Decommissioning in Germany

November 2007

Current Status

In Germany, 19 nuclear power plants (NPPs) and prototype reactors were permanently shut down (see Table 1). Two of them (KKN in Niederaichbach and HDR in Grosswelzheim) were completely dismantled. The sites were restored to "green-field conditions" and released from nuclear regulatory control. Two of the NPPs (KWL in Lingen and THTR-300 in Hamm-Uentrop) are in safe enclosure. For the other 15 NPPs the dismantling is in progress with "green-field conditions" being the planning target. The 357 MW Obrigheim NPP was shut down in May 2005 and it is earmarked for immediate dismantling. An application for a decommissioning licence has been filed already ahead in December 2004.

Tab.1: Decommissioning of NPPs and prototype reactors

	Nuclear power plant	Type of Reactor	Electr. Power MW_e	First Criticality	Shut down	Decommissioning start | end
1	KNK II	FBR	21	10.10.1977	23.08.1991	26.08.1993
2	MZFR	PWR (D_2O)	57	29.09.1965	03.05.1984	17.11.1987
3	Gundremmingen-A	BWR	250	14.08.1966	13.01.1977	26.05.1983
4	VAK	BWR	16	13.11.1960	25.11.1985	05.05.1988
5	HDR Großwelzheim	BWR	25	14.10.1969	20.04.1971	16.02.1983 | 15.10.1998
6	Niederaichbach	HWGCR	106	17.12.1972	31.07.1974	21.10.1975 | 17.08.1995
7	Rheinsberg	WWER	70	11.03.1966	01.06.1990	28.04.1995
8	Greifswald-1	WWER	440	03.12.1973	18.12.1990	30.06.1995
9	Greifswald-2	WWER	440	03.12.1974	14.02.1990	„
10	Greifswald-3	WWER	440	06.10.1977	28.02.1990	„
11	Greifswald-4	WWER	440	22.07.1979	02.06.1990	„
12	Greifswald-5	WWER	440	26.03.1989	30.11.1989	„
13	AVR Jülich	HTGR	15	26.08.1966	31.12.1988	09.03.1994
14	THTR-300	HTGR	308	13.09.1983	29.09.1988	22.10.1993 | Okt.1997; in SE
15	Würgassen	BWR	670	22.10.1971	26.08.1994	14.04.1997
16	Lingen	BWR	252	31.01.1968	05.01.1977	21.11.1985 | 30.03.1988; in SE
17	Mülheim-Kärlich	PWR	1302	01.03.1986	12.06.2001	16.07.2004
18	Stade	PWR	672	08.01.1972	14.11.2003	07.09.2005
19	Obrigheim	PWR	357	22.09.1968	11.05.2005	Application for D & D filed on 21.12.2004

SE = Safe enclosure FBR = Fast breeder reactor PWR = Pressurised water reactor
BWR = Boiling water reactor HWGCR = Heavy water moderated, gas cooled reactor
WWER = Water cooled water moderated reactor HTGR = High temperature gas cooled reactor

Additionally, 34 research reactors were permanently shut down. Up to now 24 research reactors were completely dismantled. Two of the research reactors are in safe enclosure. Dismantling of the other 8 research reactors is either in progress or in preparation.

Finally, 11 nuclear fuel cycle facilities (mostly fuel fabrication and fuel reprocessing facilities) were permanently shut down and 7 of them were completely dismantled or released from regulatory control. Dismantling is in progress at the other 4 facilities.

Purpose / Objectives of D&D

The German Government reached an agreement with the power industry to phase out of nuclear energy generation. The details of the phase out have been laid down in the amendment of the Atomic Energy Act of April 2002. The remaining operational period of an individual NPP is characterised by its residual amount of electricity production which is calculated from a nominal operating time of 32 years (see chapter “Perspectives”). The transfer of remaining electricity generation between NPPs is possible. As a consequence, NPPs will be gradually closed down over a period of about 20 years and subsequently dismantled.

The policy of the German Government is aiming at immediate dismantling, in general to “green field” conditions. This is in line with the present strategy of the NPP operators, who are in favour of this strategy, mainly in order to benefit from existing experience and the availability of qualified and trained staff, and because of social aspects and cost considerations. On the other hand, operators consider to wait with the dismantling of nuclear facilities until a repository for radioactive waste will be available in Germany (see chapter “Radioactive Waste Management”). It is up to the operator to decide on the decommissioning strategy and in the past both options, i.e. immediate dismantling and safe enclosure with subsequent dismantling, have been chosen.

The German legal framework requires a licence for the decommissioning of nuclear facilities which is based on an application by the operator to the respective regulator. In practice, there is a transfer from the operational to the decommissioning licence. After shut down of a nuclear facility, nuclear fuel or other residual radioactive material and radioactive waste is removed typically within the scope of the operational licence. The decommissioning licence terminates the operational licence and covers all activities up to the end point of decommissioning, which is in general the release of the site from nuclear regulatory control. In the case of larger facilities, a stepwise licensing process is typically applied, with the regime of the residual operation and the overall decommissioning concept being the subject of the first licence. Such a process enhances flexibility and allows the introduction of experience gained.

The time frame for the dismantling of nuclear facilities depends on the type and complexity of the individual project. Practical experience shows that the dismantling of a NPP will take a period of more than 10 years. Based on the present boundary conditions it can be estimated that the German NPPs will be decommissioned in the 2030ies.

Furthermore, the German policy is aiming at minimising (radioactive) waste and at recycling and reuse of materials. In this context, the release of materials, buildings and sites from nuclear regulatory control is of high importance. The German Radiation

Protection Ordinance of July 2001 includes a comprehensive and consistent set of quantitative and radionuclide specific data for the release of materials, buildings and sites from nuclear regulatory control. This is a profound basis for terminating such controls. In practice, the implementation of such an approach requires a great number of measurements, in particular by the operator, in order to demonstrate compliance with legal requirements.

Social and Environmental Aspects

Nuclear facilities are generally located in sparsely populated regions within the borders of small communities and are often the major source of employment and public income in the region. The closing down of a nuclear facility and the decommissioning to “green field conditions” are major changes and can be associated with social impacts. In order to soften such impacts, immediate dismantling will help to keep a good deal of the staff employed and the local suppliers busy.

In the long term, political and economical skills are required to find replacements for the nuclear industry and the associated jobs. Such an approach is, for example, taken in the case of the Greifswald NPPs which are located in an economically depressed area.

Environmental impacts other than the radiological ones are also to be taken into account in the decommissioning of nuclear facilities and an environmental impact assessment (EIA) is required by law (Environmental Impact Assessment Act of September 2001) as an integral part of the nuclear licensing process. The Act deals with the procedures for conducting an EIA, from scoping via the EIA to the decision of the regulatory body. It is also devoted to the public participation in the licensing process.

Competent Bodies and Roles

In Germany the legal and regulatory framework is designed to be applicable to all types of nuclear facilities / activities including the decommissioning of nuclear facilities. This generic approach has been developed for regulating nuclear activities over the many years of nuclear experience. Provisions applicable to an individual subject area, such as decommissioning of nuclear facilities, are “scattered” in the various documents of the national legal and regulatory framework. In order to provide assistance to those who are dealing with decommissioning of nuclear facilities, a “Guide to Decommissioning” was published in 1996, which compiled all regulations relevant for licensing and supervising the decommissioning of nuclear facilities and also helps to harmonize the overall licensing process.

A great number of amendments were made to the legal and regulatory provisions in recent years, in particular on the phase out of nuclear energy generation, on the environmental impact assessment, and on the release of buildings, materials and sites from nuclear regulatory control. As a consequence, the “Guide to Decommissioning” is being updated.

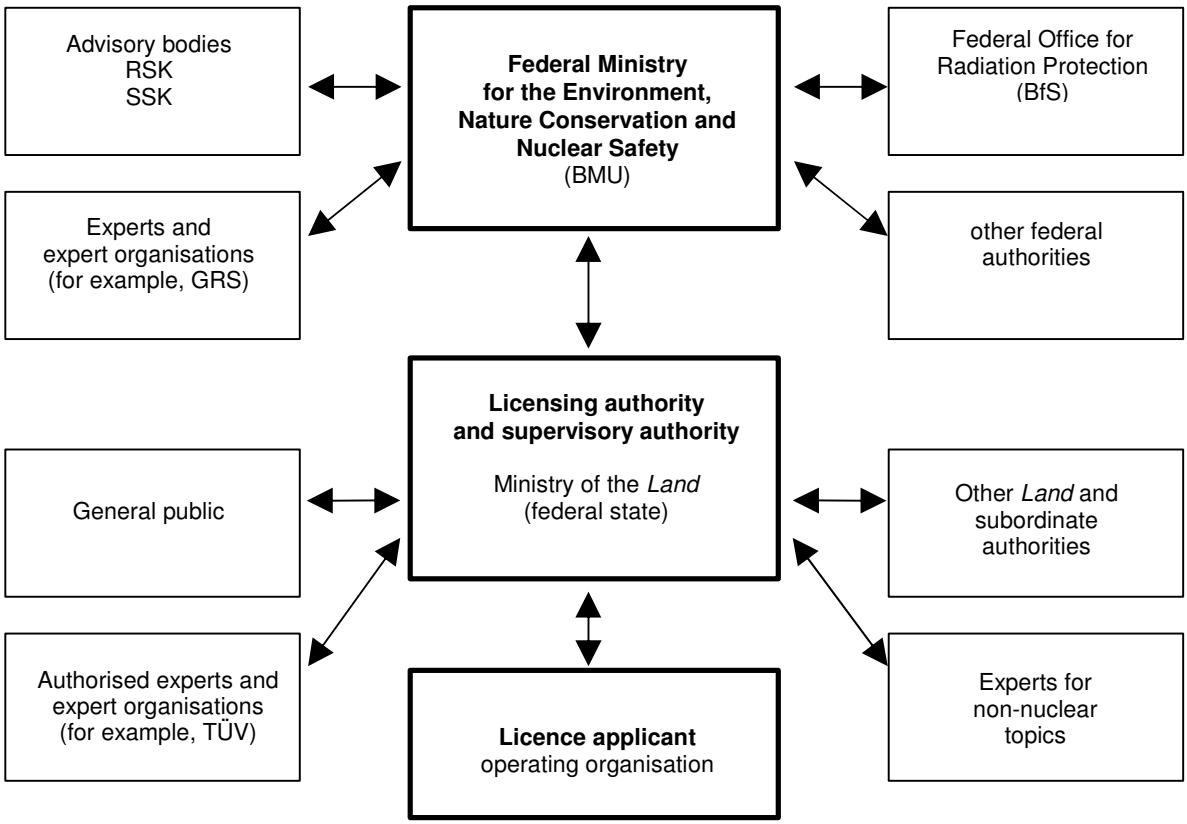
The Atomic Energy Act is the key document for all nuclear regulatory activities in Germany, including decommissioning of nuclear facilities. It includes the provision that decommissioning of nuclear facilities needs to be licensed by the respective regulatory body. The regulatory body has also to ensure that all the requirements and conditions

stated in the decommissioning licence are fulfilled by the operator. It has also to decide on the termination of a licence and the respective release of an operator from his obligations. In order to discharge its duties, the regulatory body involves experts or expert organisations which must be independent of the operator.

Licensing and inspection of nuclear facilities and activities, including decommissioning of nuclear facilities, is the responsibility of the respective Federal State (Land). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supervises the activities of the Federal States and harmonises the application of the legal framework. If necessary, the BMU may give directives to the regulatory body of the respective Federal State. The licensing procedure includes the participation of the public. The following figure provides an overview over the relations among the parties involved.

The Atomic Energy Act is supplemented by several ordinances, in particular the Radiation Protection Ordinance and the Nuclear Licensing Procedure Ordinance. The Radiation Protection Ordinance lays down, for example, the radiation protection principles and the permissible occupational and public radiation exposures. The Nuclear

Figure: Participants in the Nuclear Licensing and Supervisory Procedure
for the decommissioning of nuclear facilities; §7 (3) Atomic Energy Act



Licensing Procedure Ordinance provides guidance, for example, on the licensing procedure, the involvement of the public and on how to carry out an environmental impact assessment.

Funding Arrangements

In Germany, the “polluter pays” principle is applied to the management of spent fuel and radioactive waste, including the decommissioning of nuclear facilities.

In the case of publicly owned or inherited facilities (research reactors; facilities within research centres or at universities; prototype reactors and the Greifswald and Rheinsberg nuclear power plants), decommissioning funds are being provided within the annual Federal budget. In the case of research and prototype facilities the Federal Government typically covers 90 % of the costs, while the rest is borne by the respective Land. The decommissioning of the nuclear power plants in Greifswald and Rheinsberg, inherited from the former GDR, is completely financed by the Federal Government.

In the case of privately owned facilities (for example, NPPs and fuel cycle facilities) financial reserves have to be accumulated during the operational phase by the owner of the respective facility. These reserves will have to cover the management of radioactive waste and spent fuel including decommissioning. The reserves are held in the portfolio of and managed by the owners of facilities. Reserves reduce the income of the operators subject to taxation. Annual cost calculations have to be prepared in order to justify the amount of the respective reserves which are reviewed by tax authorities.

Decommissioning Techniques and Inspection

Decontamination and Release of Materials, Buildings and Sites from Nuclear Regulatory Control

A radiological survey of the facility to be decommissioned is of primary importance as the type, level and location of activation / contamination is decisive for the technical and logistical approach to the decommissioning of a nuclear facility.

Activated components are normally concentrated in the reactor core area. They are characterised by high levels of radiation resulting, in particular, from short lived radionuclides. Decay of such radionuclides eases decommissioning and therefore it is a logical approach in the decommissioning of a reactor to work from contaminated, less radioactive zones to the activated, higher radioactive core.

Contaminated components, in particular metallic materials, can be decontaminated effectively. The respective technologies and methods are available in Germany. Dismantling of a component or facility is normally preceded by decontamination steps in order to avoid unnecessary exposures of personnel. In many instances materials can be effectively decontaminated down to trivial levels of contamination which allows release of materials from nuclear regulatory control and recycle and reuse of materials or disposal as conventional waste.

In Germany quantitative requirements for the release of materials, buildings, and sites from nuclear regulatory control were introduced into the Radiation Protection Ordinance (StrlSchV) in 2001.

The quantitative, radionuclide specific release levels are based on the internationally accepted 10 µSv concept, which means that public exposures caused by release shall not be higher than about 10 µSv/a. Extensive and sophisticated radiological model calculations for various pathways to humans for about 300 radionuclides and for various release options were carried out to determine quantitative release levels for individual radionuclides. These data were finally laid down in the StrlSchV. The limits that have been defined in this way are in compliance with the European Radiation Protection Directive 96/29 EURATOM and with international expert opinion.

It is an important task to provide proof for the compliance with the requirements of the StrlSchV with reasonable means. In order to ensure compliance with the requirements any material to be released from a nuclear facility has to pass an officially regulated process with many stages of quality control. This process is supervised by the regulatory body and its independent experts.

The practical experience in Germany shows, that the application of such a procedure allows the release of considerable parts of the plants from nuclear regulatory control. Less than 5 % of the total mass of a plant remains as radioactive waste.

Dismantling

Decommissioning of nuclear facilities involves various dismantling techniques, e.g. mechanical or thermal cutting, sawing and finally a demolition of buildings. These techniques are available in the non-nuclear area and have been adapted to the decommissioning of nuclear facilities in such a way that the protection of the environment and the protection of individuals from incorporation of radionuclides and from direct radiation is effectively ensured. The required protection is provided by applying, for example, remote techniques, working under water, providing shielding and installation of appropriate ventilation systems. A good amount of experience is available in Germany with the application of such techniques to the decommissioning of nuclear facilities.

A new development in dismantling is increasingly the removal of complete undismantled large components and their transport to and storage in interim storage facilities. In 2007 licences were granted to the Greifswald (units 1 to 4) and Rheinsberg NPPs (both EWN GmbH) for the removal of the complete undismantled reactor vessels and their transport to the interim storage facility at Lubmin. During the period of interim storage, the radionuclide inventory of the components will decrease due to radioactive decay and the following segmentation of the component can be done with less radiation protection measures. After start of operation of a final disposal facility it must be decided, whether the segmented components can be released from nuclear regulatory control or must be disposed of as radioactive waste. One further example is the high-temperature reactor in Jülich (AVR GmbH, subcompany of EWN GmbH). It is planned to fill the reactor tank of AVR with light-weight concrete and to lift the complete reactor tank out of the reactor building. Subsequently the reactor tank will be stored in a nearby interim storage facility.

Regulatory Inspection

Operational activities at nuclear facilities, from the start of the construction to the end of the decommissioning, are subject to continuous regulatory inspection and supervision in accordance with the Atomic Energy Act and the respective ordinances. The responsibility for inspection lies with the respective Federal State (Land) authority (see Figure). Basically, the philosophy and programme for regulatory inspections are similar during operation and decommissioning. The supervisory authority pays particular attention to the compliance with the legal framework and the licensing requirements. It monitors, with the help of authorised experts, in particular,

- compliance with operating procedures,
- discharge limits,
- criteria for the release of materials, buildings and sites from nuclear regulatory control, and
- occupational and public radiation protection.

The operators have to provide written reports to the regulatory body at regular intervals. Additionally, comprehensive documentation will be necessary in the case that a facility is going into safe enclosure also upon termination of the decommissioning activities. This documentation will have to be stored and maintained properly in order to ensure that information can be made available when needed.

Radioactive Waste Management

In the Federal Republic of Germany it is intended to dispose of all types of radioactive waste in deep geologic formations. Following the Federal Elections on 18 September 2005 a Grand Coalition was formed by the Christian Democratic Party (CDU/CSU) and the Social Democratic Party (SPD). Pursuant to the coalition agreement CDU/CSU and SPD acknowledge the national responsibility for the safe disposal of radioactive waste and will work on this topic efficiently and result oriented to come to a solution within this legislative period.

The Konrad repository had been licensed on 22 May 2002 for all kinds of radioactive waste with negligible heat generation. All suits, that were filed against it, had been rejected by the competent court by 8 March 2006. Complaints against the courts decision have been definitely rejected by the federal administrative court on 3 April 2007. Following necessary planning adjustments the former iron ore mine will then be converted into a repository for radioactive waste with negligible heat generation. On 30 May 2007 BMU has ordered the Federal Office for Radiation Protection (BfS) as the competent authority to conduct this work. BfS has set up a project group and immediately started the work, which is planned to be completed within a period of six years in the year of 2013.

Perspectives

As laid down in the Atomic Energy Act, Germany decided to phase out of nuclear energy in a systematic manner. This means that - as next steps - the operating NPPs will be shut down in the foreseeable future when the fixed target amount of electricity has been

generated. The status on residual electricity production rights as of December 2006 was published in the ”Bundesanzeiger” (Federal Gazette) on 16 March 2007.

A forecast of a potential shut down date is given in Table 2. It should be noted that it is not possible to give exact dates of individual NPPs as, for example, unplanned outages or standstills will slow down the electricity generation and defer the shut down. Furthermore, it is permitted to transfer, under specified conditions, electricity generation quantities among NPPs.

Table 2: Operating German nuclear power plants and residual electricity generation as of 1 January 2000 (Annex 3, Atomic Energy Act)

Nuclear Power Plant	Type of Reactor	Gross El. Power [MW_{el}]	Residual El. Generation (TWh)	Forecast shut down date (estimation)
Biblis A (KWB A)	PWR	1225	62,0	2009
Neckarwestheim-1 (GKN 1)	PWR	840	57,4	2009
Biblis B (KWB B)	PWR	1300	81,5	2010
Brunsbüttel (KKB)	BWR	806	47,7	2009
Isar-1 (KKI 1)	BWR	912	78,4	2011
Unterweser (KKU)	PWR	1410	118,0	2012
Philippsburg-1 (KKP 1)	BWR	926	87,1	2012
Grafenrheinfeld (KKG)	PWR	1345	150,0	2014
Krümmel (KKK)	BWR	1316	158,2	2016
Gundremmingen B (KRB B)	BWR	1344	160,9	2016
Gundremmingen C (KRB C)	BWR	1344	168,4	2016
Grohnde (KWG)	PWR	1430	200,9	2017
Philippsburg-2 (KKP 2)	PWR	1458	198,6	2017
Brokdorf (KBR)	PWR	1440	217,9	2019
Isar-2 (KKI 2)	PWR	1475	231,2	2020
Emsland (KKE)	PWR	1400	230,1	2020
Neckarwestheim-2 (GKN 2)	PWR	1365	236,0	2021

The following organisations on the federal level provide public information:

- **Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU)**
  Referat Öffentlichkeitsarbeit
  D-11055 Berlin
  Tel.: +49-1888-305-3355
  E-Mail: service@bmu.de
  Internet: www.bmu.de

  A comprehensive brochure entitled:
  Decommissioning of Nuclear Facilities
  (September 2001)
  is available upon request from the BMU in English and German.

- **Bundesministerium für Bildung und Forschung (BMBF)**
  Heinemannstr. 2
  D-53175 Bonn
  or:
  Hannoversche Str. 30
  D-10115 Berlin
  Tel.: +49-1888-57-0

  Information about decommissioning projects in Germany can be found in the BMBF booklet:
  Stilllegung und Rückbau kerntechnischer Anlagen
  2. neu bearbeitete Auflage
  Mai 2000

- **Bundesamt für Strahlenschutz (BfS)**
  Willy-Brandt-Str.5
  D-38226 Salzgitter-Lebenstedt
  Tel.: +49-1888-333-1547
  E-Mail: info@bfs.de
  Internet: www.bfs.de/kerntechnik/stilllegung

Information on selected decommissioning projects in Germany is available from the following addresses:

- **Kernkraftwerk Würgassen**
  An der Kreisstraße 338
  D-37688 Beverungen
  Tel.: +49-5273-38-0
  E-Mail: info-kernkraft@eon-energie.com
  Internet: www.eon-kernkraft.com

- **Kernkraftwerk Stade**
  Bassenflether Chaussee
  D-21713 Stade
  Tel.: +49-4141-77-2390
  E-Mail: detlef.hubert@eon-energie.com
  Internet: www.eon-kernkraft.com

- **Kernkraftwerk Mülheim-Kärlich**
  Postfach 1432
  D-56210 Mülheim-Kärlich
  Tel: +49-2637-644 456
  E-Mail: werner.herig@kkw.rwe.com
  Internet: www.rwepower.com

- **Kernkraftwerk Obrigheim**
  Kraftwerksstr. 1
  D-74847 Obrigheim a.N.
  Tel.: +49-6261-65-0
  E-Mail: info@kwobrigheim.de
  Internet: www.enbw.com

- **Versuchsatomkraftwerk Kahl GmbH**
  Postfach 6
  D-63791 Karlstein
  Tel.: +49-6188-499-125
  E-Mail: vak@energie.rwe.de
  Internet: www.vak.rweenergie.de

- **Energiewerke Nord (EWN GmbH)**
  Postfach 1125
  Abteilung Öffentlichkeitsarbeit
  D-17507 Lubmin
  Tel.: +49-38354-48030
  E-Mail: info@ewn-gmbh.de
  Internet: www.ewn-gmbh.de

- **Forschungszentrum Karlsruhe GmbH**
  Hermann-von-Helmholtz-Platz 1
  D-76344 Eggenstein-Leopoldshafen
  Tel: +49-7247-82-0
  E-Mail: info@fzk.de
  Internet: www-pbs.fzk.de/projekte.htm

- **Wiederaufarbeitungsanlage Karlsruhe Betriebsgesellschaft mbH**
  Postfach 1263
  D-76339 Eggenstein-Leopoldshafen
  Tel.: +49-7247-88-0
  E-Mail: kontakt@wak.fzk.de
  Internet: www.wak-karlsruhe.de