Outlook for RWE’s nuclear operations

Prof. Dr. Gerd Jäger
London, 16 January 2012
Overview of German nuclear power plants

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Net capacity MW</th>
<th>Commercial commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biblis A</td>
<td>1,167</td>
<td>1975</td>
</tr>
<tr>
<td>Neckarwestheim I</td>
<td>785</td>
<td>1976</td>
</tr>
<tr>
<td>Biblis B</td>
<td>1,227</td>
<td>1977</td>
</tr>
<tr>
<td>Brunsbüttel</td>
<td>771</td>
<td>1977</td>
</tr>
<tr>
<td>Isar 1</td>
<td>878</td>
<td>1979</td>
</tr>
<tr>
<td>Unterweser</td>
<td>1,345</td>
<td>1979</td>
</tr>
<tr>
<td>Philippsburg 1</td>
<td>890</td>
<td>1980</td>
</tr>
<tr>
<td>Krümmel</td>
<td>1,346</td>
<td>1984</td>
</tr>
<tr>
<td>Grafenrheinfeld</td>
<td>1,275</td>
<td>1982</td>
</tr>
<tr>
<td>Gundremmingen B</td>
<td>1,284</td>
<td>1984</td>
</tr>
<tr>
<td>Philippsburg 2</td>
<td>1,392</td>
<td>1985</td>
</tr>
<tr>
<td>Grohnde</td>
<td>1,360</td>
<td>1985</td>
</tr>
<tr>
<td>Gundremmingen C</td>
<td>1,288</td>
<td>1985</td>
</tr>
<tr>
<td>Brokdorf</td>
<td>1,410</td>
<td>1986</td>
</tr>
<tr>
<td>Isar 2</td>
<td>1,400</td>
<td>1988</td>
</tr>
<tr>
<td>Emsland</td>
<td>1,329</td>
<td>1988</td>
</tr>
<tr>
<td>Neckarwestheim II</td>
<td>1,310</td>
<td>1989</td>
</tr>
</tbody>
</table>

In 2011: 8,409 MW

31.12.2015
31.12.2017
31.12.2019
31.12.2021
4,058 MW
31.12.2022
4,039 MW

20,457

RWE power plants.
Agenda

1. Operational outlook for the nuclear fleet
2. The nuclear stress tests
3. Decommissioning of nuclear power plants
NPP in stable baseload as long as in the market

German Merit Order

- German NPP remain in stable base load position in the German merit order.
- Until final shut down NPPs with high economic value.
- Flexibility to buffer fluctuating RE through large fleet of mid-load plants and export capacities.
- Redispatch of NPP as result of high RE inflow at best as a exception.
Stable base load characteristic for NPP in all scenarios at least in the medium perspective

> Even in scenarios with very high RE-production NPP in stable base-load position with >7500 h/y.

> Load following flexibility enables NPP even in hours with massive overproduction to react flexibly by power reduction on stable part load level.

> Export as further flexible valve for short-term overproduction.

Production pattern of German base-load plant 2015*

* Szenario with maximum RE, 2015
> German NPP designed for flexible and part load operation.

> Load ramps of +/- 15 MW/min used in today's operation mode.

> Load ramps of +/- 60 MW/min technically feasible.

> Load abatements used even today in case of low demand and high RE production.
Agenda

1. Operational outlook for the nuclear fleet
2. The nuclear stress tests
3. Decommissioning of nuclear power plants
German Safety Review and EU stress tests

> German Safety Review (RSK-SÜ, by Nuclear Safety Commission) well before the EU stress tests started.

> Thus, the German operators are considerably advanced in investigating "Fukushima"-topics for their plants.

> **Result of RSK-SÜ:** High level of protection and robustness in all plants
  - No systematic relation between safety, type, generation or age of the plants.
  - A high robustness of the German NPPs is demonstrated with reasonable safety margins for all postulated severe accident scenarios even beyond design.
  - Consequences of the review results are under discussion with the relevant authorities.

> **Result of EU stress tests:** No new findings for German power plants.
EU-Stressstest – Process overview

> Safety review process by licensees and regulators completed end of 2011.

> Fifteen national nuclear regulators of the EU member states as well as Switzerland and Ukraine submitted final national reports for more than 140 NPP units.

> The results are subject to a Peer-review process until end of April 2012 consisting of a
  - Topical review investigating the technical details of the presented results and a
  - Country review verifying the regulatory processes applied.

> Public meeting of stakeholders will take place on 17th January 2012 in Brussels.

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1 European Nuclear Safety Regulators Group
Agenda

1. Operational outlook for the nuclear fleet
2. The nuclear stress tests
3. Decommissioning of nuclear power plants
What are the special challenges of decommissioning?

> NPPs in multiyear post-operation phase legally stay under their operating license.

> Decommissioning license necessary to start major dismantling works.

> Availability of vital safety functions in post-operation and dismantling phase under strict supervision of regulators, experts and radiation protection.

> Minimization of the economic burden under preservation of adequate safety levels.
Example: Biblis nuclear power station
Comparison to the decommissioning of a car
Decommissioning Options (I)
Definitions and Phases

Operation | Post operational Phase | Decommissioning
---|---|---

- **Deferred Dismantling (Safe Enclosure)**
  - For the time being, fuel elements are being cooled in fuel pools until they are suitable for dry-cask (CASTOR) storage on site
  - Systems no longer needed to be shut down
  - Treatment of operating materials and waste

- **Immediate Dismantling**
  - Partially dismantling
  - Modification of infrastructure
  - Care and Maintenance
  - Dismantling planning and licensing
  - Preparatory work
  - Dismantling of contaminated and activated systems, structures and components
  - Materials and waste management (treatment, conditioning, packaging)

5-7 years

- Preparation of Safe Enclosure (SE)
  - Partially dismantling
  - Modification of infrastructure

15-20 years

- Operation of Safe Enclosure
  - Care and Maintenance

Appr. 50 years (30 years of Safe Enclosure)

- Transition from SE to dismantling
  - Dismantling planning and licensing
  - Preparatory work
  - Dismantling of contaminated and activated systems, structures and components
  - Materials and waste management (treatment, conditioning, packaging)

- Dismantling
  - Dismantling of contaminated and activated systems, structures and components
  - Materials and waste management (treatment, conditioning, packaging)
Decommissioning Options (II)
Cash flows and decision criteria

Immediate dismantling:
+ staff / know-how available
+ higher public & political acceptance
+ site available for future use
- earlier cash-out
- Interim storage facilities necessary

Safe enclosure:
+ dose reduction by radioactive decay
+ costs postponed to the future
+ Independent from interim storage /final repository
- Irreversible loss of staff / know-how
# Nuclear Provisions

## Provisions for uncertain liabilities as per IAS 37

### Public-law liabilities under Sec. 9a of the Germany Atomic Energy Act:
- „Polluter-pays-principle“
- operator is responsible for waste-management and decommissioning
- obligation by the operator, to deliver all radioactive waste to the state
- obligation by the state to build and operate final repositories

### Provisions are made for

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposal of spent nuclear fuel assemblies</td>
<td>€4,831 million</td>
</tr>
<tr>
<td>Flasks, transport, conditioning, intermediate and final storage</td>
<td></td>
</tr>
<tr>
<td>Decommissioning of nuclear power plants</td>
<td>€4,490 million</td>
</tr>
<tr>
<td>Post-operation phase, dismantling, removal, final storage</td>
<td></td>
</tr>
<tr>
<td>Disposal of radioactive operating waste (e.g. cleaning cloths, oils, resins)</td>
<td>€689 million</td>
</tr>
<tr>
<td>Conditioning, flasks, intermediate and final storage</td>
<td></td>
</tr>
</tbody>
</table>

RWE fiscal year 2010: €10,010 million

Inflation of current cost to the assumed disposal date by a set inflation rate; then discounting of the result back to today (discount rate 5.0%)
How the Size of the Provision is Determined

Schematic description

1. Total cost at the shut-down date
2. Escalation rate (specific cost increase)
3. Discount rate (discount to net present value)
4. Annual interest accretion

Amount payable

€

2010 2010 2011 2012 2013
Decommissioning Success Factors

> Shift from operational excellence to dismantling project

> Dismantling is long term demolishing under strong restrictions regarding radiation protection

> Flexible dismantling and materials/waste management planning
  - Logistic and waste stream concept
  - Optimization of plant service operation, e.g. new modular systems for energy and media supply, ventilation and evaporation
  - Combination of off-site and on-site dismantling as well as waste treatment

> Optimisation of the licensing strategy
  (reduction of partial licences, in an extreme case only one overall licence)

RWE has a broad experience in all these fields
# RWE Decommissioning Experience – Examples

<table>
<thead>
<tr>
<th>Immediate Dismantling</th>
<th>Deferred Dismantling</th>
</tr>
</thead>
</table>
| **NPP Kahl**  
(BWR, 16 MW<sub>e</sub>)  
Green Field (10/2010) |
| **NPP Gundremmingen**  
Unit A (BWR, 250 MW<sub>e</sub>)  
Dismantling nearly completed |
| **NPP Mülheim-Kärlich**  
(PWR, 1,219 MW<sub>e</sub>)  
Dismantling of contaminated parts |
| **NPP Lingen**  
(BWR, 240 MW<sub>e</sub>)  
Transition from SE to dismantling |

**Experiences:**

- Dismantling and Decontamination Technology Developments
- Waste treatment optimization
- Final release of buildings and site
- Future nuclear use (Technology Centre Unit A)

- Shut down and simplification of systems
- New “mobile” systems as surrogate for existing residual operation systems
- Partial release of buildings and terrain

**Conclusions:**

- Extensive experiences from decommissioning of nuclear power plants since more than 2 decades
- Technical feasibility in compliance with safety and radiation protection standards is proofed
- All necessary technologies are available and were employed effective several times
- Qualified service providers are available
- Provision calculation model is established, well accepted and reliable
# Dismantling Process (I)
(Immediate dismantling)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Licence procedure</td>
</tr>
<tr>
<td>2</td>
<td>Dismantling of contaminated systems and components</td>
</tr>
<tr>
<td>3</td>
<td>Dismantling of activated components (RPV*)</td>
</tr>
</tbody>
</table>

* Reactor pressure vessel
## Dismantling Process (II) (Immediate dismantling)

<table>
<thead>
<tr>
<th>4</th>
<th>Dismantling of biological shield</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Dismantling of remaining components</td>
</tr>
</tbody>
</table>
Dismantling Process (III)
(Immediate dismantling)

6
Decontamination and release of buildings

7
Pulling down of buildings
Dismantling Process (IV)
(Immediate dismantling)

Release of terrain
(greenfield)
# Final repository sites Konrad & Gorleben

<table>
<thead>
<tr>
<th>Konrad</th>
<th>Gorleben</th>
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<tbody>
<tr>
<td>Final repository for non-heat-generating waste (low- and intermediate-level waste, also medical waste)</td>
<td>Final repository for heat-generating waste (fuel rods, waste from reprocessing etc.)</td>
</tr>
<tr>
<td>&gt; Former ore mine (1957 – 1976)</td>
<td>&gt; Unused salt dome</td>
</tr>
<tr>
<td>&gt; Consented for 303.000 m³ of waste packages, sufficient for all non-heat-generating waste from operation and decommissioning</td>
<td>&gt; Begin of selection process from 140 salt domes in the 70ies, Federal government selected Gorleben in 1977</td>
</tr>
<tr>
<td>&gt; Approx. 95% of total waste volume is non-heat-generating</td>
<td>&gt; Exploration 1979 to 1999</td>
</tr>
<tr>
<td>&gt; Planning approval procedure started in 1982</td>
<td>&gt; Moratorium from 2000 to 2010</td>
</tr>
<tr>
<td>&gt; Consent in 2002, last instance in 2007</td>
<td>&gt; Search for alternative locations currently under discussion</td>
</tr>
<tr>
<td>&gt; Costs so far: 1.2 billion €*</td>
<td>&gt; Costs so far: 1.6 billion €**</td>
</tr>
<tr>
<td>&gt; Total costs: ca. 3.2 billion €</td>
<td>&gt; Total costs: ca. 3.9 billion €</td>
</tr>
</tbody>
</table>

**Commissioning around 2019 expected**

**Commissioning in 2030ies possible**

* Utility share: 64.4%
** Utility share: 96.5%
Conclusions

> The recent change in German energy policy leads to the final shutdown of 8 nuclear power plants, of which 2 belong to RWE

> Different decommissioning options
  - Immediate dismantling
  - Safe enclosure

> Provisions for decommissioning and final storage were made in sufficient amount

> RWE has a solid expertise in all important fields of decommissioning
  - Immediate Dismantling: VAK, Mülheim-Kärlich, Gundremmingen A
  - Safe enclosure: THTR, Lingen

> Industrial market for materials and waste treatment well established

> The availability of the final repository site Konrad is an essential success factor

VAK = Versuchsatomkraftwerk Kahl
THTR = Thorium-Hoch-Temperatur-Reaktor