in case of temperature limit violation

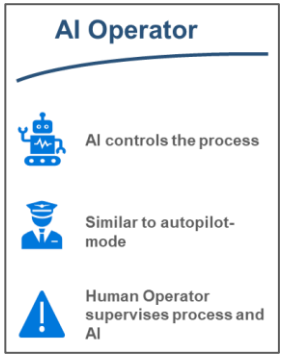
Solution

Step 1: AI-Assistant

- Recommendations for optimal control of vortex air and the return flue gas
- Operator control

Step 2: AI-Operator

- Automation of the frequency converter for the vortex air and the control flap of the return flue gas
- The Operator can switch the AI-operator on/off at any time



Example: AI-Assistant/ AI-Operator - 3

Project Setup

Type	**Gas-fired power station**
Fuel	Gas
Automation	Fire-Rate-Control
Location	GER, Bayern

Challenges & goals of the pilot project:

- NO2 can only be influenced directly by the firing process
- Control of the combustion air to achieve optimum CO, NO2 and O2

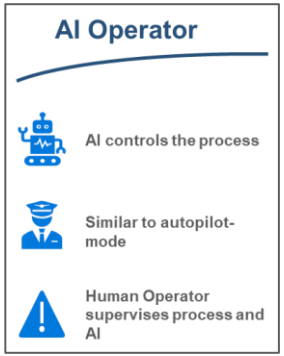
Solution

Step 1: AI-Assistant

- Recommendations for the Lambda correction (fuel/air ratio) to achieve optimum CO, NO2 and O2 at full load
- Operator control

Schritt 2: AI-Operator

- Automate the Lambda Correction
- The Operator can switch the AI-operator on/off at any time



Different operating modes are possible

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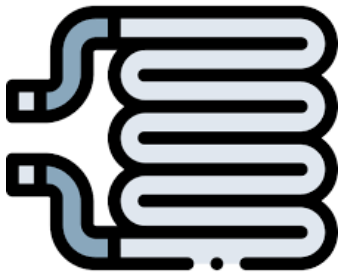
Predicting Process Variables with AI

- NeuronalNetWorks! GmbH (NNW) is currently specialized in the prediction of process engineering variables for reducing consumables and costs such as:
  - Steam production



  - NOx/NH3 in flue gas

Example: AI-Prediction – 1 and indirect control

Projekt Setup

Type	**Waste incineration plant**
Fuel	Waste (447.000 t/a)
Automation	Fire-Rate-Control
Location	GER

Challenges & Goals:

- Fresh, damp waste will be delivered around 8:00 a.m.
- The Fire-rate-control interprets the data incorrectly, it will heap the grate
- This regularly leads to steam drops
- Oil use is required to reach combustion temperature again

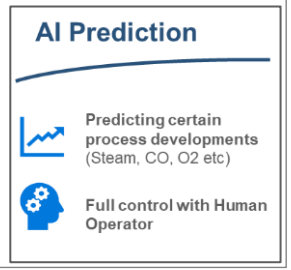
Solution

Step 1: AI-Prediction Tool

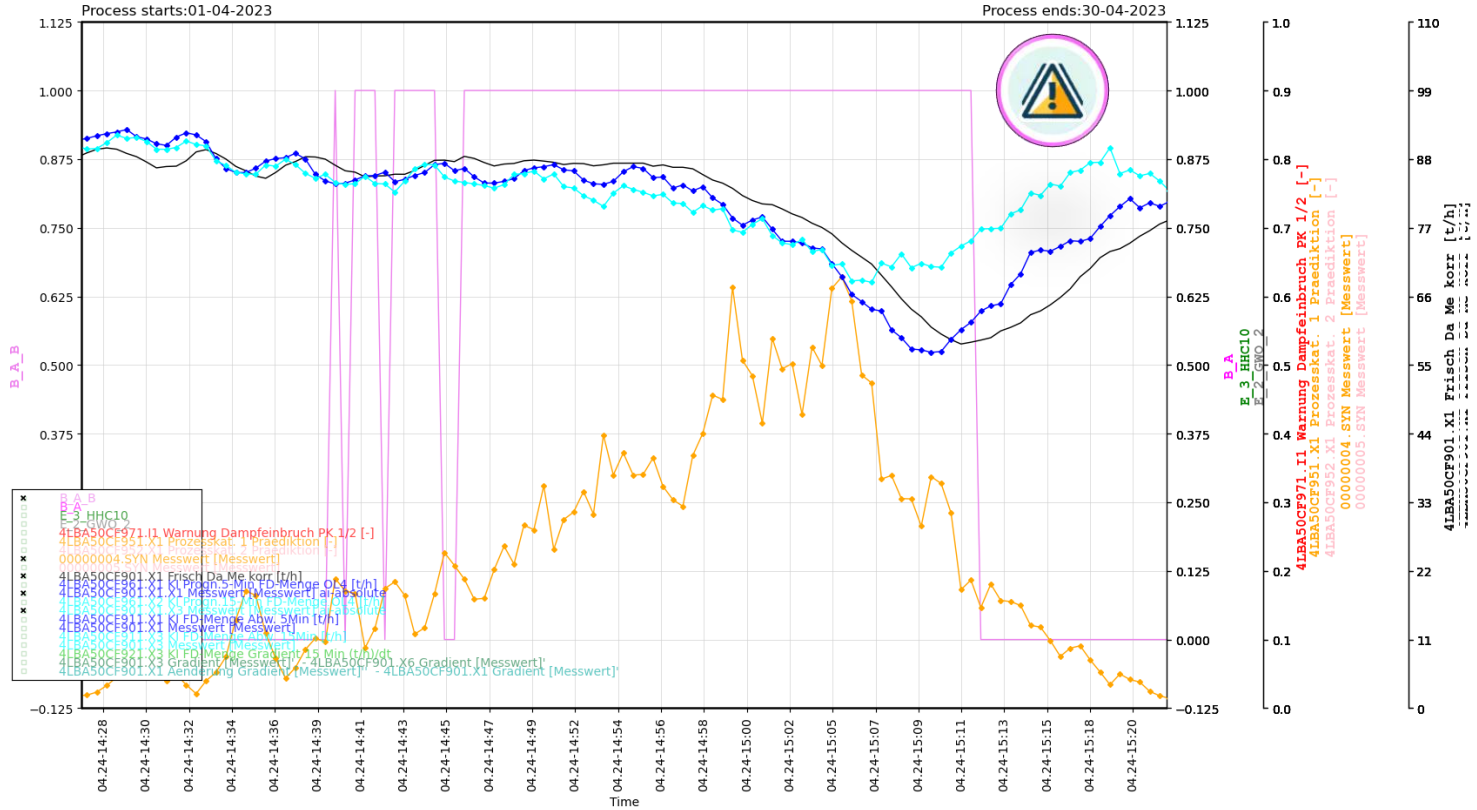
- Prediction of steam production
- Based on the forecast, measures can be taken to avoid the steam drop
- Avoidance of steam drops, maintaining temperature and more efficient combustion
- **This is the concept of indirect control!**

Step 2: AI-Operator (planned)

- Training of the AI operator on the basis of the optimized manual operation with the help of AI Prediction!



Prediction - Example



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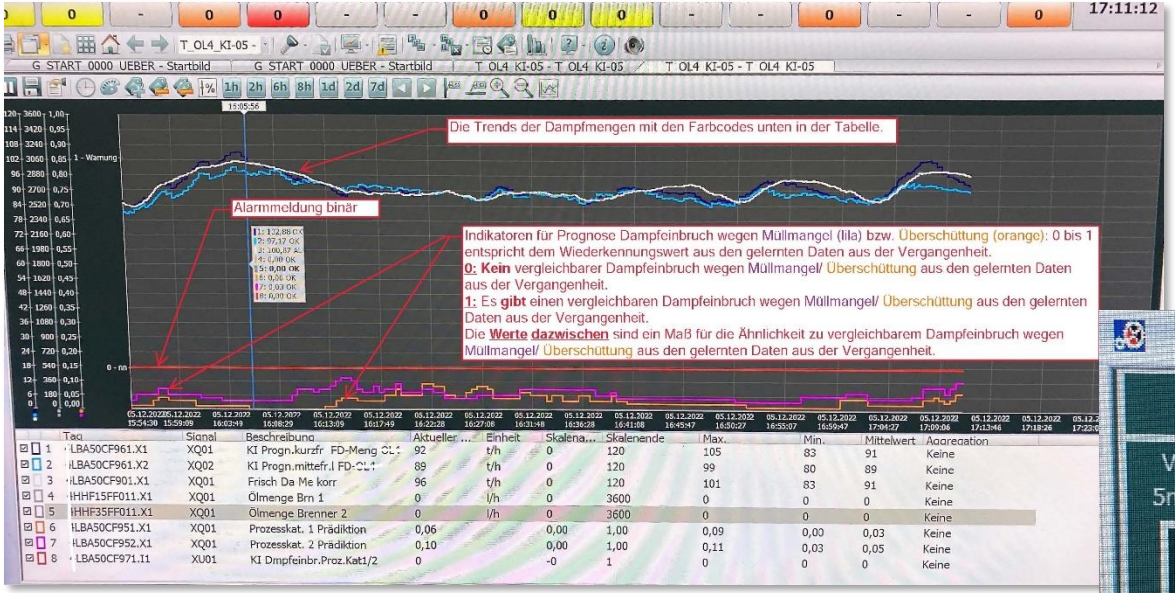
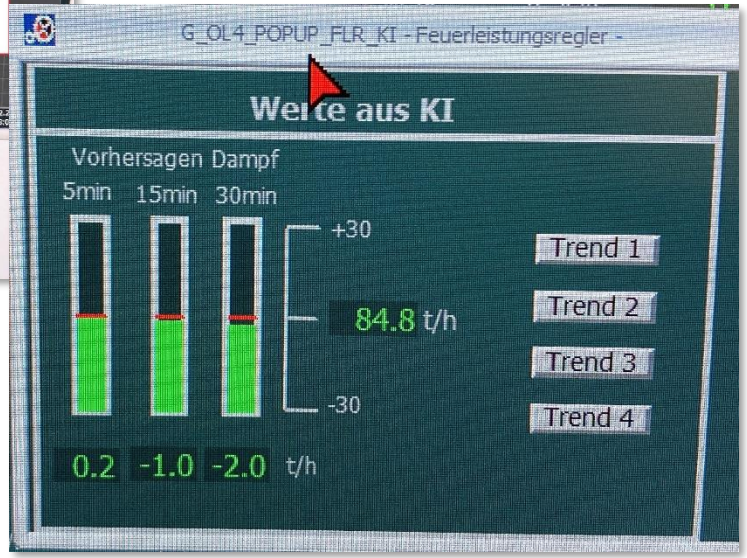
Deterministic AI implemented in the DCS (i.e. ABB)





Example: AI-Prediction – 2 and indirect control

Projekt Setup

Type	**Waste incineration plant**
Fuel	Waste (350.000 t/a)
Location	NL

Challenges & Goals:

- The NH3 slip controller does not work well
- Too much NH3 is used to reduce NOx
- A neural network serves as a digital twin for the prediction of NOx and NH3
- Furthermore, the synapse weights of the neural network are used to find the causes of the faulty NH3 injection

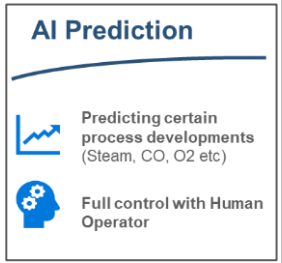
Solution

Step 1: AI-Prediction Tool

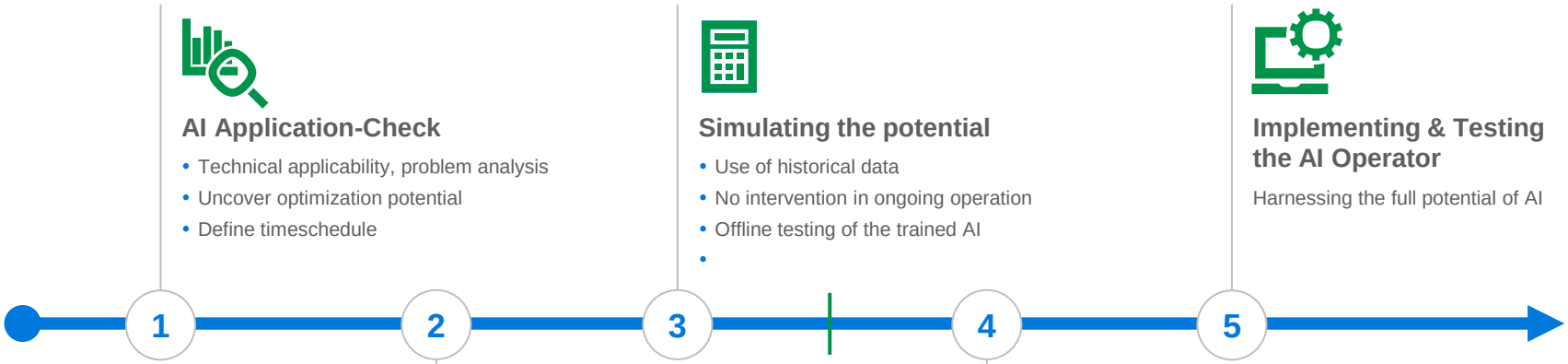
- Prediction of NOx and NH3
- Based on the forecast, measures can be taken to avoid the NH3-slip
- Avoidance of NH3-slips, less costs for NH3 combined with environmental protection, because of less NH3 and NOx in the flue gas
- **This is the concept of indirect control!**

Step 2: AI-Operator

- Training of the AI operator on the basis of the optimized manual operation with the help of AI Prediction!



5 simple steps to a successful AI project



1

AI Application-Check

- Technical applicability, problem analysis
- Uncover optimization potential
- Define timeschedule

2

Engineering

- Defining good operating modes
- Adapting AI with your own process knowledge
- Export historical DCS data

3

Simulating the potential

- Use of historical data
- No intervention in ongoing operation
- Offline testing of the trained AI
-

Checkpoint

4

Implementing & Testing the AI-Prediction or the AI Assistant

Test phase with:

- Prediction
- recommendations for the human plant operator

5

Implementing & Testing the AI Operator

Harnessing the full potential of AI

We have developed our AI for different use cases

Project References (excerpt)

Grate firing: waste / biomass

- **Steam drop forecast***
- **Forecast NOx and NH3 peaks***
- **Forecast CO peaks***
- Reducing emissions and increasing steam production and waste throughput by optimising the incineration process*
- Reduction of boiler contamination / extension of travel time by reducing boiler temperature*

Fluidized bed

- Combustion air control**

Gas boiler

- Increased maximum performance by trimming combustion air (gas boiler)**

* Focus NNW
** with predecessor companies

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