EUROPEAN FUEL PRICE CONFERENCE

RWE's Innovations Strategy for Coal Fired Plants – Including the Products for a Zero CO\(_2\) Plant with CO\(_2\) Storage

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Fossil fuels will continue to be the pillars of global electricity generation in future.

Global electricity generation
in bn MWh

Reference scenario
33.7

Alternative scenario
29.8

Electricity generation mix
of RWE* in 2005

219.5 bn kWh

Nuclear
20 %

Hydro and o. r.
3 %

Gas
12 %

Hard coal
30 %

Lignite
35 %

Hydro and other renewables
25 %

Nuclear
14 %

Oil
3 %

Gas
21 %

Coal
37 %

* RWE Group including RWE npower and MATRA

Source: IEA: World Energy Outlook 2006
RWE Power • PFM-IB GZ D06/0184-PCK-W - 2
Our geographic focus is Europe

UK: Strengthen position as top tier power and gas player

Germany: Strengthen gas position to complement power

Netherlands: Become a leading gas and power company

Eastern Europe: Expand existing CEE\(^1\) positions (and selectively occupy positions in SEE\(^2\))

European Gas: Expand pipeline and storage business, secure access to LNG\(^3\)

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1 CEE = Central Eastern Europe
2 SEE = South Eastern Europe
3 LNG = Liquefied Natural Gas
Power plant renewal programme of RWE Power – innovation horizons

for today
Efficiency boosted by renewal, currently BoA 2/3, HC-fired twin unit

for tomorrow
WTA prototype
700°C test facilities
First dry lignite-fired PP
700 °C demonstr. PP

for the day after tomorrow
New projekt: Zero-CO₂ 450-MW IGCC with carbon storage
New projekt: CO₂ scrubbing for conv. power plant
First zero-CO₂ IGCC
First retrofit/new-build plant with CO₂ scrubbing
Horizon 1 example lignite: RWE puts focus on state-of-the-art power plant technology

- **Neurath power plant**
  - Under construction, planned commercial operation: 2010
  - Capacity: 2 x 1,050 MW
  - Efficiency: > 43 % LHV
  - Budget: € 2.2 billion

- **Mátra power plant**
  - Final construction decision: beginning of 2008
  - Capacity: 400 MW
  - Budget: € 0.75 billion (including extension of surface mine Bükkrá bány)
Horizon 1 example hard coal:
RWE puts focus on state-of-the-art power plant technology

- Example: Westfalen power plant
  - Approval planning / procurement phase, planned commercial operation: 2011
  - Net. el. capacity: 2 x 765 MW
  - Net el. Efficiency: ~ 46 %
  - Main steam condition: 285 bar/600 °C
  - Reheat steam condition: 60 bar/610 °C

- Hard coal convoy programme of up to six units established
- Two twin units are planned in Germany (locations: Westfalen PP, Ensdorf PP)
- One twin unit is planned in the Netherlands
- Technical concept secures high efficiency and good flexibility
- Budget: € 6.1 billion
Horizon 2: RWE Power actively involved in further efficiency increase

<table>
<thead>
<tr>
<th>2015</th>
<th>2020</th>
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<tbody>
<tr>
<td><strong>Dry lignite-fired power plant</strong></td>
<td><strong>700°C power plant (L + HC)</strong></td>
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<td>$\eta$: + 4% points</td>
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<tr>
<td><strong>RWE project: WTA prototype:</strong></td>
<td><strong>Joint COMTES700 project of operator and supplier industry:</strong></td>
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<td>1:1 prototype of the drying plant connected to the new 1000MW unit at Niederaußem</td>
<td>All components for 700°C tested in Scholven power plant</td>
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<tr>
<td>■ Developed by RWE</td>
<td>■ Red-hot main steam line</td>
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<td>■ Budget: € 50 mill.</td>
<td>■ Start of operation June 2005</td>
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The initiated measures will enable coal-fired power plants to pass the 50%-efficiency threshold in the medium term.
Horizon 3: Power plants with CO₂ capture Technology lines

- **Post**-combustion CO₂ capture (steam power plants)
  - Conv. PP with CO₂ scrubber
    - Coal
    - Air
    - Convent. steam power plant
    - Flue gas cleaning
    - CO₂ capture
    - 1,000 m³/s, 13% vol CO₂

- Oxyfuel process
  - Coal
  - O₂
  - Boiler
  - Flue gas cleaning
  - Condensation
  - CO₂ / H₂O

- **Pre**-combustion CO₂ capture (IGCC power plants)
  - IGCC process
    - Coal
    - O₂
    - Gasification
    - Gas cleaning CO shift
    - CO₂ capture
    - CCGT with H₂ turbine
    - 10 m³/s, 45% vol CO₂

(Development demand)
RWE’s decisions dealing with CCS

1. RWE Power develops and builds a zero-\(\text{CO}_2\) 450 MW coal-fired power plant based on IGCC technology incl. \(\text{CO}_2\) transport and storage.

2. In parallel, RWE will develop the technology of \(\text{CO}_2\) scrubbing for future advanced coal-fired steam power plants and as a retrofit option for modern installations.

RWE Power thus makes its generation business more future-proof.
The RWE project of a zero-CO₂ 450 MW power plant with CO₂ storage (IGCC-CCS)

- Basic technology: IGCC
- El. capacity: 450 MW\textsubscript{gross}, 360 MW\textsubscript{net}
- Net efficiency: 40 %
- CO₂ storage: 2.3 mill. t/a
- CO₂ storage in depleted gas reservoir or saline aquifer
- Commissioning: 2014
- RWE budget: approx. € 1 billion
IGCC offers favourable preconditions as zero-CO₂ power plant technology

- All process steps are commercially available
- Technical and economic statements are robust
- Power plant can also be operated efficiently without capture
- IGCC has reserves for further reducing classic emissions
- High fuel flexibility
- High product flexibility
Fuel and product flexibility of the IGCC process

The flexibility of the IGCC process opens up additional fuel and product options that offer economic potential.

- Lignite: 1 t → ~580 m³ → ~270 kg → ~140 l
- Biomass → ~580 m³
- Waste → ~180 m³

Gasifier → Gas treatment → CO₂ capture → CCGT → Electricity

- ~580 m³
- ~180 m³
- ~270 kg
- ~140 l

CO₂ → H₂ → SNG → Methanol → Motor fuels
Production costs of coal-to-liquid products: syngas and Fischer-Tropsch diesel

20 million tons of lignite cover some 3% of German motor fuel consumption or 4.6% of German natural gas/SNG demand.
Development of CO₂ storage site
Tasks and current status of work

- **Phase 1: Selection of storage site (2006 - 2008)**
  - Setting up the storage site portfolio
  - Analysing basic methods for evaluating storage potentials
  - Detailed feasibility study for 2-3 selected sites

- **Phase 2: Evaluation of storage sites (2008 - 2010)**
  - 3D seismics of potential storage sites
  - Exploration drilling, formation tests
  - Selection of a storage site, application + approval

- **Phase 3: Construction of storage facility (2011 - 2014)**
  - Production drilling
  - Trial operation, if appropriate
  - Surface facilities, pipeline


**CO₂ storage is the critical element of CCS success**

- **Technical challenges**
  - No recognized methods for the identification and suitability evaluation of storage sites and, in particular, their long-term tightness.
  - High uncertainty as regards costs and time needs due to geological imponderabilities.
  - Injection of 2 mill. t CO₂/a would currently be the largest volume world-wide.

- **No legal bases for CO₂ storage**
  - Applicable rule of law is unclear and regulatory framework below the law level is lacking.
  - Fundamental rules are open, e.g. right of access to storage site, liability issue.
  - Consideration of CCS in the CO₂ regulatory framework required after 2012.

- **Public acceptance must be reached**

The storage task will not be a simple one. But we think it can be tackled if all those involved cooperate!
RWE’s IGCC - CCS Project - Time schedule

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<tbody>
<tr>
<td>Project development</td>
<td>Preselection of technology</td>
<td>Fixing of technology</td>
<td>Fixing of process design</td>
<td>Approval decision to build</td>
<td>First grid connection</td>
<td>Start commercial operation</td>
</tr>
<tr>
<td>Engineering, approval procedure</td>
<td>Fixing of location</td>
<td>Start of process design</td>
<td>Start of basic engineering</td>
<td>Approval decision to build</td>
<td>First grid connection</td>
<td>Start commercial operation</td>
</tr>
<tr>
<td>Construction, commissioning</td>
<td>Construction, commissioning</td>
<td>Construction, commissioning</td>
<td>Test operation</td>
<td>Test operation</td>
<td>Test operation</td>
<td>Test operation</td>
</tr>
<tr>
<td>CO₂ storage</td>
<td>Screening, exploration, approval procedure</td>
<td>Construction, commissioning</td>
<td>Test operation</td>
<td>Test operation</td>
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RWE involvement:
First pilot plant for HC in operation at the Esbjerg power plant (DK) as part of the EU CASTOR project

RWE development for lignite:
- until 2008: pilot project
- from 2009: demonstration plant (start of engineering)

Currently formation of partnerships with plant manufactures and chemical industry for the development and optimization of the scrubbing process

RWE budget for research and investment:
approx. € 90 mill.
RWE npower will conduct a feasibility study for clean coal technology at Tilbury

- Within the RWE group, RWE npower will concentrate on CO₂ scrubbing for hard coal.

- The new carbon capture and storage technology could be ready by 2016 and could reduce the station's CO₂ emissions levels by as much as 90%.

- Key elements of the study are
  - Increase in efficiency of plants using carbon capture
  - Geological carbon storage sites off the British east coast
Conclusion

- Coal is the most important energy source for power supply and it will retain this position in the future.

- RWE Power has resolved a comprehensive investment programme involving some € 10 billion until 2014 to be spent on coal fired power plants. With this programme, we make a crucial contribution to secure, low-cost and environmentally compatible power generation.

- RWE Power's "450 MW IGCC incl carbon capture and storage" project is the response to future tasks of coal-based power generation.

- The IGCC technology offers an additional coal-to-liquid option and opens up further market opportunities.