Renovation and Modernization of Lignite fired Power Plant Boxberg

4th EU South Africa Coal and Clean Coal Working Group Meeting

Johannesburg, 5-6 Nov 2012

Guenter Heimann
Vattenfall Europe Generation AG, BU Lignite

Confidentiality - None (C1)
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Vattenfall in brief
Vattenfall: a leading European energy company

- Vattenfall is one of Europe's largest generators of electricity and largest producer of heat
- Operations were conducted in Sweden, the Netherlands, Germany, Finland, Denmark, Poland, Belgium, France and the UK with up to 7.8 millions of electricity costumers
- Electricity: generation, transmission and distribution
- Heat: production, transmission and distribution
- Gas: transmission and distribution
- Energy trading and lignite mining
- Consulting and contracting activities in the energy sectors
- approximately 38,000 employees
- The parent company, Vattenfall AB, is 100 % owned by the Swedish state
Vattenfall structure

Board of Directors

Chief Executive Officer

Staff Functions

Chief Financial Officer

BD Asset Development
- BU R&D Projects
- BU Engineering
- BU Thermal Projects
- BU Nuclear & Hydro Power Projects
- BU Project Governance & Improvement

BD Production
- BU Lignite
- BU Nuclear
- BU Thermal Projects
- BU Thermal and Heat

BD Asset Optimisation and Trading
- BU Asset Optimisation Continental
- BU Asset Optimisation Nordic
- BU Trading
- BU Operations

BD Distribution and Sales
- BU Customer Service
- BU Sales B2C
- BU Sales B2B
- BU Heat
- BU Distribution
- BU Energy Related Services

BD Renewables
- BU Onshore Wind Projects
- BU Offshore Wind Projects
- BU Generation Wind
- BU Biomass

Organisation since 1st January 2011
Vattenfall’s electricity generation 2011

Electricity Production [TWh]

166.7 TWh

- Biomass / Waste
- Wind
- Fossil
- Nuclear
- Hydro

Key figures 2011

Availability
Lignite: 89.7 %

Power generation
Lignite: 52,913 TWh

CO2 absolute:
56.9 million t

Coal quantity:
59,367 kt

Source: Year End Report 2011
Power plants of BU Lignite Mining & Generation

500 MW units

- power plant Jänschwalde
  - capacity: 6 * 500 MW
  - initial start-up: 1981-1989
  - efficiency: 36%

- power plant Boxberg blocks N/P
  - capacity: 2 * 500 MW
  - initial start-up: 1979/1980
  - efficiency: 36%

800/900 MW units

- power plant Lippendorf
  - capacity: 2 * 920 MW (50 % share)
  - initial start-up: 1999/2000
  - efficiency: 43%

- power plant Boxberg block Q
  - capacity: 900 MW
  - initial start-up: 2000
  - efficiency: 43%

- power plant Schwarze Pumpe
  - capacity: 2 * 800 MW
  - efficiency: 41%

---

**gloss capacity**

<table>
<thead>
<tr>
<th>Lignite power plants</th>
<th>7,420 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 MW units</td>
<td>4,000 MW</td>
</tr>
<tr>
<td>800/900 units</td>
<td>3,420 MW</td>
</tr>
</tbody>
</table>

**Boxberg unit R**

- 675 MW

- new build

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7 | 4th EU - South Africa Coal & Clean Coal Working Group Meeting | 2012-11-05
Confidentiality - None (C1)
Further Coal PP of Vattenfall Group

- Hard Coal PP Hemweg (NL) 630 MWel
- Hard Coal PP Buggenum (NL) 240 MWel
- Hard Coal PP Moorburg (GE) 2 x 820 MWel under Construction
- Hard Coal PP Reuter West (GE) 560 MWel
- Hard Coal PP Amagervaerket (DK) 319 MWel
- Hard Coal PP Fynsvaerket (DK) 409 MWel
- Hard Coal PP Nordjyllandsvaerket (DK) 660 MWel
- Hard Coal PP Tiefstack (GE) 320 MWel

Installed Capacity based on Hard Coal > 5.000 MW
## Overview on Vattenfall’s lignite assets

<table>
<thead>
<tr>
<th>Power plant</th>
<th>commissioning</th>
<th>Gross capacity</th>
<th>Net efficiency</th>
<th>Life steam parameter</th>
<th>Flexibility [%-(P_N/min)]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boxberg units N/P</strong></td>
<td>1978 / 79</td>
<td>2 x 500 MW</td>
<td>35.0 %</td>
<td>535°C 163 bar</td>
<td>2</td>
</tr>
<tr>
<td><strong>Jänschwalde</strong></td>
<td>1981-88</td>
<td>6 x 500 MW</td>
<td>35.5 %</td>
<td>535°C 163 bar</td>
<td>2</td>
</tr>
<tr>
<td><strong>Schwarze Pumpe</strong></td>
<td>1997 / 98</td>
<td>2 x 800 MW</td>
<td>41.2 %</td>
<td>547°C 260 bar</td>
<td>3</td>
</tr>
<tr>
<td><strong>Lippendorf unit R</strong></td>
<td>2000</td>
<td>933 MW</td>
<td>42.8 %</td>
<td>554°C 267 bar</td>
<td>4</td>
</tr>
<tr>
<td><strong>Boxberg unit Q</strong></td>
<td>2000</td>
<td>907 MW</td>
<td>42.4 %</td>
<td>545°C 266.4 bar</td>
<td>3</td>
</tr>
</tbody>
</table>
Development of availability of lignite assets

<table>
<thead>
<tr>
<th>Year</th>
<th>Unplanned Downtime</th>
<th>Planned Downtime</th>
<th>Availability for Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.8</td>
<td>8.5</td>
<td>88.7</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>3.6</td>
<td>93.4</td>
</tr>
<tr>
<td>2008</td>
<td>4.4</td>
<td>8.4</td>
<td>87.2</td>
</tr>
<tr>
<td>2009</td>
<td>5.6</td>
<td>8.8</td>
<td>85.6</td>
</tr>
<tr>
<td>2010</td>
<td>2.9</td>
<td>10.3</td>
<td>86.7</td>
</tr>
<tr>
<td>2011</td>
<td>3.5</td>
<td>6.9</td>
<td>89.5</td>
</tr>
</tbody>
</table>
Renovation & Modernization of Boxberg Power Plant
Start-up modules I / II / III / IV

2575 MW

as of 2012
unit R 675 MW

3500 MW

3000 MW

20 MW
Aerial view Boxberg site

- **Old 210 MW units decommissioned**
- **Unit N+P** 2 x 500 MW_{el}
- **Unit Q** 900 MW_{el}
- **Unit R** 675 MW_{el}
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Output el</td>
<td>2 x 500 MW</td>
</tr>
<tr>
<td>Operating hours</td>
<td>N: 240,000</td>
</tr>
<tr>
<td></td>
<td>P: 237,000</td>
</tr>
<tr>
<td>Raw coal output</td>
<td>560 t/h per unit</td>
</tr>
<tr>
<td>Caloric value lignite</td>
<td>8.7 – 9.1 MJ/kg</td>
</tr>
<tr>
<td>Live steam quantity</td>
<td>2x815 t/h per unit</td>
</tr>
<tr>
<td>Live steam pressure</td>
<td>163 bar</td>
</tr>
<tr>
<td>Live steam temperature</td>
<td>530 ºC</td>
</tr>
<tr>
<td>Intermediate steam temperature</td>
<td>540 ºC</td>
</tr>
<tr>
<td>Net efficiency</td>
<td>35 %</td>
</tr>
<tr>
<td>District heating</td>
<td>125 MJ/s</td>
</tr>
</tbody>
</table>
## Power Plant Boxberg – Technical Parameter

<table>
<thead>
<tr>
<th></th>
<th>Unit N and P</th>
<th>Unit Q</th>
<th>Unit R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross Output el</strong></td>
<td>2 x 500 MW</td>
<td>900 MW</td>
<td>675 MW</td>
</tr>
<tr>
<td><strong>Operating hours</strong></td>
<td>N: 240,000</td>
<td>100,000</td>
<td>&gt;1,400</td>
</tr>
<tr>
<td></td>
<td>P: 237,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Raw coal output</strong></td>
<td>560 t/h per unit</td>
<td>890 t/h</td>
<td>612 t/h</td>
</tr>
<tr>
<td><strong>Caloric value lignite</strong></td>
<td>8.7 – 9.1 MJ/kg</td>
<td>8.7 – 9.1 MJ/kg</td>
<td>8.0 – 9.2 MJ/kg</td>
</tr>
<tr>
<td><strong>Live steam quantity</strong></td>
<td>2x815 t/h per unit</td>
<td>2 422 t/h</td>
<td>1710 t/h</td>
</tr>
<tr>
<td><strong>Live steam pressure</strong></td>
<td>163 bar</td>
<td>258 bar</td>
<td>285 bar</td>
</tr>
<tr>
<td><strong>Live steam temperature</strong></td>
<td>530 °C</td>
<td>541 °C</td>
<td>600 °C</td>
</tr>
<tr>
<td><strong>Intermediate steam temperature</strong></td>
<td>540 °C</td>
<td>578 °C</td>
<td>610 °C</td>
</tr>
<tr>
<td><strong>Net efficiency</strong></td>
<td>35 %</td>
<td>42 %</td>
<td>43.7 %</td>
</tr>
<tr>
<td><strong>District heating</strong></td>
<td>125 MJ/s</td>
<td>150 MJ/s</td>
<td>-</td>
</tr>
</tbody>
</table>
500 MW Renovation & Modernization Program

Phase I
1991 - 1996

Phase II
2002 - 2006

Phase III
2006 - 2014

„B500“
Respective actions:
- Modernization of the steam generator
- Retrofit of the low pressure turbines
- Installation of flue gas desulphurization plants (FGD)
- Modernization of the electro filter
- Change of the control system
Modernization of the steam boiler

Objective: compliance of all limit values and increase of the efficiency

- **Reduction of NO\textsubscript{x} emission**
  1. Conversion of the burner as low-NO\textsubscript{x}-burner
  2. Retrofit of over-fire-air-nozzles for a better CO-burnout
  3. Reduction of the combustion air surplus

- **Increase of the efficiency**
  1. Increase of the controlled air content from 55 % to > 85 %
  2. Decline of the exhaust temperature
  3. Reduction of the unburnt in slag and fly ash

Results:

\[ \Delta \eta_{\text{boiler}} \approx + 4.2 - 5.8 \text{ % points} \]
\[ \Delta \eta_{\text{unit, net}} \approx + 1.5 - 2.2 \text{ % points} \]
Objective: Capture of SO$_2$ of the flue gas

- construction of the FGD each boiler with flue gas dissipation in den cooling tower
- combining flue gas duct of e-filter over FGD to the cooling tower
- renovation of the cooling tower with optimization of the installations

Result:
- Unit auxiliary power requirements: + 2 % points
  $\Delta n_{\text{unit, net}} \approx - 0.7 \%$ points

Flow chart
Retrofit of LP Turbine

Target: Increase in Efficiency

Measures:

- Replacement of LP rotor and inner casing to achieve
  - Flow improvement
  - performance increase
  - Elimination of Erosion

Results:

- $\Delta \eta_{\text{ND-Turbine}}$ up to + 7 \%-Punkte
- $\Delta \eta_{\text{Block, netto}}$ + 1,5 - 1,9 \%-Punkte
Modernization of ESP

**Target: reduction of dust emission**
- Increase of precipitation by
  - replacing & optimizing the installed equipment
  - Optimizing the performance of electrodes
  - Reducing pressure loss
- Avoiding operation below acid dew point by
  - Reducing ration of leak air
  - Improving insulation

![Diagram of modernization of ESP]

Dry Ash
Replacement of Control System

Legal and technical Requirements:
- NO$_x$-low Operation of the Steam boiler
- Optimization E-Filter Control
- Integration FGD into I&C systems
- Grid control

Due to the existing I&C Ursarmar 4000 was obsolete as well as the unavailability of spare parts the exchange to processor-based I&C system was required!

Results:
- Conformity with environmental and economic requirements
- Higher level of automation and simplified operation
- Common control room for two units with one operator for each unit
Modernization phase II (2002-2006) 500MW units

- Modernization of the control system
- Retrofit to reach incineration of secondary fuels
- Retrofit of the HD turbines
Example: Retrofit HP-turbines 500MW Unit N+P

**Before**
- Fixed pressure operation
- Equal pressure turbine blades (8 stages)
- Central drilling at rotor
- High maintenance expense – opening once in 4 years necessary
- Efficiency: $\eta_{\text{HP-turbine}} = 76 – 79 \%$

**After**
- Still fixed pressure operation
- Optimised 3-D reaction pressure blades (16 stages) pre-twisted with integral shroud bands
- Opening only once in **100,000 operating hours**
- Efficiency: $\eta_{\text{HP-turbine}} \approx 89 \%$

$\sum 3.5 \text{ mill. EUR each turbine}$
# Modernization Phase 3 - B500 Retrofit Program

## Project goals

- Maintenance of the technical safety and an availability of at least 90%
- Further operation of the eight 500-MW-units on the site of Jänschwalde by 2029 and of **Boxberg** by 2031

## Fundamentals

- Integration of the required measures into the revision cycle of 4/8 years during the period of time from 2008 to 2014
- Maintenance of the known characteristics of the 500-MW-equipment
- Basis of the project are the maintenance projects planned in medium-term planning
- Realisation of provable economic measures only
- Project period from 2008 to 2014

- Avoidance of additional downtime
- Technical innovations result in improvements
B500 Program

Project Study

• Inspection/assessment of the 500-MW-units at the Jänschwalde and **Boxberg** Power Plants within the framework of a Study in the years 2005/2006
• This Study included the cost finding of the determined scope of the project

  ➡️ Requests to suppliers for information offers as far as the required measures in 01/2006 are concerned
  ➡️ Integration of the measures into the Revision Plan 2008-2014

Approval of the project

• In December 2006 the project was approved by Vattenfall Board based on economical evaluations.
• This value scope corresponded to the cost estimate determined within the framework of the study.
B500 Measures at the 500MW units at Boxberg

• Replacement HZÜ (reheater) steam pipe at units N+P
• Replacement/Recoiling unit transformer at units N+P
• Replacement SPAT (feed water power turbine)
  (4 TSP (turbo feed pump)- power turbines)
• Replacement of automation system until 2014
• Replacement of electrical feed pumps
• Coil end stabilisation generator at units N+P
• Waste water treatment for service water
• Raw water supply, new section
• Auxiliary cooling and service water pipes
• Replacement of 10-kV-engines
**Scope of supply:**
- New IP Rotor with 3D Reaction Type Blading
- New IP Inner Casing and Blade Carriers with 3D Reaction Type Blading
- Gland Casing seals and Coupling Parts
- Installation and Alignment into the existing Outer Casing

**expected results:**
- Power increase of > 6,3 MW (green)
- Reduce of Heat Consumption of > 90 kJ/kWh
- Save more than 45,000 t/CO₂ per Year
- Reducing Overhaul Costs
- Improving Reliability and Availability for the remaining Life Time
Renovation & Modernization Program 500 MW Units

Results
Overview of Main Measures of Modernization Program from 1990-2014

- Replacement of the heat recovery adjunct except ECO and HD1 (high pressure) and improvement of the control
- Replacement of automation system
- Raw water supply
- Waste water treatment
- Conversion of the firing system
- Conversion of the ignition oil supply towards light fuel oil
- Complete replacement of control and communication technology
- Introduction of workstations
- Increased levels of automatisation
- New 1000 MW – unit control room
- HD- Retrofit
  - Replacement of MD (medium pressure)-rotor
  - Complete replacement of control and communication technology
- Partial replacement of E-technology
- Rewiring of 650 km cable
- REA retrofitting
- Modernisation of the cooling tower – installation of high performance frigistors
- Partial replacement of E-technology
- Rewiring of 650 km cable
- Installation of Taprogge facility
- Replacement of sealed bearings
- Auxiliary cooling water and service water

Legend: black improvements during the 1990ies
purple extension of operation B500
Results of Retrofits of 500 MW Turbines

Main Steam Turbine Set

Electrical Power
+ 52 MW

Heat Consumption
- 680 kJ/kWh

Δ = + 10 / 13
Δ = + 3.4
Δ = + 11
Δ = + 7.6

Before Modernization

After Modernization

@ EFFICIENCY [%]
Results of the modernization till 2006

Ø Operating performance
Comparison 1989 and 2005

Net efficiency
Comparison 1989 and 2005
Results of the modernization till 2006

- **boiler**
- **e-filter**
- **Flue gas desulphurization plant**

**NO\textsubscript{x}**

<table>
<thead>
<tr>
<th>Year</th>
<th>NO\textsubscript{x} [g/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>1.95</td>
</tr>
<tr>
<td>2005</td>
<td>0.88</td>
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</table>

**Dust**

<table>
<thead>
<tr>
<th>Year</th>
<th>Dust [g/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>0.68</td>
</tr>
<tr>
<td>2005</td>
<td>0.02</td>
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**SO\textsubscript{2}**

<table>
<thead>
<tr>
<th>Year</th>
<th>SO\textsubscript{2} [g/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>16.45</td>
</tr>
<tr>
<td>2005</td>
<td>0.99</td>
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The USC Units
BoxQ and R
### Boxberg Q – Technical Key Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Output el</td>
<td>900 MW</td>
</tr>
<tr>
<td>Operating hours</td>
<td>100,000</td>
</tr>
<tr>
<td>Raw coal output</td>
<td>890 t/h</td>
</tr>
<tr>
<td>Caloric value lignite</td>
<td>8.7 – 9.1 MJ/kg</td>
</tr>
<tr>
<td>Live steam quantity</td>
<td>2 422 t/h</td>
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<tr>
<td>Live steam pressure</td>
<td>258 bar</td>
</tr>
<tr>
<td>Live steam temperature</td>
<td>541 °C</td>
</tr>
<tr>
<td>Intermediate steam temperature</td>
<td>578 °C</td>
</tr>
<tr>
<td>Net efficiency</td>
<td>42 %</td>
</tr>
<tr>
<td>District heating</td>
<td>150 MJ/s</td>
</tr>
</tbody>
</table>
**Unit Q – Steam Boiler 2,422 t/h**

<table>
<thead>
<tr>
<th>Cleaning plants</th>
<th></th>
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<tbody>
<tr>
<td>Water lance blowers</td>
<td>16 pieces</td>
</tr>
<tr>
<td>Retractable soot blowers</td>
<td>84 pieces</td>
</tr>
<tr>
<td>Lance blowers</td>
<td>42 pieces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live steam - quantity</td>
<td>673 kg/s</td>
</tr>
<tr>
<td>Intermediate steam quantity</td>
<td>581 kg/s</td>
</tr>
<tr>
<td>Live steam pressure</td>
<td>266 bar</td>
</tr>
<tr>
<td>Intermediate steam temperature</td>
<td>58 bar</td>
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<tr>
<td>Live steam temperature</td>
<td>545 °C</td>
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<tr>
<td>Intermediate steam temperature</td>
<td>580 °C</td>
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<tr>
<td>Type</td>
<td>forced flow</td>
</tr>
<tr>
<td>Number of mills</td>
<td>8</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>-</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Fuel</td>
<td>-</td>
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<tr>
<td>Power Output brutto</td>
<td>MW</td>
</tr>
<tr>
<td>Aux Power</td>
<td>MW</td>
</tr>
<tr>
<td>Power Output net</td>
<td>MW</td>
</tr>
<tr>
<td>Unit Efficiency brutto</td>
<td>%</td>
</tr>
<tr>
<td>Unit Efficiency net</td>
<td>%</td>
</tr>
<tr>
<td>Feedwater Preheating</td>
<td>Stages</td>
</tr>
<tr>
<td>Feedwater - Boiler Inlet Temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Live Steam</td>
<td>°C / bar</td>
</tr>
<tr>
<td>Intermediate Steam</td>
<td>°C / bar</td>
</tr>
<tr>
<td>LP- Exhaust Pressure</td>
<td>mbar</td>
</tr>
<tr>
<td>Cooling system</td>
<td>-</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>mill t/a</td>
</tr>
<tr>
<td>spec CO₂-Emission</td>
<td>g/kWh&lt;sub&gt;net&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
4. Outlook
Coal had a share of 43.5% of Germany's electricity production in 2011.

Overall electricity production (gross): 614.5 TWh
Overall installed capacity: 167,820 MW

Source: BDEW 03/2012
Growth of wind and solar capacity in Germany

The increasing share of discontinuous generated electricity from renewable plants with **feed-in priority** requires a **significantly higher controllability** of conventional power plants.

The graph shows the growth of wind and solar capacity with installed capacities in GW from 2000 to 2050. The bar chart indicates that wind capacity is projected to increase from 0.1 GW in 2000 to 46 GW in 2020, 63 GW in 2030, 76 GW in 2040, and 79 GW in 2050. Solar capacity is projected to increase from 1.8 GW in 2005 to 65 GW in 2050.

Source: Prognos, base scenario 2010A, September 2011
Development perspective

• challenges today and in the future
  Security of supply
  Economic efficiency
  Environmental compatibility
  Flexibility

• this means the meaningful use of all different types of production
  regenerative ↔ coal ↔ gas

• massive expansion of the electricity grid and development of the storage technology

  (Lignite) power plants are an indispensable part of the German electricity supply in the technical and economic view
Thank you for your attention!