Flexible Operation of Coal Fired Power Stations

Marinus Tabak

Agenda

1. Introduction of RWE
2. The German *Energiewende* and the need for flexibility
3. What is power station flexibility
4. Conclusion

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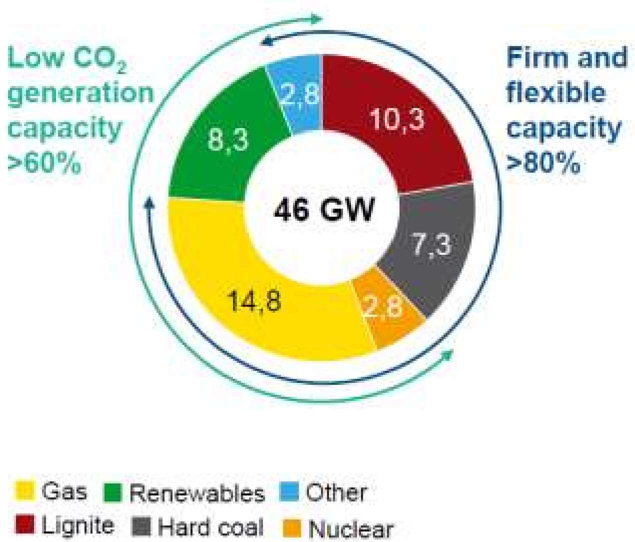
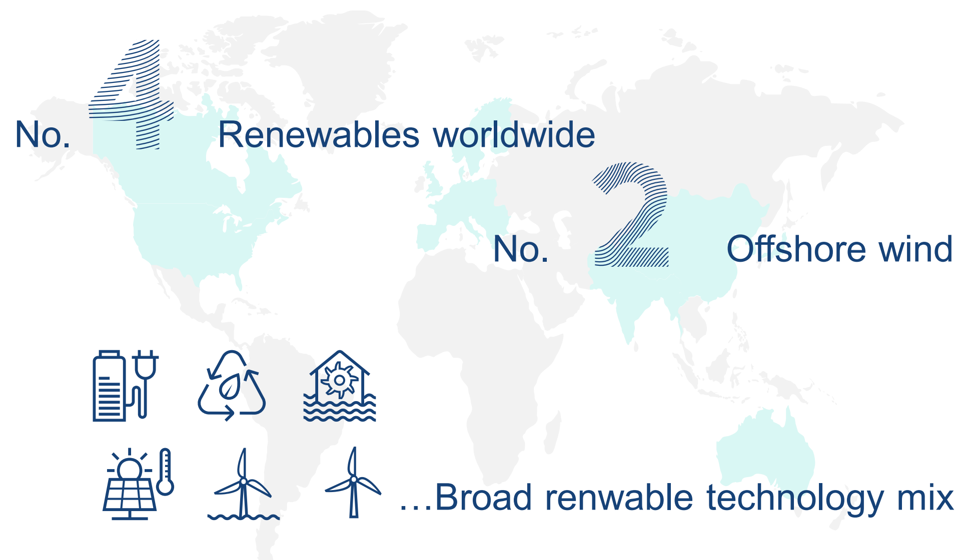
The New RWE: Our energy for a sustainable life

Clear goal: CO_2 neutral in 2040 and -70% CO_2 in 2030

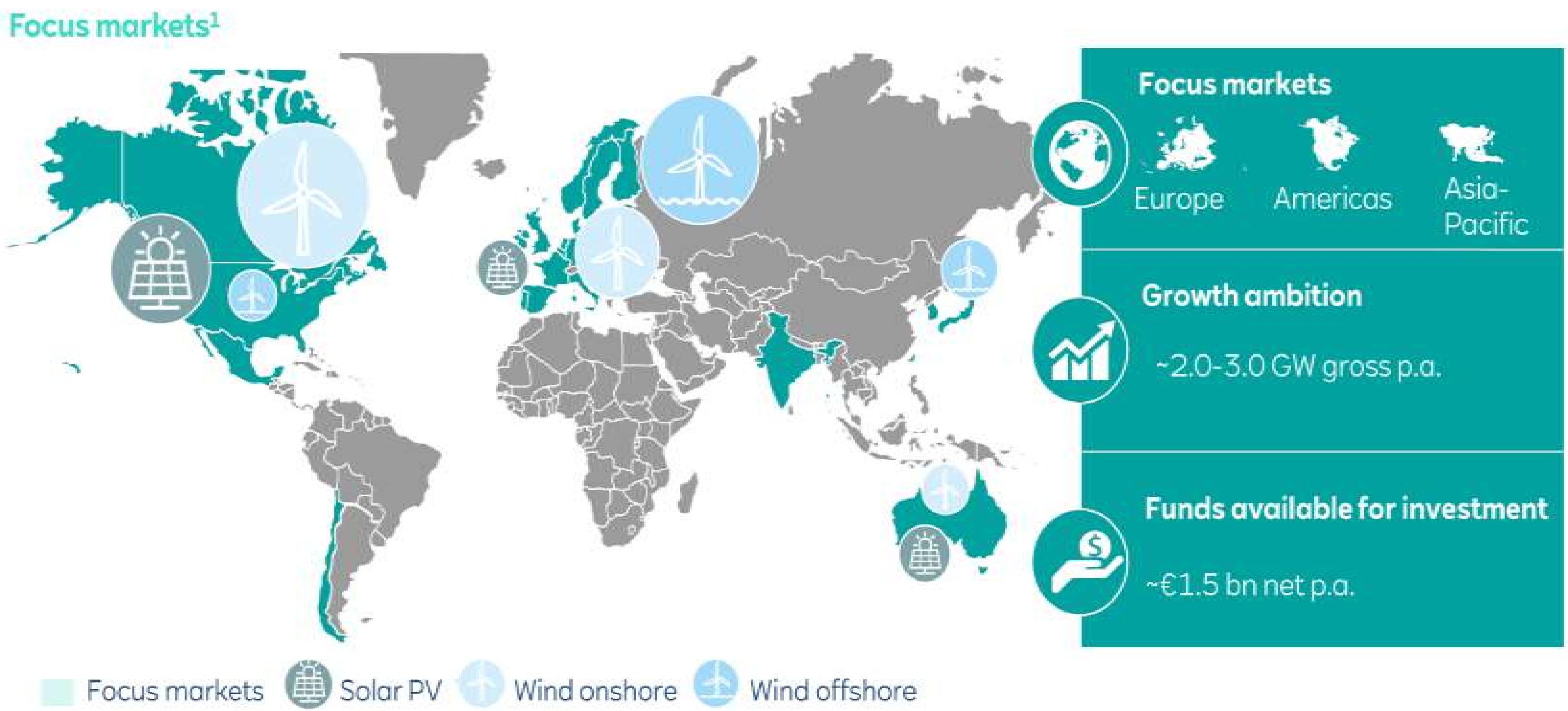
- We are the second largest electricity producer in Europe with #1 position in Germany and the Netherlands, and #2 in the United Kingdom.
- We consistently reduce our CO2 emissions in order to be **carbon neutral by 2040**.





RWE has a large global presence in renewables

Growth ambition 2 – 3 GW per year with a project pipeline >18GW



[1] Size of bubble indicates current approximate growth ambitions in GW.

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Energiewende: analysis of the German model

What can we learn from a frontrunner

80 million inhabitants, total energy consumption 13.550 PJ of which 13% renewable

Electricity consumption
40.000 MW (night)
80.000 MW (day)

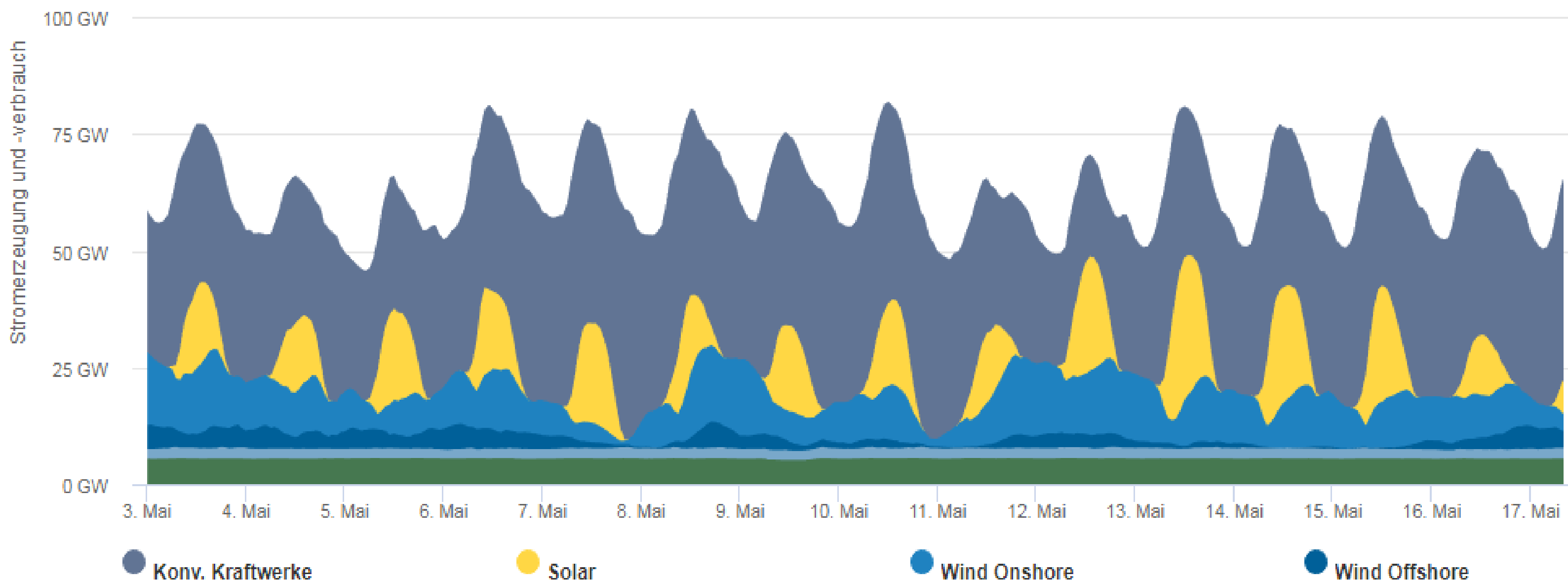
56.000 MW installed capacity wind

44.000 MW installed capacity solar

90.000 MW installed capacity conventional, however: nuclear phase out: +/- 9,5 GW and +/- 6 GW old capacity will be phased out.

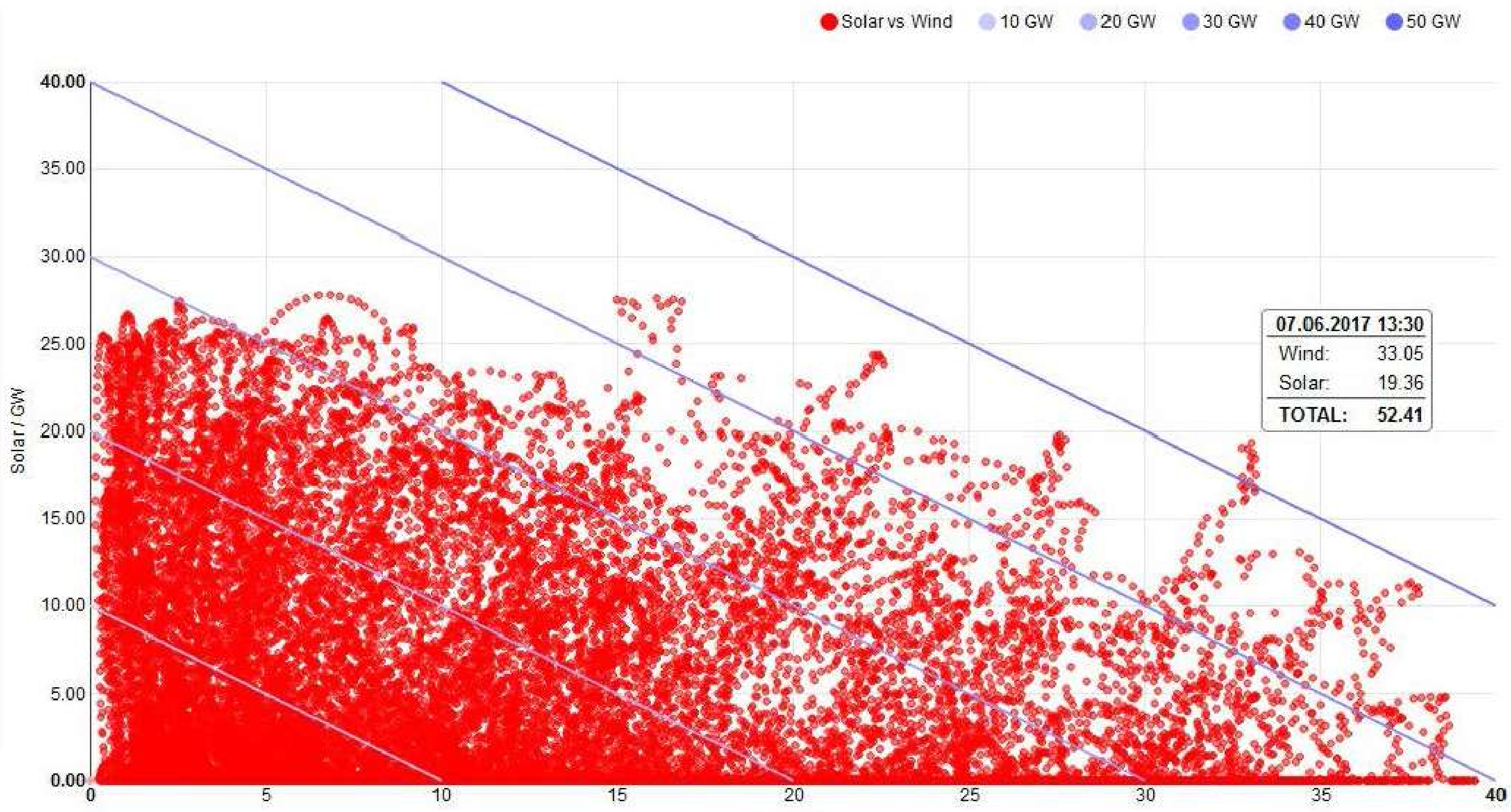
Electricity production in Germany in an average week

We had some excellent sunny days, wind was average, conventional steady



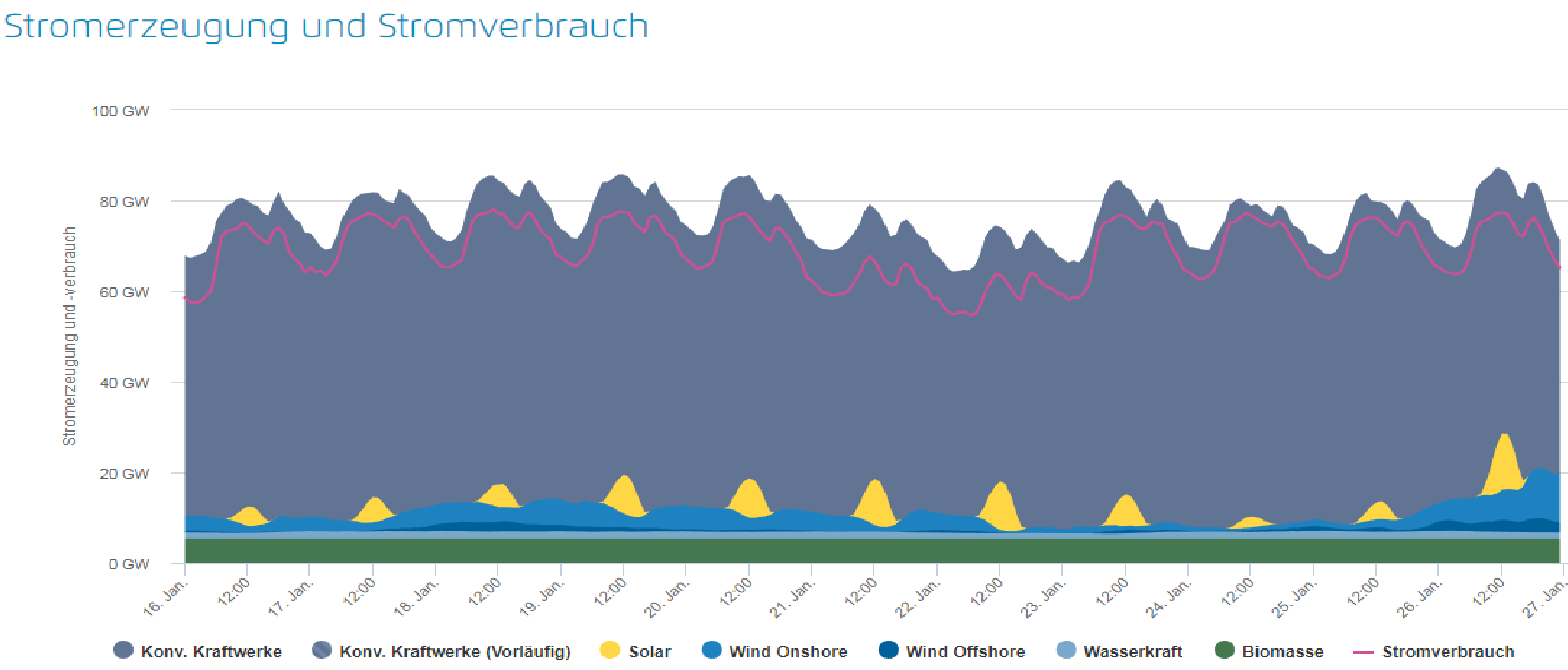
All the 15 min. data points of the year 2017 of wind + solar

The peak was 52.410 MW production, but halve of the data points are below 20.000 MW



In the winter time we see days of no sun and wind

Longest period without sun and wind is about two weeks



Calculation: how many batteries do you need?

Variables: +/- 60.000MW for 14 days, capacity of 1 tesla power wall 6,4 kWh @ € 3.000

14 days x 24 hour = 336 hour
60.000MW x 336 = 20.160.000 MWh
20.160.000 x 1000 = 20.160.000.000 kWh

20.160.000.000 / 6,4 kWh = 3,15 billion power walls

Capital needed: 9.450 billion euro

Gross domestic product Germany: 3.500 billion euro

The main challenge is to store electricity, we need to use all options, batteries, flexible CO2 neutral power stations, hydro, hydrogen etc.

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What is power station flexibility?

Technical Design

Operating window of the power station, ramp up/down, material abilities, boiler design, start-up sequence etc.

Technology

Automation of the power station, flexibility tools like heat storage, batteries, hydrogen etc.

Fuel Flexibility

Ability to run on diverse blend and alternative fuels like biomass, waste etc.

Maintenance strategy

Different load regimes require different maintenance strategies – increased start-stop or load flexibility requires different maintenance.

Organisational set-up

Depending on the operating mode you have different organisational models that suit the situation best

Flexibility Products

There are different flexibility products like balancing, black-start, reactive power, frequency control

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Due to the set-up of the electricity market, we see a demand for a wide variability of flex products that can be commercialised

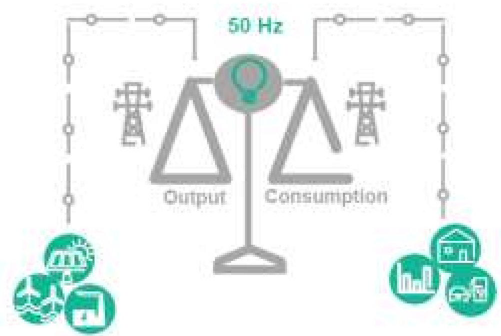
Generation | **Trading** | **Transmission** | **Distribution** | **Retail/end user supply**

The balancing market:

- A market operated by Transmission Grid Operators (TSOs) to maintain the power/frequency balance
- It is needed to ensure a continuous and stable frequency in the short term (e.g. when unexpected incidents occur - power plant breakdown)

Ancillary services:

- Necessary tools / products which TSOs contract from generators in order to maintain system stability and security



System products

Reactive power (voltage support) provides the important function of voltage regulation

Constraint Management

Countertrading – grid operators deal on exchange or OTC (Continental)

(Regulated) Redispatch – ramp-down or ramp-up power stations to relieve power flows from congested grid lines

Maintains healthy grid quality

Energy products

Frequency Control & Reserves – to maintain system frequency at 50Hz ± 1% and to provide additional energy when needed

- UCTE / Germany: primary, secondary, tertiary and time control levels (FCR, aFRR/mFRR, RR)
- UK: frequency response (FFR, MFR, EFR) and reserve (Fast Reserve, STOR, BM start up)

Maintains energy balance

Security products / emergency assistance

Blackstart ability to restart a grid following a blackout

Intertrips – automatically disconnect a generator

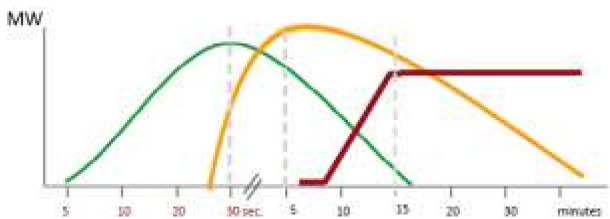
SO-SO trading (system operator to system operator trades) – determines the direction of electricity flow

Dedicated to restarting the grid

Overview of the several reserve products and their timescales

	Primary reserve	Secondary reserve	Tertiary reserve
Reaction time	30 seconds (100%)	5 minutes (100%)	7 - 15 minutes (100%)
System	UCTE[1]	Control area	Control area
Activation	Automatic and decentralised activation via governor control	Centralised (TSO); active call through IT	Centralised (TSO); active call through phone / IT
Reserved capacity	3,000 MW in UCTE (600 MW in Germany)	Decided by TSO (2,500 MW in Germany)	Decided by TSO (2,500 MW in Germany)
Auction	Weekly	Weekly	Daily
Remuneration	Pay-as-bid	Pay-as-bid	Pay-as-bid
Typical suppliers	Synchronised generators:[2] run-of-river plants, storage and pumped storage hydro plants, large-scale battery storage systems	Storage and pumped storage hydro plants; gas turbine power plants; CHP; large-scale battery storage systems	Storage and pumped storage hydro plants; gas turbine power plants; CHP

A sudden drop in frequency triggers automated response to correct the frequency, followed by manual interventions by power system operators.



[1] The Union for the Coordination of the Transmission of Electricity.
[2] Primary regulating units are required to reserve ~2% of their nominal power ('primary control reserve', updated every year).

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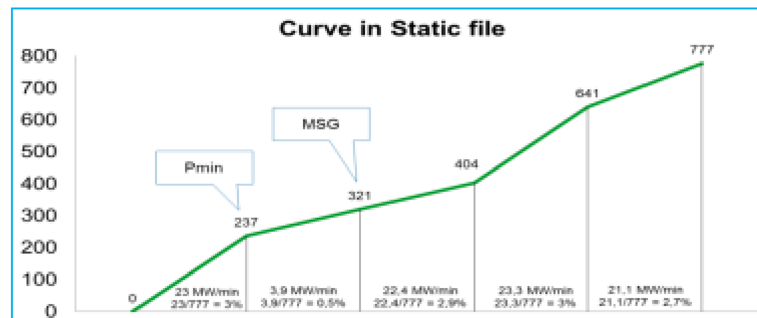
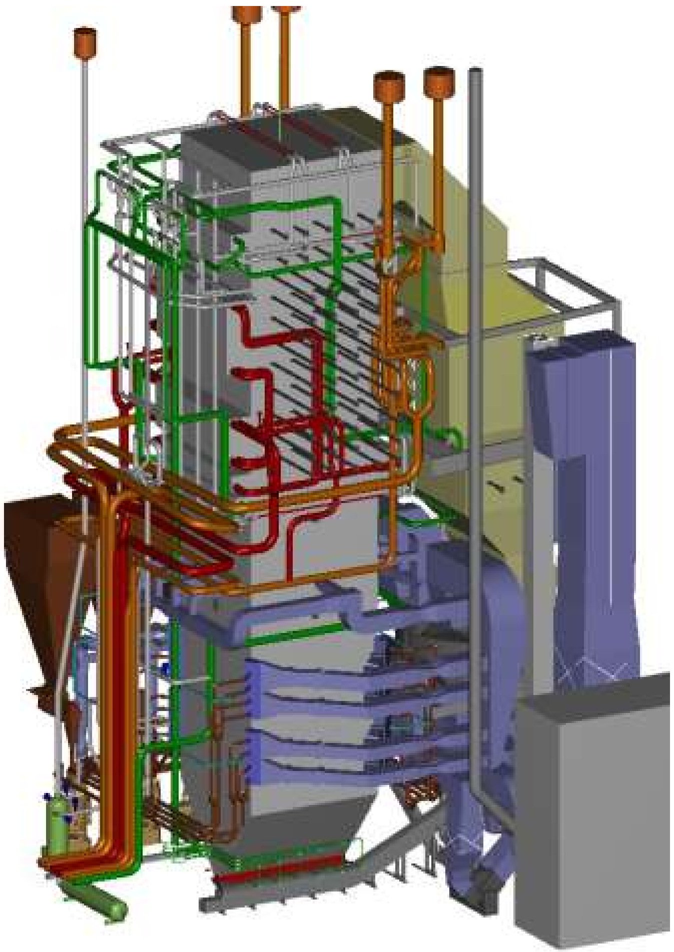
Eemshaven power station: 2x800 MW ramping up and down with 22 MW per minute – min. load at 224 MW

Eemshaven is the cleanest and most efficient hard coal fired power station of western Europe, at the same time it can ramp up and down with >22MW a minute and start up in a matter of hours.

	Eemshaven		
Component	30 min average	Day average	Year average
Stikstofoxiden (NO_x)	200 mg/nm^3	100 mg/nm^3 (1)	60 mg/nm^3
Zwaveldioxide (SO_2)	200 mg/nm^3	50 mg/nm^3 (1)	40 mg/nm^3
Stof (Staub)	20 mg/nm^3	5 mg/nm^3 (1)	3 mg/nm^3
Waterstofchloride (HCl)	n.a.	n.a.	1,2 mg/nm^3
Fluorwaterstof (HF)	n.a.	n.a.	0,5 mg/nm^3
Cadmium (Cd) en thallium (Tl)	n.a.	n.a.	0,06 µg/nm^3
Kwik (Hg)	n.a.	n.a.	2,8 µg/nm^3
Overige zware metalen (2)	n.a.	n.a.	14 µg/nm^3
Dioxinen/furanen (PCDD/PCDF)	n.a.	n.a.	0,0026 ng/nm^3
Koolstofmonoxide (CO)	n.a.	100 mg/nm^3	50 mg/nm^3
Totaal koolwaterstoffen (C_xH_y) (3)	n.a.	5 mg/nm^3	1 mg/nm^3



Boiler design



Technical data

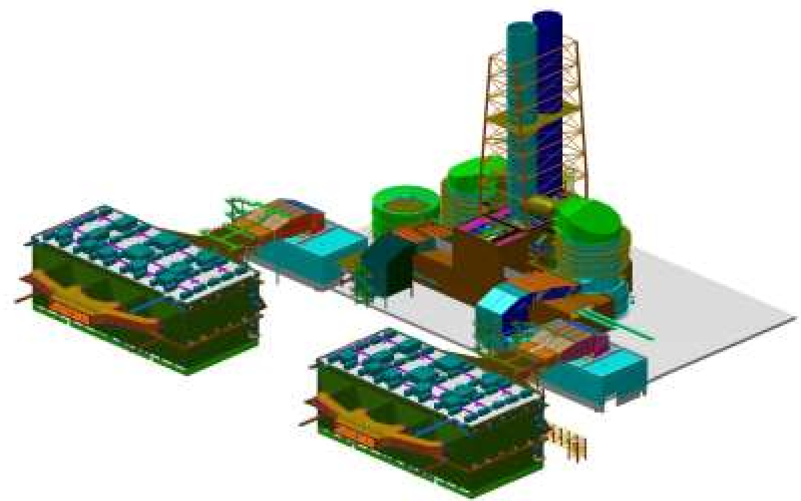
		HP	RH
Steam flow	t/h	2 171	1 782
Steam pressure	bar	285	59
Steam temperature	°C	600	610
Feedwater temperature	°C	308	
Cold RH temperature	°C		359
Flue gas temperature	°C	115	
Boiler efficiency	%	95.3	

Flue gas cleaning

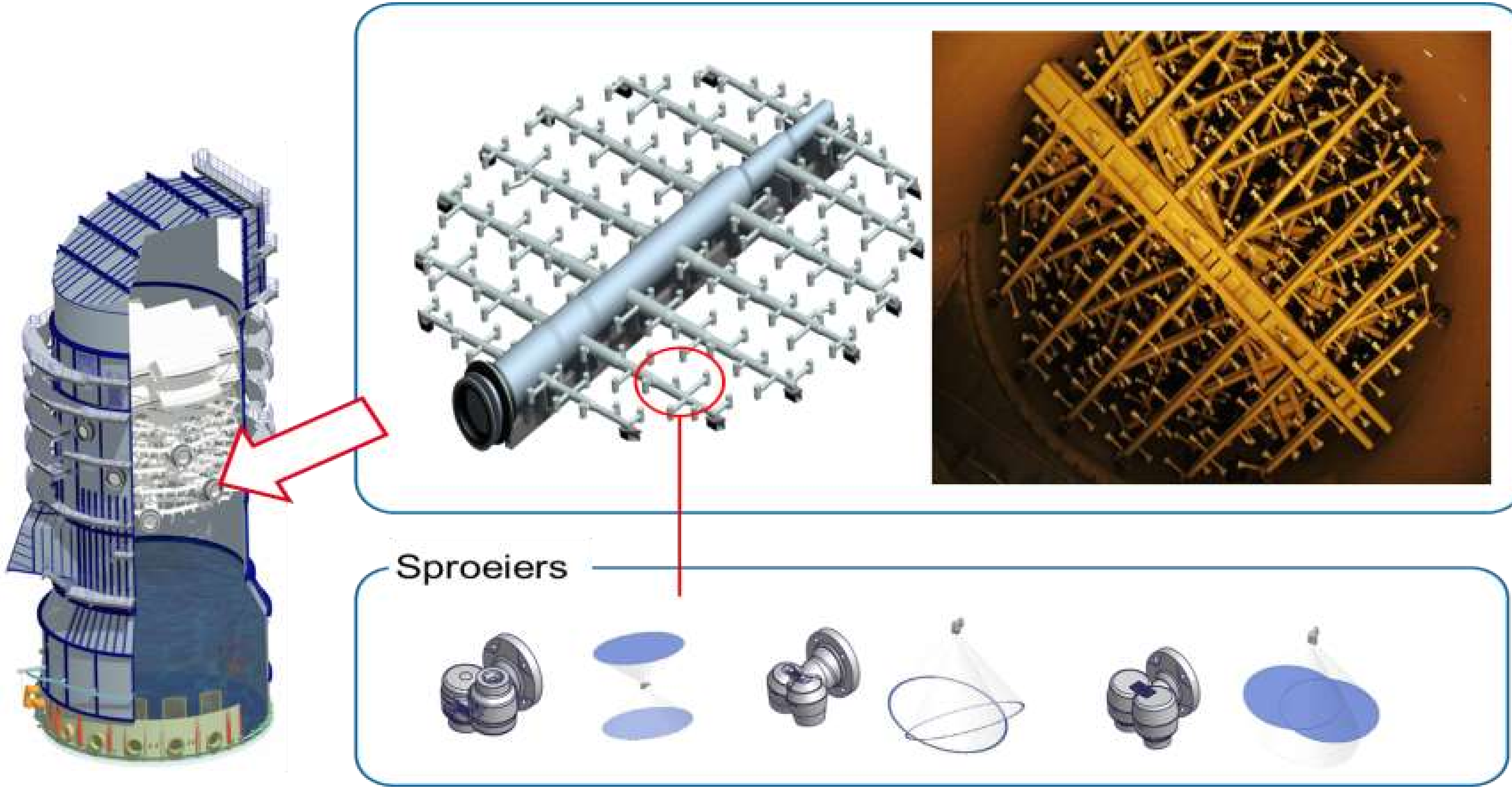
Technical data

Boiler fuel	Hard coal
Plant capacity	2 x 800 MW
FGD process	Wet limestone-gypsum
Flue gas discharge	Wet stack
Gas flow rate	2,116,000 m³N/h
Inlet gas temperature	115 – 140 °C
Inlet SO_2 concentration	max. 4,100 mg/Nm³ dry
SO_2 removal efficiency	98.5 (5 levels)
Absorber type	Single-loop in-situ oxidation process

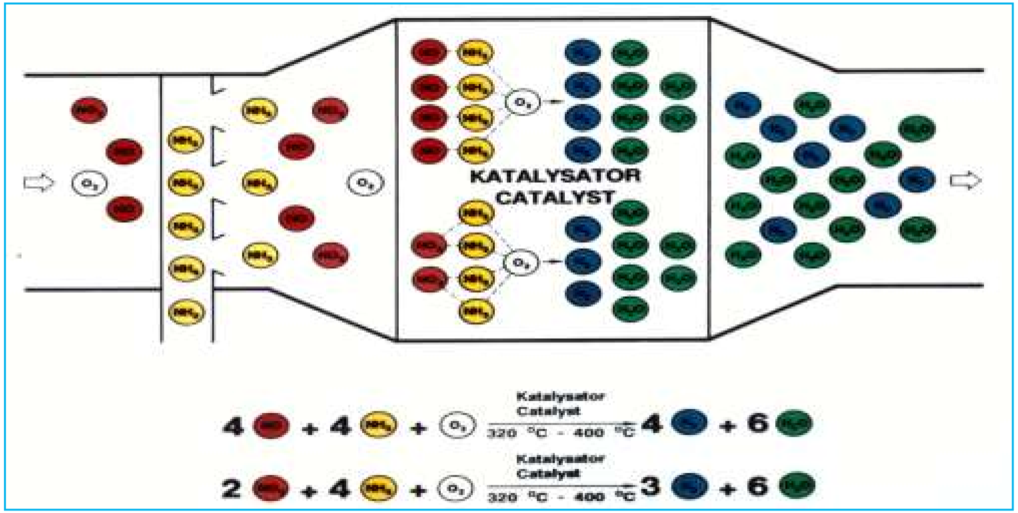
- ESP 5 cells
- Ash collection and transport
- ID fan
- FGD
- Waste-water treatment plant



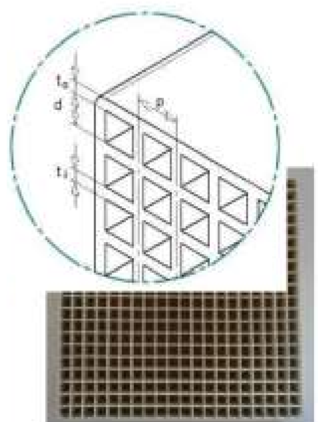
Flue gas cleaning

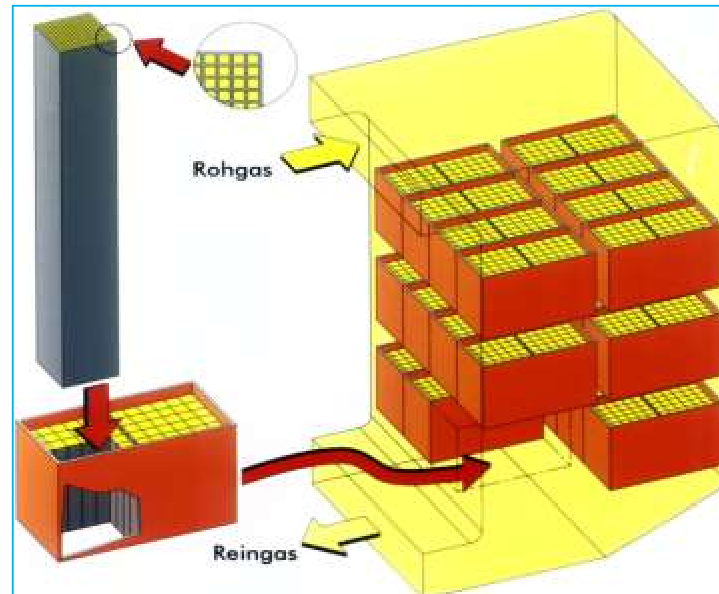


Flue gas cleaning: SCR



Wabenkatalysatoren





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Biomass the CO_2 neutral fuel and feedstock

Biomass is much more than wood, we also look towards agricultural residues

Biomass is:

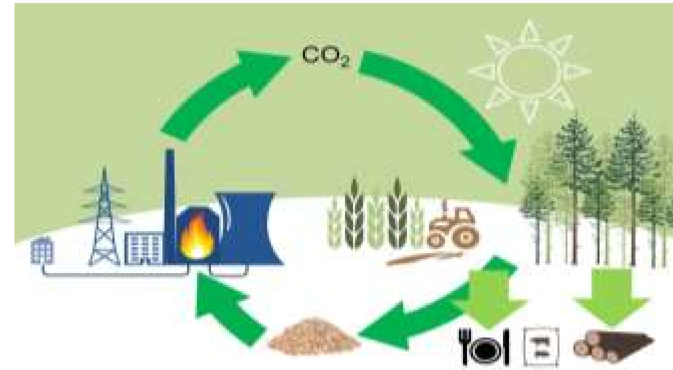
- Stored solar energy: for example, nature is 20x as efficient in storing energy then us using batteries (in other words: 1kg of biomass contains the same energy as 20kg of lithium ion batteries)

- CO_2 neutral fuel and feedstock

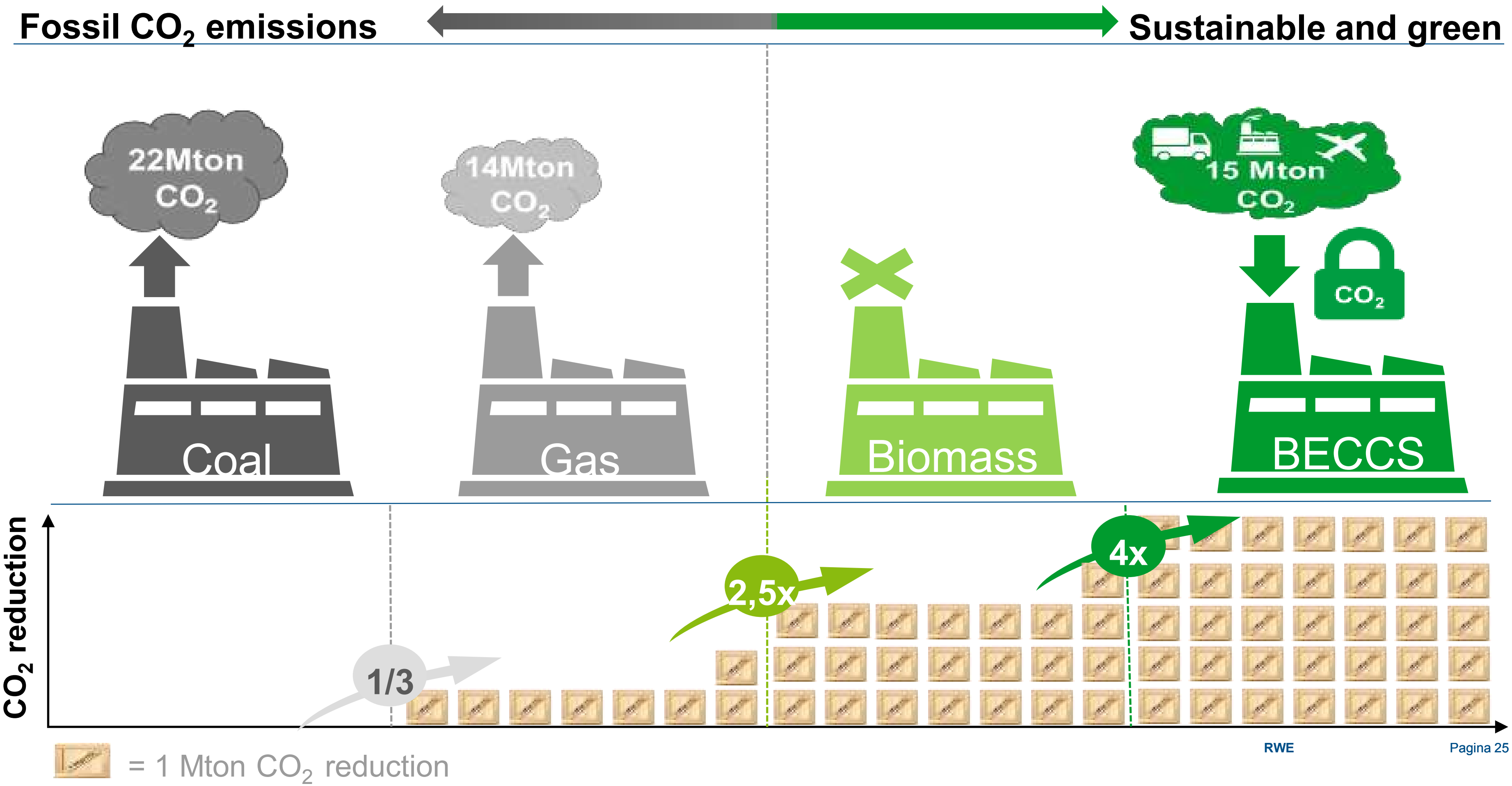
- Abundantly available - but the Netherlands needs to import e.g. from the USA

- Crucial source of carbon to make industry fossil free and according IPCC key in developing CO2 negative sources (Bio-Energy Carbon Capture)

- Valuable and therefore we need to use it in an intelligent way e.g. cascading the biomass in refineries



With the same power station, we can go from fossil, to green and from green to CO2 negative…



And biomass comes in many shapes and forms…

Example:

Millions of tons of biomass are simply burned, having negative consequences

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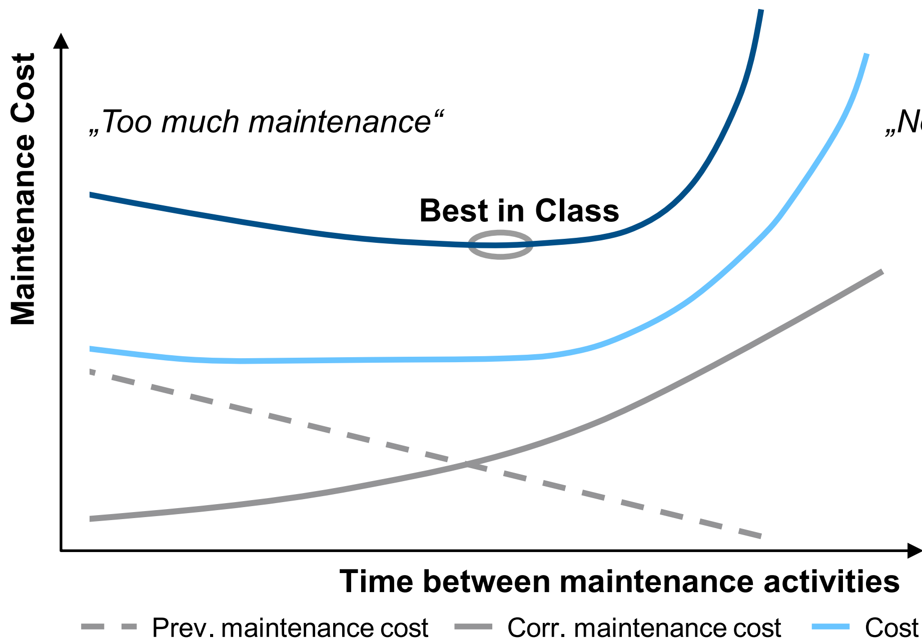
Becoming „Best in Class“ means reaching optimal costs and optimizing availability and efficiency with available resources

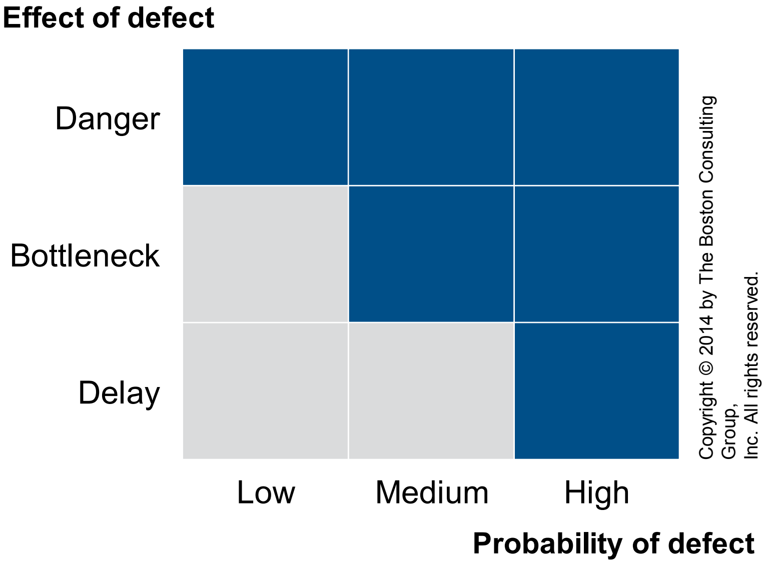
Schematic: most optimal structure of maintenance cost and “cost of unavailability”



Eemshaven aims at implementing the most optimal maintenance strategy and excelling in operational performance based on a multilayered approach. The approach consists of several initiatives all of which focus on the highest impact the available resources can deliver and on a continuously improving performance culture.

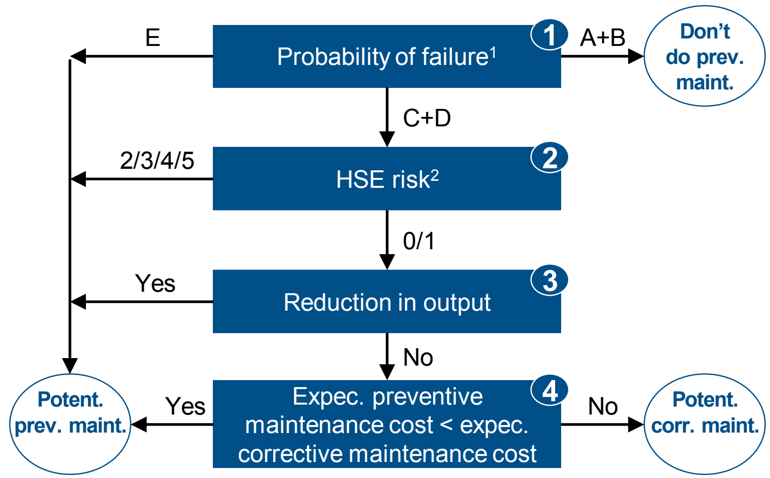
Taking probabilities, HSE risks, unavailability and cost into consideration, the objective of the two-step "IBC" initiative is to ultimately be carried out for the whole installation

1. Overall Risk Assessment



All areas define the most important systems within their part of the installation. Systems/sub-systems rated within the dark blue areas of the matrix are the first **to be further evaluated using the decision tree**

2. Detailed Decision Tree



The decision tree gives guidance whether preventive or corrective maintenance is the more favorable option for (sub-)aggregates of the respective system. It can also give a hint to modify the installation if neither is acceptable.

[1] A=unlikely; B=rarely; C=barely; D=frequently; E=often

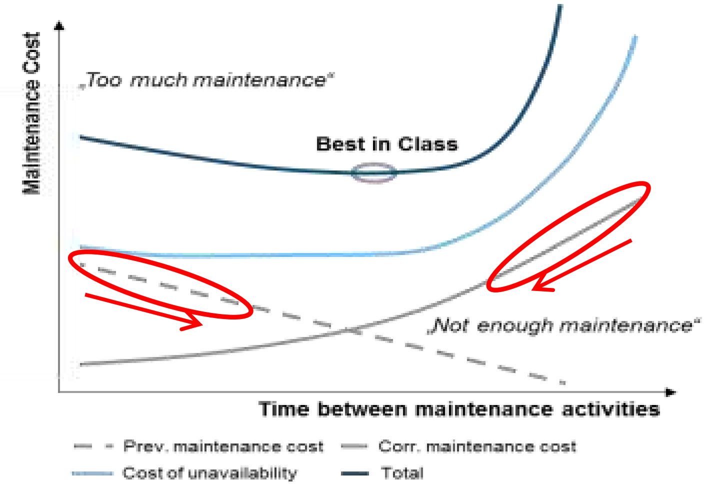
[2] 0=none; 1=slight; 2=limited; 3=serious; 4=severe; 5=calamitous

The "Cost Driver" initiative focuses on reducing the highest costs for both preventive and corrective maintenance

Objective:
- Reduce the highest unnecessary costs for both
  - Preventive maintenance
  - Corrective maintenance

Logic:
- Identify highest historical maintenance costs for systems/aggregates that…
  - Preventive: have never/hardly caused corrective action
  - Corrective: are not maintained preventively or/and are maintained preventively but still cause corrective action
- Analyze root cause, develop and implement strategies to lower costs, e.g:
  - extend/reduce time between preventive maintenance activities
  - switch to corrective/preventive maintenance
  - Improve/develop monitoring strategies for condition based maintenance (usage of PQO and/or SPC system)
  - improve operating procedures of installation
  - consider modification of installation

Method:
- RATIO (root cause analysis)



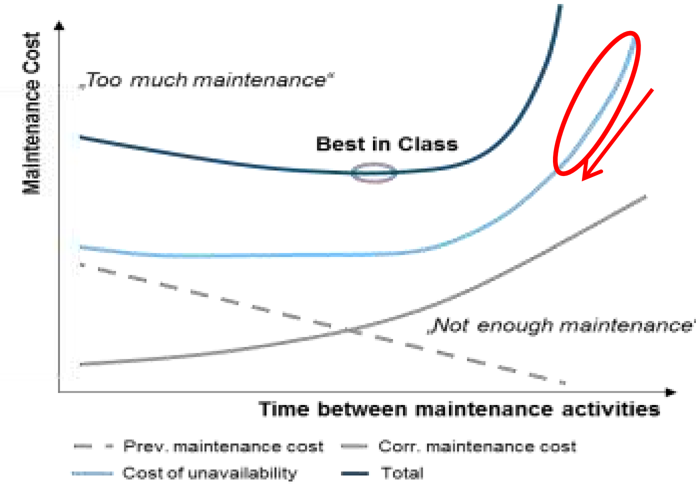
In addition to savings on maintenance costs, we expect an even better condition of the installation. The initiative is not planned as one-off but will become part of our Eemshaven heartbeat. Shifting employees from the E&M department own the initiative, our RATIO facilitators (ambassadors) support. This way, not only will we improve on cost and performance but also further develop our continuous improvement mindset and culture.

The "Performance Killer" initiative focuses on reducing the highest "costs of unavailability"

Objective:
- Reduce the highest unnecessary costs of unavailability

Logic:
- Identify highest historical unavailability's (duration of unavailability x limitation of maximal output, e.g. based on ProPer)
- Screen for "unnecessary" unavailability
- Analyze root cause, develop and implement strategies to lower costs, e.g:
  - improve operating procedures of installation
  - Improve/develop process monitoring strategies (usage of PQO and/or SPC system)
  - Train employees
  - Improve maintenance concept (see "Cost Driver" initiative)

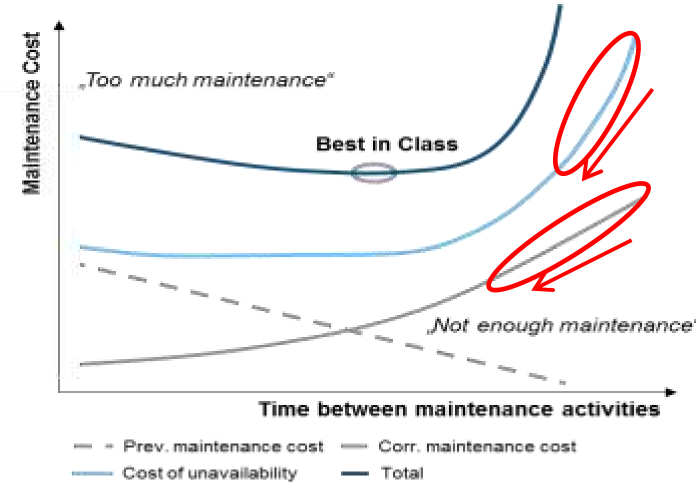
Method:
- RATIO (root cause analysis)



Same as the "Cost Driver" initiative, this initiative is not planned as one-off but will become part of our Eemshaven heartbeat. Shifting employees from the Operations department own the initiative, our RATIO facilitators (ambassadors) support. In addition to generating a higher income due to higher availability, this way we will also further develop our continuous improvement mindset and culture.

The "Bad Actor" initiative focuses on reducing the number of M5 notifications, particularly priority 1 notifications

Objective:
- Reduce the number of "unnecessary" M5 notifications in order to
    - Reduce maintenance costs
    - Improve on plant performance
    - Reduce interference of processes (e.g. number of work orders, planning, throughput time)
    - Enable people to transform wasted time into value adding time



Logic:
- Identify systems/aggregates with highest historical number of (priority 1) M5 notifications
- Analyze root cause, develop and implement strategies to lower number of (priority 1) notifications, e.g:
    - improve operating procedures (see "Performance Killer" initiative)
    - Improve maintenance concept (see "Cost Driver" initiative)
    - Improve/implement usage of PQO and/or SPC system
    - consider modification of installation

Method:
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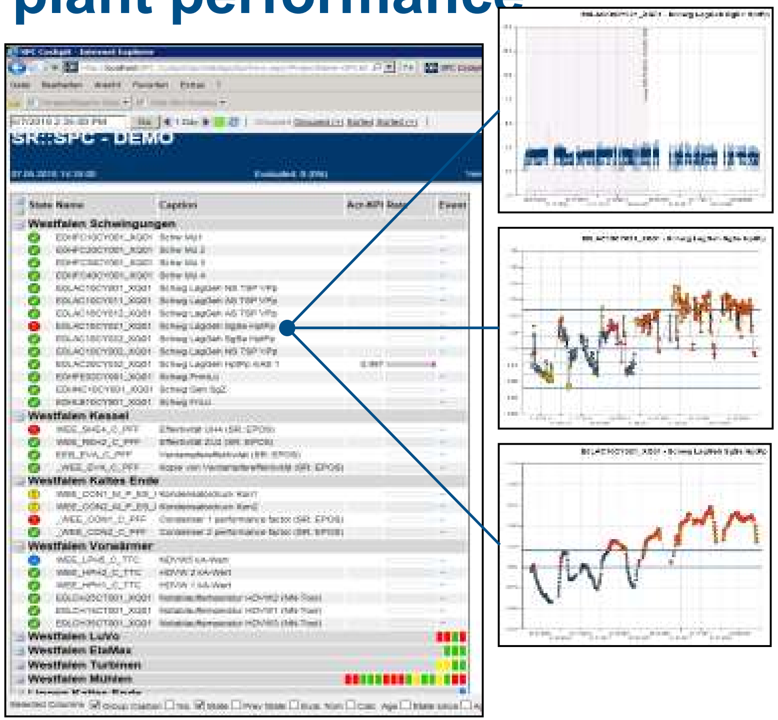
Same as the "Cost Driver" and "Performance Killer" initiatives, this initiative is not planned as one-off but will become part of our Eemshaven heartbeat. Shifting employees from the E&M department own the initiative, our RATIO facilitators (ambassadors) support. A big surplus of this initiative is to enable employees to use their time in a planned rather than an ad-hoc way and thus creating time for value adding topics

The “SPC” initiative focuses on taking the next step towards predictive maintenance and next level plant performance

Objective:
- Expand usage of Statistical Process Control functionality in addition to well established Process Quality Optimization (PQO) tool for thermodynamic process optimization in order to
  - Improve plant performance (increase availability and efficiency)
  - Make steps towards predictive maintenance (reduce cost, reduce (unplanned) unavailability)

Logic:
- Identify KPI’s that reflect
  - Condition of the thermodynamic process
  - Condition of the installation
- “Train” the SPC with historical data related to KPI’s (knowledge of physical context of neural network not required)
- Automatically identify performance and plant related issues
- Where needed, analyze root cause and develop strategies and
  - Improve plant performance
  - Plan and execute maintenance



Method:
- KPI development and SR::SPC based RATIO (root cause analysis)

Other than pure corrective or preventive maintenance and “manual” analysis based on PQO tool only, the big advantage of SPC is that “only” knowledge of the most optimal KPI’s is needed as basis for good results. Based on “supervised learning”, the system analyses interdependencies and automatically alerts the user in case of relevant deviations. This way, maintenance needs can be met more precisely.

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What is power station flexibility: many things, but above all a mind-set that we can deliver it!!

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