Operational Decommissioning Experiences in Germany

7th International Summer School on Nuclear Decommissioning and Waste Management

Ispra, Italy, September 14th-18th, 2015

Przemyslaw Imielski
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
Germany

Contents

Analysing the current nuclear situation in Germany

- German phase-out decision
- Overview on decommissioning projects in Germany
- The German regulatory system

Lessons learned from past and present decommissioning projects in Germany

- Decommissioning experiences
  - Phased approach
  - Industrial development at the site
  - Large component removal
  - Clearance

Examining the current challenges (and future opportunities)

German Phase-out Decision

After the events at Japanese Nuclear Power Plant (NPP) Fukushima Daiichi in March 2011 the German government decided to

- "end the use of nuclear energy for the commercial generation of electricity at the earliest possible time – by gradually phasing it out."
- This decision resulted in an Amendment of the German Atomic Energy Act of July 31st, 2011
  - Withdrawing the authorisation to operate an installation for the fission of nuclear fuel for the commercial production of electricity for the seven oldest NPPs and NPP Krümmel on August 6th, 2011
  - Setting end-dates for the authorisation for the remaining 9 NPPs on a step-by-step-basis until 2022 at the latest

German Phase-out Decision

Timetable for shut down of **commercial reactors** in operation

Name	Abbrev.	Reactor type	Power MW_e	Date of final shut down
Grafenrheinfeld	KKG	PWR	1345	31.12.2015*
Gundremmingen B	KRB-II-B	BWR	1344	31.12.2017
Philippsburg 2	KKP 2	PWR	1468	31.12.2019
Grohnde	KWG	PWR	1430	31.12.2021
Gundremmingen C	KRB-II-C	BWR	1344	31.12.2021
Brokdorf	KBR	PWR	1480	31.12.2021
Isar 2	KKI 2	PWR	1485	31.12.2022
Emsland	KKE	PWR	1400	31.12.2022
Neckarwestheim 2	GKN 2	PWR	1400	31.12.2022

** Application for decommission license on 28.03.2014*

Overview on Decommissioning Projects in Germany

Decommissioning of nuclear facilities in Germany – experiences since 1970th

- Prototype / Commercial Reactor shut down / under decommissioning
- Prototype / Commercial reactor decommissioning completed
- Research Reactor shut down / under decommissioning
- Research Reactor decommissioning completed
- Nuclear Fuel Cycle Facility shut down / under decommissioning
- Nuclear Fuel Cycle Facility decommissioning completed

Overview on Decommissioning Projects in Germany

Past and current decommissioning projects of **prototype or commercial reactors**

- Total: 19
- Removed: 3
- Under dismantling: 16
- Safe enclosure: 2
- Reactor types:
  - PWR
  - BWR
  - Fast breeder
  - High temperature gas cooled
  - Heavy water gas cooled

© Forschungszentrum Karlsruhe

Overview on Decommissioning Projects in Germany

Past and current decommissioning projects of **prototype or commercial reactors**

Name	Abbrev.	Reactor type	Power MW_e	Decom. started	Strategy
Mehrzweckforschungsreaktor	MZFR	PWR/D_2O	57	1987	RS
Kompakte Natriumgekühlte Kernanlage	KNK II	SNR	21	1993	RS
Arbeitsgemeinschaft Versuchsreaktor Jülich	AVR	HTR	15	1994	RS
Greifswald 1-5	KGR 1-5	PWR/WWER	440	1995	RS
Rheinsberg	KKR	PWR/WWER	70	1995	RS
Würgassen	KWW	BWR	670	1997	RS
Mülheim-Kärlich	KMK	PWR	1302	2004	RS
Stade	KKS	PWR	672	2005	RS
Obrigheim	KWO	PWR	357	2008	RS

RS: release of site from regulatory control

Overview on Decommissioning Projects in Germany

Past and current decommissioning projects of **prototype or commercial reactors**

Name	Abbrev.	Reactor type	Power MW_e	Decom. started	Strategy
Heissdampfreaktor Grosswelzheim	HDR	HDR	25	1983	RS in 1998
Niederaichbach	KKN	DRR	106	1975	RS in 1994
Versuchsatomkraftwerk Kahl	VAK	BWR	16	1988	RS in 2010
Gundremmingen-A	KRB-A	BWR	250	1983	RCA KRB-II
Lingen	KWL	BWR	252	1985	SE since 1988
Thorium-Hochtemperatur-reaktor	THTR-300	HTR	308	1993	SE since 1997

RCA: radiation controlled area, new license
SE: safe enclosure
RS: release of site from regulatory control

Overview on Decommissioning Projects in Germany

Outlook for **prototype or commercial reactors**
(Finally shut down, no decommissioning license issued)

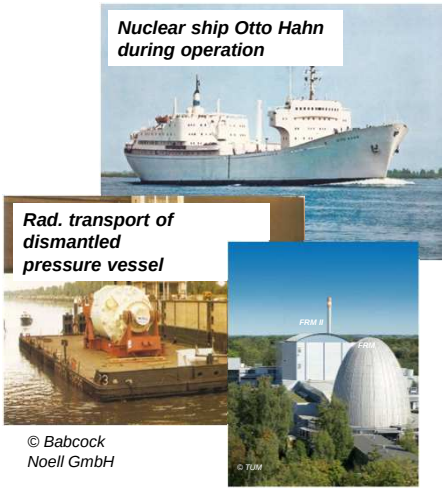
Name	Abbrev.	Reactor type	Power MW_e	Date of application
Lingen	KWL	BWR	252	15.12.2008*
Isar-1	KKI 1	BWR	912	04.05.2012
Unterweser	KKU	BWR	1410	04.05.2012**
Biblis-A	KWB A	PWR	1225	06.08.2012
Biblis-B	KWB B	PWR	1300	06.08.2012
Brunsbüttel	KKB	BWR	806	01.11.2012
Neckarwestheim-1	GKN 1	PWR	840	24.04.2013
Philippsburg-1	KKP 1	BWR	926	24.04.2013
Krümmel	KKK	BWR	1402	24.08.2015
Grafenrheinfeld	KKG	PWR	1345	28.03.2014***

** Dismantling after safe enclosure*
*** Application changed on 20.12.2013*
***** Date of final shut down 31.12.2015

Overview on Decommissioning Projects in Germany

Past and current decommissioning projects of **research reactors**

- Total: 35
- Removed: 29
- Under dismantling: 6
- Safe enclosure: 2
- Finally shut down, no decommissioning license issued: 4
- Variety of types of research reactors
  - Argonaut type
  - Critical assembly
  - Educational reactors
  - Liquid homogenous reactor
  - Propulsion reactor
  - Pool reactor (incl. TRIGA type)
  - Heavy water reactor (incl. DIDO type)



© Babcock Noell GmbH

Overview on Decommissioning Projects in Germany

Past and current decommissioning projects of
nuclear fuel cycle facilities

- Total: 11
- Removed: 10
- Safe enclosure: 0
- Under dismantling: 1

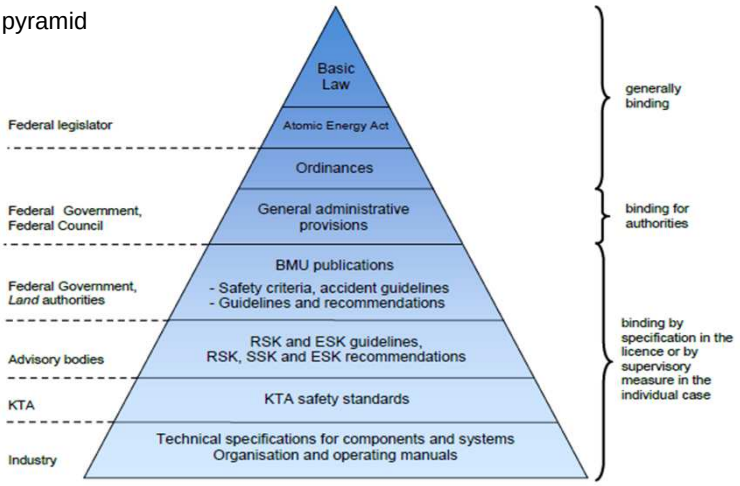
Former storage building for vitrification waste at WAK with additional building for remote dismantling and packaging of decommissioning waste

Slave support system for remote dismantling at WAK

© W. Dander et al. (WAK GmbH), 2010 Annual Meeting of German Nuclear Society

The German Regulatory System

Hierarchical structure of the regulations
Regulatory pyramid



As of the Report of the Federal Republic of Germany for the Fifth Review Meeting of the Joint Convention (May 2015)

The German Regulatory System

Brief overview on the (Federal) Decommissioning Guide

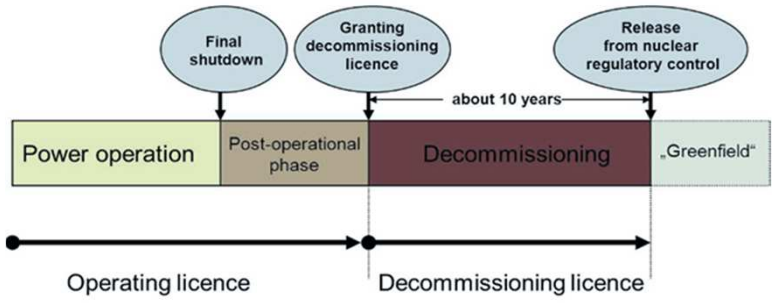
- Objective:
  - **harmonize the procedures among all Länder authorities**
- Comprehensive collection of existing requirements and recommendations on the decommissioning of nuclear facilities in Germany
  - Jointly applied by all Länder authorities
  - Strong focus on procedural licensing and supervisory aspects
- Contains among others
  - Comprehensive list of individual elements of the guidelines, recommendations and safety standards to be applied
  - Description of fundamental factors to be considered during determining the decommissioning strategy
  - Aspects to be considered during the safety assessment
- Available also in English language

➔**(Federal) Decommissioning Guide** represents good practice in Germany from regulatory point of view

The German Regulatory System

- Regulation of decommissioning in Germany
  - § 7 (3) of the German Atomic Energy Act

    The decommissioning of an installation […] as well as the safe confinement of an installation, or the dismantling of an installation or of parts thereof shall require a license […].
- View point: phase in lifetime of a facility



The German Regulatory System

Basic requirements

- The German Atomic Energy Act allows either
  - to **immediate dismantle** or
  - to dismantle after a **safe enclosure**

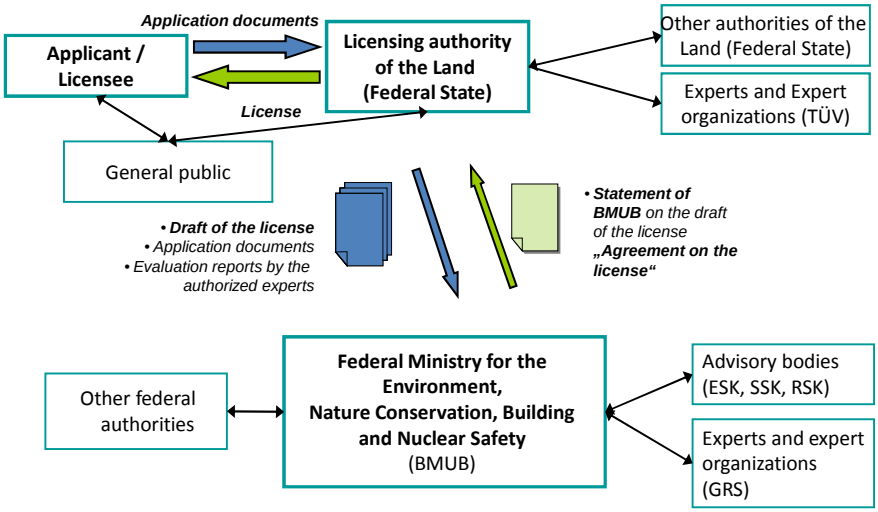
  a nuclear facility

  Note: **no entombment** (near surface disposal) is allowed
- The **operator** of a nuclear facility is **fully responsible** for the decommissioning and dismantling of a nuclear facility
  - He decides on the decommissioning strategy and the timeframe
  - He decides on the scope of a license he applies for

  Note: the operator has to ensure at any time the safety of the facility and any precautionary measures are taken
- Decommissioning and dismantling are subject to **one or more licenses**
- Decommissioning activities are subject to an **intensive regulatory supervision**, involving technical experts and on-site presence during the full project

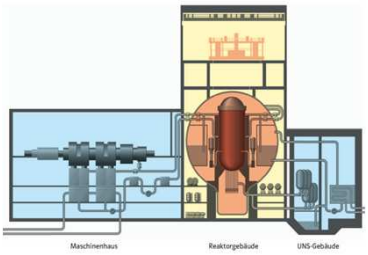
The German Regulatory System

Process of licensing



Decommissioning Experiences – Phased Approach

- Typically large decommissioning projects
  - are divided into phases (corresponding to large work packages)
  - work from “outside to inside”
    - Phase 1: blue
    - Phase 2: yellow / orange
    - Phase 3: red

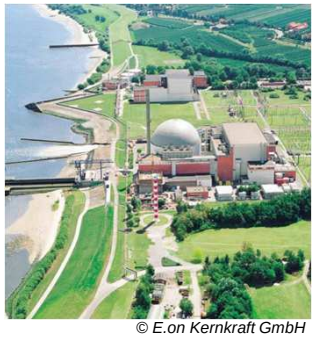


© E.ON Kernkraft GmbH

- A phase
  - corresponds to a large work package
  - can be reflected by an individual license
- Advantages
  - allows to structure large complex technical systems
  - allows to gain further information needed for later work packages
  - allows flexibility in adapting changes in future phases not licensed yet

Decommissioning Experiences – Phased Approach

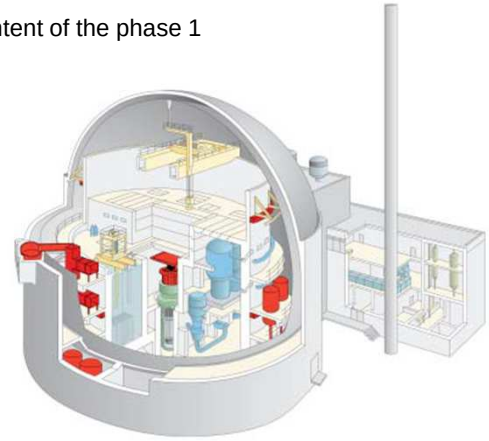
- A typical & recent decommissioning project – decommissioning of Stade NPP
  - Design features
    - Reactor type: PWR
    - Electrical power: 672 MWe
    - Operation: 1972 – 2003
    - Operator: Kernkraftwerk Stade GmbH & Co. KG
  - Decommissioning “features”
    - Decommissioning due to economic reasons
    - 4 phases approach on immediate dismantling
    - End-state: release of the site for unrestricted use, proposed for 2015
    - Inventory: total of 10^{17} Bq, mobile contamination of 10^{13} Bq



© E.on Kernkraft GmbH

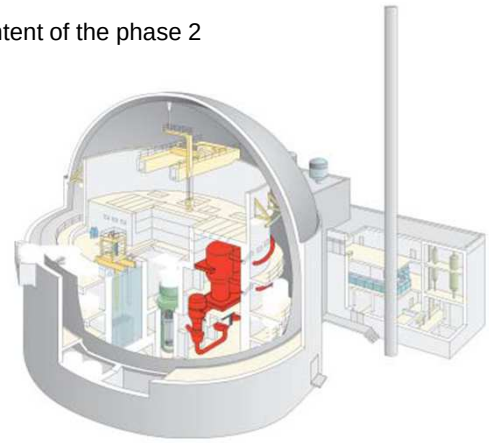
Decommissioning Experiences – Phased Approach

- Stade NPP Decommissioning: Content of the phase 1
  - Removal of contaminated systems and components
  - Objectives:
    - Free space for later dismantling work
    - Preparation of later dismantling work
    - Removal of systems and components



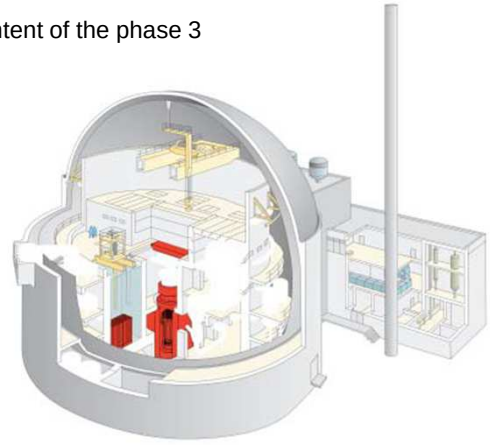
Decommissioning Experiences – Phased Approach

- Stade NPP Decommissioning: Content of the phase 2
  - Removal of large components, including
    - Pipes and pumps of the primary circuit
    - Steam generator (transfer to Studsvik for processing)



Decommissioning Experiences – Phased Approach

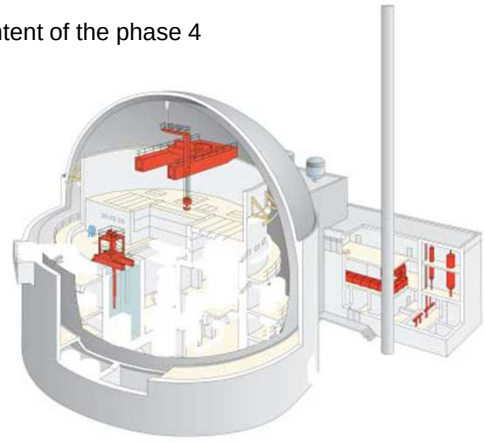
- Stade NPP Decommissioning: Content of the phase 3
  - Removal of activated systems and components
    - – Core internals
    - – Spent fuel pond internals
    - – In-situ dismantling of reactor vessel
      - ◆ Cutting of large parts
      - ◆ Drum size cutting in former spent fuel pond
    - – Biological shielding
    - – …



© E.on Kernkraft GmbH

Decommissioning Experiences – Phased Approach

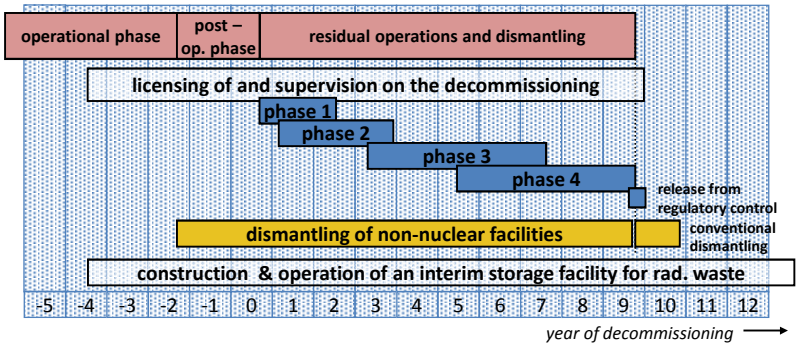
- Stade NPP Decommissioning: Content of the phase 4
  - Removal of remaining systems and components
    - – Fuel load machine
    - – Reactor crane
    - – Ventilation system
    - – Water treatment system
  - Preparation for clearance for unrestricted use



© E.on Kernkraft GmbH

Decommissioning Experiences – Phased Approach

- Example of 4 Phases @ Stade NPP



Phase 1 *Phase 2* *Phase 3* *Phase 4*

© E.on Kernkraft GmbH

Decommissioning Experiences – Industrial Development at the Site

- Decommissioning of the Greifswald NPPs
  - Design features
    - Reactor type: 4 WWER-440/W-230
      2 WWER-440/W-213
      2 more planned
    - Electrical power: 2x220 MWe per unit
    - Operation: 1974/75/78/79/89 – 1989
    - Operator: EWN GmbH
  - Decommissioning “features”
    - Decommissioning due to technical reasons after German reunification
    - 8 phases approach on immediate dismantling
    - **End-state: release of the site for (conventional) re-use**
    - Inventory: total of $4x10^{17}$ Bq

Site of the Greifswald NPP

© EWN GmbH

Production of cranes in the former turbine hall

Production of ship components in the former turbine hall

Decommissioning Experiences – Large Component Removal

- Dismantling of large components – German practice shows following options
  - In-situ dismantling
  - Partial in-situ dismantling
    - Post-processing on-site or off-site
  - Removal and ex-situ dismantling (typically for components of metal)
    - On-site dismantling
      - Immediate dismantling
      - Deferred dismantling (if appropriate: dismantling after decay storage)
    - Off-site dismantling
      - At external service providers (cutting, decontamination / melting, clearance – in a foreign country: still according to German requirements, return of material and radioactive waste)

© B. Jünger

© GNS

Decommissioning Experiences – Large Component Removal

- Examples of large component removal for off-site dismantling

KWO steam generator shipment for interim storage at Greifswald NPP

© nadir.org

© ndr.de

KGR reactor vessel removal to Interim Storage Facility North

© R. Borchardt, G. Hillebrecht, EWN, 2010 Annual Meeting of German Nuclear Society

Decommissioning Experiences – Clearance

- Character of “Clearance”
  - Administrative act which effects the exemption of radioactive substances and any movable goods, of buildings, soil areas, installations or parts of installations which are activated or contaminated by radioactive substances and which originate from practices from regulatory control
  - Clearance of radioactive substances and movable goods, buildings, soil areas, facilities or parts of facilities which are activated or contaminated material, can be granted by the regulatory body (“license”) only if relevant radiological requirements are fulfilled
  - Regulated in detail § 29 of the German Radiation Protection Ordinance (StrlSchV)

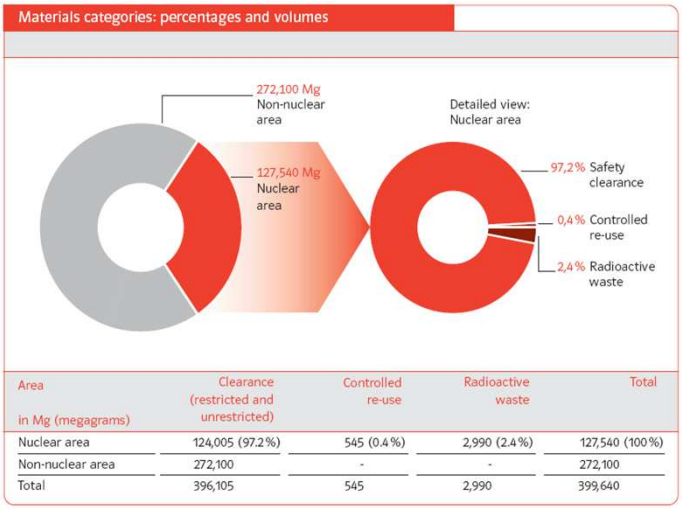
Decommissioning Experiences – Clearance

- Basic radiological requirement / concept: “De Minimis Principle”
  radioactive activation and contamination of the material, ... to be cleared, shall be such, that the exposure of a member of the public is no more than about 10µSv/a
- For simplification and to avoid long lasting calculations: for a set of radionuclides clearance levels have been calculated and are available as appendix III of StrlSchV
- Different clearance levels for different clearance options:

unrestricted clearance (“use as you like”):	clearance for specific purposes (“the use is predicted”):
solid material	solid material for disposal (100t, 1000t) incineration (100t, 1000t)
liquids	liquids for disposal in a waste incineration plant
building rubble and excavated soil with an expected mass of more than 1,000 t/a	buildings for demolition
sites	scrap metal for recycling
buildings for reuse and further use	

Decommissioning Experiences – Clearance

- Example on the masses from a recent decommissioning project



Area in Mg (megagrams)	Clearance (restricted and unrestricted)	Controlled re-use	Radioactive waste	Total
Nuclear area	124,005 (97.2 %)	545 (0.4 %)	2,990 (2.4 %)	127,540 (100 %)
Non-nuclear area	272,100	-	-	272,100
Total	396,105	545	2,990	399,640

© E.ON Kernkraft GmbH Stade NPP

Current challenges

Decommissioning of NPPs with fuel elements still present

Name	Abbrev.	Storage of fuel elements
Neckarwestheim 1	GKN 1	Cooling pond
Philippsburg 1	KKP 1	Cooling pond
Isar 1	KKI 1	Cooling pond
Biblis Block A	KWB A	Cooling pond
Biblis Block B	KWB B	Cooling pond
Unterweser	KKU	Cooling pond
Brunsbüttel	KKB	Reactor pressure vessel and cooling pond
Krümmel	KKK	Cooling pond

- (Re-)Classification of systems
- Demonstrating absence of impact when dismantling structures, systems and components

Current challenges

Waste management

- Timeline of waste generation
- Clearance options
- Treatment and conditioning capacities
- Long-term interim storage of fuel and decommissioning waste

Knowledge management

- Maintenance of competence at all levels
  - Operators
  - Regulatory body
  - Technical support organisations

Summary

- In Germany a large number of decommissioning projects was successfully performed
- Recent decommissioning experiences relate among others to
  - Phased approach
  - Industrial development at the site
  - Large component removal
  - Clearance
- Challenges
  - Fuel elements still present
  - Waste management
  - Knowledge Management

Removed NPP Niederaichbach

© Backcock Noell GmbH

Thank you for your attention!
Any Questions?