Flexibility optimization of new and existing fossil fired power plants

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RWE

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> What does Flexibility mean?

> Flexibility for new built Plants

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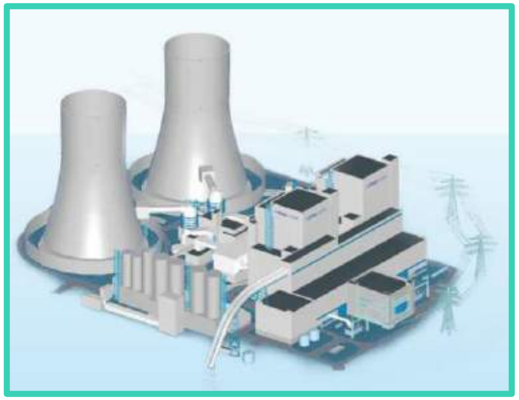
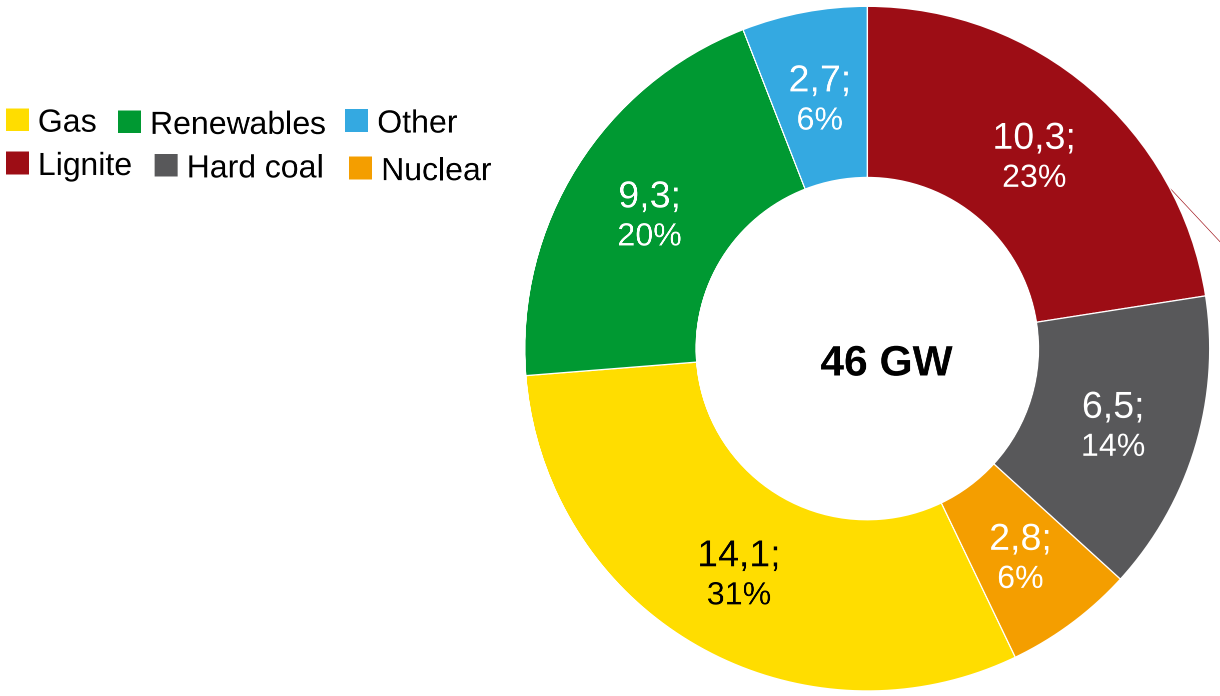


Who is RWE?

Largest Generator in Germany / Major assets in NL/UK.

Pro forma combined electricity generation capacity[1]



Fuelled by RWE's own lignite mines:

- Hambach
- Garzweiler
- Inden

Total production
86 Mio t/y (2018)

[1] RWE stand-alone plus E.ON's and innogy's renewables businesses.

(as of 1 January 2019)

RWE Technology International (RWE-TI):

Engineering. Consulting. Utility roots.

Our advice is based on the experience as **owner and operator** of world-class assets.

We enable clients to advance **efficiency, safety and sustainability** of their businesses.

Our **services** include: thermal power, utility-scale renewables and open-cast mining.

50+ years established as engineering consultant	**100+** countries we have experience in	**120+** years of heritage as pioneers of power industry	**200+** highly qualified engineers and consultants	**1000+** successful projects performed world-wide

RWETI: Our core services

Mining

Mining is our heritage. We have over 50 years of unique continuous mining tradition and conveyer belt know-how that customers all over the world are taking advantage of.

Thermal Generation

We have advised on over 300 thermal projects around the world, helping customers to increase efficiency, reliability and manage costs in projects and operations.

Renewables

We offer technical advisory services and investment support for renewables, covering a variety of technologies including solar, wind, hydro, biofuels and energy storage.

What does flexibility mean?

High flexibility can be described as follows:

Dynamic flexibility

> High operational gradient (load change speeds)
> Short start-up time and short minimum downtime
> Lowest possible minimum load and options to temporarily maximize the load

Operational flexibility

> High number of start ups and load cycles at reduced lifetime consumption
> High efficiency at lowest possible minimum load
> Uniform, high efficiency curve across the load
> Fuel flexibility

RWE's philosophy regarding flexibility:

→ Create value by combining technical solutions, process improvements, culture change and market focus!

RWE made a lot of effort to increase flexibility and efficiency of its plants in the last decades – Example Lignite:

150 MW-Blöcke | 300 MW - Blöcke | 600 MW - Blöcke | 1000 MW - BoA - Block

Next Project:

2x 550 MW

Pre-dried lignite

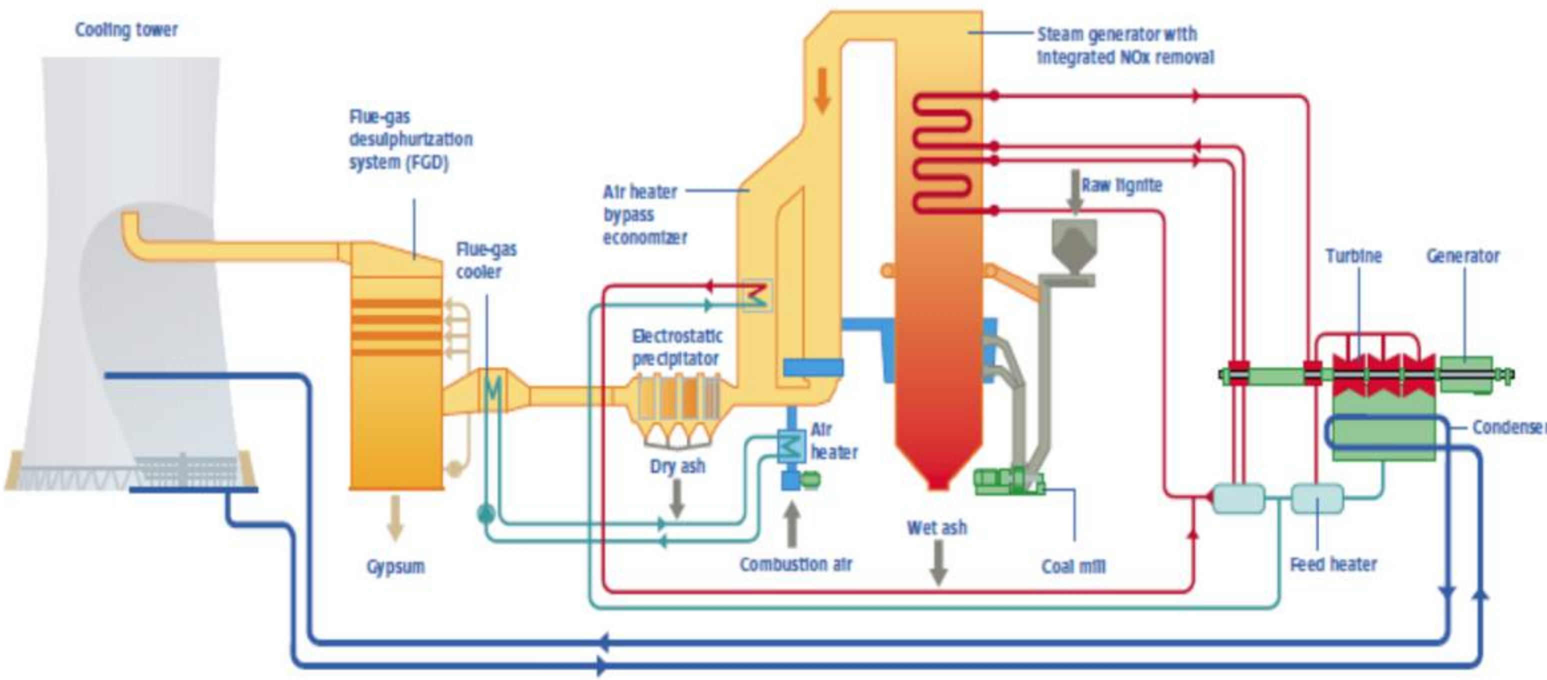
CFBC Units

?

COD:	1963	1965 - 1971	1974	2003
η:	31%	32-34%	35-36%	> 43%
Coal:	1,2 kg/kWh	1,1 kg/kWh	1,1 kg/kWh	0,9 kg/kWh

Average Efficiency gain along the Power Plant Process

Average net efficiency of a 150 MW unit	Average net efficiency of a 600 MW unit	Reduced condenser pressure thanks to optimized cooling tower	Waste-gas heat utilization	Increase in steam parameters	Process optimization	Improved turbine efficiency thanks to advanced steam turbine	Reduced auxiliary power requirements	Net efficiency of BoA
31 %	35.5 %	+ 1.4 %	+ 0.9 %	+ 1.3 %	+ 1.1 %	+ 1.7 %	+ 1.3 %	43.2 %
1957	1976							Today



Design specifications of new power plants

Example: 800 MW_e Power plant Westfalen, Germany

Operational characteristics
(Hard Coal, 800 MW)

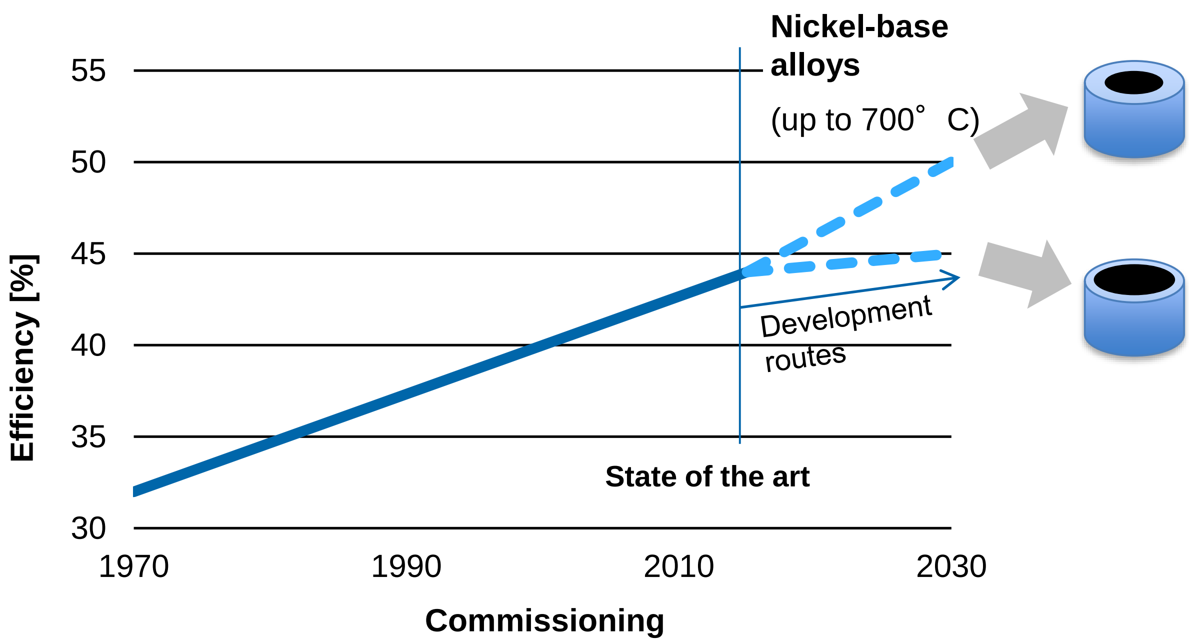
- Base and medium load
- Plant runs through in times of low demand
- Minimum load 25 - 30%, 7,500 operation hours per year

Operation Mode	yearly	40 years
Cold Starts	6	240
Warm Starts	42	1,680
Hot Starts	84	3,360
Load Cycles	1,200	48,000

→ Flexibility requirements are assessed and taken into account during the design stage of the plant.

New advanced materials allow increase in flexibility or efficiency

Efficiency development of lignite-fired plants



High efficiency
Increase in steam parameters for new build plants (700ºC power plant)

High flexibility
Constant steam parameters in existing and new plants (600ºC live steam temperature)

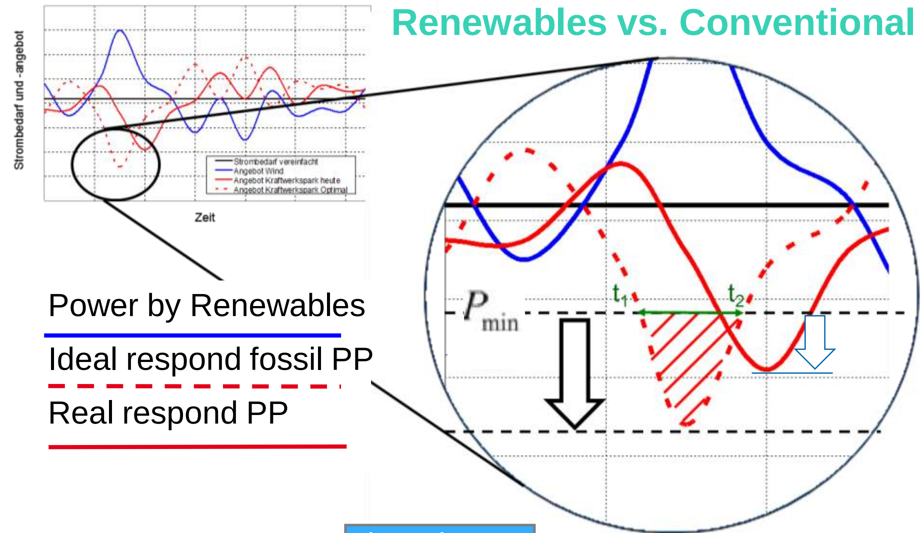
→ Use of nickel-base alloys depends on operating conditions of future power plants.

Short minimum downtime

Lifetime consumption consideration

- After command “fire off" measures must be carried out to bring the unit fast back into the "Ready" operating state. Hereby, the condition of the unit must be considered.
- Time leader in coal firing is the pre-ventilation due to security.
- Gentle cooling of the steam generator before air purging, which increases the life time but is time-consuming. This measure avoids the temperature stresses.

Renewables vs. Conventional PP



in todays market

Minimum downtime	With low Life Time reduction	With high Life Time reduction
hard coal / lignite	< 240 min	min. 30 min

→ Lifetime consumption is considered in the design and in the operation of our plants.

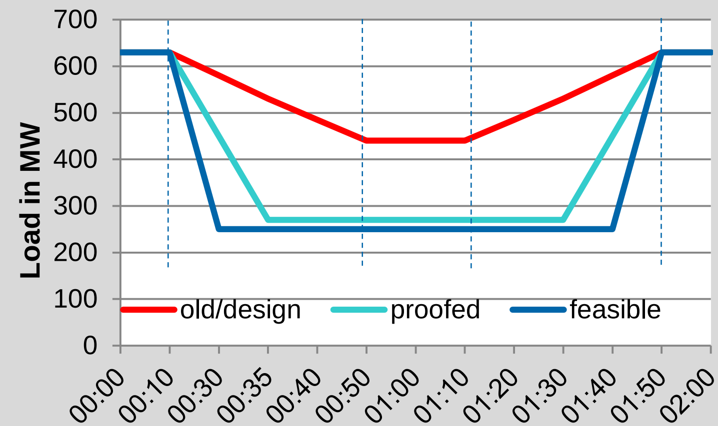
I&C optimization makes modern power plants even faster

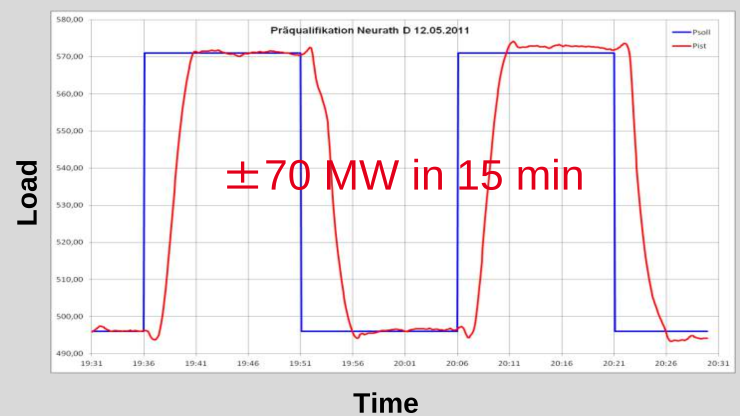
Coal-fired power plants
(e.g. 600 MW unit D, Neurath)

> **Reduction in <u>minimum load</u>: 20%-points**

> **Increase in <u>load change rate:</u> 5 MW/min → 15 MW/min**

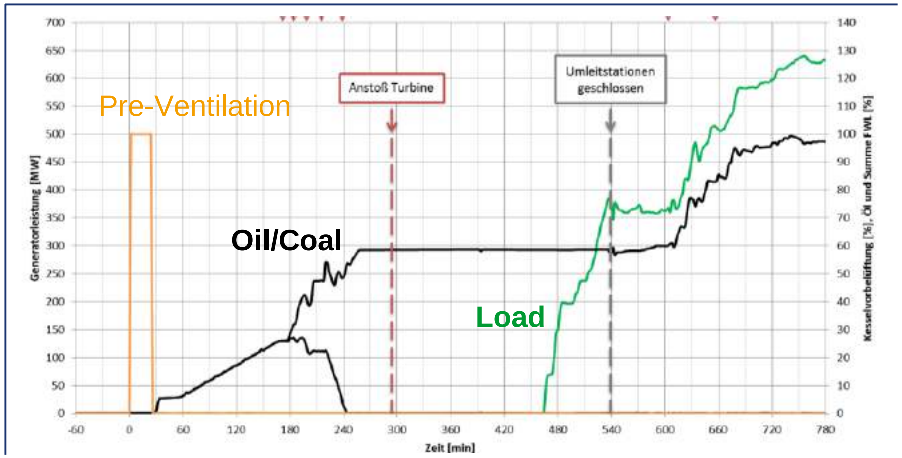
> **<u>Secondary reserve</u> capability: ±70 MW in 15 min**



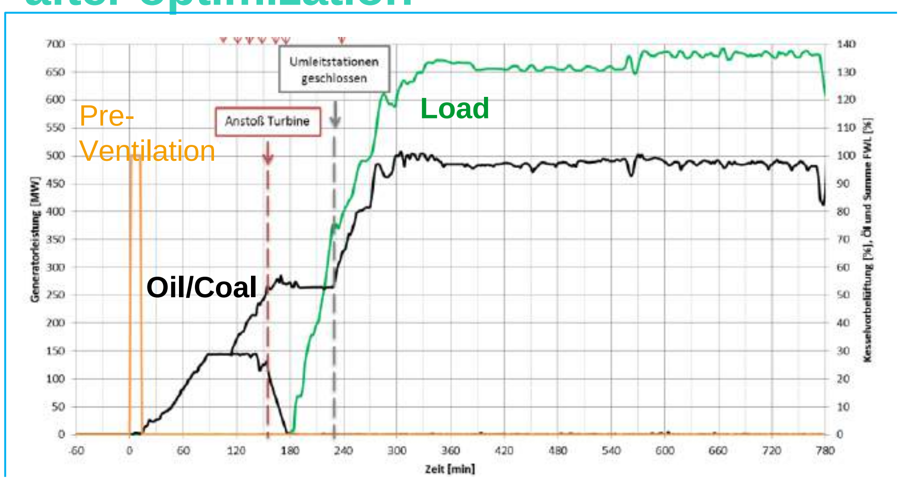


Start up optimization at a 600 MW unit

before optimization



after optimization



> Question limitations and boundary values

> Parallelize processes

> Minimize waiting times

> Assess of components were the maintenance is crucial and ensure good condition of these components

> Faster startups …

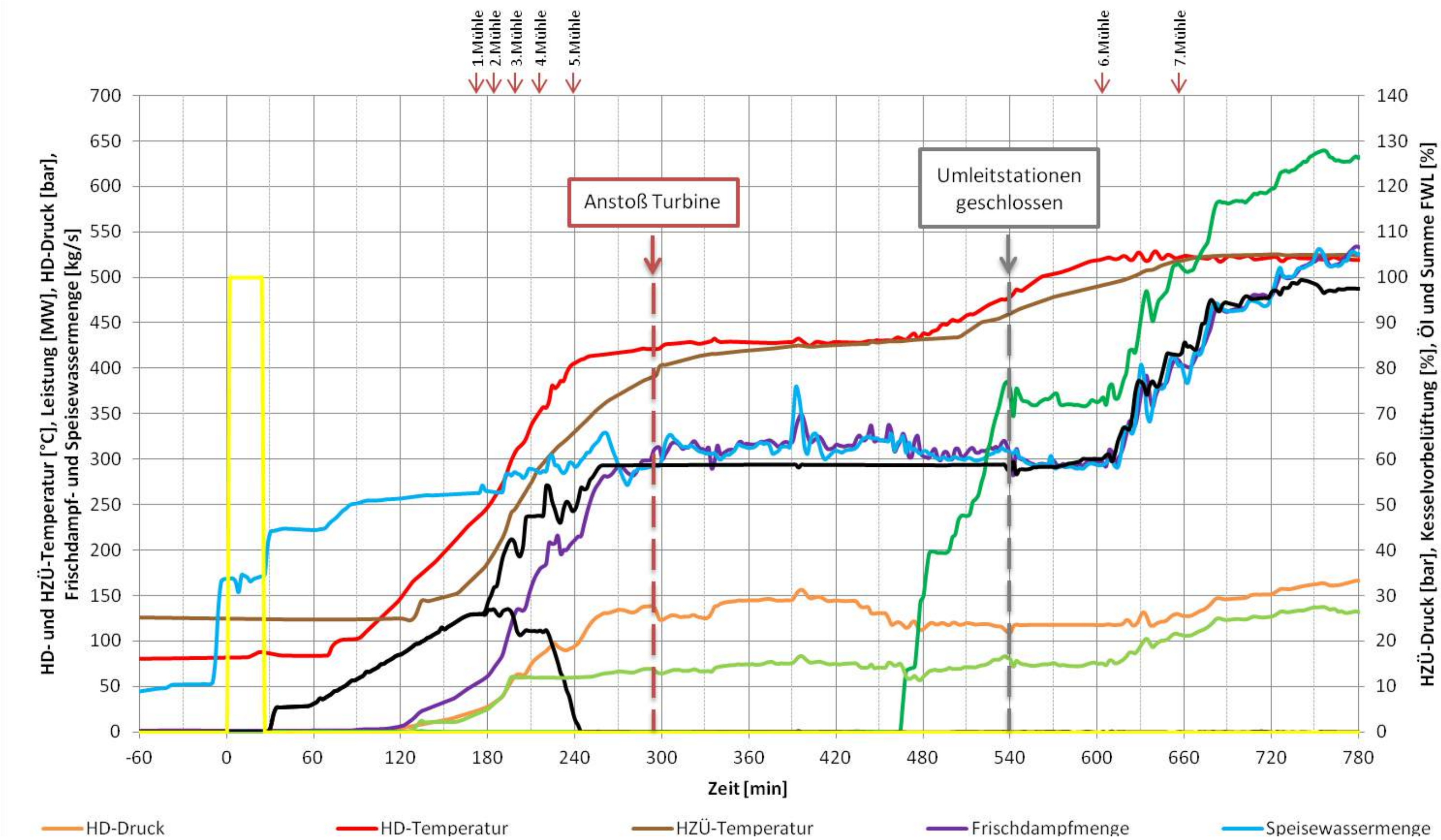
… without increased lifetime consumption

... without reduced plant safety

→ Key to success: Combination of expertise in process technology and I&C optimization.

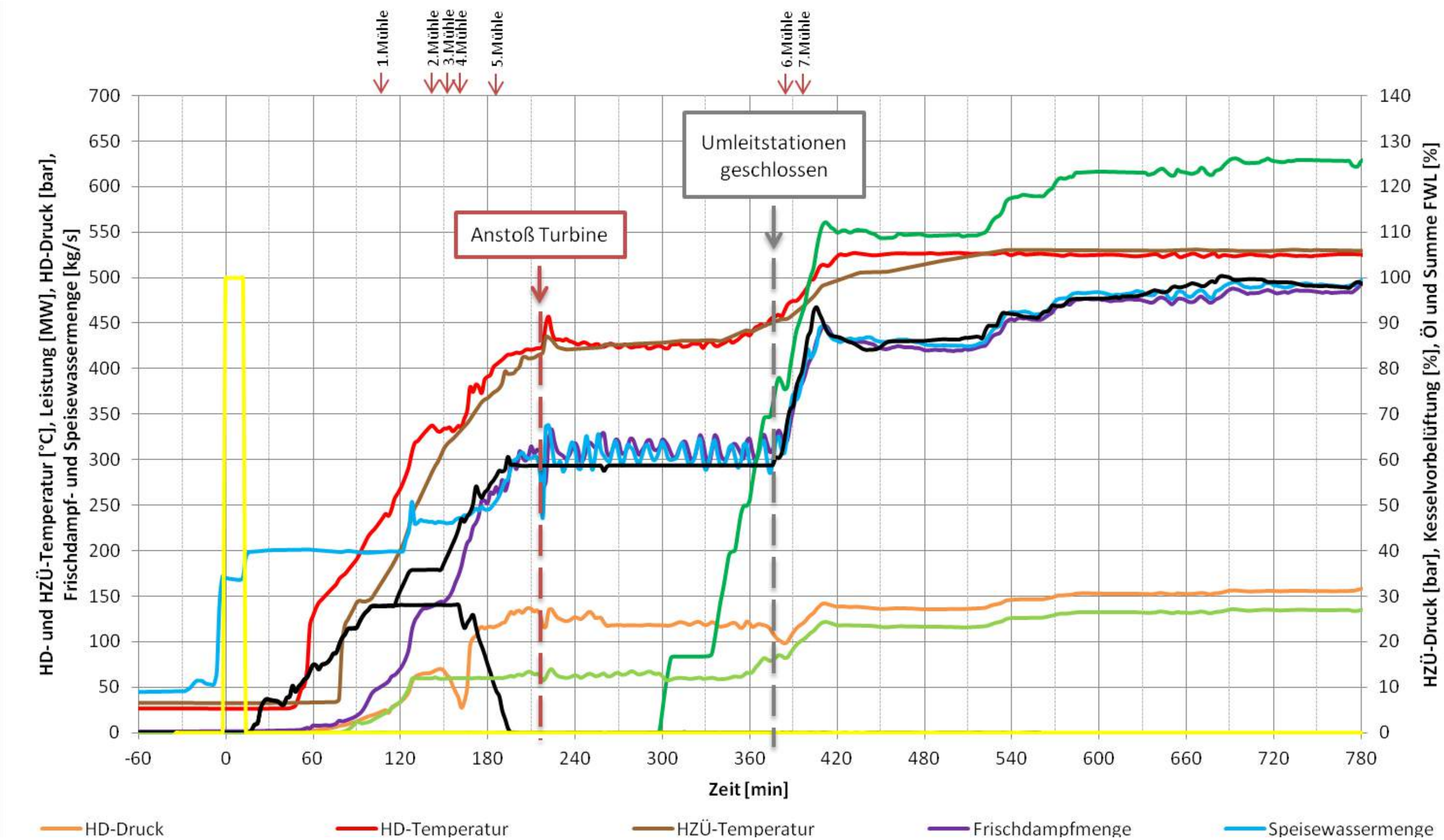
Start up optimization steps at a 600 MW unit

Starting Point (cold start in year 2010)



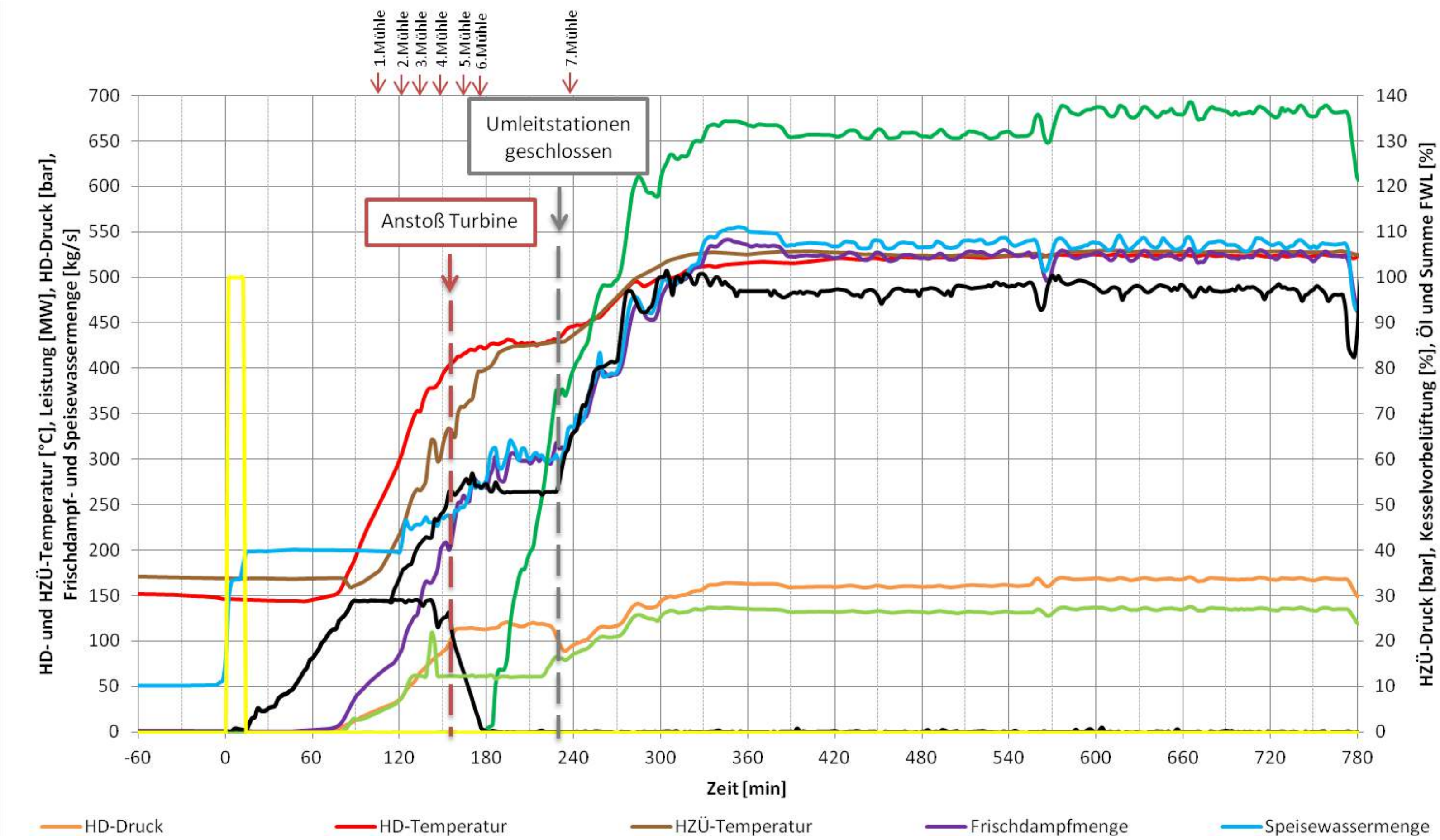
Start up optimization steps at a 600 MW unit

First optimisation stage (cold ctart in year 2011)



Start up optimization steps at a 600 MW unit

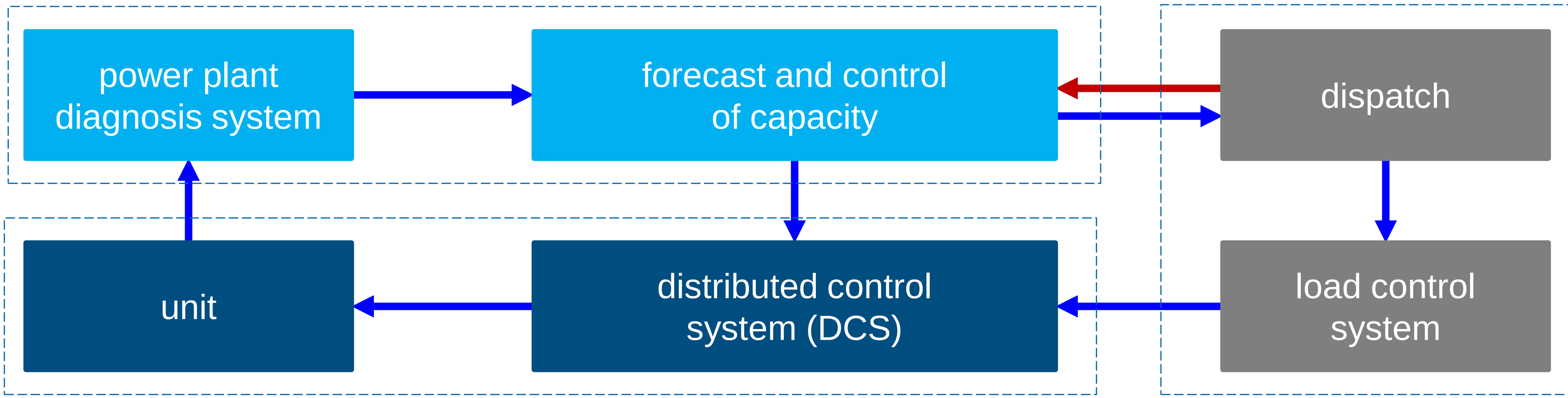
Second optimisation stage (cold start in year 2013)



Market-oriented control

Forecasting of available performance

Closed loop process that combines RWE's expertise as operator and trader

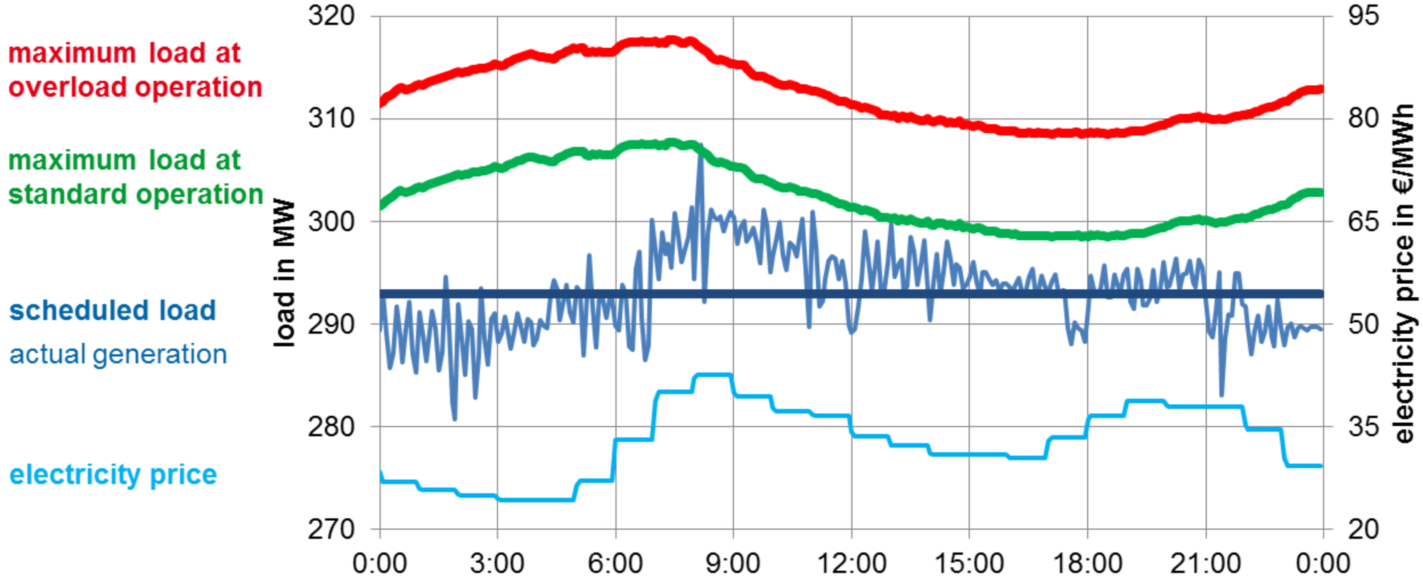


- **Technically established forecast** increases transparency and forecast accuracy (day ahead and intraday)
- **Market-oriented** control of the load capacity
- More accurate **following of schedule** by units
- Substantial **simplification of daily business** (communication dispatch and power plant)

Application: Maximal load optimization

Control and forecasting of available performance

Prognosis tool based on data from a process quality optimization system



- Fully automated market-oriented provision of power (incl. options such as preheater operation, etc.)
- Consideration of the current condition of the unit and external influences

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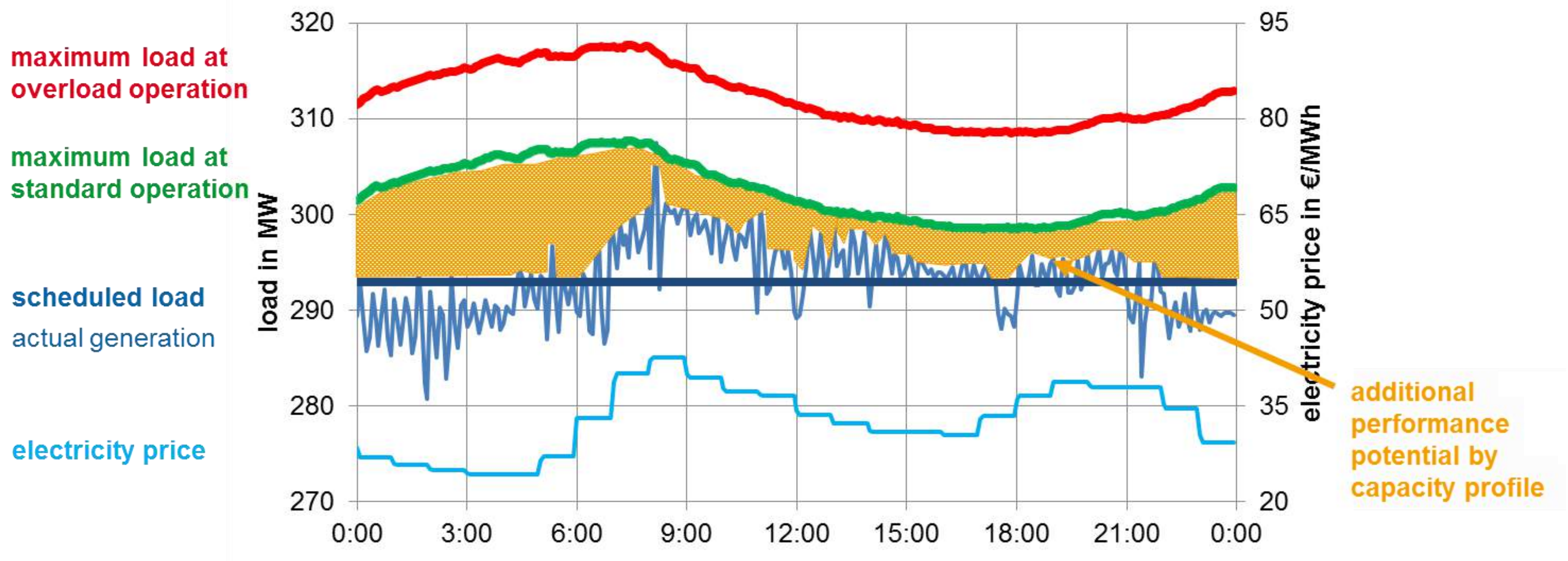

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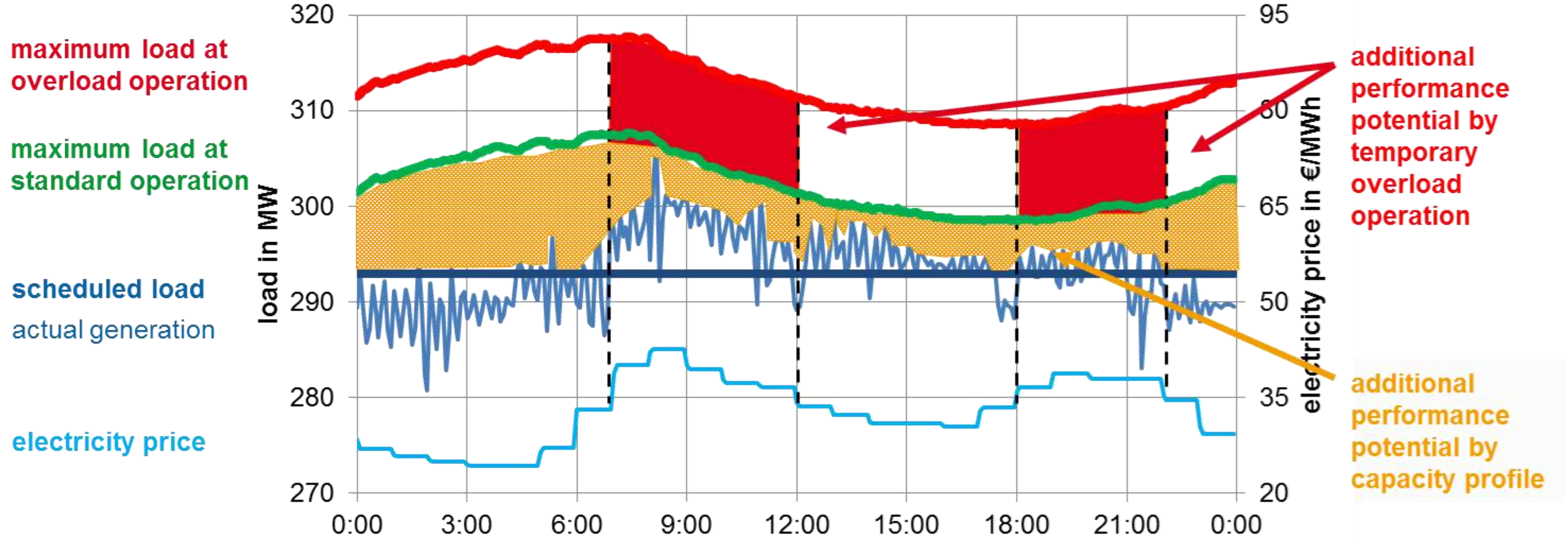

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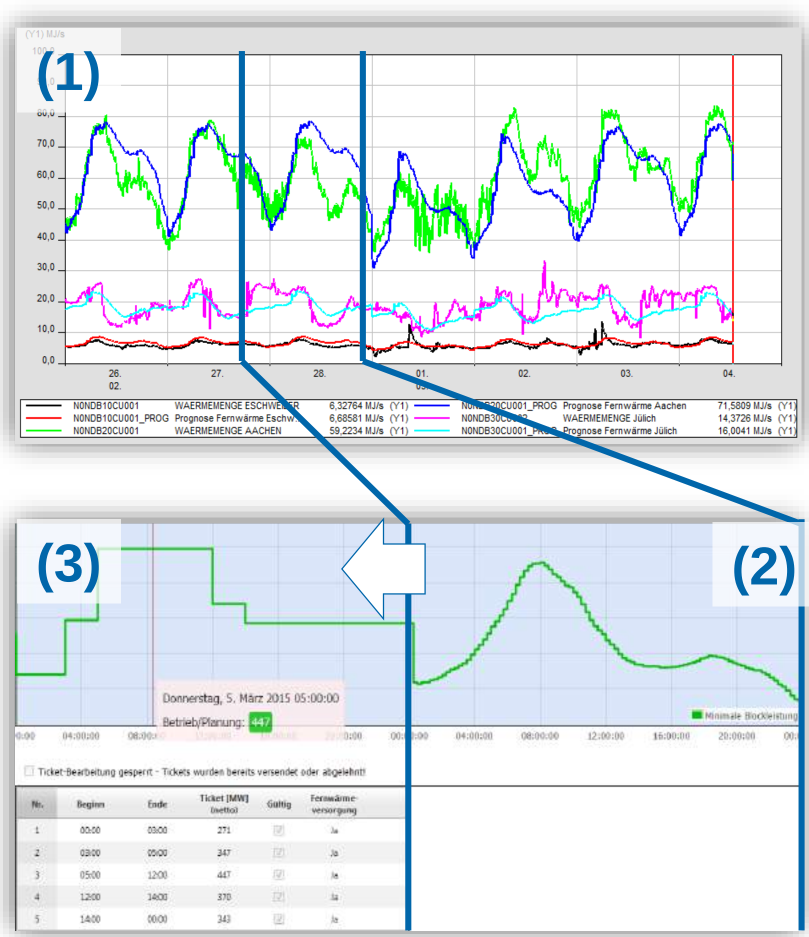
- Consideration of the current condition of the unit and external influences

Predicting dynamic minimal load

Example: Combined heat and power plant (CHP)



Big Data based prognosis tool

1. Forecast of heat demand of different consumers (must run plant)
2. Minimal load prognosis based on heat demand forecast
3. Processed information to be utilized by the dispatcher

→ BENEFITS

> **Minimize losses due to must run conditions**

> **Avoid start of backup heat supply unit by minimizing minimal load**

Fuel Flexibility in Power Plants

Quality Requirements on Coals

From the view of fuel purchaser and power plant operator

Fuel Purchaser	Power Plant Operator
• Low-price purchase • Undisturbed transport • Universal and low-priced coal input • Few restrictions relating to coal quality • By-products marketing	• Handling and storage • Milling and firing • Ignition stability, flame stability • Compliance with all limit values of emissions • Avoiding mid-term & long-term damages
→ **“Price Thinking”**	→ **“Costs-Thinking”**

Fuel Properties– complete analysis required

- > ***Proximate analysis***
  - – H2O, ash and volatile matter (VM)
- > ***Calorific value***
  - – Lower calorific value, higher calorific value
- > ***Elementary analysis***
  - – C, H, N, O, S, Cl, F
- > ***Ash analysis of macro-elements (XRF)***
  - – SiO_2, Al_2O_3, TiO_2, Fe_2O_3, CaO, MgO, K_2O, Na_2O, P_2O_5, SO_3
- > ***Ash fusion trajectory in oxidizing and reducing atmosphere***
  - – Initial deformation temperature (IDT)
  - – Softening temperature (ST)
  - – Hemispherical temperature (HT)
  - – Fluid temperature (FT)
- – ***Grindability (HGI, PMI)***

Coal Type: UN-EC	Coal Type: USA (ASTM)	Coal Type: Deutschland (DIN)			Moisture (ar %)	Heating Value (af kJ/kg)	Volatiles (daf %)
Peat	Peat	Torf					
					75	6,700	
Ortho-Lignite	Lignite	WEICHBRAUNKOHLE					
					35	16,500	
Meta-Lignite	Lignite	Mattbraunkohle		HARTKOHLE			
					25	19,000	
Subbitum. Coal	Sub-bituminous Coal	Glanzbraunkohle		HARTKOHLE			
					10	25,000	45
Bituminous Coal	High Volatile Bituminous Coal	Flammkohle	Steinkohle	HARTKOHLE			40
Bituminous Coal	High Volatile Bituminous Coal	Gasflammkohle	Steinkohle	HARTKOHLE			35
Bituminous Coal	High Volatile Bituminous Coal	Gaskohle	Steinkohle	HARTKOHLE		Kokskohle36,000	28
Bituminous Coal	Medium Vol. Bitumin. Coal	Fettkohle	Steinkohle	HARTKOHLE			19
Bituminous Coal	Low Vol. Bitumin. Coal	Eßkohle	Steinkohle	HARTKOHLE			14
Anthracite	Semi-Anthracite	Magerkohle	Steinkohle	HARTKOHLE	3	36,000	10
Anthracite	Anthracite	Anthrazit		HARTKOHLE			

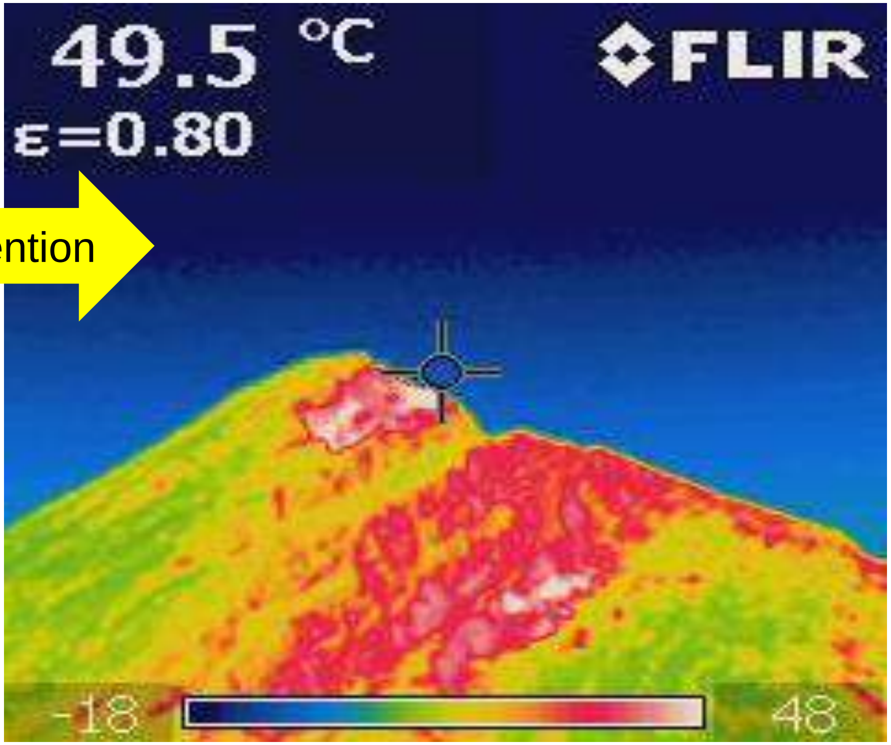
* ar = as received **af = ash free ***daf = dry and ash free

Quelle: BGR

→ **Complete analysis gives the whole picture of the combustion behaviour of a fuel**

Fuel Handling
Preventing self ignition and fire

Prevention

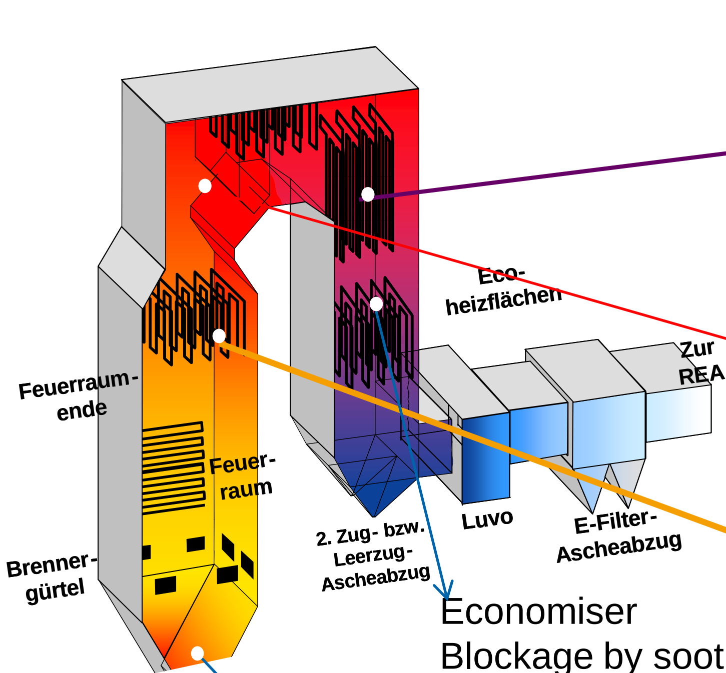


→ **RWE has installed Online Temperature Monitoring for all Stock Piles**

→ **Fuel Management System (FMS) controls detail storage and Coal Properties Data (incl. Ash Composition)**

Influence of Coal Impurities

Fouling and Slagging is a major Issue (Ash Impurities)



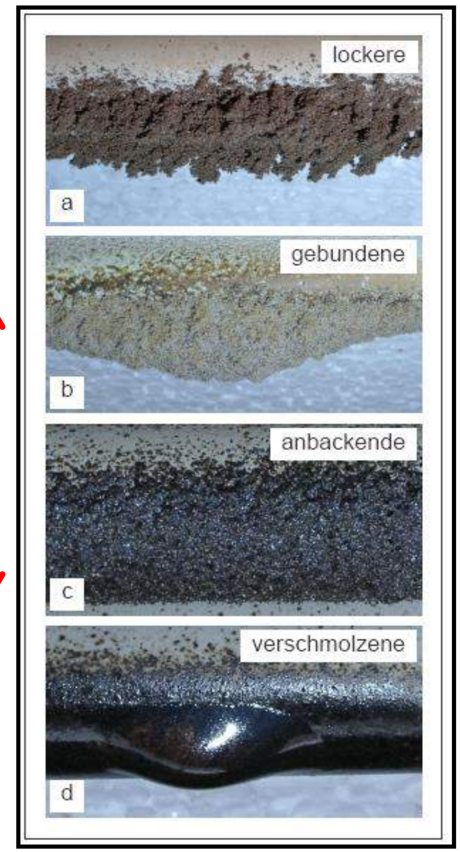
Economiser
Blockage by soot blowing

Ash Extraction
blockage

Fouling Zone

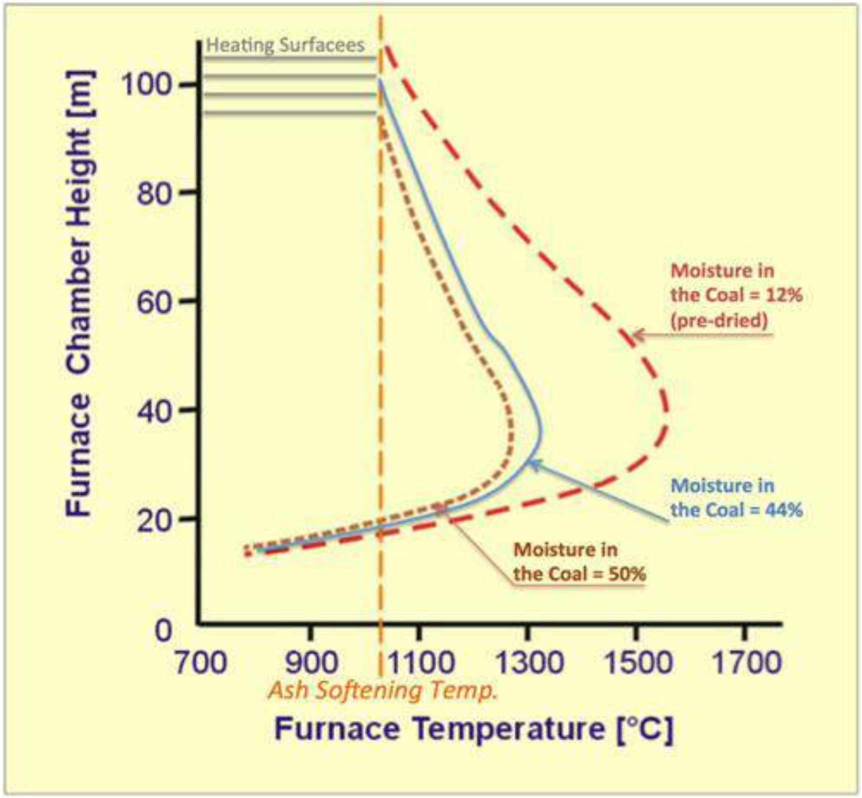
Sintering Zone

Slagging Zone



Influence on the Combustion

Furnace Temperature Distribution



→ **The Furnace Exit Gas Temperature (FEGT) must be kept bellow the Ash Softening Temperature**

Retrofit based of CFD Calculations

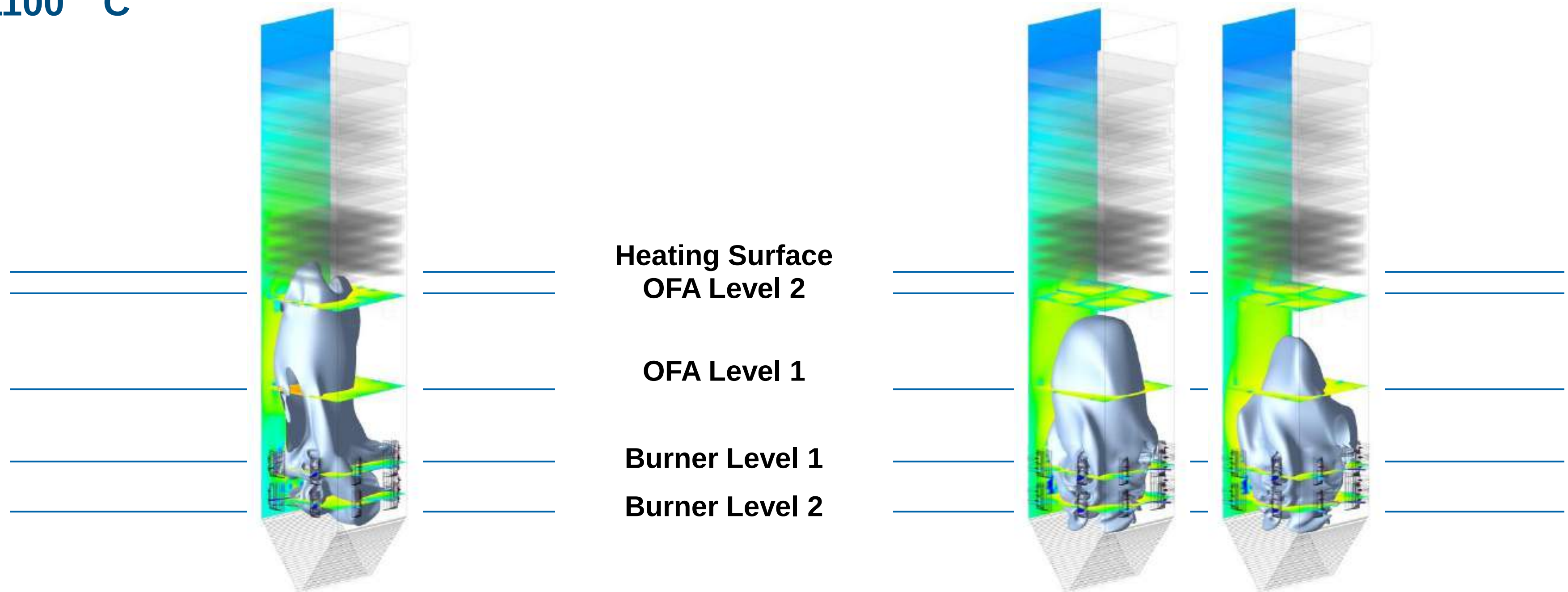
Example: Retrofit of a 600 MW_e Lignite Unit

Before retrofit

FEGT > Ash Softening Point = 1100° C

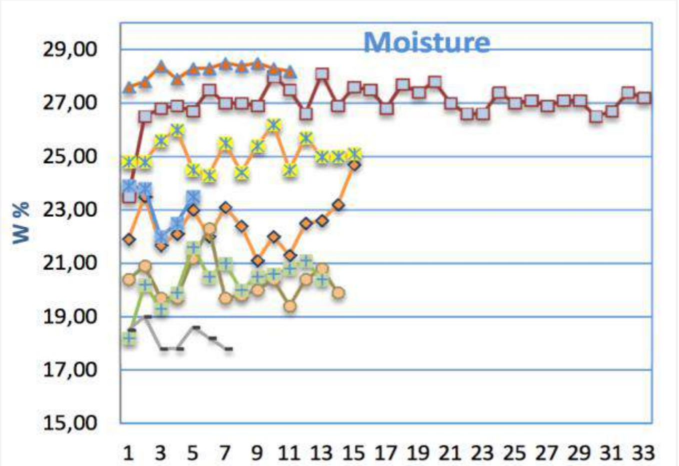
After Burner retrofit

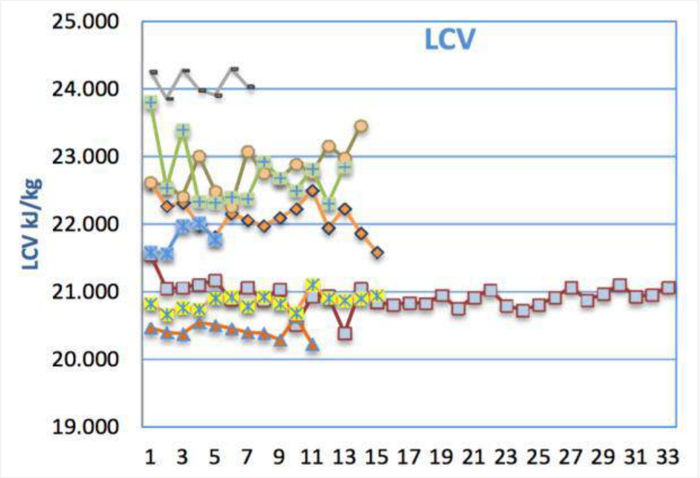
FEGT << Ash Softening Point = 1100° C

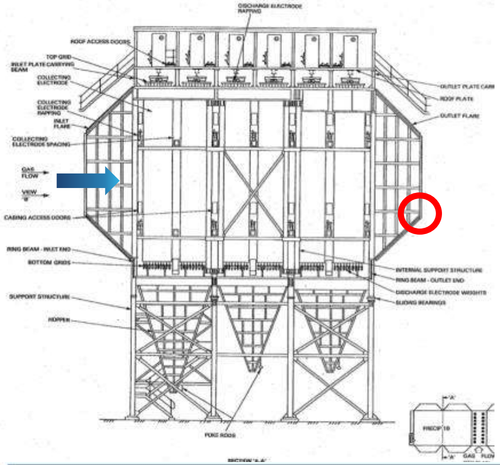


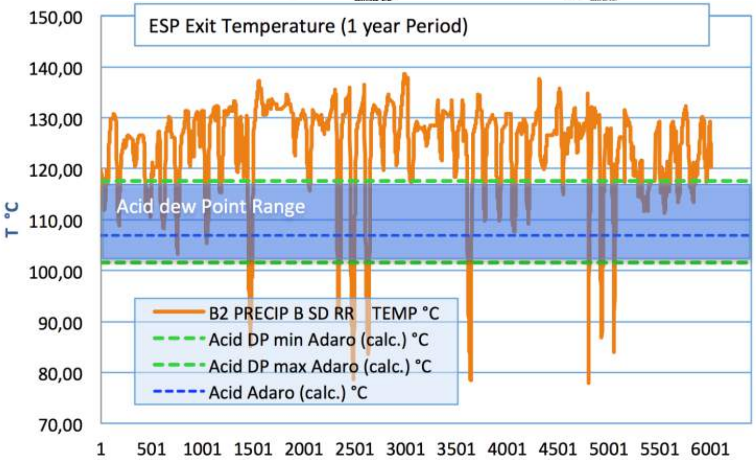
Influence on Power Plant Components

Example: ESP Corrosion in a 700 MW_e Hard Coal Plant, South China







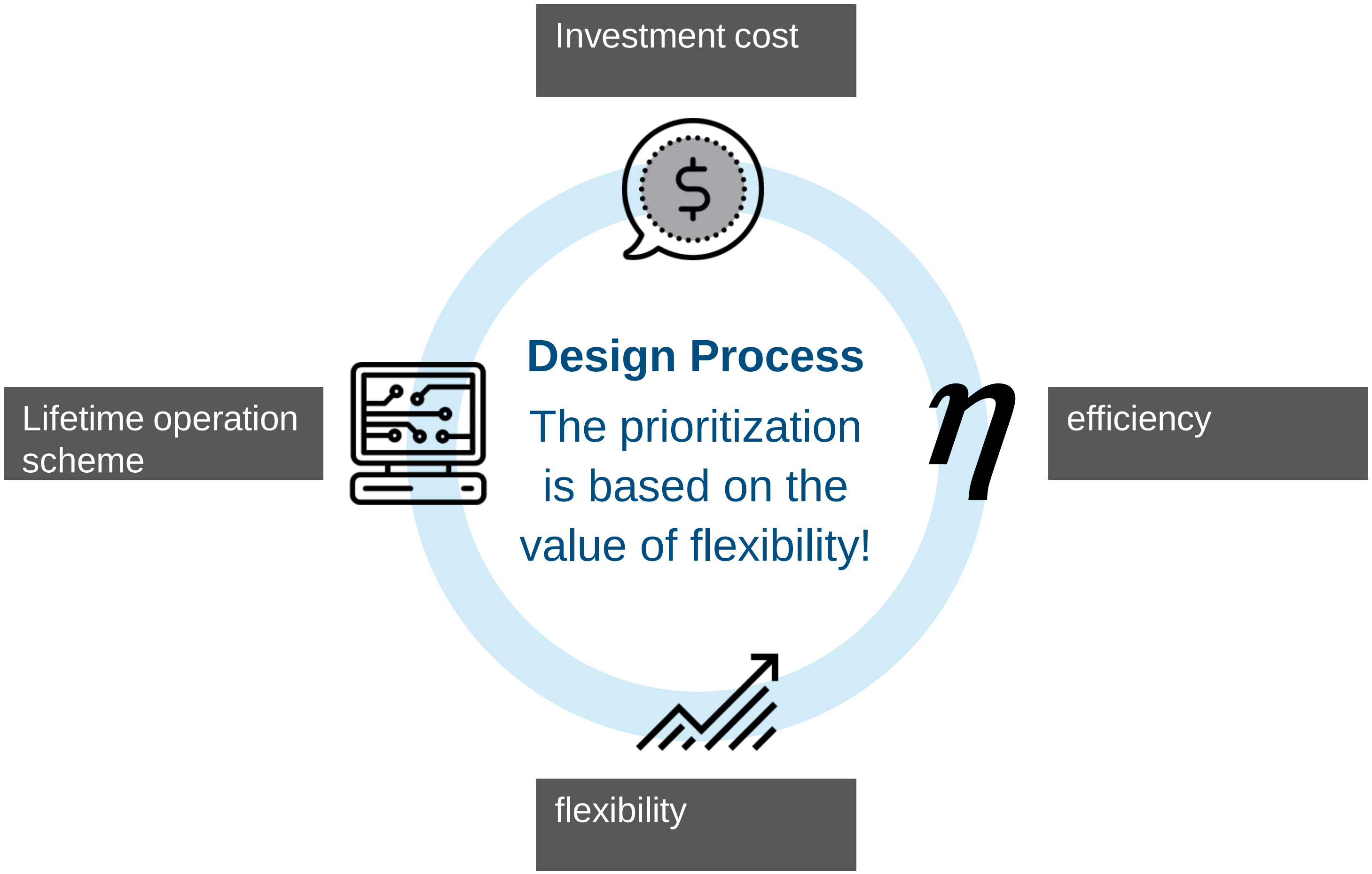


→ **Due to combustion of particular imported coals the flue gas temp. is critically close to the acid dew point and in some periods bellow it**

R&D activities related to flexibility increase

> - **New materials** for thin-walled flexible components
> - **New measurement methods** and IT based monitoring to assess the life consumption to avoid damage of highly stressed components
> - **Big Data** for predictive maintenance, monitoring components and forecasting of market data and power plant operation
> - **Temporary electricity storage**, when the produced electricity from conventional power plants is not required
> - **New combustion systems** for lignite based dry lignite in order to increase the flexibility
> - **Fuel Flexibility** by optimization of coal online analysis and coal management system

Future design and optimization priorities



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