Spent Fuel Management and Storage in Germany

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Nuclear power plants (NPP) in Germany

82 Mio inhabitants
357,104 km²

In total: 17 active NPP
Thereof: 11 PWR and 6 BWR
450 tons annual discharge of spent fuel

NPP in operation/on-site SFSF
NPP cut-off or closed-down
NPP completely dismantled
Research/waste treatment plant
Centralized dry SFSF
L/ILW: Final repository
Operating plan licence 2007
Emplacement stopped
HLW; exploration phase
Energy mix in Germany – status 2009

- Nuclear energy: 22.6% (ca. 135 TWh)
- Brown coal: 24.6%
- Anthracite coal: 18.3%
- Natural gas: 12.9%
- Wind: 6.3%
- Water: 3.2%
- Others: 12.1%

Electrical power produced 2009: ca. 135 TWh

Energy mix: 22.6% Nuclear energy, 24.6% Brown coal, 18.3% Anthracite coal, 12.9% Natural gas, 6.3% Wind, 3.2% Water, Others 12.1%
Disposal route in Germany

Reprocessing

• Sole disposal route up to the 1980/90s
• Since June 2005 any delivery of SFA to a reprocessing plant is prohibited.
• Completion of the reprocessed waste return is expected in 2024.

Direct Disposal

Sole potential disposal route since June 2005

• Development began in 1970s as so-called reference concept
• Completion of the pilot conditioning plant (Pilotkonditionierungsanlage, PKA) in 2000

Today’s policy: Once through nuclear fuel cycle
Disposal of spent fuel assemblies (SFA) in Germany

Spent fuel assemblies
About 6,400 t HM
About 10,000 t HM

Intermediate Storage
Central and decentralized on-site-dry-storage facilities

Conditioning
Pilot conditioning plant

MOX
Reprocessing
Waste from Reprocessing

Final repository
Return of waste from reprocessing plants

The reprocessed spent fuel (about 6,000 t HM) yields the following waste types and amounts:

<table>
<thead>
<tr>
<th>Reprocessing plant</th>
<th>Spent fuel reprocessed</th>
<th>Casks</th>
<th>Waste type</th>
<th>Number of casks</th>
<th>Return period</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREVA-NC</td>
<td>5,309 t</td>
<td>TS 28V, CASTOR® HAW20/28CG, TN85, CASTOR® HAW28M</td>
<td>CSD-V ≈ HLW</td>
<td>108</td>
<td>until 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TGC 36</td>
<td>CSD-C</td>
<td>≈ 150</td>
<td>from 2015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CASTOR® HAW28M</td>
<td>CSD-B ≈ ILW</td>
<td>≈ 20</td>
<td>from 2014</td>
</tr>
<tr>
<td>NDA</td>
<td>768 t</td>
<td>CASTOR® HAW28M</td>
<td>HLW</td>
<td>21</td>
<td>from 2014</td>
</tr>
</tbody>
</table>

LLW vitrified ILW vitrified

CSD-V CSD-B

CSD-C

Compacted hulls, endpieces
New development: CASTOR® HAW28M

2010 - 2011  Loading of 22 casks

<table>
<thead>
<tr>
<th>Dimensions:</th>
<th>H = 6120 mm, Ø = 2430 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cask Weight loaded:</td>
<td>114.3 t max.</td>
</tr>
<tr>
<td>Loading:</td>
<td>28 canisters with vitrified HLW</td>
</tr>
<tr>
<td>Inventory:</td>
<td>55 GWd/ MGHM - equivalent</td>
</tr>
<tr>
<td>Max. Heat Load:</td>
<td>56 kW</td>
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<tr>
<td>Total Activity:</td>
<td>1270 PBq</td>
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</table>
Storage hall for the HLW-casks returned to Gorleben

Vitrified HLW-Waste currently from France, from 2014 from United Kingdom: centralized storage at Gorleben

Compacted hulls and endpieces: planned for centralized storage at Ahaus

1st transport to Gorleben: May 1996

75 CASTOR® HAW-casks \( \equiv \) 7500 t
\( \equiv \) 1 Eiffel Tower

Since 2009 additional 11 TN85-casks
Accumulation of spent fuel

- **Total amount**
  - Accumulated by 31 Dec 2009: 17,300 SFA, 5,700 t HM
  - in reactor pools and dry storage

- **Intermediate storage** in about 1,000 transport-/storage casks
  without considering the extension of reactor life time

- **Final repository**
  - Reference concept POLLUX: about 2,000 casks
  - Fuel rod container BSK3: about 6,800 containers
### CASTOR® V/19

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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<tbody>
<tr>
<td>H</td>
<td>5860 mm,</td>
</tr>
<tr>
<td>Ø</td>
<td>2440 mm</td>
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<tr>
<td>Cask Weight Loaded</td>
<td>125.6 t max.</td>
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<tr>
<td>Capacity</td>
<td>19 PWR F.A.</td>
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<tr>
<td>Max. Initial Enrichment</td>
<td>4.45 wt % U-235</td>
</tr>
<tr>
<td>Max. Average Burn-up</td>
<td>65 GWd/MTHM</td>
</tr>
<tr>
<td>Max. Heat Load</td>
<td>39 kW</td>
</tr>
<tr>
<td>Total Activity</td>
<td>5.5·E+17 Bq</td>
</tr>
</tbody>
</table>

### CASTOR® V/52

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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<tr>
<td>H</td>
<td>5450 mm,</td>
</tr>
<tr>
<td>Ø</td>
<td>2440 mm</td>
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<tr>
<td>Cask Weight Loaded</td>
<td>123.4 t max.</td>
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<tr>
<td>Capacity</td>
<td>52 BWR F.A.</td>
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<tr>
<td>Max. Initial Enrichment</td>
<td>4.6 wt % U-235</td>
</tr>
<tr>
<td>Max. Average Burn-up</td>
<td>65 GWd/MTHM</td>
</tr>
<tr>
<td>Max. Heat Load</td>
<td>40 kW</td>
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<tr>
<td>Total Activity</td>
<td>1.2·E+18 Bq</td>
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</table>
Loading of a CASTOR®V-casks
Intermediate storage of CASTOR®-casks filled with SFA

Status: 31th December 2009

- Total: 249
- Ahaus: 6
- Gorleben: 5
- Biblis: 41
- Neckarwestheim: 32
- Philippsburg: 31
- Emsland: 28
- Gundremmingen: 25
- Krümmel: 17
- Grafenrheinfeld: 13
- Isar: 16
- Grohnde: 12
- Brokdorf: 12
- Brunsbüttel: 6
- Unterweser: 5

12 on-site intermediate dry storage facilities with 1435 storing positions

2 centralized dry storage facilities Ahaus & Gorleben

12 + 3 decentralized storage facilities on-site near NPP
Pilot Conditioning Plant (PKA) at Gorleben

TSC
TSC without secondary lid
Fuel elements
Fuel rods
Cans with fuel rods

POLLUX®
POLLUX® with welded lid

Staff recreation area

1. Unloading cell

Area for cask handling

2. Disassembling cell

Three hot cells

3. Loading cell

Handling sequence at the PKA
Hot cells of Pilot Conditioning Plant

Unloading

Disassembling

Loading
POLLUX®-Reference concept

POLLUX® - cask

Concept status: end of 1990s

- 5 t HM
- 10 PWR-FA
- 60 t

Underground transportation

Aboveground disposal tests

Disposal system
Additional Disposal Concepts for SFA

Reference concept

Intermediate storage in

CASTOR® V

Conditioning after intermediate storage

Disassembling of SFA

CASTOR® V

Reloading

BSK 3

Transfer to the final repository

CASTOR® V

Emplacement in

Drift

BSK 3

Status

Aboveground testing finished in 2000, basis for repository layout

Additional concepts

Aboveground testing finished in 2009

Feasibility studies ongoing

DIREGT

CASTOR® V

CASTOR® V

BSK 3

Transfer cask

CASTOR® V

Borehole (BSK 3)

Borehole
Way ahead

- Resumption of exploration work of the salt dome in Gorleben 2010 - 2015
- Development of a site related suitability statement 2015 - 2016
- Decision on site 2019
- Planning of the final repository layout and plan submission from 2020
- Finishing of the plan approval procedure 2028
- Construction until operational start 2035

Start of the final disposal at the earliest 2035

58 years!
Conclusion

- The reprocessing of spent fuel is technologically mature and well experienced but was prohibited by the German AtG.
- There are proved procedures for transport, intermediate storage and the conditioning of spent fuel.
- The disposal of spent fuel is technologically already solved to a large extent.
- The exploration results obtained so far strongly suggest that the salt dome of Gorleben is suitable to host a repository for heat-generating waste and spent fuel.
- The political decision on resuming the exploration of the salt dome in Gorleben and commissioning the first tentative safety analysis are important steps to move ahead on the way to a deep geological repository for heat-generating HLW. A concept for an appropriate participation of the public would be desirable.