Investigations of Cost-Effective ESP-Upgrade Measures for a Life-Time-Extension in a Grid-Stability Operating Scenario

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MICHAEL FRANK

- First 13 years with OEMs in Air Pollution Control (Walther, Lurgi, Rothemühle)
  First practical experience in South Africa @ Kendal Power Station in 1990
- Change to an Owner & Operator/Utility in 2003…
  4 years Plant Manager (2.200 MW, 6 hard-coal fired units and district heating peaker plants)
- Various MD/CEO positions in engineering, industrial services and sales/business development
- Ex-Executive Board Member vgbe energy and VAIS
- Since 2023: President International Society for Electrostatic Precipitation – ISESP
- Since 2024
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A case study…

1. Starting Point
2. Analysis
3. Development of solutions
4. Potential check
5. Conclusion

Starting Point

56 years of service and yet no end – fossil generation indispensable for securing electricity supply supporting transition to a carbon free future.

7 more years to back up grid system.

Environmental compliance guaranteed?

Coal exit is law. Despite security of supply now being top of agenda, it might still be even accelerated…

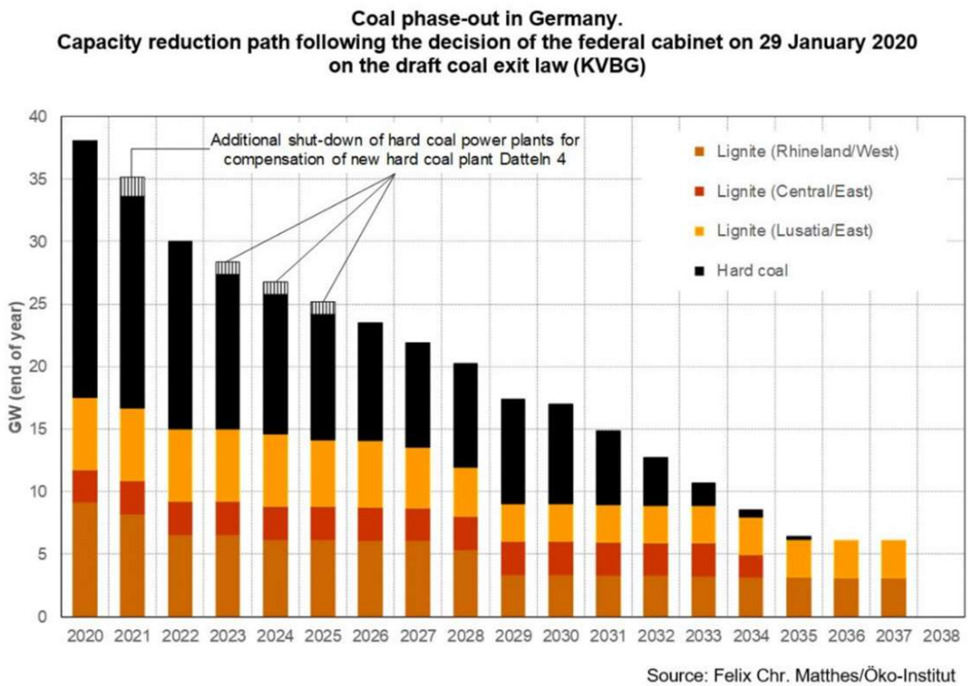


Photo: Ende Gelände

- ➢ **Operators have already planned for shut-down of plants**
- ➢ **Ad-hoc LTE's are massive challenge for maintenance and ops teams**

Even before Coal Exit, situation of the electrostatic precipitators in (German) power plants was not ideal…

- Electrostatic precipitators were the first highly efficient environmental protection systems and are therefore usually among the oldest components in the power plant
- Original design for ash from domestic fuels or defined fuel basket with emission limit values according to legislation at the time of installation
- Retrofitting of FGDs usually compensated for reduced performance due to ageing and new imported fuels
- Even newer plants are now operating with different fuels than design fuels due to volatile markets
- Load regimes changed significantly from base load to peak/fluctuating

➢ **Existing plants are mostly operated far beyond their original design parameters and have to comply with much lower ELV's**

ESP-focus: Specific requirements for the grid reserve

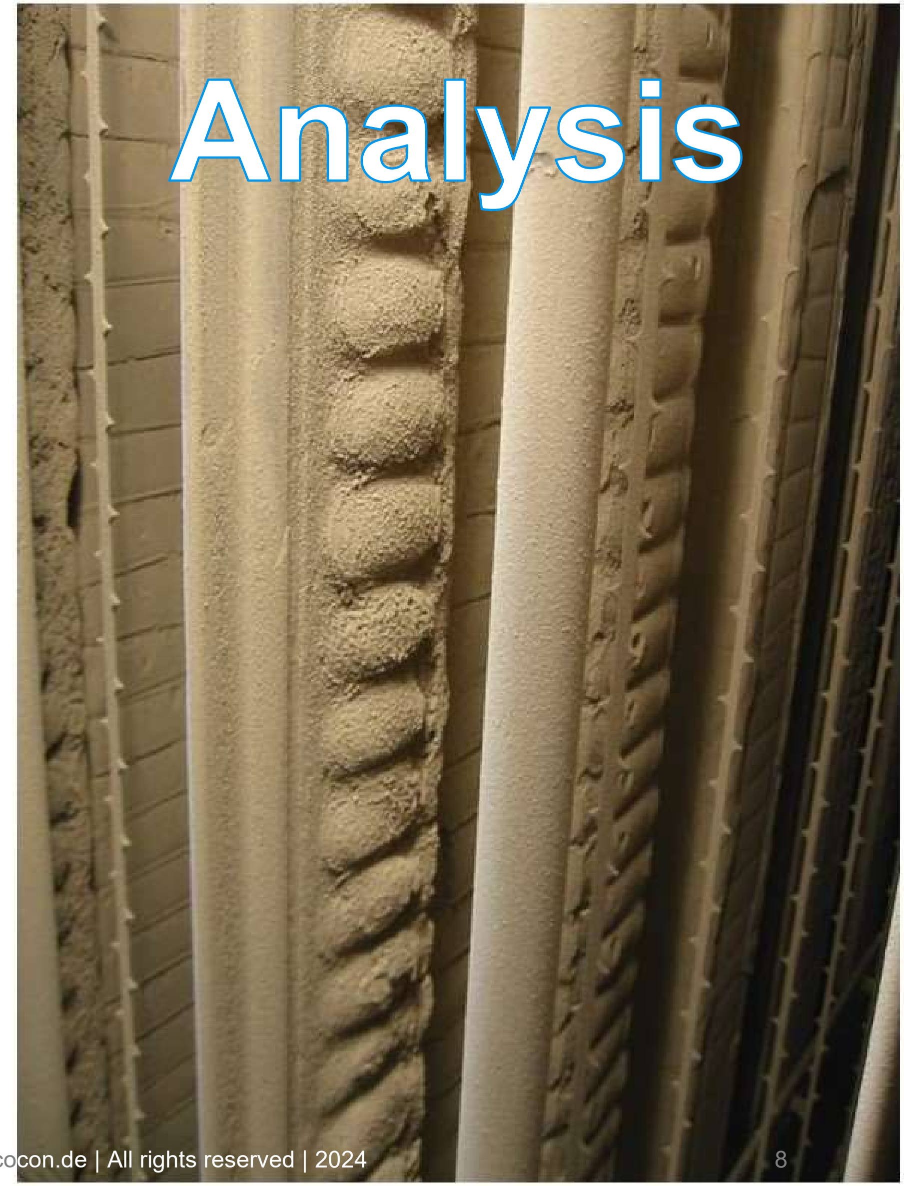
1. **Only 100 – 150 operating hours per year expected**.
   Probably one mandatory start-up per month to maintain staff competence and skills…
2. **Environmental compliance from start-up**.
   Annual average emission limit 8mg/Nm^3. Due to the low absolute number of operating hours, little to no chance to compensate higher values especially since daily average is 10mg/m^3.
3. **No continuous load expected**
   Load dictated by grid requirements, i.e. compensation of fluctuations from renewables. Boiler plant will most probably not operate in a steady state condition

- **ESP needs maximum resilience against fluctuations**
- **Margins towards emission limit needs to be increased by enhancing controllability and other optimization measures**

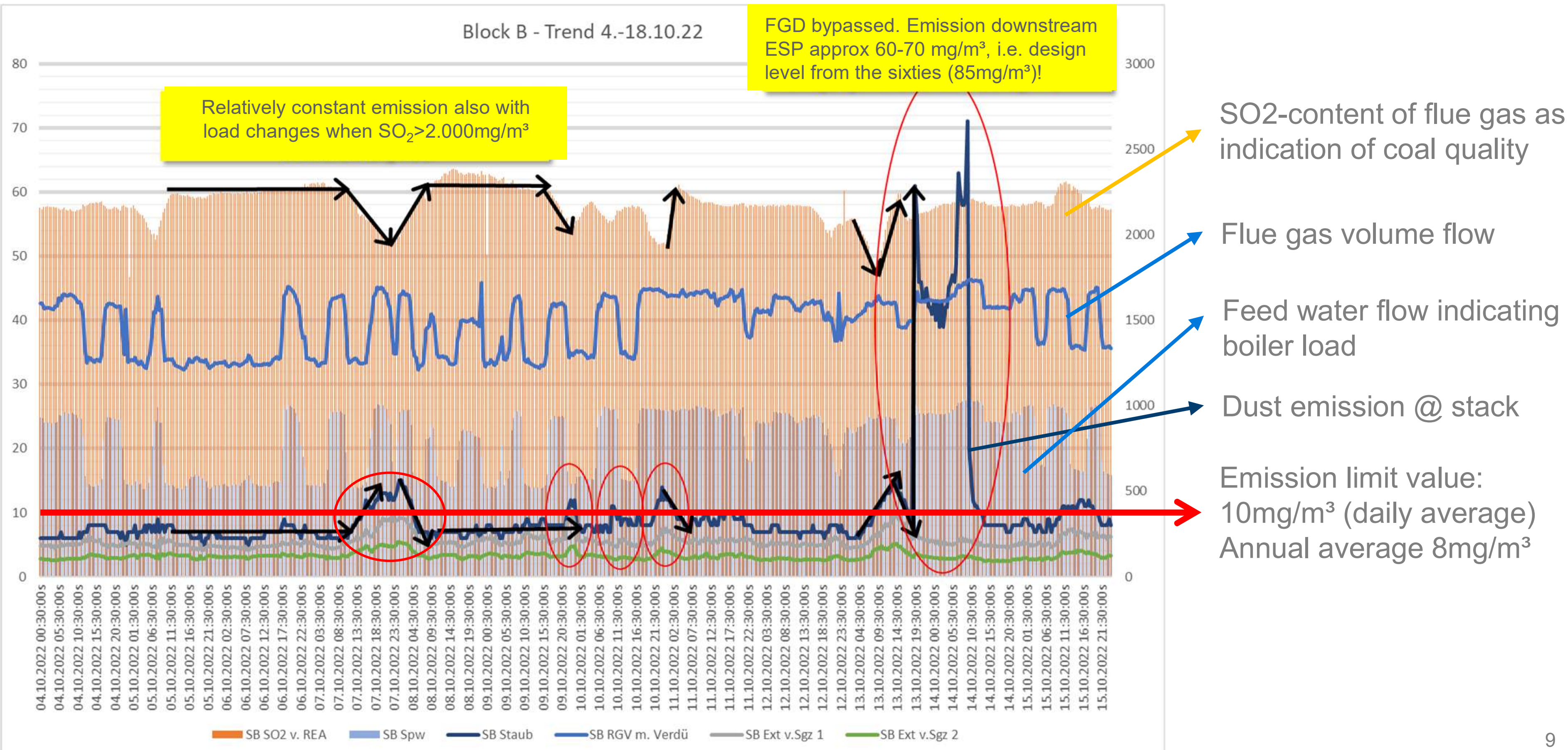
3P-360°: A comprehensive analysis…

Process Periphery Precipitator

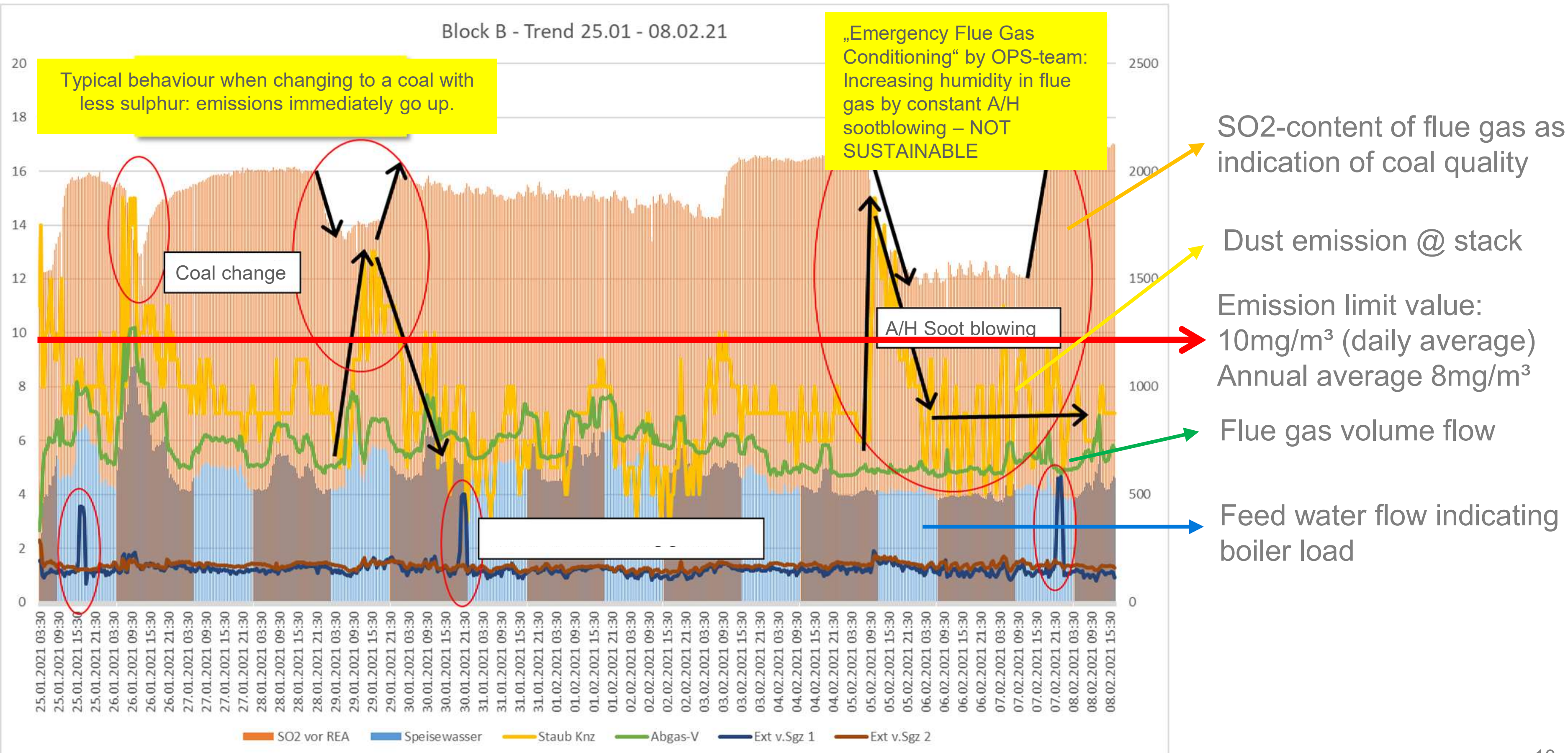
1. **Process**
   1. Boiler operations & load regime
   2. Analysis of Test & Measurement data
   3. Fuel supply & quality
   4. Conditioning systems
   5. „Operational habits“
2. **Periphery**
   1. Ash extraction & -transport
   2. Boiler ash treatment
   3. Ductwork, air heaters and ID-fans
3. **Precipitator**
   1. Inspection (Casing, Electrode systems, Rapping systems, Flow internals, etc.)
   2. Configuration (Aspect ratio, Bus section size, etc.)
   3. Equipment (T/R-sets, controllers, heaters, etc.)



Analysis of operating regime indicates strong coal quality impact and sensivity to load changes. FGD indispensable for dust emission.

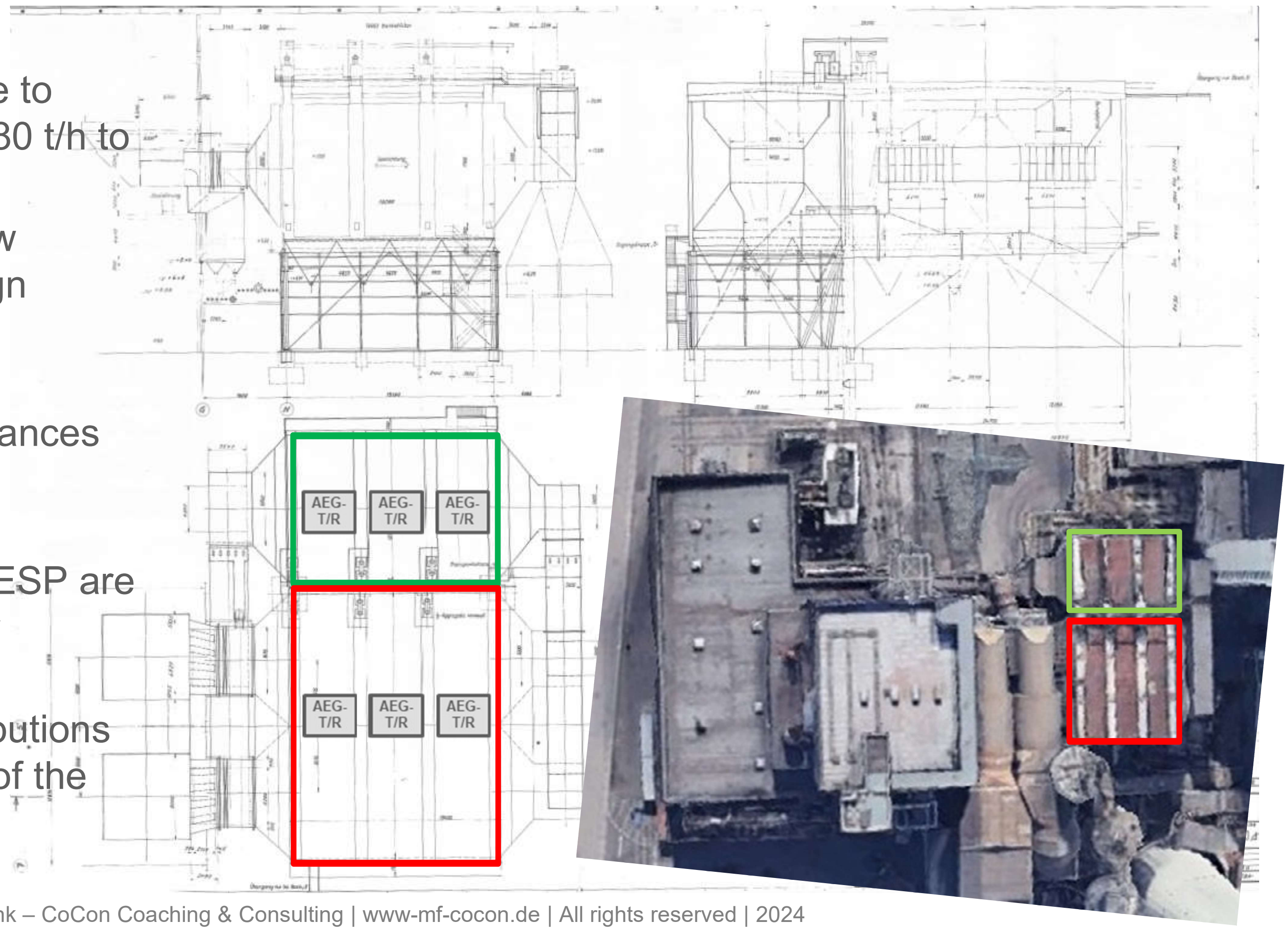


Ops-Team is battling uphill: changing coal stock and continuous A/H-sootblowing only emergency solutions – not sustainable!



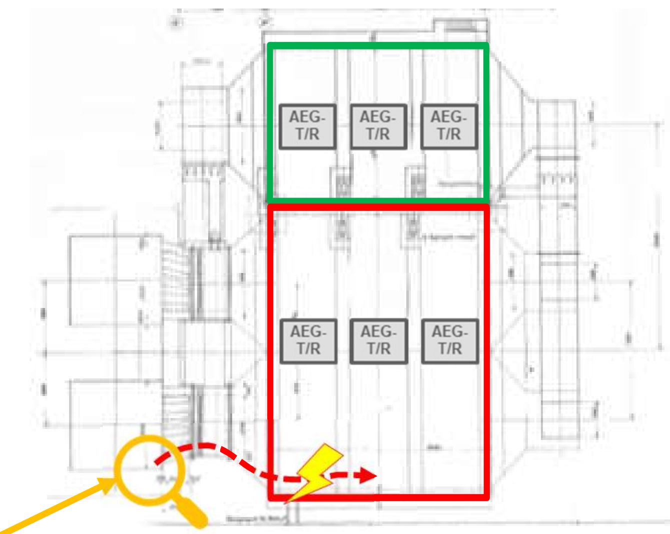
The ESP configuration is part of the problem: addition of slipstream ESP and relatively large electrical bus sections of the main ESP…

- Slipstream ESP added later due to increase of boiler load from 1.080 t/h to 1.200 t/h
- Flow test: Actual split of gas flow significantly deviates from design
  Design MF: 64% SSF: 36%
  Flow Test: MF: 71% SSF: 29%
- ESP inlets see significant imbalances of key process parameters (temperature, ash load, flow)
- Electrical bus sections of main ESP are very large compared to industry practise
- Any disturbances and maldistributions have large impact on one third of the collecting area of the main ESP

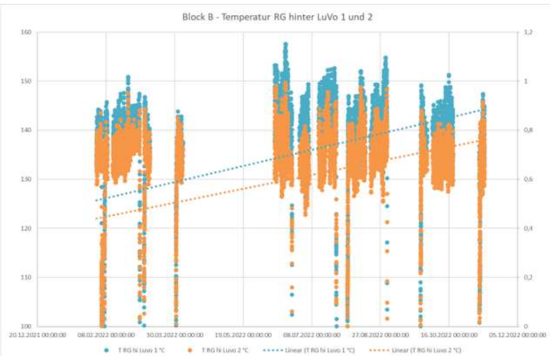


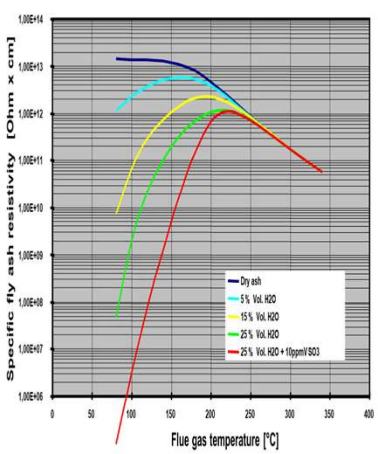
Small details may make a huge difference: Boiler ash (2nd pass) injection upstream ESP

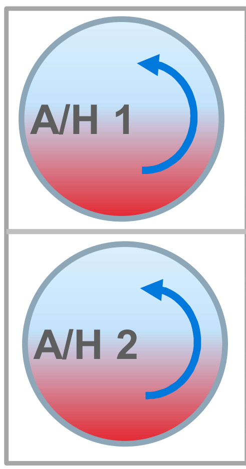
- Boiler ash injection from hopper under 2nd pass ends upstream ESP under A/H
- Gas/ash-flow significantly colder and highly dust-laden compared to flue gas stream
- No internal distribution device existent, only wear protection!!
- Injected stream is likely to be conserved up to ESP inlet field due to different temperature and excellent guide vanes
- Ash will be “injected” into inlet field of Main ESP and likely cause major flashovers

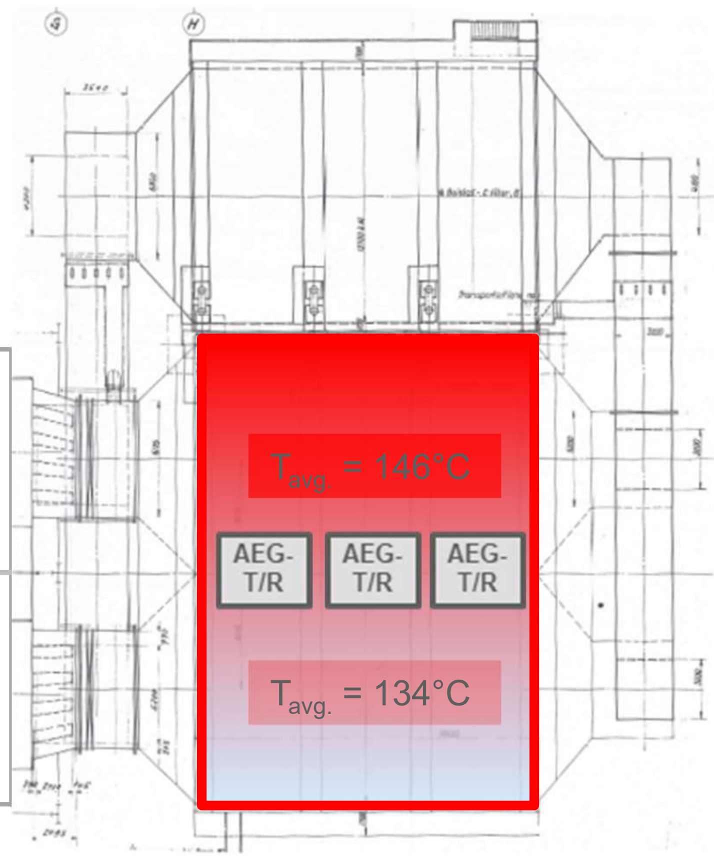


Temperature distribution massively skewed due to A/H condition – strong impact on ESP performance







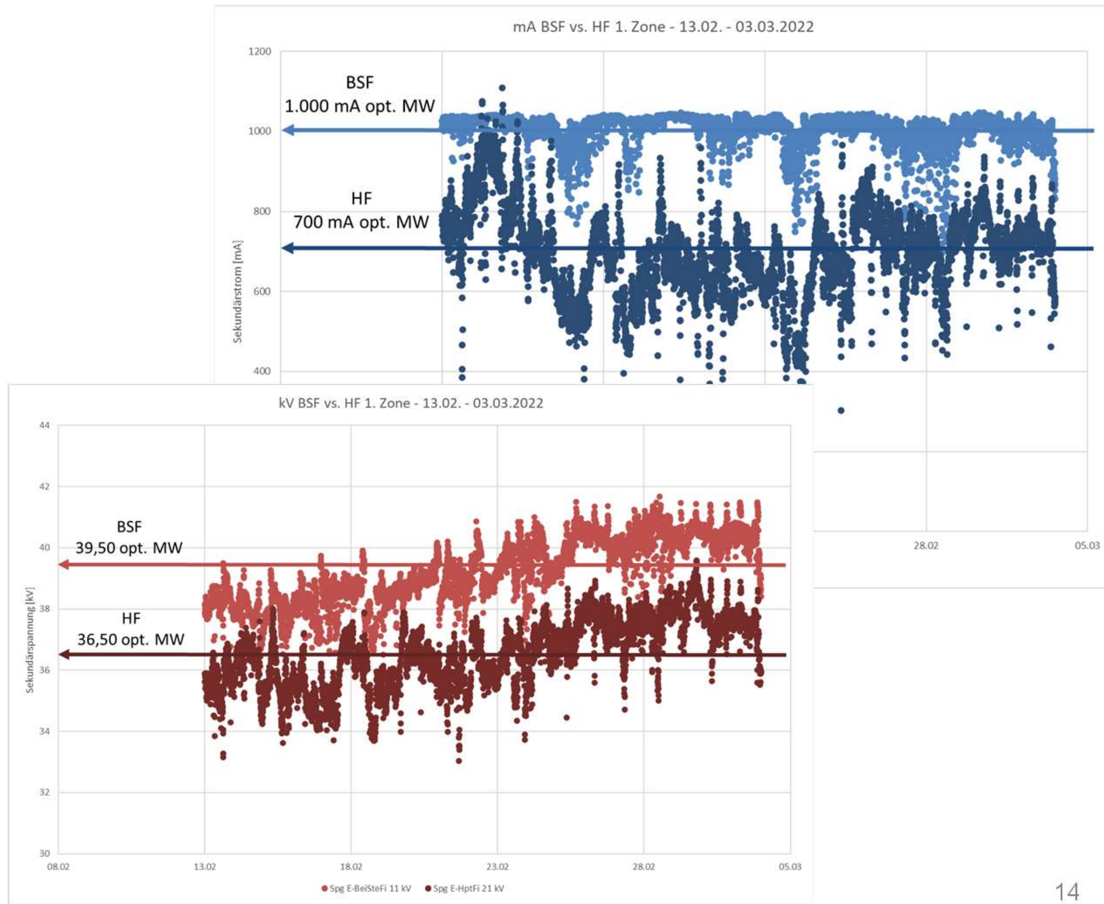


- Flue gas temperature significantly different between A/H 1 and 2
- Strong influence on ash resistivity and flash over threshold
- Main ESP's operating conditions dictated by weakest point in whole bus section

➢ **Process controllability in current plant configuration very much limited**

Inlet fields of MF and SSF with significantly different power consumption…

- The different electrical operating values indicate different dust concentrations in the inlet of Main ESP and Slipstream ESP
- Larger fluctuation range of the secondary current and lower voltage level indicate higher dust loading in the Main ESP
- A flexible and fast control capability of the ESP controllers is critical for good dust separation
- Large electrical fields also very disadvantageous with high flashover frequency



Upgrade-Measures: Improvement of emissions starts upstream of the ESP...

1. Boiler Process & Operations Optimization
2. Mechanical Repairwork
3. Gas Flow Distribution
   (upstream ESP & internal)
4. ESP-Controller & HV-Supply Upgrade
5. Flue Gas Conditioning
6. New Internals / ESP-Enlargement
7. ESP-to-Fabric-Filter Conversion
8. Hybrid Filters & New Technologies

Operations, Maintenance and Fuel Purchasing need to support basic measures (step 1 & 2)…

1. **Coal is not coal…**
   Because of the obvious impact of sulphur (and other components) in coal, a defined coal blend should be purchased. Benefits from being able to operate will by far outweigh procurement savings…
2. **Start-up and Shut-down operation**
   Specific procedures regarding ESP rapping and ash transport need to be adopted to enable longer standby periods without ash deposits and clogging.
3. **Mechanical Repairwork**
   It goes without saying (really?): the mechanical condition and alignment of electrodes needs to be absolutely in order!

Analysis of ESP and inlet duct configuration reveals potential for effective upgrades (step 3 & 4)…

1. **Increasing number of bus-sections**
   Separating electrical bus sections results in better resilience against process imbalances and controllability of ESP
2. **New HV technologies in the first field** New T/R
   3-phase or SMPS HV units in the first field can again significantly increase the power input into the field and thus significantly improve the separation.
3. **New T/R-sets for SF and fields 2 and 3 of MF** New T/R
4. **New voltage controllers** µP
   Better and faster response and control under fluctuating conditions
5. **Flow distribution/balance**
   CFD-Analysis and corresponding flow correction/mixing devices bring back volume flow to design values

Upgrade-Measures: Improvement of emissions starts upstream of the ESP...

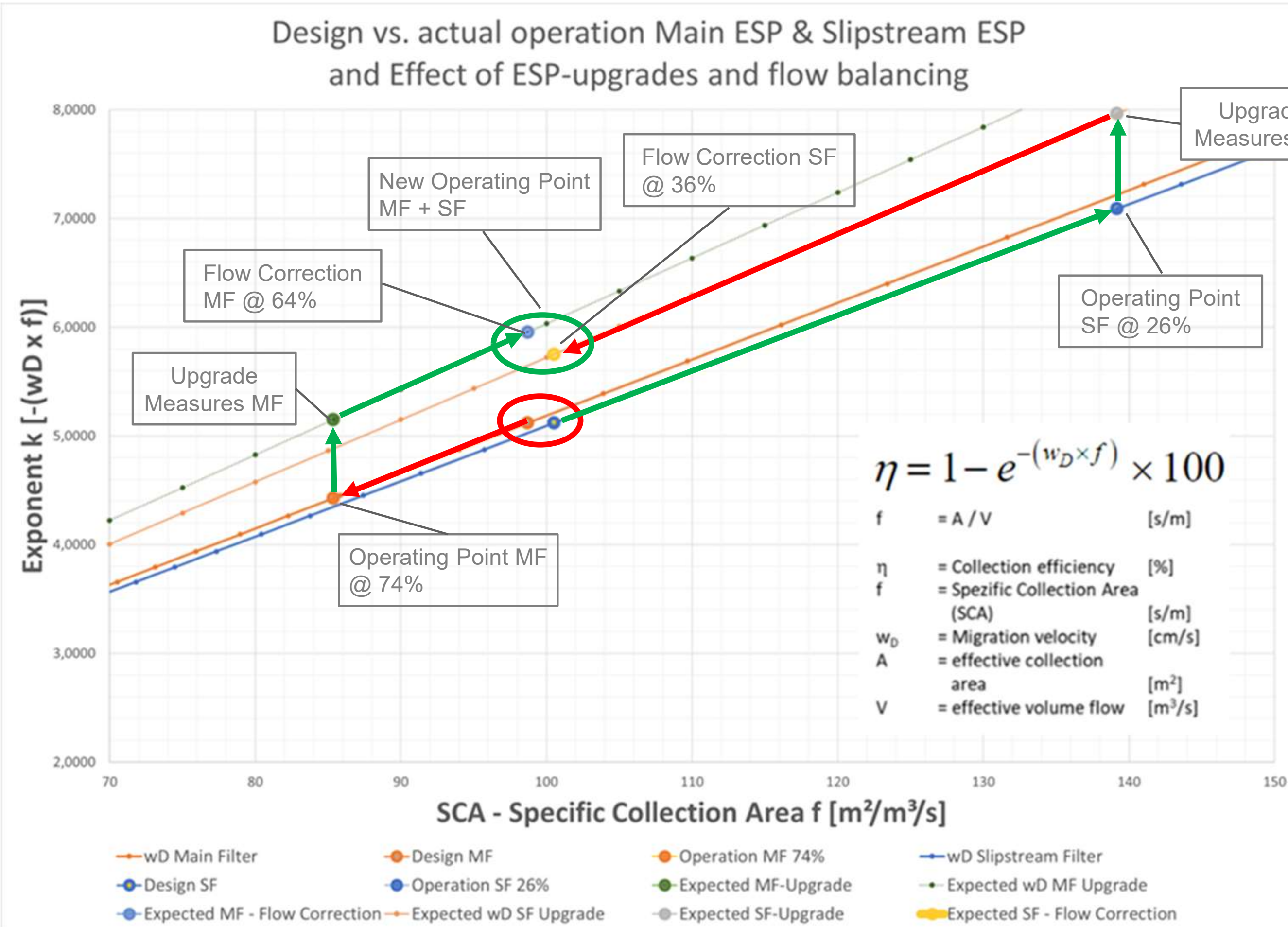
- ✓ 1. Boiler Process & Operations Optimization
- ✓ 2. Mechanical Repairwork
- ✓ 3. Gas Flow Distribution (upstream ESP & internal)
- ✓ 4. ESP-Controller & HV-Supply Upgrade
- ✗ 5. Flue Gas Conditioning
- ✗ 6. New Internals / ESP-Enlargement
- ✗ 7. ESP-to-Fabric-Filter Conversion
- ✗ 8. Hybrid Filters & New Technologies

Potential Check

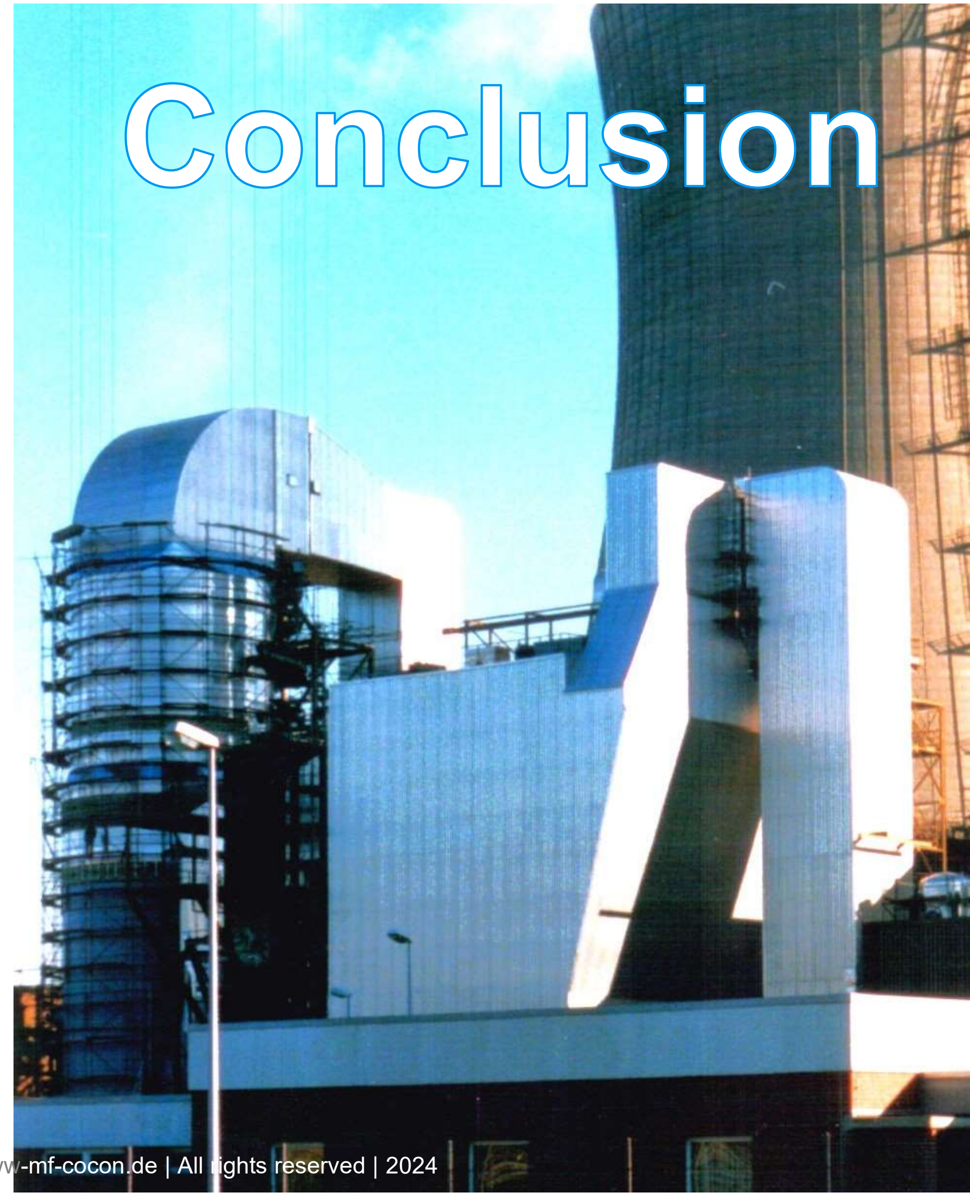
Mission accomplished?

All measures selected expected to reinstate sufficient operational emission margin to absorb most fluctuations experienced so far…

- Original design 1967 85mg/m³ w/o downstream FGD system
- FGD dust collection estimated at 90% (and validated from experience)
- ESP modelling based on T&M data so very good process fit of reference. No further corrections required.
- Combination of improved ESP performance compensating adverse ops conditions plus FGD collection is sufficient for required emission margin
- Any volume flow balance correction will further contribute to a lower emission

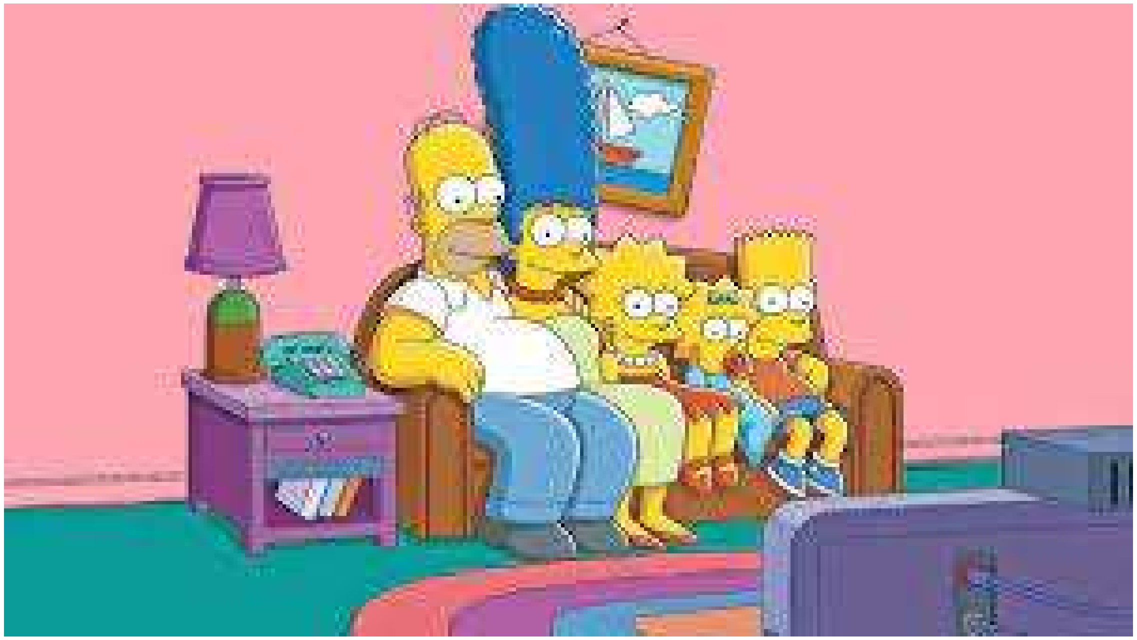


Expected Emissions		HF		BSF	
		Upgrade	PlusFlow	Upgrade	PlusFlow
V	m³/s	397	343	142	197
A	m²/m³/s	33.869	33.869	19.793	19.793
SCA	m²/m³/s	85	99	139	101
w_D	cm/s	6,03	6,03	5,72	5,72
η_{ESP}	%	99,42	99,74	99,97	99,68
S_e	g/m³	8	8	8	8
S_a	mg/m³	46	21	3	25
Avg Upgrade	mg/m³	**35**			
Avg Flow	mg/m³	**22**			
η_{FGD}	%	90%			
S_a Stack U	mg/m³	**3**			
S_a Stack F	mg/m132	**2**			



- Vintage ESP-plants, especially those which haven‘t seen much upgrades can have significant potential for emission improvements
- It takes thorough analysis and a look beyond the precipitator inlet and outlet: biggest potential may be in the periphery or in the process
- It‘s a joint effort: Operations, Maintenance, Fuel Management as well as OEM‘s have their share to successfully reach a sustainable outcome
- No plant is the same – but the methodology is universal:

Process Periphery Precipitator



Stay tuned…

Thank You!

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