Post Combustion Capture R&D as part of a utility’s strategy for CCS

1st IEA GHG Post Combustion Conference
17th - 19th May 2011, Abu Dhabi

Dr. Arnim Wauschkuhn EnBW AG,
Dr. Sven Unterberger EnBW Kraftwerke AG
Agenda

› Introducing EnBW
› EnBW activities concerning CCS
› Post Combustion Capture R&D
› CCS: The way ahead
## Introducing EnBW
- At a Glance -

<table>
<thead>
<tr>
<th><strong>EnBW group</strong></th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>External sales</td>
<td>m €</td>
</tr>
<tr>
<td>Employees (annual average)</td>
<td></td>
</tr>
<tr>
<td>Customers</td>
<td>in Mio.</td>
</tr>
<tr>
<td>Unit sales electricity</td>
<td>bn kWh</td>
</tr>
<tr>
<td>Unit sales gas</td>
<td>bn kWh</td>
</tr>
</tbody>
</table>

März 2010
### Electricity generation and trading

<table>
<thead>
<tr>
<th>Generation</th>
<th>Trading/procurement</th>
<th>Transmission and distribution</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnBW Kraftwerke AG</td>
<td>EnBW Trading GmbH</td>
<td>EnBW Transportnetze AG</td>
<td>EnBW Vertriebs- und Servicegesellschaft mbH</td>
</tr>
<tr>
<td>EnBW Kernkraft GmbH</td>
<td></td>
<td>EnBW Regional AG</td>
<td>Yello Strom GmbH</td>
</tr>
<tr>
<td>EnBW Erneuerbare Energien GmbH</td>
<td></td>
<td></td>
<td>WattDeutschland GmbH</td>
</tr>
</tbody>
</table>

### Gas

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EnBW Gas Midstream GmbH</td>
<td>EnBW Gas Midstream GmbH</td>
<td>GVS Netz GmbH</td>
<td>GasVersorgung Süd-deutschland GmbH</td>
</tr>
<tr>
<td>GasVersorgung Süd-deutschland GmbH</td>
<td>EnBW Trading GmbH</td>
<td>EnBW Gasnetz GmbH</td>
<td>EnBW Gas GmbH</td>
</tr>
<tr>
<td>EnBW Gas GmbH</td>
<td>GasVersorgung Süd-deutschland GmbH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Midstream

- EnBW Gas Midstream GmbH
- GasVersorgung Süd-deutschland GmbH
- EnBW Gas GmbH

#### Downstream

### Energy and environmental services

| Companies with service functions | | |
|----------------------------------|| |
| EnBW Energy Solutions GmbH | EnBW Kraftwerke AG | EnBW Regional AG |
| EnBW Systeme Infrastruktur Support GmbH | Stadtwerke Düsseldorf AG | RBS wave GmbH |
EnBW: A Brief Portrait
- Our Locations in Germany -

1. EnBW operates some 80 hydro-electric power stations and numerous other renewable energy facilities. We have therefore only presented some of the major locations.
2. Operations ceased on 11 May 2005 as a result of the nuclear energy agreement.
EnBW: A Brief Portrait
- Shareholdings in Europe -

- Wrocław (Kogeneracja)
- Rybnik (ERSA)
- Prague (PRE)
- Maria Enzersdorf (EVN)
- Bregenz (VIW)
- Sellrain-Sitz (TIWAG)
- Laufenburg (ED)
- Visp (EnAlpin)
- Budapest (ELMU)
- Miskolc (EMASZ)
- Visonta (MATRA)
- Istanbul (Borusan EnBW Enerji)
Introducing EnBW
- EnBW's Generation Mix*

As Germany's third-largest energy company we do take sustainable and responsible action for both the company and the society as a whole.

EnBW generation portfolio electrical output

- Conventional power stations: 2,835 MW
- Nuclear power plants**: 4,856 MW
- Hydrothermal power plants: 259 MW
- Other renewable energies: 7,548 MW

*status quo: Dec 31, 2010
**incl. contracts
Pathways to a Sustainable and Responsible Energy Supply

Sustainable and Responsible Energy Supply

- Security of Energy Supply
  - Modernization and extension of grid
  - Complementary sources of energy generation

- High Efficiency
  - Energy efficiency
  - Economic efficiency

- Environmental Conservation
  - Renewable Energies
  - Low Emissions (NO\textsubscript{x}, SO\textsubscript{x}, dust, noise, ...)

CCS is an option to fulfil our obligation
Agenda

› Introducing EnBW

➢ EnBW activities concerning CCS

➢ Post Combustion Capture R&D

➢ CCS: The way ahead
EnBW Activities Concerning CCS
- CO₂ Capture -

Technology development
- Carbonate Looping
  - Test plant at Stuttgart University (IFK)
- Co-operations
  - R&D
  - Industrial

Operational experience
- Test plant Heilbronn
  - Day-to-day operation
  - Scheduled test programme
  - Further test with suppliers of technologies and within projects

Establishing know-how /Engineering
- Study on CO₂ capture at a 400 MW CCGT
- Feasibility study of retrofitting CCS at RDK 8
EnBW Activities Concerning CCS
- CO₂ Transport -

**Project-related transport**
- Shipping CO₂ via barges
- Assessment of CO₂ transport via pipeline

**Transport infrastructure**
- National and international CO₂-hubs and sub-hubs
- Study on a necessary framework for the deployment of a national CO₂ infrastructure
EnBW Activities Concerning CCS
- CO$_2$ Storage -

**CO$_2$**

- **Onshore / Offshore storage**
  - Industrial co-operations
  - Investigation of options in terms of deployment
  - R&D projects (Mustang, COORAL, MoPa)
  - Catalogue of storage capacities in Germany

- **Alternative storage options / Re-Use**
  - Methanation
  - Cultivation of algae
  - Biochar / Torrification
  - CO$_2$ as resource

\[2 \text{NH}_3 + \text{CO}_2 \rightarrow \text{H}_2\text{N} - \text{C} - \text{NH}_2 + \text{H}_2\text{O}\]

\[\text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}\]

\[\text{PhOH} + \text{CO}_2 + \text{NaOH} \rightarrow \text{PhOH} + \text{CO}_3\text{Na} + \text{NaOH} \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{H}_2\text{SO}_4 \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{H}_2\text{O}\]
EnBW Activities Concerning CCS
- Political Participation -

- Participation in national and international panels dealing with political as well as social issues concerning the implementation of CCS

- International level
  - Zero Emissions Platform
  - IEA GHG
  - CO₂Net

- National level
  - IZ Klima – information centre for CO₂ technologies
  - COORETEC – national funded programme on CO₂ reduction technologies
Agenda

› Introducing EnBW
› EnBW activities concerning CCS
› Post Combustion Capture R&D
› CCS: The way ahead
CCS: EnBW R&D Activities
- Carbon Dioxide Capture -

› Share in various projects on a national as well as international level
› Research being done in all technology routes (pre-, post-combustion capture and oxyfuel)

Project examples

Industrial Partner in CLEO (Carbon Lean Energy Generation) Project associated to CESAR

200 kW_{th} Carbonate Looping test plant at the Institute of Combustion and Power Plant Technology (IFK, Stuttgart University)

5 MW_{th} Chilled Ammonia pilot plant in Pleasant Prairie (Operated by Alstom, EPRI and WE Energies)
Amine Scrubber Pilot Plant
Characteristics

› Site: EnBW CHP Plant Heilbronn, unit 7
  hard coal fired, approx. 815 MW\textsubscript{el, gross},
downstream FGD

› Flue gas volume flow: ca. 1,150 Nm\textsuperscript{3}/h

› CO\textsubscript{2} capture rate: > 90%

› Captured CO\textsubscript{2} quantity: ~ 300 kg/h (back to flue gas channel)

› Space requirements: ca. 10 x 15 x 5 m + 2 columns,
  height: absorber ~ 40 m; desorber ~ 25 m

› Engineering/
  Manufacturing: atea Anlagentechnik GmbH
  Ransbach-Baumbach

› Investment costs: 1.8 Mio. €
Amine Scrubber Pilot Plant
Process Flow Sheet

Low-temperature section (polypropylene)
- Pre-Scrubber
- CO$_2$-lean flue gas

High-temperature section (stainless steel)
- Absorber
- Desorber
- CO$_2$

From FGD
- NaOH
- 1,150 Nm$^3$/h at 50 °C

To stack
- 0.3 t CO$_2$/h
Designed for Flexibility

Operational

- Controlled $SO_2$ input into absorber by pre-scrubber
- Flexible absorber cooling concept by pre-scrubber, inter-cooling and lean solvent cooler
- Alternative material concept (polypropylene, 1,4571/AISI 316 Ti) allowing for broad solvent variety and high concentrations
- Changeable/replaceable random packing

Cooperation

- Commercially available plant design; operated by a utility company
- Open and interested for cooperation with manufacturers, solvent developers, academia
- Plant may serve as a future reference plant, e.g. in EU-projects, for solvent comparison, ...
Absorber Details
Amine Scrubber Pilot Plant
Pre-Scrubber – Bottom Installations
Carbonate Looping Post-combustion CO₂ Capture

- CaO + CO₂ → CaCO₃
- CO₂-Adsorption (Carbonator) 600 – 700 °C
- Flue gas from power plant
- CO₂-Desorption (Calciner) 850 – 920 °C
- CO₂-lean flue gas
- Lime → CaCO₃ → CaO + CO₂
- Limestone
- Coal
- Oxygen

- Comparably low parasitic power loss
- Retains well-proven pulverised coal power plant technology
- Retrofit option
- Builds on existing FB-technology
- Well-known sorbent (FGD)
- No release of further pollutants
- Needs further R&D and demonstration activities
- Research project in cooperation with Stuttgart University
- Build and operate carbonate looping test facility
Dual Fluidised Bed Test Facility
First Carbonate Looping Results

Further Details: Dieter et. al.; High Temperature CO₂ Capture with CaO in a 200 kWth Dual Fluidized Bed Pilot Facility; 2nd Int. Conf. on Energy Process Engineering, Frankfurt, 20-22 June 2011
Agenda

› Introducing EnBW
› EnBW activities concerning CCS
› Post Combustion Capture R&D
› CCS: The way ahead
Our goal:

EnBW to be prepared for a future of conventional energy generation with feasible CCS and actively participates in shaping it.

The road to success:

- further combining EnBW's competences (R&D, Engineering, Business Development, ...)
- defining EnBW's role along the CCS chain (operator vs. user)
- integrating CCS into EnBW's business model
- expanding EnBW's CCS knowledge by:
  - further participation in national and international projects
  - entering co-operations
  - developing own projects