State and Development of Nuclear Energy Utilization in the Federal Republic of Germany 2015

Department of Nuclear Safety

Ines Bredberg

Johann Hutter

Kerstin Kühn

Katarzyna Niedzwiedz

Frank Philippczyk

Achim Thömmes

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SUMMARY

This report describes the use of nuclear energy in the Federal Republic of Germany as at 31 December 2015. It contains the essential data of all nuclear power plants, research reactors and the facilities of the nuclear fuel cycle. At the reporting moment 31 December 2015, eight nuclear power plant units were in operation. The power generation from nuclear energy in 2015 amounted to altogether 91.8 TWh (2014: 97.1 TWh). This is a share of 14.1 % of the total gross electricity production (2014: 15.8 %).

The report summarises the essential operational results of the nuclear power plants and information on granted licences. A short description of the present state of the nuclear power plants that have been shut down or decommissioned and of the stopped projects is given. Concerning research reactors essential data on type, characteristics (thermal power, thermal neutron flux) and purpose of the facility are represented. Furthermore, an overview is given of the licensing and operation history and the present state of the operating condition. For the facilities of the nuclear fuel cycle data on purpose and capacity and output are given.Furthermore, the licensing history and the present status of operation and licensing are represented. The works on the running repository projects ERAM and Konrad and on the Asse II mine and the Gorleben mine are presented. To give a survey, the data is summarised in tabular form at the end of in the report (Annexes). The report is updated and published once a year.

LIST OF ABBREVIATIONS

A2B	ASSE II Monitoring Group
ADIBKA	Burn-up measurement of differential fuel elements with critical assembly
AGEB	Energy Balances Working Group
AKR-2	Training reactor Technische Universität Dresden
ANEX	Facility for homopolar power experiments
ANF (AREVA)	Advanced Nuclear Fuels GmbH, French industrial company, main line of business: nuclear technology
AtG	Atomic Energy Act
AtVfV	Nuclear Licensing Procedure Ordinance
AVR	Atomversuchskernkraftwerk Jülich, Jülich Experimental NPP
BB	Brandenburg
BBergG	Federal Mining Law
BDEW	Bundesverband der Energie- und Wasserwirtschaft e.V., Federal Association of Energy and Water Economy e.V.
BE	Berlin
BER II	Berliner-Experimentier-Reaktor II, Berlin Experimental Reactor Unit II
BfS	Federal Office for Radiation Protection
BGR	Bundesanstalt für Geowissenschaft und Rohstoffe, Federal Institute for Geosciences and Natural Resources
BLG	Brennelementlager Gorleben GmbH, Gorleben Fuel Element Storage Facility
BMBF	Bundesministerium für Bildung und Forschung, Federal Ministry of Education and Research
BMFT	Bundesministerium für Forschung und Technologie, Federal Ministry of Research and Technology
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (renamed to BMUB on 17.12.2013)
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (previously BMU)
BNFL	British Nuclear Fuels Ltd.
Bq	Becquerel
BVerfG	Federal Constitutional Court
BVerwG	Federal Administrative Court
BW	Baden-Württemberg
BWE	Bundesverband WindEnergie e.V., German Wind Energy Association
BY	Bavaria
BZA	Ahaus Interim Storage Facility for Spent Fuel Elements
CASTOR®	Cask for Storage and Transport of Radioactive material
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
CLAB	Central interim storage facility for spent fuel elements in Sweden
COGEMA	Compagnie Générale des Matières Nucléaires, AREVA-Group
CSD-C	Colis Standard de Déchets Compactés
DAHER-NCS	Nuclear Cargo + Service GmbH
DBE	German Company for the Construction and Operation of Waste Repositories
DBG	Permanent operating licence
DDR	German Democratic Republic
DIDO	Heavy water moderated and cooled research reactor in the Jülich Research Center
DKFZ	German Cancer Research Center
DWK	German Company for the Reprocessing of Nuclear Fuels
E.ON	E.ON Kernkraft GmbH
ELK	Emplacement chamber
ELMA	Extended storage facility for intermediate-level radioactive waste
EnBW	Energiewerke Baden-Württemberg AG
EnKK	EnBW Kernkraft GmbH
ERAM	Morsleben Repository for Radioactive Waste
ERU	Enriched-Uranium
ESK	Waste Management Commission
EVU	Utilities

EWN	Energiewerke Nord GmbH
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EnBW	Energiewerke Baden-Württemberg AG
EnKK	EnBW Kernkraft GmbH
E.ON	E.ON Kernkraft GmbH
ERAM	Morsleben Repository for Radioactive Waste
ERU	Enriched-Uranium
ESK	Waste Management Commission
EVU	Utilities
EWN	Energiewerke Nord GmbH

BWR	Boiling water reactor (BWR)
FBR	Sodium-cooled Fast Breeder Reactor
FDR	Advanced Pressurised Water Reactor
FMRB	Research and Measuring Reactor Braunschweig
FR 2	Research Reactor Karlsruhe Unit 2
FRF 1	Research Reactor Frankfurt Unit 1
FRF 2	Research Reactor Frankfurt Unit 1
FRG-1	Research Reactor Geesthacht Unit 1
FRG-2	Research Reactor Geesthacht Unit 1
FRH	Research Reactor of the Hannover Medical School
FRJ-1	Research Reactor Jülich Unit 1
FRJ-2	Research Reactor Jülich Unit 2
FRM	Forschungsreaktor München, Research Reactor Munich
FRM-II	Research Reactor Munich, high-flux neutron source
FRMZ	TRIGA Mark II Research Reactor of the Mainz University
FRN	Research Reactor Neuherberg
FZJ	Jülich Research Center
FZK	Karlsruhe Research Center
GKN 1	Neckarwestheim NPP Unit 1
GKN 2	Neckarwestheim NPP Unit 2
GKSS	Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH, now: Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH
GNS	Gesellschaft für Nuklear Service mbH
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit mbH
GWh	Gigawatt hour
HAW	High-Active Waste
HAWC	High-Active Waste Concentrate
HB	Free Hanseatic City of Bremen
HE	Hesse
HEU	High-Enriched Uranium
HH	Free and Hanseatic City of Hamburg
HKG	Hochtemperatur-Kernkraftwerk GmbH
HMGU	Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt GmbH
HOBEG	Hochtemperatur-Brennelement Gesellschaft
HTR	High-temperature gas-cooled reactor
HWL	High-Active Waste Storage Facility
JEN	Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH
K	Kelvin
KAHTER	Critical facility for high-temperature reactors
KBR	Brokdorf NPP
KEITER	Critical experiment on in core thermionics reactor
KGR	Greifswald nuclear power plant
KIT	Karlsruhe Institute of Technology
KKB	Brunsbüttel nuclear power plant
KKE	Emsland nuclear power plant
KKG	Grafenrheinfeld nuclear power plant
KKI 1	Isar nuclear power plant Unit 1
KKI 2	Isar nuclear power plant Unit 2
KKK	Krümmel nuclear power plant
KKN	Niederaichbach nuclear power plant
KKP 1	Philippsburg nuclear power plant Unit 1
KKP 2	Philippsburg nuclear power plant Unit 2
KKR	Rheinsberg nuclear power plant
KKS	Stade nuclear power plant
KKU	Unterweser nuclear power plant
KMK	Mülheim-Kärlich nuclear power plant
KNK II	Karlsruhe Sodium-cooled Reactor

KRB A	Gundremmingen nuclear power plant Unit A
KRB-II-B	Gundremmingen nuclear power plant Unit B
KRB-II-C	Gundremmingen nuclear power plant Unit C
KTA	Nuclear Safety Standards Commission
KWB A	Biblis nuclear power plant Unit A
KWB B	Biblis nuclear power plant Unit B
KWG	Grohnde nuclear power plant
KWL	Lingen nuclear power plant
KWO	Obrigheim nuclear power plant
KWU	Siemens AG, Fachbereich Kraftwerk-Union
KWW	Würgassen nuclear power plant
LAVA	Facility for the Storage and Vaporisation of High-Active Waste Liquids
LAW	Low-Active Waste
LBEG	State Authority for Mining, Energy and Geology
LEU	Low-Enriched Uranium
LWR	Light Water Reactor
MERLIN	Medium Energy Research Light Water Moderated Industrial Nuclear Reactor in the Jülich Research Center (FZJ)
MEU	Medium-Enriched Uranium
MLU	Saxony-Anhalt Ministry for Agriculture and the Environment
MOX	Mixed-oxide (fuel)
MTR	Materials Testing Reactor
MV	Mecklenburg-Vorpommern
MW_e	Megawatt electrical power
MWEIMH NRW	Ministry of Economic Affairs, Energy, Industry, Middle Class and Trade of the Land of North Rhine-Westphalia
MWh	Megawatt hour
MW_{th}	Megawatt thermal power
MZFR	Multipurpose Research Reactor Karlsruhe
NBauO	Lower Saxon Building Code
NCS	Nuclear Cargo + Service GmbH, since 01.10.2015 DAHER-NCS
NI	Lower Saxony
NMU	Lower Saxon Ministry for the Environment, Energy and Climate Protection
NPP	Nuclear Power Plant
NUKEM	NUKEM GmbH Alzenau
NW	North Rhine-Westphalia
OH	Otto Hahn
oHG	General Partnership
OVG	Higher Administrative Court
PFB	Plan-approval decision
PKA	Pilot conditioning plant
PTB	Physikalisch-Technische Bundesanstalt
PuO_2	Plutonium dioxide
PWR	Druckwasserreaktor, Pressurised Water Reactor (PWR)
RAKE	Rossendorf assembly for critical experiments
RDB	Reactor pressure vessel
RFR	Research Reactor Rossendorf
RP	Rhineland-Palatinate
RRR	Rossendorf ring zone reactor
RRRFR	Russian Research Reactor Fuel Return
RSK	Reactor Safety Commission
RWE	Rheinisch-Westfälische Elektrizitätsgesellschaft
SAAS	Federal Office for Nuclear Safety and Radiation Protection (of the former GDR)
SAR	Siemens Argonaut Reactor
SE	Safe enclosure
SG	Decommissioning licence
SH	Schleswig-Holstein
SL	Saarland

SM	Schwermetall, heavy metal (HM)
SMUL	Saxon State Ministry for the Environment and Agriculture
SN	Saxony
SNEAK	Fast Zero-Power Facility
SSK	German Commission on Radiological Protection
SSR	Großwelzheim Superheated Steam Reactor
ST	Saxony-Anhalt
STARK	Fast Thermal Argonaut Reactor
StMUV	Bavarian State Ministry of the Environment and Consumer Protection
StrlSchV	Radiation Protection Ordinance
SUA	Siemens Subcritical Assembly
SUR	Siemens Training Reactor
SZL	On-site interim storage facilities
TBG	Partial operating licence
TBL	Transport cask storage facility
TBL-A	Ahaus Transport Cask Storage Facility
TBL-G	Gorleben Transport Cask Storage Facility
TEG	Partial construction licence
TG	Partial licence
TH	Thuringia
THTR-300	Hamm-Uentrop Thorium High-Temperature Reactor
TRIGA HD I	TRIGA HD I Research Reactor Heidelberg
TRIGA HD II	TRIGA HD II Research Reactor Heidelberg
TRIGA	Training Research Isotope General Atomics
TSG	Partial decommissioning licence
TUM	Technische Universität München
TWh	Terawatt hour
U-235	Uranium isotope 235
U_3O_8	Triuranium octoxide
UAG	Gronau Uranium Enrichment Plant
UF_6	Uranium hexafluoride
UNS	Independent Emergency System
UO_2	Uranium dioxide
UTA	Uranium separative work
UVP	Environmental Impact Assessment
VAK	Kahl Test Nuclear Power Plant
VBA	Lost concrete shielding
VDEW	Verband der Elektrizitätswirtschaft (e.V.)
VDMA	Verband Deutscher Maschinen- und Anlagenbau e.V.
VEK	Karlsruhe Vitrification Facility
VGB	Technische Vereinigung der Großkraftwerksbetreiber (e.V.)
VKTA	Radiation Protection, Analytics and Waste Management Rossendorf (e.V.)
WAK	Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs-GmbH
WAW	Wiederaufarbeitungsanlage Wackersdorf, Wackersdorf Reprocessing Plant
WWER	Water-cooled water-moderated energy reactor (Russian type PWR)
WWR-S (M)	Water-cooled water-moderated reactor of the Russian type, S stands for serial production and M for modification (RFR: Modifications of core and fuel)
ZLN	Interim Storage

1 ELECTRIC ENERGY PRODUCTION IN GERMANY

1.1 GENERAL

In 2015, altogether approximately 651.8 TWh (2014: ca. 627.8 TWh) of electric energy was produced in the Federal Republic of Germany (gross electricity production including electricity transfers, i.e. without electricity balance). The total gross electricity production in Germany increased compared with the preceding year (cf. Table 1.1).

According to preliminary calculations, the share of renewables in electricity production increased to about 30% in the year under report. The upward trend of wind energy continued also in 2015. Thus, 546 offshore wind turbines were connected to the grid with an installed capacity of 2,282.4 MW. (Source: BWE). Altogether, on- and offshore wind turbines produced ca. 88 TWh of electric energy (2014: 57.3 TWh) and thus the major share.

The share of nuclear energy in the total gross electricity production reduced from 15.5 % in 2014 to 14.1 % in 2015 (source: BDEW).

Table 1.1: Share of energy sources in the total gross electricity production in per cent

***	2012		2013		2014*		2015*	
	TWh	%	TWh	%	TWh	%	TWh	%
Nuclear energy	99.5	15.8	97.3	15.2	97.1	15.5	91.8	14.1
Lignite	160.7	25.5	160.9	25.2	155.8	24.8	155.0	23.8
Hard coal	116.4	18.5	127.3	19.9	118.6	18.9	118.0	18.1
Mineral oil	7.6	1.2	7.2	1.1	5.7	0.9	5.4	0.8
Natural gas	76.4	12.1	67.5	10.6	61.1	9.7	59.6	9.1
Renewables, among these	143.8	22.8	152.4	3.9	162.5	25.9	195.9	30.1
Wind	50.7	8.0	51.7	8.1	57.3	9.1	88.0	13.5
Water	22.1	3.5	23.0	3.6	19.6	3.1	19.3	3.0
Biomass	39.7	6.3	41.2	6.4	43.3	6.9	44.2	6.8
Photovoltaic systems	26.4	4.2	31.0	4.9	36.1	5.8	38.4	5.9
Garbage (just renewable share)	5.0	0.8	5.4	0.8	6.1	1.0	5.8	0.9
Geothermal energy	****	****	0.1	****	0.1	****	0.1	****
Others (total)**	25.7	4.1	26.2	4.1	27.0	4.3	26.1	4.0
TOTAL	630.1	100.0	638.8	100.0	627.8	100.0	651.8	100.0

* All figures relating to the years 2014 and 2015 are preliminary estimations, part of them estimated.

** In the data of BDEW, the classification “Other” energy sources is specified as pump storage, domestic waste (non-regenerative share) and industrial waste.

*** all values are rounded

**** Value very small, therefore not given here

[Source: BDEW, as at March 2016]

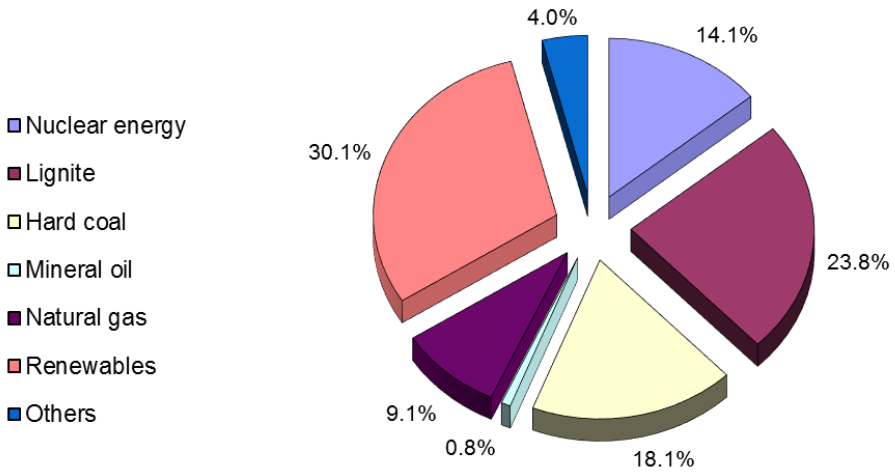


Fig. 1: Share of energy sources in the total gross electricity production in 2015 (basis: 651.8 TWh)

1.2 THE RENEWABLE ENERGIES ACT

The increased utilisation of renewables is a component of the German climate protection strategy. This is stipulated in the Renewable Energies Act (EEG) that became effective in 2000 and has been continually developed further since. The EEG amendment 2014 has been effective since 01.08.2014. Accordingly, the share of renewables in power supply is to be increased to minimum 40 to 45% until the year 2025, to 55 to 60% until the year 2035, and to at least 80% until the year 2050. The objective of the EEG amendment of 2014 is still to promote the use and development of renewables. In order to be able to better steer the expansion, specific expansion corridors have been determined for the annual growth of the various renewable energy technologies.

- Solar energy: Annual growth of 2.4 to 2.6 GW (gross)
- Wind energy (onshore): Annual growth of 2.4 to 2.6 GW (net)
- Biomass: Annual growth of 100 MW (gross), and
- Wind energy (offshore): Installation of 6.5 GW until 2020 and 15 GW until 2030.

(Source: BMWi)

1.3 PHASE-OUT OF ELECTRICITY PRODUCTION THROUGH NUCLEAR ENERGY

The use of nuclear energy for commercial power generation will gradually phase out in Germany. It is planned to shut down the last nuclear power plant in 2022.

The end of the individual power plants' operating times has been laid down in the Atomic Energy Act (AtG). The final shutdown of a nuclear power plant is followed by the post-operational phase during which works to prepare decommissioning are carried out.

1.3.1 Consequences of the reactor accident in Fukushima

As a result of the reactor accident in the Fukushima Daiichi Nuclear Power Plant, Japan, on 11 March 2011, the federal government decided in a moratorium on 14 March 2011 to take all German nuclear power plants that had been commissioned until and including 1980 from the grid and shut them down for a transitional period of three months. This affected the nuclear power plants Biblis A and Biblis B, Neckarwestheim 1, Brunsbüttel, Isar 1, Unterweser and Philippsburg 1. The nuclear power plants Biblis B, Brunsbüttel and Krümmel had already been taken from the grid at that point in time.

For these eight shut-down nuclear power plants and the nine Nuclear Power Plants still in operation at that time, the Reactor Safety Commission (RSK) conducted a safety check. The results and the cross-social dialogue with the participation of the Ethics Commission "Secure Provision of Energy" have led to a re-

evaluation of the risks associated with the use of nuclear energy in Germany. The federal government decided to end the use of nuclear energy for commercial power generation in Germany.

1.3.2 Current nuclear legislation in Germany

The 13th Law amending the Atomic Energy Act of 31 July 2011 specifies that the last nuclear power plants in Germany be shut down at the end of 2022.

When the new Atomic Energy Act became effective on 6 August 2011, the further authorisation for power operation expired for the eight nuclear power plants Biblis A and B, Neckarwestheim 1, Brunsbüttel, Isar 1, Unterweser, Philippsburg 1 and Krümmel. The installations are therefore entirely shut down. The operator of the Grafenrheinfeld plant (KKG) had already publicly announced in 2014 to take KKG from the grid prematurely. On 27 June 2015 the KKG was finally taken from the grid.

The following dates for the end of operating times or, respectively for the final shutdown of the remaining eight nuclear power plants still in operation have been laid down in the Atomic Energy Act:

31.12.2017 Gundremmingen NPP unit B

31.12.2019 Philippsburg NPP unit 2

31.12.2021 Grohnde NPP, Gundremmingen NPP unit C and Brokdorf NPP

31.12.2022 Isar NPP unit 2, Emsland NPP and Neckarwestheim NPP unit 2.

1.3.3 Electricity volumes generated in Germany

Already in June 2001 the federal government and the utilities agreed upon a certain electricity volume for each nuclear power plant which the respective plant is authorised to produce with reference date 1 January 2000. This resulted in an operating time of approximately 32 years for each nuclear power plant, which was determined in the Atomic Energy Act in April 2002. In 2010 the Federal Government decided to extend by eight years the operating times of the nuclear power plants that had taken up power operation until and including 1980 or, respectively, to extend the operating times of the younger nuclear power plants by 14 years. Correspondingly, the Atomic Energy Act as amended in December 2010 allocated additional electricity volumes to individual nuclear power plants. In the wake of the reactor accident in Fukushima Daiichi, the federal government decided to end the use of nuclear energy for commercial power generation. As a result, the Atomic Energy Act was amended in August 2011. It does again specify exclusively the electricity volumes for each individual nuclear power plant that had already been set out in the previous version of the Atomic Energy Act of April 2002. The extension of operating times laid down in December 2010 was revoked and the additional electricity volumes were cancelled.

With the Amendment to the Atomic Energy Act in August 2011 a concrete date was set by law for each single nuclear power plant to shut down. Furthermore, the Atomic Energy Act specifies in Column 2 of Annex 3 to § 7 para. 1a the electricity volumes that can still be produced with reference date 1 January 2000 (cf. Column 2 of the Table in Fig. 2). Once they have been produced, the authorisation for operating the plant will expire. According to the Atomic Energy Act the transfer of electricity volumes from one nuclear power plant to another is an option. They may be transferred in part or as a whole from one – usually older and smaller – nuclear power plant to another. The transfer of the remaining electricity volumes of the nuclear power plants shut down according to Atomic Energy Act on 6 August 2011 (Biblis A, Neckarwestheim 1, Biblis B, Brunsbüttel, Isar 1, Unterweser, Philippsburg and Krümmel) is also an option. According to the Atomic Energy Act, any transfer from a newer onto an older nuclear power plant is subject to the approval of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), in agreement with the Federal Chancellery and the Ministry of Economics and Technology. From the BMUB point of view, it is necessary in this case to compare the safety level of both nuclear power plants involved in the transfer. Transfers of electricity volumes must be reported to the Federal Office for Radiation Protection and are taken into account when registering the electricity volumes.

1.3.4 Tasks of the Federal Office for Radiation Protection

The Federal Office for Radiation Protection (BfS) registers and documents the net electricity volumes produced in the German nuclear power plants and the electricity volumes remaining according to Atomic Energy Act. The utilities measure the generated net electricity and, since May 2002, have reported the data to the BfS once a month. They arrange for the measuring devices to be tested by independent expert organisations and certify the annually reported electricity volumes assisted by a public accountant. The functional inspection reports and the certificates by the public accountant are submitted to the BfS.

The BfS has been publishing the produced, transferred and remaining electricity volumes according to Atomic Energy Act in the Bundesanzeiger (Federal Gazette) since 10 July 2002. The figures are published annually. Fig. 2 depicts the status of the electricity volumes on 31 December 2015 which was published on 10 March 2016 as annual statement in the Bundesanzeiger. Its current version can also be viewed at the BfS website http://www.bfs.de/EN/topics/ns/ni-germany/npp/operating-times/operating-times.html.

Should an operating time of less than six months be expected due to the residual electricity volumes, the figures are published monthly.

Announcement acc. to § 7 para. 1c Atomic Energy Act (AtG) – annual statement 2015 –

Electricity volumes produced, transferred and remaining during the period from 1 January 2000 to 31 December 2015 [GWh net] acc. to § 7 para. 1a annex 3 column 2 AtG

Nuclear Power Plant	Electricity volume From 1 January 2000	1 January 2000 until 31 December 2012	Total 2013	Total 2014	Total 2015	Electricity volumes transferred until 31 December 2015	Remaining Electricity volume
1	2	3	4	5	6	7	8
Biblis A[1) 4)]	62000.00	64591.29	0.00	0.00	0.00	4785.53	2194.24
Neckarwestheim 1[4)]	57350.00	57350.00	0.00	0.00	0.00		0.00
Biblis B[3) 4)]	81460.00	81737.52	0.00	0.00	0.00	8100.00	7822.48
Brunsbüttel[4)]	47670.00	36670.33	0.00	0.00	0.00		10999.67
Isar 1[4)]	78350.00	76325.88	0.00	0.00	0.00		2024.12
Unterweser[4) 6) 7)]	117980.00	106777.14	0.00	0.00	0.00	-3800.00	7402.86
Philippsburg 1[2) 4)]	87140.00	73185.87	0.00	0.00	0.00	-5499.89	8454.24
Grafenrheinfeld[7) 4)]	150030.00	126673.89	9664.79	9853.99	4090.52	500.00	246.81
Krümmel[4)]	158220.00	69974.89	0.00	0.00	0.00		88245.11
Gundremmingen B[5) 6)]	160920.00	130874.05	9647.36	9527.08	10333.30	11200.00	11738.21
Philippsburg 2	198610.00	139060.18	8714.52	9631.53	10621.39		30582.38
Grohnde	200900.00	139905.94	10420.06	9481.18	9864.56		31228.26
Gundremmingen C[5) 6)]	168350.00	129387.28	10015.72	10031.13	9841.63	2000.00	11074.24
Brokdorf	217880.00	143738.90	11146.17	10974.17	10624.78		41395.98
Isar 2	231210.00	149478.87	11402.05	10794.90	10505.18		49029.00
Emsland	230070.00	142788.37	10912.11	10954.90	10396.15		55018.47
Neckarwestheim 2	236040.00	136722.46	10218.74	10588.09	10532.84		67977.87
Total	**2484180.00**	**1805242.86**	**92141.52**	**91836.97**	**86810.35**		**425433.94**
Stade[1)]	23180.00	18394.47				-4785.53	0.00
Obrigheim[2)]	8700.00	14199.89				5499.89	0.00
Mülheim-Kärlich[3) 5)]	107250.00					-18000.00	89250.00
Sum total	**2623310.00**						**514683.94**

The data in column 6 "Total 2015" contains the values examined by certified accountants according to § 7 para. 1a AtG.

[1)] The Stade NPP was shut down on 14 November 2003 and was decommissioned on 7 September 2005. The remaining electricity volume of the Stade nuclear power plant amounting to 4785.53 GWh was transferred to the Biblis A nuclear power plant on 11 May 2010.

[2)] The Obrigheim NPP was shut down on 11 May 2005 and was decommissioned on 28 August 2008. The remaining electricity volume of the Obrigheim nuclear power plant amounting to 0.11 GWh was transferred back to the Philippsburg 1 nuclear power plant.

[3)] With letter of 30 June 2010 PNN/Dr.Pa the RWE Power AG reported the transfer of 8,100 GWh of the electricity volume allocated to the decommissioned plant Mülheim-Kärlich (KMK) to the Biblis B plant (KWB B) acc. to § 7 para. 1c Atomic Energy Act. Prior to the transfer on 30 June 2010 the remaining electricity volume of the KWB B amounted to 5889.11 GWh.

[4)] Since the 13th Law concerning the Amendment to the Atomic Energy Act became effective on 6 August 2011, the nuclear power plants Biblis A, Biblis B, Brunsbüttel, Neckarwestheim 1, Isar 1, Unterweser, Krümmel and Philippsburg 1 are no longer authorised for power operation and have been exempted from the reporting obligation according to § 7 para. 1c sentence 1 no. 1 and 2 of the Atomic Energy Act (AtG). From 1 October 2015, the Grafenrheinfeld plant has been exempted from the monthly reporting obligation.

[5)] Transfer of 8400.00 GWh to the Gundremmingen nuclear power plant B as well as 1500.00 GWh to the Gundremmingen nuclear power plant C from the remaining electricity volume of the decommissioned Mülhein-Kärlich nuclear power plant on 28 May 2015 (column 7)

[5)] Transfer of 2800.00 GWh to the Gundremmingen nuclear power plant B as well as 500.00 GWh to the Gundremmingen nuclear power plant C from the remaining electricity volume of the shut-down Unterweser nuclear power plant on 28 May 2015 (column 7)

[7)] Transfer of 500.00 GWh to the Grafenrheinfeld nuclear power plant from the electricity volume oft he shut-down Unterweser nuclear power plant on 5 June 2015 (column 7).

Fig. 2: Generated, transferred and remaining electricity volumes (net) of German nuclear power plants (annual statement, Bundesanzeiger: 10 March 2016)

2 NUCLEAR POWER PLANTS IN GERMANY

As at 31 December 2015, the status of the nuclear power plants in Germany was as follows:

8 Nuclear power plants in operation

9 Nuclear power plants finally shut down,

16 Nuclear power plants under decommissioning

3 Nuclear power plants decommissioned and released from regulatory control, and

6 Nuclear power plant projects stopped.

Table 2.1: Nuclear power plants in Germany 2015

Status	Pressurised water reactor (PWR)		Boiling water reactor (SWR)		Others		TOTAL	
	Number	MWe (gross)	Number	MWe (gross)	Number	MWe (gross)	Number	MWe (gross)
In operation	6	8,669	2	2,688	—	—	8	11,357
Finally shut down	5	6,120	4	4,046	—	—	9	10,166
Under decommis-sioning	10	4,658	3	1,172	3	344	16	6,174
Entirely dismantled	—	—	1	16	2	131	3	147
Project stopped	5	3,320	—	—	1	327	6	3,647

The operational status of the individual nuclear power plants is described in Chapters 2.1 to 2.5 and in the corresponding tables contained in Annex I. A survey of the sites of all NPPs in the Federal Republic of Germany is given in Figure I at the end of the report in Annex I. Furthermore, the operating times of the nuclear power plants in Germany since their first criticality are shown in the following Figure.

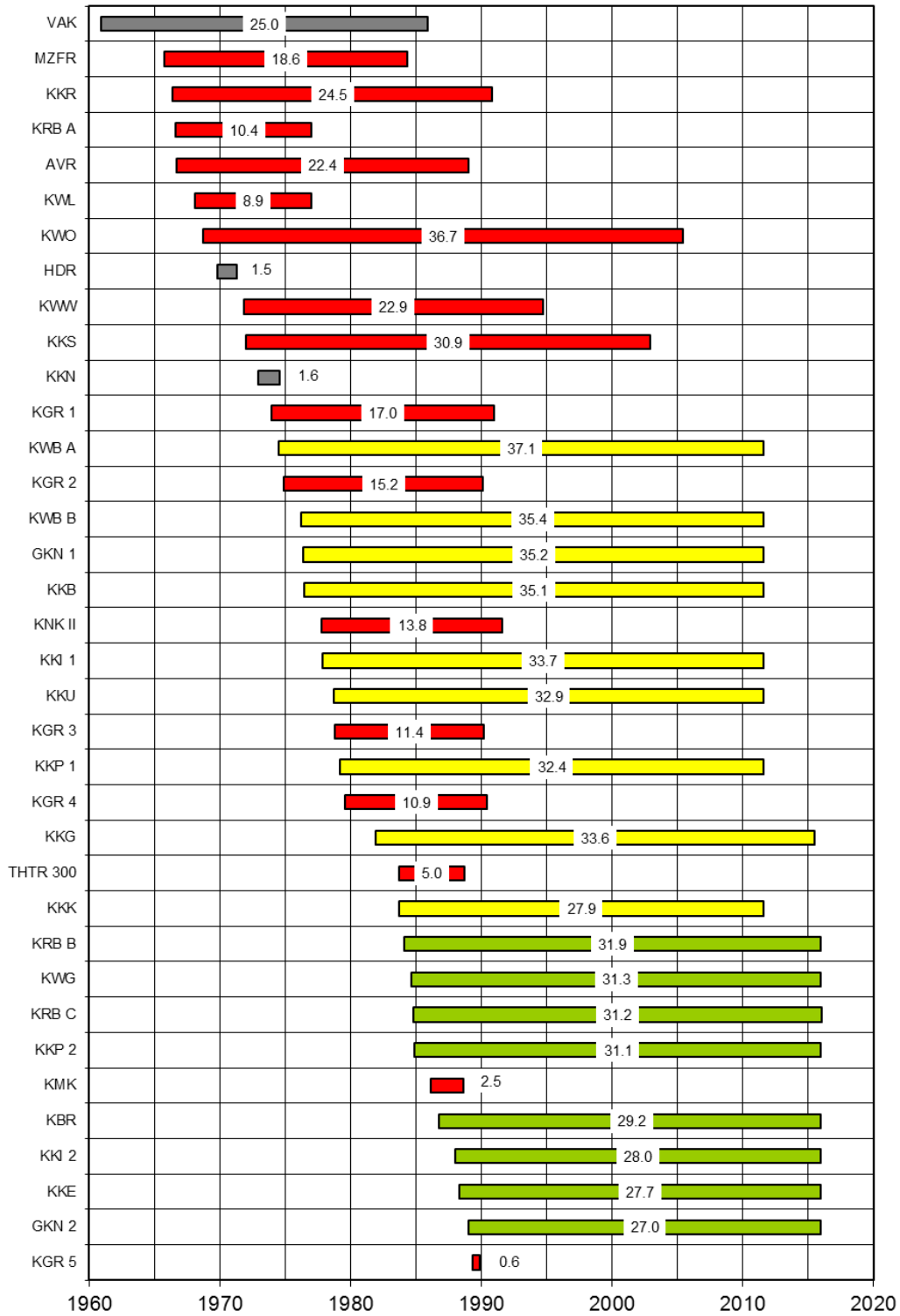


Fig. 3: Nuclear power plant operating times in Germany, given in years since first criticality, as at 31 December 2015

2.1 NUCLEAR POWER PLANTS IN OPERATION

A list of the nine nuclear power plants in operation with their essential features is given in Table 1.2 in Annex I.

2.1.1 Availabilities and reportable events

Table 2.2 shows a list of the respective availabilities and reportable events of German nuclear power plants over the past ten years. The BfS publishes annual reports and, since January 2010, also monthly reports on reportable events. These reports contain events in nuclear power plants and research reactors of the Federal Republic of Germany that have been reported on the basis of the Nuclear Safety Officer and Reporting Ordinance (AtSMV). The events are registered by the BfS Incident Registration Centre.

Details and more information on reportable events can be found on the BfS website by clicking http://www.bfs.de/EN/topics/ns/events/events_node.html.

Table 2.2: Average availabilities and total number of reportable events in nuclear power plants

Year	Time availability* [%]	Energy availability* [%]	Capacity availability* [%]	Number of reportable events
2015	91.8	91.2	82.2	60
2014	90.6	89.1	86.8	67
2013	89.2	88.7	87.2	78
2012	91.0	90.5	88.9	79
2011	82.1	81.9	68.2	103
2010	76.4	77.5	74.0	81
2009	73.2	74.2	71.2	104
2008	80.0	80.9	78.4	92
2007	76.0	76.4	74.4	118
2006	91.1	90.8	89.1	130

*Source: Technische Vereinigung der Großkraftwerksbetreiber e.V. (VGB)

2.1.2 Plant- and licensing status

The following section gives a short description of the nuclear power plants in operation and provides information about the licences according to § 7 AtG granted in the year under report by the competent federal state authorities under nuclear law as shown in Table I.1 (Annex I). Also licensing procedures in progress are dealt with if they are of special relevance to the plant and licensing status.

The terrorist attacks of 11 September 2001 in the USA have also directed attention to nuclear facilities as possible targets. Although the security authorities opine that there is no particular concrete risk for nuclear facilities, German nuclear power plants have also been included into the packages of measures for the protection from terrorist attacks with airliners. One target is to make interference with air traffic more difficult, another target is to reduce possible consequences. Apart from a number of in-plant measures which could be implemented immediately, also applications for aggravating the targeting precision in case of a targeted terrorist air crash (camouflage protection through artificial smokescreen) were filed in the scope of this overall complex. For some plants the corresponding nuclear licences according to § 7 AtG have already been granted and implemented.

Neckarwestheim nuclear power plant Unit 2 (GKN 2)

Neckarwestheim Unit 2 is a pressurised water reactor (PWR) of the 4th generation, a Convoy plant which was commissioned in 1988 with a capacity of 1,316 MW_e. The current reactor output of 1,400 MW_e results from several thermal and electric power changes.

Commissioned in December 1988, the Neckarwestheim nuclear power plant 2 is the youngest nuclear power plant operated in Germany.

In the year under report, no nuclear licence according to § 7 AtG was granted.

Philippsburg nuclear power plant Unit 2 (KKP 2)

The Philippsburg nuclear power plant 2 is a pressurised water reactor (PWR) of the 3rd generation, a pre-Convoy plant. The plant was commissioned in 1984 with a capacity of 1,349 MW_e. The electrical output of the plant was gradually increased to 1,468 MW_e by several thermal and electrical capacity increases.

In the year under report, no nuclear licence according to § 7 AtG was granted.

Isar nuclear power plant Unit 2 (KKI 2)

The Isar nuclear power plant Unit 2 is a Convoy plant with PWR of the 4th generation. As the first of three Convoy plants (Neckarwestheim 2, Emsland) it was commissioned in 1988 with a capacity of 1,370 MW_e. The current reactor output of 1,485 MW_e results from two thermal capacity increases and several electrical capacity increase measures. Thus the KKI 2 is currently the most powerful nuclear power plant unit in Germany. In the year under report, no nuclear licence according to § 7 AtG was granted.

Gundremmingen nuclear power plant Unit B and Unit C (KRB-II-B and KRB-II-C)

Gundremmingen is a dual-unit plant with the two units KRB-II-B and KRB-II-C that are of identical design. Each is a boiling-water reactor (BWR) auf design series 72. Either unit was commissioned in 1984 with a capacity of 1,310 MW_e. The current reactor output of 1,344 MW_e each is a result of two electrical capacity increases of either reactor. In terms of electrical capacity, the Gundremmingen NPP is the largest German nuclear power plant.

On 11 December 2014, the operator filed an application for the dismantling of plant components in Unit B. This application was filed as a preparatory measure, power operation of Unit B ceasing in 2017.

To use the fuel elements more efficiently, the RWE filed an application on 27 August 2015 for operating the plant with replaceable fuel elements of the Atrium 11 type up to an enrichment of nominally 4.6 w/o U-235 in the mixed core.

In the year under report, no nuclear licence according to § 7 AtG was granted.

Grohnde nuclear power plant (KWG)

The Grohnde nuclear power plant is a PWR of the 3rd generation and was commissioned in 1984 with a capacity of 1,365 MW_e. One thermal and two electrical capacity increases have led to the current reactor output of 1,430 MW_e.

The application according to § 7 Atomic Energy Act for the modification of the safety-related parameter “Hold-down force for fuel elements” for the design and operation of the reactor core was withdrawn with letter dated 26 August 2014.

In the year under report, no nuclear licence according to § 7 AtG was granted.

Emsland nuclear power plant (KKE)

The Emsland plant is a PWR of the 4th generation and thus one of three Convoy plants in the Federal Republic of Germany. The plant was commissioned in 1988 with a capacity of 1,316 MW_e. The current reactor output of 1,406 MW_e results from one thermal and several electrical capacity increases. The last capacity increase by 6 MW occurred in May 2014 by exchanging the high-pressure turbine.

In the year under report, no nuclear licence according to § 7 AtG was granted.

Brokdorf nuclear power plant (KBR)

The Brokdorf nuclear power plant is a PWR of the 3rd generation (pre-Convoy). The plant was commissioned in 1986 with a capacity of 1,380 MW_e. The reactor output is currently 1,480 MW_e resulting from two thermal and several electrical capacity increases.

The application according to § 7 Atomic Energy Act for the modification of the safety-related parameter “Hold-down force for fuel elements” was withdrawn with letter dated 31 March 2014.

In the year under report, no nuclear licence according to § 7 AtG was granted.

2.2 NUCLEAR POWER PLANTS FINALLY SHUT DOWN

In the following Chapter, the nuclear power plants are described that were shut down finally on 6 August 2011, when the Amendment to the Atomic Energy Act (AtG) became effective. In the year under report 2015, the Grafenrheinfeld nuclear power plant (KKG) was taken from the grid prematurely by the operator. Thus this plant is among the nuclear power plants that are finally shut down. Table I.3 of Annex I contains the most important data on the nuclear power plants of this category.

Neckarwestheim nuclear power plant Unit 1 (GKN 1)

The Neckarwestheim nuclear power plant Unit 1 is a pressurised water reactor (PWR) of the 2nd generation and was commissioned in 1976 with a capacity of 855 MW_e. The reactor output was at last 840 MW_e resulting from a power decrease due to an exchange of condenser pipes in 1990. On 16 March 2011 the federal government gave order to shut down the plant, which has been in the post-operational phase since.

The authorisation for power operation expired with the Amendment to the Atomic Energy Act of 6 August 2011 (cf. Chapter 1.3). The fuel elements were removed from the reactor and taken into the fuel pond.

The 1st licence for decommissioning and dismantling was applied for on 24 April 2013. The project was announced on 9 January 2015. The documents were displayed between 19 January and 18 March 2015. A public hearing took place on 16 and 17 June 2015.

Radioactive wastes produced in the process of dismantling are to be stored in the planned on-site waste storage facility Neckarwestheim (SAL-N), for which a licence according to § 7 StrlSchV was applied for on 23 April 2014.

The EnBW energy company, operator of the GKN 1, brought an action against the Federal Republic of Germany and the federal state of Baden-Württemberg on 23 December 2014. From the EnBW point of view, the reason for this was the damage resulting from the moratorium against eight nuclear power plants (cf. Chapter 1.3.1) adopted in 2011.

Philippsburg nuclear power plant Unit 1 (KKP 1)

Just like the Isar NPP Unit 1, Brunsbüttel NPP and Krümmel NPP, the Philippsburg NPP Unit 1 is a boiling water reactor (BWR) of design series 69 and was commissioned in 1979 with a capacity of 900 MW_e. The reactor output valid when the reactor shut down in 2011 was 926 MW_e, and resulted from two electrical capacity increases. The authorisation for power operation expired with the Amendment to the Atomic Energy Act on 6 August 2011 (cf. Chapter 1.3). The KKP 1 is in the post-operational phase. Since the beginning of 2012 the fuel elements are in the fuel pond.

On 24 April 2013, application pursuant to § 7 para. 3 Atomic Energy Act was filed for a 1st decommissioning and dismantling licence. The project was announced in the Bundesanzeiger on 28 January 2015. The documents were displayed between 16 February and 15 April 2015. A public hearing took place from 16 to 18 July 2015. The application for modification of the fuel pool cooling and emergency power supply of the facility which was filed on 24 May 2013 was withdrawn in 2015.

It is planned to store radioactive wastes produced in the process of dismantling in the planned on-site waste storage facility Philippsburg (SAL-P), for which a licence according to § 7 StrlSchV was applied for on 3 June 2014.

The EnBW energy company, operator of the KKP 1, brought an action against the Federal Republic of Germany and the federal state of Baden-Württemberg on 23 December 2014. From the operator's point of view, the reason for this was the damage resulting from the moratorium against eight nuclear power plants (cf. Chapter 1.3.1) adopted in 2011.

Grafenrheinfeld nuclear power plant (KKG)

The Grafenrheinfeld nuclear power plant is a PWR of the 3rd generation (pre-Convoy plant) and was commissioned in 1981 with a capacity of 1,299 MW_e. The reactor output was last 1,345 MW_e and was a result of two electrical capacity increases.

The operator filed an application for the decommissioning and dismantling of the plant on 28 March 2014. The operator took the plant from the grid prematurely on 27 June 2015. A scoping meeting was held on 19 March 2015 as part of the environmental impact assessment.

Isar nuclear power plant Unit 1 (KKI 1)

Isar 1 is also a BWR of design series 69 and was commissioned in 1977 with an electrical output of 907 MW_e. The last valid electrical reactor output was 912 MW_e. Since 17 March 2011 KKI 1 has permanently shut down. The authorisation for power operation expired with the Amendment to the Atomic Energy Act on 6 August 2011 (cf. Chapter 1.3). The reactor core was entirely unloaded; the fuel elements are in the fuel pond.

On 4 May 2012, an application was filed according to § 7 para. 3 Atomic Energy Act for the decommissioning and dismantling of the KKI 1 plant. In the scope of public participation in the licensing procedure, a public hearing took place on 22 July 2014. The licensing procedure has made good progress.

The E.ON energy company brought an action for damages against the Federation and the Free State of Bavaria on 1 October 2014. The reason for this is the moratorium adopted in 2011 as a result of the reactor accident in Fukushima.

Biblis nuclear power plant – Unit A (KWB A) and B (KWB B)

The plants Biblis A and B are among the eight nuclear power plants that had to finally cease power operation in 2011 on the basis of the Amendment to the Atomic Energy Act (cf. Chapter 1.3).

Biblis A with a PWR of the 2nd generation was commissioned in 1974 with a capacity of 1,204 MW_e. The last valid electrical reactor output was 1,225 MW_e. The Biblis nuclear power plant was designed as dual-unit plant. Unit B, which is also a PWR of the 2nd generation, was commissioned in 1976 with an electrical capacity of 1,300 MW_e. This output was also the last effective one. The fuel elements of both units have already been unloaded and are in the fuel pond.

On 6 August 2012, applications according to § 7 para. 3 Atomic Energy Act were filed for the decommissioning and dismantling of Units A and B of the Biblis nuclear power plant. The procedure is in the appraisal stage.

On 16 January 2013, RWE filed an application according to § 7 StrlSchV for the handling of radioactive materials in a storage facility to be constructed (LAW storage facility 2). Low-level and intermediate-level radioactive wastes from the operation and dismantling of the units are to be stored there.

On 25 August 2014, the RWE Power brought an action for damages at the district court of Essen that were caused by the moratorium provisions of March 2011.

Unterweser nuclear power plant (KKU)

The Unterweser NPP was commissioned in 1978 with a capacity of 1,300 MW_e. It is a nuclear power plant with PWR of the 2nd generation. The last reactor output was 1,410 MW_e. Power operation stopped on 6 August 2011 when the 13th Amendment to the Atomic Energy Act became effective (cf. Chapter 1.3). The fuel elements were removed from the reactor core and are now in the fuel element pond.

On 4 May 2012, application pursuant to § 7 para. 3 Atomic Energy Act was filed for the decommissioning and dismantling the KKU plant. The application was extended with letter of 20 December 2013, to the extent that the dismantling of the KKU was to begin already when some fuel elements were still inside the plant. The project was announced in the Bundesanzeiger on 21 September 2015. The documents were displayed from 1 October until 30 November 2015.

An application pursuant to § 7 Radiation Protection Ordinance (StrlSchV) for the construction of a storage facility for radioactive waste (LUnA) for the interim storage of low-level and intermediate-level radioactive waste was submitted to the competent federal state authority on 20 June 2013. The project was announced in the Bundesanzeiger and displayed, together with the application for the decommissioning and dismantling of the KKU.

It is planned to store radioactive wastes produced in the process of dismantling in the planned on-site waste storage facility Unterweser (LUnA), for which a licence according to § 7 StrlSchV was applied for on 20 June 2013.

The E.ON energy company brought an action for damages against the Federation and the Federal State of Lower Saxony on 1 October 2014. The reason for this is the moratorium adopted in 2011 as a result of the reactor accident in Fukushima.

Brunsbüttel NPP (KKB)

The Brunsbüttel NPP, the oldest BWR of design series 69, was granted its first operation licence on 22 June 1976. The reactor output of 806 MW_e has not changed since it was commissioned. The plant has been in shutdown operation mode since summer 2007.

Brunsbüttel is one of the eight nuclear power plants in Germany that were finally shut down in 2011 as a result of the Amendment to the German Atomic Energy Act (cf. chapter 1.3). The NPP is in the post-operational phase. Part of the reactor has been unloaded.

On 1 November 2012, application acc. to § 7 para. 3 AtG for the decommissioning and dismantling of the KKB plant was filed and specified with letter of 19 December 2014. The project was announced in the Bundesanzeiger on 13 February 2015. The documents were displayed between 24 February and 15 April 2015. A public hearing took place on 6 and 7 July 2015.

On 5 May 2014 an application pursuant to § 7 StrlSchV was filed for the handling of radioactive substances in the storage facility for radioactive waste and residues (LasmA) to be built.

In October 2014, the Swedish Vattenfall energy company brought an action against the Federal Republic of Germany to an international court of arbitration. This was done against the background of the expiry of the licence for power operation of the nuclear power plants of Brunsbüttel and Krümmel in 2011 due to the amendment to the Atomic Energy Act.

Krümmel NPP (KKK)

The Krümmel NPP is the BWR of the design series 69 with the largest electrical capacity. The plant was commissioned in 1983 with a capacity of 1,316 MW_e. At the time power operation ceased, the reactor output was 1,402 MW_e.

As a result of a fire in a transformer in June 2007 the plant shut down. In June 2009, another short-circuit occurred in a machine transformer after a brief start-up of the reactor. The KKK has been shut down since.

As a result of the Amendment to the Atomic Energy Act in 2011 the plant ultimately ceased power operation (cf. Chapter 1.3). The reactor was unloaded. The fuel elements are in the fuel pool.

On 24 August 2015 the operator filed an application for the decommissioning and dismantling of the Krümmel nuclear power plant.

In October 2014, the Swedish Vattenfall energy company brought an action against the Federal Republic of Germany to an international court of arbitration. This was done against the background of the expiry of the licence for power operation of the nuclear power plants of Brunsbüttel and Krümmel in 2011 due to the Amendment to the Atomic Energy Act.

2.3 NUCLEAR POWER PLANTS UNDER DECOMMISSIONING

In the year under report, 16 nuclear power plant units were under decommissioning in the Federal Republic of Germany (cf. Table I.4 in Annex I). The thorium high-temperature reactor Hamm-Uentrop is the last German nuclear power plant that is operated in safe enclosure. The other nuclear power plants continue to be dismantled with the objective of “green field”.

Rheinsberg NPP (KKR)

The Rheinsberg NPP with a capacity of 70 MW_e (WWER reactor type) was commissioned in 1966. It served the autonomous development of reactors in the GDR. The produced electric energy was fed into the state grid. After 24 years of operation, the plant finally shut down in 1990. Since 9 May 2001, all nuclear fuel has been removed from the site, the fuel elements were delivered to the Interim Storage Facility North (ZLN). It is planned to entirely dismantle the plant. The first decommissioning licence was granted on 28 April 1995. Decommissioning work is carried out step by step with the relevant licences.

The transport of the reactor pressure vessel to the Interim Storage Facility North (ZLN) was carried out on 30 October 2007. Thus the activity inventory in the plant has considerably decreased.

On 3 July 2013 the operator filed an application for modifying the licence I/95 for the decommissioning and partial dismantling of the KKR according to § 7 AtG. This application deals with the concept of long-term storage. On 9 February 2015 the applicant requested to suspend the application. A revised concept for the further dismantling of the KKR was presented to the licensing authority on 27 August 2015. According to this concept, the direct dismantling will be completed by 2025.

On 14 February 2014 an application was filed for a licence pursuant to § 7 para. 3 Atomic Energy Act for the construction and operation of an external ventilation system with exhaust air monitoring

Karlsruhe Sodium-Cooled Reactor (KNK II)

The Karlsruhe Sodium-Cooled Reactor served to develop the breeder technology. The plant contained a 21-MWe sodium-cooled fast-breeder reactor and was commissioned in 1977. After the test programme was completed, the reactor finally shut down on 23 August 1991.

The decommissioning concept provides for a dismantling of the plant in ten steps eight of which having already been carried out. The first licence for the decommissioning of the plant was granted on 26 August 1993. Since 28 May 1994, the plant has been free of nuclear fuel, which was transported to Cadarache (F).

The removal of the primary shielding in the scope of the 9th decommissioning licence was completed in the year under report. The next component to be dismantled by remote control is the activated part of the biological shield.

The objective of decommissioning is to release the plant from regulatory control and the conventional demolition of the residual structures.

Karlsruhe Multi-Purpose Research Reactor (MZFR)

The Karlsruhe Multi-Purpose Reactor with a 57-MW_e heavy-water cooled pressure vessel reactor was operated from 1965 to 1984. Apart from electricity production, it also served the heat supply of the Karlsruhe Research Center on account of the combined heat and power generation. After it had finally shut down, it was decided to dismantle the plant immediately and entirely. The spent fuel elements were reprocessed in

the Karlsruhe Reprocessing Plant (WAK). Dismantling has since been carried out gradually, each stage with an extra nuclear licence (partial decommissioning licences).

With the 8th decommissioning licence of 31 January 2007 the dismantling of the activated part of the biological shield, the dismantling of all systems and equipment, the decontamination and the dismantling of all building structures were approved. The remote-controlled dismantling of parts of the MZFR concluded with the dismantling of the activated concrete of the biological shield in 2011. The demolition of the nuclear auxiliary building was completed in the first half of 2015. The work is currently focussing on preparing the reactor building for demolition.

Dismantling and decontamination of the collecting tank building and the assembly and storage building have made great progress.

Obrigheim NPP (KWO)

The Obrigheim NPP, a PWR with a capacity of 357 MW_e went critical for the first time on 22 September 1968, and started up power operation in 1969. After 36 years of operation, the KWO was finally shut down on 11 May 2005, since the licence for power operation according to § 7 para. 1a AtG had expired.

Dismantling is to be carried out in altogether four independent licensing steps. The nuclear fuel was removed from the core. The fuel elements that had still been in the internal fuel pool were brought into the external wet storage facility in the emergency building. Dry storage in CASTOR® casks was planned at the Obrigheim site, and an application for a licence according to § 6 AtG was submitted to the BfS on 22 April 2005. Currently the procedure is suspended, since taking the KWO fuel elements to the Neckarwestheim interim storage facility is being pursued alternatively. The application for the modification to the storage licence was submitted to the BfS on 10 December 2013 (cf. Chapter 4.3.2).

The first decommissioning and dismantling licence (SG) to finally and permanently shut down operation was granted on 28 August 2008. Among others, the 2nd decommissioning and dismantling licence granted on 24 October 2011 regulates the dismantling of plant components and allocated auxiliary systems in the control area (such as reactor coolant system and steam generator) and the operating procedures for continuing decommissioning operations. The Mannheim administrative court rejected a pending legal action of four citizens concerning the 2nd decommissioning licence on 30 October 2014.

On 30 April 2013, the 3rd licence was granted for the dismantling of the lower part of the reactor pressure vessel (RDB), the reactor pressure vessel installations, the biological shield and single building components inside the reactor pressure vessel. Dismantling of the reactor vessel internals has been completed. The peripheral components of the reactor vessel were dismounted. The transport of the about 135-Mg-heavy reactor vessel into the dismantling area inside the reactor building was completed in August 2015.

On 2 November 2015 the fourth dismantling stage was applied for. It comprises the dismantling of residual systems and components beyond dismantling licences 1 to 3. These are in particular parts of ventilation systems, freight elevators and the crane inside the reactor building.

Gundremmingen NPP Unit A (KRB A)

The Gundremmingen NPP Unit A (BWR) was commissioned in August 1966 with a capacity of 250 MW_e. Characteristic of this plant was a water-steam separating and steam-drying device in the reactor which was used for the first time in a BWR. After an incident in 1977, the operator decided in 1980 not to repair the plant but to shut it down finally for economic reasons. The last fuel elements were removed from the plant by 1989 and were subsequently reprocessed. The decommissioning licence according to § 7 para. 3 AtG was granted on 26 May 1983, followed by the facility's entire dismantling in three phases on the basis of the existing nuclear licences. Dismantling is well advanced. The systems and components inside the machine building and the reactor building that are no longer needed have been dismantled.

The former technical building (not including reactor building) of Unit A has been used as technology centre since 1 January 2015. Decontamination and waste treatment works relating to the still operating Units KRB-II-B and KRB-II-C are carried out there.

Greifswald NPP (KGR) Units 1 to 5

The construction of the Greifswald NPP (PWR) traces back to a decision made in 1955 by the government of the former GDR to use nuclear energy for electrical energy production. Of the eight PWR units of the KGR of the Russian WWER type (Reactor W-230 and W-213) with 440 MW_e each, Unit 1 was commissioned in 1973. Units 2 to 4 were commissioned in 1974, 1977 and 1979. Units 1 to 4 shut down on the basis of a safety assessment made by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) and the Federal Office for Nuclear Safety and Radiation Protection (SAAS) of the former GDR. It was furthermore decided to decommission Unit 5, too, which went critical for the first time in 1989 and whose commissioning was

stopped by the SAAS, the regulatory authority at that time. Due to the dual-unit construction, Unit 5 is connected to Unit 6. All six units are to be dismantled without a longer period of prior safe enclosure. Units 6 to 8 were still under construction at that time (cf. Chapter 2.5).

Since 22 May 2006 all nuclear fuel has been removed from the Greifswald NPP.

The first decommissioning licence according to § 7 para. 3 AtG for the decommissioning of the entire plant and for the dismantling of plant components was granted on 30 June 1995. More licences and modification licences for decommissioning and dismantling have been granted since. The EWN GmbH had last submitted another application for the decommissioning licence on 27 June 2014. The application deals with the expansion of the release procedure re the release of solid substances to be deposited and combusted without taking into account the surface activity. The application pursuant to § 7 para. 1 and 3 AtG for the demolition and dismantling of no longer needed building structures of special building Nord I submitted on 29 November 2013 is in the appraisal phase. An application for long-term storage of no longer used buildings of the KGR with interior contamination was withdrawn in March 2015.

Dismantling has made great progress. About 85% of the dismantling of the plant components of the control area including special buildings of Units 1-5 has been completed. 95% of the plant components of the monitoring area have already been dismantled.

Stade NPP (KKS)

The Stade NPP, a PWR with a capacity of 672 MW_e was in operation from 1972 until 2003. Final shut-down was on 14 November 2003. With letter of 23 July 2001, the operator E.ON applied for the direct dismantling of the plant. The fuel elements were transported to France for reprocessing at the end of April 2005. Dismantling is planned in five phases. The last phase (phase four) was authorised on 4 February 2011. It concerns the further dismantling of the plant and measures to clear buildings and ground surfaces. Currently residual operational adjustments, dismantling and waste management measures and measures to release buildings and soil are taking place.

In the context of the demolition activities, contamination was detected at the bottom of the containment in January 2014. It is assumed that this contamination stems from the phase the plant was in power operation. As a result, it is not possible to release the corresponding concrete area by a clearance measurement of the standing building structure following a rough decontamination; instead it must be dismantled. Depending on the activity content, the originating building rubble has to be managed as radioactive waste or to be released pursuant to § 29 StrlSchV, either for disposal on heaps or without restrictions. A concept for further procedure was presented

Lingen NPP (KWL)

The Lingen plant, a BWR with a capacity of 252 MW_e, was commissioned in 1968. After 9 years of power operation the plant was shut down in January 1977 due to steam-to-steam heat exchangers being damaged, in order to install new ones. More serious damages were detected, so that the operator decided in March 1979 to decommission the nuclear part and to use the existing steam turbine with a natural gas fired high-temperature gas turbine that had still to be installed. On the basis of the licence of 21 November 1985 the plant was operated in safe enclosure (SE) since 1988. Prior to safe enclosure the fuel elements were transported to Sellafield (UK). The safe enclosure was monitored by the adjacent Emsland NPP (KKE).

In December 2007, Kernkraftwerk Lingen GmbH announced the withdrawal of the application for continuation of safe enclosure. On 15 December 2008, the operator filed an application according to § 7 para. 3 AtG for dismantling the plant. The dismantling of the residual plant is to be carried out in three partial projects. The licence for the first licensing stage (Partial Project 1) for the dismantling of the Lingen NPP was granted on 21 December 2015. This stage comprises the dismantling of all non-contaminated and contaminated plant components unless they are required for further dismantling operation and further dismantling. A second licensing step to be applied for later on (Partial Project 2) is to include the dismantling of the reactor pressure vessel including installations, the biological shield, the residual dismantling, decontamination, and the plant's release from nuclear regulatory control. The third partial project comprises the conventional dismantling of buildings.

Arbeitsgemeinschaft Versuchsreaktor Jülich (AVR)

The Jülich Experimental NPP was an experimental reactor exclusively developed in Germany. It was commissioned in 1966 with a 15-MW_e pebble bed high-temperature reactor (HTR) and served the development of this reactor type – which had started in Germany - with ball-shaped graphite fuel elements containing uranium and thorium containing coated particles. It was finally shut down at the end of 1988 when the further development of this technology was no longer pursued in Germany as a result of the

decommissioning of the prototype reactor THTR-300 (308 MW_e) in Hamm-Uentrop. When it was in operation, the AVR fed ca. 1,500 GWh electric energy into the public grid. On 9 March 1994 the licence for decommissioning, unloading of the reactor core, dismantling of plant components and safe enclosure was granted. The unloading of the ball-shaped fuel elements into the central interim storage facility at the site of the Jülich Research Center was completed in June 1998, leaving only maximum 197 pieces. Until the reactor containment has been disassembled it is impossible to recover the remaining ball-shaped fuel elements at reasonable cost and with sufficient radiation protection measures.

After the former AVR GmbH had been taken over by EWN GmbH in 2003, the operator decided to change the concept of dismantling. The safe enclosure was terminated and direct dismantling was applied for. The licence for the entire dismantling of the plant was granted on 31. March 2009. Once the preparatory works for lifting the reactor vessel had concluded, the reactor vessel was lifted from its previous position in November 2014. Then it was placed and aligned on the storage rack of the material lock. On a 600-m-long transport line, the reactor vessel was transported on 23 May 2015 to the reactor vessel interim storage facility constructed at the site. The licence for the operation of the interim storage facility was granted on 1 March 2010. This storage facility serves solely the interim storage of the AVR reactor vessel and has been designed for an interim storage period of 30 to 60 years.

On 1 September 2015 the Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN) was founded. This company comprises the nuclear businesses of the Jülich Research Center and the Arbeitsgemeinschaft Versuchsreaktor (AVR) GmbH.

Würgassen NPP (KWW)

The Würgassen NPP, a boiling water reactor with a capacity of 670 MW_e, was in operation from 1971 to 1994. Since cracks were found at the core shroud of the reactor during a scheduled major plant revision in 1994, the former operator PreussenElektra decided to finally shut down the plant. Since October 1996, there is no more nuclear fuel in the plant. The fuel elements were delivered to La Hague (F) for reprocessing.

The first decommissioning licence was granted on 14 April 1997. Three further decommissioning licences for the plant have been granted since.

In the year under report, one continued to carry out final measurements for buildings to be demolished and clearance measurements on the outside grounds. The interim storage facility for radioactive waste has remained, where solely low-level and intermediate-level radioactive waste from the dismantling and operation of the plant is stored. The technical infrastructure has been adapted to the requirements.

Hamm-Uentrop Gas-cooled High-temperature Pebble Bed Reactor (THTR-300)

The THTR-300 with a helium-cooled pebble-bed high-temperature reactor (308-MW_e) was commissioned in 1983. In September 1989, the final decommissioning of the plant was decided after it had been shut down on 29 September 1988 for the scheduled annual revision. On 13 November 1989, the federal government, the Federal State of North Rhine-Westphalia, the HKG operating company and its partners signed a framework agreement concerning the completion of the THTR-300 project. The first partial licence for the decommissioning, unloading of the reactor core and the dismantling of plant components was granted on 22 October 1993. Since then the ball-shaped fuel elements have been removed from the reactor core and delivered in CASTOR® casks to the Ahaus fuel element interim storage facility (BZA). The reactor core has been unloaded since 1995. On 21 May 1997, the licence for the operation of safe enclosure (maintenance operation) was granted. Since October 1997, the plant has been in safe enclosure which is to cover a period of approximately 30 years.

Mülheim-Kärlich NPP (KMK)

The Mülheim-Kärlich NPP, a PWR with a capacity of 1.302 MW_e was commissioned in 1986. After the Federal Administrative Court had withdrawn the first partial licence it has been shut down since 9 September 1988.

The applications according to § 7 AtG for the first partial licence for the construction and operation of the KMK and of the partial licence (continuous operation) that had not been decided on, were withdrawn by RWE Power AG with letter dated 21 June 2001. The spent fuel elements were taken to La Hague (F) for reprocessing. New fuel elements intended for the reloading of the reactor were given back to the manufacturer in Belgium.

The KMK is to be dismantled in three independent steps. Step 1 includes the final decommissioning of the plant. In the second step, among others, the reactor coolant system equipment is to be dismantled. Step 3 provides for, among others, the release of the buildings and the premises from nuclear supervision. The demolition of the released buildings is then to take place according to building law provisions.

Dismantling measures continued in the year under report on the basis of the licence for dismantling phase 1a granted on 16 July 2004 and the modification licence to licence 1a granted on 23 February 2006.

The application for dismantling phase 2b for the dismantling of the two steam generators, the reactor pressure vessel including its core components and the activated areas at the biological shield received a positive response on 8 October 2015.

The notification of 31 January 2014 pursuant to § 7 para. 3 Atomic Energy Act regulates the clearance and release of ground areas and the structural facilities (licence 3c). On this basis the supervisory procedure to clear and release the site was carried out for the monitoring area south and west of the plant site. The former site comprised 30 hectares. It was downsized to 2.8 hectares which is needed for the further dismantling and the residual plant operation and further areas of about 6 hectares for administration and carpark.

The licence pursuant to § 7 para. 3 for downsizing the site was granted on 16 September 2014 (licence West 3b).

The licensing procedure for the on-site storage facility and the treatment centre for radioactive waste discontinued after RWE Power AG had withdrawn the construction application in December 2014.

2.4 NUCLEAR POWER PLANTS RELEASED FROM REGULATORY CONTROL

In the Federal Republic of Germany three nuclear power plants have been entirely dismantled and released from regulatory control so far. Annex I, Table 1.5 show key data of these plants.

Großwelzheim Superheated Steam Reactor (SSR)

As prototype and experimental plant, the Großwelzheim Superheated Steam Reactor with a capacity of 25 MW_e served to develop this reactor design series. It was commissioned in 1969. After only 1.5 years of operation, the plant finally shut down in 1971 because of deformations at the cladding tubes of the novel superheat fuel elements. The spent fuel elements were reprocessed in the WAK. From 1974 to 1991, the reactor building and the installed systems were used for the performance of non-nuclear investigations of nuclear power plant behaviour in case of severe accidents (among others, earthquakes). The decommissioning of the reactor was licensed on 16 February 1983. The plant was entirely dismantled.

In the middle of May 1998 the plant could be released from regulatory control. The residual conventional dismantling work was completed by the middle of October 1998.

Niederaichbach NPP (KKN)

The Niederaichbach NPP is a prototype NPP with a capacity of 106 MW_e. It is characterised by the use of natural uranium and a heavy-water moderated pressure tube reactor with CO_2 gas cooling. By using the pressure tube system thick-walled pressure vessels normally required for LWR reactors should be avoided and the objective was to be able to use reactors of nearly any building size.

The commissioning licence was granted on 11 December 1972. The reactor went critical for the first time on 17 December 1972. Technical problems and the then already established light-water reactor design series contributed to the owner’s decision to shut down the reactor finally. The development of this reactor type was thus stopped. With the shut-down on 31 July 1974 it was decided to decommission the KKN. Thus the nuclear power plant was in operation for 18.3 full-load days. The licence for establishing the state of safe enclosure for the plant was granted on 21 October 1975 and the licence for “safe enclosure” on 20 October 1981. The fuel elements were taken to the CEA (Commissariat à l’Energie Atomique et aux Energies Alternatives) in France. The entire dismantling of the plant was licensed on 6 June 1986. On 17 August 1995, the decommissioning of the KKN was completed and the NPP was released from regulatory control. The ground slabs of the reactor building and of the tomb building have remained in the soil as a groundwater lowering would have been necessary for complete removal. The residual ground slabs and underground pipes were removed. The KKN was the first nuclear power plant in the world with a capacity worth mentioning whose decommissioning was completed by handing over the site as "greenfield". Thus it could be demonstrated for the first time in Germany that both the technical implementation of a complete removal and of the associated nuclear licensing procedure are feasible.

Kahl Experimental NPP (VAK)

The Kahl Experimental NPP with a 16-MW_e BWR was the first nuclear power plant for electrical energy production in Germany. It was commissioned in 1960. In 1985, the plant was shut down since all planned scientific and operational tests had been concluded according to statements by the operator. The first partial decommissioning licence was granted with notification of 5 May 1988. The fuel elements were removed from the plant by 1989 and transported to the Karlsruhe Reprocessing Plant (WAK) for reprocessing. Spent MOX

fuel elements that could not be reprocessed in the WAK were transported to the Central Storage Facility for Spent Fuel Elements (CLAB) in Sweden for storage and disposal.

The buildings and the plant site were released from regulatory control on 17 May 2010. Dismantling activities in the scope of conventional dismantling concluded on 24 September 2010.

2.5 STOPPED NUCLEAR POWER PLANT PROJECTS

In the following nuclear power plants have been listed that had been planned but whose construction was not finished. Table 1.5 in Annex I gives a survey of these projects.

Greifswald NPP (KGR) Units 6 to 8

In the Greifswald NPP construction and assembly works on Units 6 to 8 (440-MW_e PWR of the Russian WWER type, reactor W-213) were stopped in 1990.

Unit 6 is used as technical exhibition to demonstrate reactor technology at visiting tours. The engine house of Units 5 to 8 was entirely cleared and is now used industrially (cf. Chapter 2.3). Non-contaminated equipment of Units 7 and 8 was transported to Unit 5 where it was dissected. With it tools and equipment for the remote-controlled dissecting of reactor components were tested.

Kalkar Sodium-cooled Fast Breeder Reactor (SNR 300)

The SNR 300 with a 327-MW_e sodium-cooled fast-breeder reactor was constructed between 1973 and 1991. It was almost completed and commissioning was prepared. Before the already fabricated fuel elements were loaded, it was decided in 1991 not to commission the plant. The erected systems were then dismantled, scrapped or sold. On 1 April 1996, ownership of the site was transferred to Kern-Wasser-Wunderland Freizeitpark GmbH. The site has been used commercially since. The fuel elements were at first kept in government custody by BfS and were later delivered to France for reprocessing.

Stendal NPP

Construction of a nuclear power plant with four units was planned near Stendal. In 1979 it was decided to construct pressurised water reactors of the Russian WWER type with 1.000 MW_e each on the site. The former Federal Office for Nuclear Safety and Radiation Protection of the GDR (SAAS) granted the first construction licence for two units on 10 September 1982. The works for units A and B of the Stendal nuclear power plant that were started discontinued in 1990 after they had been delayed for several years. Part of the buildings and of the equipment was dismantled or has been used otherwise.

3 RESEARCH REACTORS

Research reactors are nuclear installations that do not serve to generate power on a commercial basis. They are used in research centres and universities, among other things for scientific experiments.

In the Federal Republic of Germany altogether 46 research reactors have to be considered of which currently (as at 31 December 2015):

7 Research reactors are in operation

4 Research reactors are finally shut down

6 Research reactors are under decommissioning and

29 Research reactors have been decommissioned. They have been released from regulatory control.

The following chapters contain information about German research reactors according to their operational and licensing status. The Tables in Annex II show the key facts on the German research reactors. A survey of still existing sites is given in Figure II.

3.1 RESEARCH REACTORS IN OPERATION

In the Federal Republic of Germany, altogether seven research reactors were in operation on 31 December 2015, among which there were three with a continuous thermal power above 50 kW_{th} and four training reactors with a thermal power of max. 2 W_{th}. In addition to the following information, the most important data on the research reactors in operation can be found in Annex II, Table II.1.

Berlin Experimental Reactor Unit II (BER II)

The BER II is a pool reactor with fuel elements of the MTR type. The thermal power is 10 MW_{th} and the thermal neutron flux is ca. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor was commissioned on 9 December 1973 and mainly serves pure and applied basic research with beam pipe experiments and the generation of radioactive isotopes.

From 1985 to 1989, the plant was comprehensively expanded, doubling the thermal power from originally 5 MW_{th} to 10 MW_{th} and increasing the thermal neutron flux to ca. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$, which is nearly the ten-fold. To reduce the proliferation risk, the operation of the BER II with fuel elements of low-enriched uranium (LEU) and, respectively, mixed loadings with fuel elements of high-enriched uranium (HEU) and LEU was licensed on 14 June 1994. Following a number of mixed loadings, a pure LEU core was built up for the first time and commissioned on 7 February 2000.

On 18 February 2015 the maintenance, retrofitting and remediation measures were completed. They had started in November 2013. Among others, they comprised the remediation of a defective sealing weld between the suction pipe of the primary circuit and the separating wall between the two reactor pool halves. The separating wall was removed and not replaced. A new high field magnet was installed. Furthermore, the implementation of the measures resulting from the plant-specific safety review of German research reactors continued taking into account the events in the Fukushima Daiichi NPP in Japan in 2011 (RSK-SÜ, 2012). Among others, an emergency manual was developed and a study on an air crash was performed.

Munich High-flux Neutron Source in Garching Unit II (FRM-II)

The FRM-II is the newest commissioned research reactor in Germany, a light-water cooled pool reactor with a compact core where high-enriched uranium (HEU) is used as fuel and heavy water as moderator. With a thermal neutron flux of $8 \cdot 10^{14}$ $1/cm^2 \cdot s$ the plant – having a comparatively low thermal power of 20 MW_{th} – is the most intensive German neutron source for beam pipe experiments and irradiations for scientific, industrial and medical purposes.

Nuclear commissioning and plant operation were regulated in the operation licence (3rd partial licence) granted on 2 May 2003. The reactor went critical for the first time on 2 March 2004. On 25 April 2005 the plant's routine operation started.

On the basis of the operating licence of 2 May 2003 and of an agreement between the Federal Government and the Free State of Bavaria of 30 May 2003, it was originally intended to convert the reactor core from HEU to fuel with a reduced enrichment level of max. 50 % uranium 235 (MEU) by 31 December 2010. However, due to unexpected delays in the international technical-scientific development of new, high-density fuels, one failed to comply with this requirement. The original agreement between the federal government and Bavaria of 30 May 2003 was amended on 22 October 2010. Now the plant needs to be converted by 31 December 2018 at the latest.

On 30 March 2015, the Technical University of Munich applied for an expansion of the existing operating permit for the FRM-II by the construction and operation of an irradiation facility for uranium targets for the production of molybdenum-99.

After 10 years of operation, the results of the first periodic safety review (PSÜ) according to § 19a AtG for the FRM-II were presented to the supervisory authority. This comprised the deterministic safety status analysis, the probabilistic safety analysis and the deterministic analysis on physical protection.

Furthermore, the implementation of the measures resulting from the plant-specific safety review of German research reactors continued taking into account the events in the Fukushima Daiichi NPP in Japan in 2011 (RSK-SÜ, 2012). Among others, the emergency manual was updated.

TRIGA Mark II Research Reactor of the Mainz University (FRMZ)

The Research Reactor of the Mainz University is an open pool reactor of the TRIGA Mark II type. It is a light-water cooled and moderated reactor with homogeneous fuel moderator elements of LEU and zirconium hydride. Nuclear commissioning of the plant was on 3 August 1965. In continuous operation the thermal power is 100 kW_{th} and the thermal neutron flux is $4 \cdot 10^{12}$ 1/cm^2•s. Additionally, the reactor can be operated in pulsed operation above 30 ms with a power peak of 250 MW_{th} and a thermal neutron flux of $8 \cdot 10^{15}$ 1/cm^2•s. The plant is operated for basic research in nuclear physics and is especially suitable for examining short-lived radionuclides with rabbit systems because of the high neutron flux density which can be managed in pulsed operation for short periods of time.

On the basis of a licence of 28 July 1992, a comprehensive modification of the reactor cycle systems was carried out.

Following the installation of an ultra-cold neutron source in 2011, peak values with neutron velocities of 5 m/s and neutron densities of 10 n/cm^3 have been achieved at the FRMZ.

In the year 2015, the plant was in normal operation. The measures resulting from the plant-specific safety review of German research reactors continued to be implemented taking into account the events in the Fukushima Daiichi NPP in Japan in 2011 (RSK-SÜ, 2012). Among others, the emergency manual's update was almost finished. Furthermore, multi-shift operation was implemented for the first time at the FRMZ in 2015 in the scope of the University Excellence Initiative PRISMA.

Training Reactor of the Technische Universität Dresden (AKR-2)

The AKR-2 is a homogeneous, solids-moderated zero-power reactor. The fuel plates consist of a homogeneous mixture of low-enriched uranium oxide (enrichment < 20% uranium-235) and polyethylene as moderator material. The reactor core is surrounded on all sides by a reflector from graphite. The maximum continuous thermal power of the reactor is 2 W_{th} and the thermal neutron flux is about $3 \cdot 10^7$ 1/cm^2·s. The AKR-2 was commissioned on 22 March 2005. It replaced the old AKR-1 plant that was operated by the TU Dresden from July 1978 to March 2004. The AKR-2 mainly serves for training purposes but it is also an instrument for research activities in national and international projects.

In the year 2015, the plant was in normal operation.

Siemens Training Reactors (SUR) 100

In Germany, three Siemens training reactors are currently in operation (Furtwangen, Stuttgart and Ulm). In the SUR plants, the reactor core consists of U_3O_8 with low uranium-235 enrichment (< 20%) and with polyethylene as moderator. In a homogeneous mixture, both materials are pressed into cylindrical fuel plates. The reactor core is surrounded by a graphite reflector on all sides. The SUR plants were commissioned in Germany mainly the 60s and 70s. The thermal reactor capacity is 100 mW_{th} and the thermal neutron flux in the central experimental channel is generally at $5 \cdot 10^6$ 1/cm^2·s. Details are given in Tab. II.1. The SUR plants are mainly used as training devices for training and tuition in the field of nuclear energy.

In the year 2015, all SUR plants were in normal operation.

3.2 RESEARCH REACTORS FINALLY SHUT DOWN

As at 31 December 2015, four research reactors have been included in the heading "Finally shut down". No decommissioning licence has been granted so far for these reactors. The key data on these reactors has been listed in Table II.2 in Annex II of the report.

Research Reactor Geesthacht Unit 1 (FRG-1)

The FRG-1 was an open pool reactor of the MTR type with a thermal power of 5 MW_{th} and a maximum thermal neutron flux of ca. $1 \cdot 10^{14}$ 1/cm^2•s. It was commissioned on 23 October 1958 with HEU. Originally the

FRG-1 served to explore nuclear ship propulsion. Later on it was mainly used for material research with steel pipe experiments and isotope production and to carry out neutron activation analyses.

From 1963, the FRG-1 was operated with the new FRG-2 reactor in a joint reactor hall but with different pools. Due to a subsequent joint operation licence of 6 September 1967, both reactors must be regarded as one reactor facility under licensing aspects. This also applies after the licence for taking the reactor out of operation and partial decommissioning of the FRG-2 was granted on 17 January 1995 (cf. section FRG-2).

During the more than 40 years of operation the FRG-1 was continuously upgraded. In February 1991 a modification from HEU to LEU was carried out for the first time at a German research reactor on the basis of a modification licence dated 4 May 1988. Apart from reducing the proliferation risk, it was possible to increase the thermal neutron flux by using fuels of significantly higher density.

On 28 June 2010, the FRG-1 was shut down finally. In the context of the operating permit which continues to be effective the plant is now in the post-closure phase. 45 MTR fuel elements were taken to the USA on 10 August 2010. Since the end of July 2012, there has been no more nuclear fuel in the reactor. On a special ship, the last 25 fuel elements that had remained in the plant were transported to the USA. The testing equipment of the research reactor was taken to research institutions in Delft (Netherlands) and St. Petersburg (Russia) for further use.

On 21 March 2013, decommissioning and dismantling of the FRG 1 and the research reactor (consisting of FRG-1 and still existing plant components of the FRG-2) as well as the release of the plant from regulatory control were applied for. It is planned to dismantle the research reactor in the scope of a single decommissioning and dismantling licence pursuant to § 7 para. 3 Atomic Energy Act. The application documents are undergoing review. A public hearing took place on 19 May 2015.

Research Reactor Geesthacht Unit 2 (FRG-2)

Just as the FRG-1, the FRG-2 was an open pool reactor of the MTR type; the thermal power was 15 MW_{th} and the maximum thermal neutron flux was ca. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. It was commissioned on 16 March 1963 as material test reactor and used for irradiation tests for the further development of nuclear power plant components and reactor safety.

The FRG-2 was operated with the FRG-1 reactor in a joint reactor hall but different pools. Since a new joint operation licence dated 6 September 1967 came into effect, both reactors must be regarded as one reactor facility under licensing aspects. This licence permitted at the same time the increase of the FRG-2's thermal capacity from 5 MW_{th} to 15 MW_{th}. During its 30 years of operation, the reactor was permanently operated with HEU.

Since orders for material testing through irradiation had decreased, GKSS, in consultation with BMFT and the industry, filed an application on 28 January 1993 for taking the FRG-2 out of operation and partially dismantling the reactor. The licence was granted on 17 January 1995. The fuel elements were taken to the USA until 20 September 2000.

On 21 March 2013, decommissioning and dismantling of the FRG 1 and the research reactor (consisting of FRG-1 and still existing plant components of the FRG-2) as well as the release of the plant from regulatory control were applied for. It is planned to dismantle the research reactor in the scope of a single decommissioning and dismantling licence pursuant to § 7 para. 3 Atomic Energy Act. The application documents are undergoing review. A public hearing took place on 19 May 2015.

Siemens Training Reactor Hanover (SUR-H)

The SUR-H was a training reactor with a thermal capacity of 100 mW_{th} and a thermal neutron flux of $6 \cdot 10^6$ $1/cm^2 \cdot s$ which was operated at the Leibniz Universität Hannover at the Institute of Nuclear Engineering and Non-Destructive Testing. The construction of the SUR reactors is described in Chapter 3.1. On 11 October 1971 the licence for the construction and operation of the SUR-H was granted by the Lower Saxon Ministry for Social Affairs. The reactor was operated from 1971 through 2008. In 2008 the fuel plates were removed according to the operating permit and taken to the Technische Universität München, Institute for Radiochemistry in Garching for conditioning and disposal. The start-up neutron source was removed in 2013 and given to Eckert & Ziegler Nuclitec GmbH for further use. The operator filed an application for decommissioning and dismantling the Siemens Training Reactor SUR 100 Hannover on 22 October 2013. Because of the low performance of the reactor, there is no need to carry out an environmental impact assessment and a public participation procedure.

Siemens Training Reactor Aachen (SUR-AA)

The Siemens Training Reactor Aachen was operated by the Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen). It was constructed by Siemens-Schuckertwerke AG in 1963 and became critical for

the first time on 22 September 1965. The thermal power of the reactor was 100 mW_{th}, the thermal neutron flux was ca. $6•10^6$ $1/cm^2•s$. The research reactor served as training reactor in the scope of training in nuclear technology and was also used for conducting experiments in the scope of seminar papers and diploma theses. The reactor was shut down in 2002. In 2008, the fuel consisting of plates from enriched uranium Uran-235 was taken to the Technical University of Munich for disposal and conditioning. In 2010 the operator filed an application for the decommissioning and dismantling of the plant to the competent federal state authority. The licensing procedure is under way. Because of the low performance of the reactor, there is no need to carry out an environmental impact assessment and a public participation procedure.

3.3 RESEARCH REACTORS UNDER DECOMMISSIONING

In the Federal Republic of Germany, six research reactors were under decommissioning at the end of 2015. Table II.3 of Annex II contains the most important data of this category.

Karlsruhe Research Reactor Unit 2 (FR 2)

The FR 2 was a closed tank reactor operated with low-enriched uranium (2%) and moderated and cooled with heavy water. It was the first nuclear reactor facility which was developed and built according to a German concept. With 44 MW_{th} it was the German research reactor with the highest performance with respect to thermal power. With a thermal neutron flux of $1•10^{14}$ $1/cm^2•s$ the FR 2 was used as neutron source for beam pipe experiments for basic research and for irradiation experiments in fuel rod development and for the production of isotopes for medical purposes.

Nuclear commissioning of the reactor with natural uranium was on 7 March 1961. To increase the original thermal neutron flux of $3.9•10^{13}$ $1/cm^2•s$ to $1•10^{14}$ $1/cm^2•s$ the facility was retrofitted in 1966 to be operated with fuel elements with low-enriched uranium (2%). The reactor's maximum thermal power was thus increased from 12 MW_{th} to 44 MW_{th} (licence of 26 January 1966).

After 20 years of operation, the plant was finally shut down on 21 December 1981 for economic reasons. By 22 October 1982, the fuel elements were delivered to the WAK for reprocessing. The first of several partial licences for decommissioning, partial decommissioning, and safe enclosure for at least thirty years was granted on 3 July 1986. Since 20 November 1996, the reactor block as the still remaining part of the plant has been in safe enclosure. Since 1997, the reactor hall has been used for a permanent exhibition about the history of nuclear engineering.

Following safe enclosure, it is intended to dismantle the plant to finally remove the reactor block. Since July 2009 the Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs-GmbH, a company of the Energiewerke Nord GmbH, has been responsible for this task. A rough dismantling concept was submitted to the competent authority at the end of 2010. No application for dismantling has been filed so far.

Research Reactor Munich (FRM)

The FRM was a pool reactor of the American type with a thermal power of 4 MW_{th} and a thermal neutron flux of $7•10^{13}$ $1/cm^2•s$. The plant was commissioned as the first reactor in Germany on 31 October 1957. The purpose of the reactor was to provide neutrons for beam pipe experiments and irradiations, such as the generation of radioisotopes, the proof of trace elements and tumour therapy.

In 1957, the plant was commissioned with LEU and a thermal power of 1 MW_{th} but was changed over to using HEU already in 1960. In the years of operation the thermal neutron flux was gradually increased from originally $1•10^{13}$ $1/cm^2•s$ to $7•10^{13}$ $1/cm^2•s$ by increasing the thermal power to 2.5 MW_{th} in 1966 and to 4 MW_{th} in 1968; additionally, a beryllium reflector was installed in 1982. Since 1991, the core has been operated as mixed core and gradually changed over from HEU to MEU.

On 14 December 1998, the Technische Universität München (TUM) applied for the plant's decommissioning in order to use it later on – following another procedural step – as supporting system to the new Munich High-flux Neutron source in Garching (FRM-II, cf. Chapter 3.1). On 28 July 2000 the reactor was finally shut down, on 3 June 2002 the still existing 47 fuel elements were taken to the USA. On 3 April 2014 the licence pursuant to § 7 Atomic Energy Act for the dismantling of the FRM Garching reactor was granted. The FRM dome, known as Garching Atomic Egg, has been made a listed building.

Research Reactor Neuherberg (FRN)

The FRN was a pool reactor of the TRIGA Mark III type with homogeneous fuel moderator elements of LEU and zirconium hydride. The thermal power was 1 MW_{th} and the thermal neutron flux was $3•10^{13}$ $1/cm^2•s$. In pulsed operation the reactor could be operated above 10 ms for short periods of time, with power peaks of up to 2,000 MW_{th}. The plant was commissioned on 23 August 1972 and was used for isotope production and beam-pipe experiments in medico-biological research.

On 16 December 1982, the reactor was finally shut down. Within the scope of the operation licence the fuel elements were removed and disposed of in the USA. The decommissioning licence of 30 May 1983 comprised the decommissioning of the plant and the dismantling of plant components as well as effecting safe enclosure of the shielding block with the former reactor pool. With a separate licence notice dated 24 May 1984 it was permitted that the facility will continue to be in the state of safe enclosure.

Research and Measuring Reactor Braunschweig (FMRB)

The FMRB was a light-water cooled and moderated pool reactor with two separate fission product zones of HEU which were neutronically coupled via a 400-l heavy-water tank. The reactor went critical for the first time on 3 October 1967. The thermal power was 1 MW_{th} and the thermal neutron flux was $6 \cdot 10^{12}$ $1/cm^2 \cdot s$. The Federal Institute of Physics and Metrology (PTB) used the facility as neutron source for irradiations and beam pipe experiments, in particular in the area of neutron metrology and dosimetry and of condensed matter physics.

The reactor was taken out of operation on 19 December 1995 for economic reasons. On 28 August 1996, the residual fuel elements were delivered to the USA. The decommissioning licence for the plant was granted on 2 March 2001. Dismantling of the facility was completed in the middle of 2004. The radioactive waste and residues accrued during the operation and dismantling of the facility were conditioned and, by May 2005, delivered to the interim storage facility that was erected in rooms of the FMRB for this particular purpose, which continues to be subject to nuclear supervision. The reactor building and other building areas and ground surfaces were gradually released from regulatory control by 28 July 2005 and can now be used by the PTB without restrictions for other purposes. The premises which the PTB operates interim storage facilities on, was legally transferred to the Bundesanstalt für Immobilienaufgaben (BIMA) on 1 January 2012.

Research Reactor Jülich (FRJ-2)

The FRJ-2 (DIDO, derived from D_2O) was a heavy-water cooled and moderated closed tank reactor of English design. It was operated with HEU. The reactor with a thermal power of 23 MW_{th} and a thermal neutron flux of $2 \cdot 10^{14}$ $1/cm^2 \cdot s$ was used for beam pipe experiments and irradiations for isotope production and neutron activation analysis.

Nuclear commissioning of the plant was on 14 November 1962. On account of the available resources being exhausted, a first capacity increase from 10 MW_{th} to 15 MW_{th} was carried out in 1967. A second capacity increase to 23 MW_{th} was achieved through conversion and retrofitting measures in 1972.

On 2 May 2006, the FRG-2 was shut down finally. Within the scope of the operation licence the spent fuel elements were transported to the USA in 2008. On 20 September 2012 the North Rhine-Westphalian federal state authority granted the licence for the decommissioning and dismantling of the reactor.

To continue scientific work, the Jülich Research Center (FZJ) installed an outstation at the new FRM-II research reactor (cf. Chapter 3.1).

On 1 September 2015 the Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN) was founded. This company comprises the nuclear businesses of the Jülich Research Center and the Arbeitsgemeinschaft Versuchsreaktor (AVR) GmbH.

Research Reactor Rossendorf (RFR)

The RFR was a light-water moderated and cooled tank reactor of the Russian WWR-S(M) type. The thermal power was at last 10 MW_{th} and the thermal neutron flux was ca. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. Basically, the facility served as neutron source for isotope production, activation analyses, material research, and additionally for training purposes in the GDR nuclear energy programme.

On 16 December 1957, the reactor was commissioned with LEU and a thermal power of 2 MW_{th}, which was gradually increased to 10 MW_{th} until 1967, among others by a conversion from LEU operation to MEU operation. From 1987 to 1989, the RFR was extensively reconstructed, e.g. by replacing the reactor vessel, improving the emergency cooling and the cooling circuits.

The operation of the reactor was approved with temporary licences, the last licence was renewed on 8 October 1990 until 30 June 1991, by the then competent nuclear authority. The reactor was finally shut down on 27 June 1991. After it had taken over competency as new nuclear authority, the Saxon State Ministry for the Environment and Agriculture (SMUL) gave supervisory order according to § 19 para. 3 AtG to stop the facility's operation which was geared to nuclear fission. The order was issued on 28 June 1991.

Between 30 May 2005 and 13 June 2005, the spent fuel elements were transported in altogether 18 CASTOR® casks to the Ahaus Transport Cask Storage Facility.

From 30 January 1998, several partial licences for the decommissioning of the plant were granted. On 9 January 2014 the licence pursuant to § 7 para. 3 Atomic Energy Act was granted for the second modification of the fourth licence 4653/18 VKTA 04/2. The modification concerns the expansion of the previous scope of the licence for the total demolition of the residual plant under radiation protection conditions. The demolition of the former reactor building started in August 2015. In October 2015 the adjoining laboratory section at the surface and the control room could be demolished.

3.4 RESEARCH REACTORS RELEASED FROM REGULATORY CONTROL

In the Federal Republic of Germany, the decommissioning of six research reactors with a continuous thermal power above 50 kW_{th} and of 23 research reactors with a thermal power of 50 kW_{th} or less was completed as at 31 December 2015. They have been released from regulatory control. A survey is given in Table II.4 in Annex II of the report.

TRIGA HD II Research Reactor Heidelberg (TRIGA HD I)

The TRIGA HD I was a pool reactor of the TRIGA Mark I type with homogeneous fuel moderator elements of LEU and zirconium hydride. The thermal power of the reactor was 250 kW_{th}, the thermal neutron flux was $1 \cdot 10^{13}$ $1/cm^2 \cdot s$. The facility was commissioned on 26 August 1966 as irradiation source for nuclear-medical applications.

As a second research reactor (TRIGA HD II, see below) was built in the German Cancer Research Center in Heidelberg (DKFZ), the reactor was finally shut down on 31 March 1977. The fuel elements were transported to the new reactor facility for further use. The licence for decommissioning the facility was granted on 30 June 1980 and comprised the dismantling of the components and the safe enclosure of the reactor tank and the biological shield, which was effected on 11 December 1980. Since it was planned to dismantle the building, the DKFZ filed an application for dismantling of the residual facility on 25 April 2003, which was approved on 16 January 2006. The dismantling of the facility and the clearance of the building structure were carried out in the first half of 2006. The facility was released from regulatory control on 13 December 2006. The facility was conventionally dismantled in 2009 within the scope of the clearance procedure and the premises were completely rehabilitated.

TRIGA HD II Research Reactor Heidelberg (TRIGA HD II)

Just as the TRIGA HD 1 (see above) the TRIGA HD II was a pool reactor of the TRIGA Mark I type with homogeneous fuel moderator elements of LEU and zirconium hydride. The thermal power of the reactor was also 250 kW_{th}, the thermal neutron flux was $1 \cdot 10^{13}$ $1/cm^2 \cdot s$. The reactor went critical for the first time on 28 February 1978; it was used for neutron activation analyses and for the production of short-lived radionuclides for medical purposes in cancer research.

Since isotope production had been taken over by an accelerator of the DKFZ and it had to be expected that there was no longer a need for the reactor to be working full capacity, the facility was shut down on 30 November 1999. On 1 June 2001, the fuel elements were shipped to the USA for disposal. A licence according to § 7 para. 3 AtG for the decommissioning and entire dismantling of the research reactor was granted on 13 September 2004. The facility was entirely dismantled in 2005 and released from regulatory control on 13 December 2006.

Research Reactor Frankfurt Unit 2 (FRF 2)

The FRF 2 was a light-water cooled and moderated reactor of the modified TRIGA type with homogeneous fuel moderator elements of LEU and zirconium hydride. The reactor was installed in the remaining buildings (reactor hall and reactor block) of the dismantled predecessor reactor FRF 1 on the basis of the construction licence of 10 January 1973. The FRF 1 was operated from 10 January 1958 to 19 March 1968 as a homogeneous fuel solution reactor of the L54 type with a thermal power of 50 kW_{th}. It was intended to use the new FRF 2 as neutron source for basic research in nuclear physics as well as in solid-state physics and for activation analyses and isotope production. According to a decision of the Hessian Ministry of Culture of 11 July 1980, an operation licence was not granted and one abstained from the nuclear commissioning of the reactor which was ready for use.

On 25 October 1982, the licence for the decommissioning of the FRF 2 and for the dismantling of plant components was granted. Those reactor fuel elements that had not been used were delivered to a foreign research reactor facility (TRIGA MARK II in Ljubljana) in 1981. The residual activity in the facility resulted exclusively from the former operation of the FRF 1 and, after parts of the facility had been dismantled, was in a state of safe enclosure. After the reactor building had meanwhile been used as interim storage facility for low-level radioactive waste produced by the Frankfurt University, the dismantling of the residual structures of

the FRF – consisting of FRF 1 and FRF 2 – was licensed on 28 December 2004. On 31 October 2006, the facility was released from regulatory control after the activated concrete structures had been dismantled and the remaining building structures and the facility site had been cleared.

Research Reactor of the Hannover Medical School (FRH)

The FRH was a pool reactor of the TRIGA Mark I type with homogeneous fuel moderator elements of LEU and zirconium hydride. The thermal power of the reactor was 250 kW_{th}, the thermal neutron flux was ca. $9 \cdot 10^{12}$ $1/cm^2 \cdot s$. Nuclear commissioning of the reactor with natural uranium was on 31 January 1973.The use as neutron source mainly included neutron activation analysis and the production and activation of short-lived radionuclides for medico-biological applications.

Due to changed production processes for radiopharmaceuticals and a decreasing demand for using the reactor, it was finally shut down on 18 December 1996. On 9 July 1999, the fuel elements were shipped to the USA. On 22 February 2002, an application for the decommissioning and dismantling of plant components was filed and approved on 8 May 2006. The dismantling of the facility and the clearance measurements were completed by August 2007. The regulatory supervision of the facility as defined in § 19 AtG was terminated on 13 March 2008.

Research Reactor Jülich 1 (FRJ-1)

The FRJ-1 (MERLIN, Medium Energy Research Light Water Moderated Industrial Nuclear Reactor) was a pool reactor of English design operated with HEU with fuel elements of the MTR type. The thermal power was at last 10 MW_{th} and the thermal neutron flux was ca. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor was commissioned on 23 February 1962 and was used for irradiations and beam pipe experiments.

In 1971, the plant was comprehensively converted to increase the neutron flux from $6 \cdot 10^{13}$ $1/cm^2 \cdot s$ to the last available level of $1.1 \cdot 10^{14}$ $1/cm^2 \cdot s$. Among others, this concerned the use of new fuel elements with a higher mass of U-235 as well as modifications in the primary and secondary cycle for the removal of the thermal power that had doubled from 5 MW_{th} to 10 MW_{th}.

On 22 March 1985, the FRJ-1 was shut down. As a requirement of the operation licence, the fuel elements were removed from the facility and transported to the USA and the UK by October 1992. The licence for the decommissioning of the plant was granted on 8 June 1995. Dismantling of the plant was carried out gradually on the basis of further partial licences and supplementary notices. At last, the decontamination of the reactor hall and reactor hall fittings and the establishment of the prerequisites for clearance and release from regulatory control were approved with licence of 29 November 2004. These works were completed in 2007 and the plant was released from regulatory control on 23 November 2007. The reactor hall and reactor hall fittings were then dismantled conventionally, so that in the course of 2008 the state of “green field” could be achieved.

Nuclear cargo vessel “Otto Hahn” (OH)

The „Otto Hahn“ was the only nuclear cargo vessel operated in Germany and was formally classified as research reactor. An “Advanced Water Reactor” with low-enriched uranium dioxide with a maximum enrichment of 5.42% of U-235 and a thermal power of 38 MW_{th} was used as drive source.

The principal task of the “Otto Hahn” was to gain operational experience for nuclear-powered ships for civil use. The “Otto Hahn” was commissioned as nuclear ship on 11 October 1968, and was taken out of operation on 22 March 1979. On 1 December 1980, a licence according to § 7 AtG in combination with §§ 3 and 4 of the Radiation Protection Ordinance (old version) was granted for the decommissioning of the "Otto Hahn”. After the reactor had been dismounted, the ship was decontaminated and cleared and was released from regulatory control on 1 September 1982.

By autumn of 1979, the fuel elements were delivered to the WAK for reprocessing, except for 49 spent and three fresh fuel elements. 52 fuel elements had initially remained with the former operator of the ship and were taken to the French CEA research centre (Commissariat à l’Energie Atomique et aux Energie Alternatives) in Cadarache in July 2010. From there they were taken to the Interim Storage Facility North in the scope of a consolidated transport, along with approximately 2,500 fuel elements from the Karlsruhe Research Center.

Research Reactors with a Capacity of 50 kW_{th} or less

Among the already dismantled research reactors with a capacity of 50 kW_{th} or less or, respectively already released from regulatory control, are 23 reactors. Of these plants, one was not licensed according to § 7 Atomic Energy Act but § 9 Atomic Energy Act (SUAK). The reactors were based on different reactor concepts. Among them are e.g. training reactors (such as SUR-KI), reactors with fuel solution (such as

ABDIKA), critical assemblies (such as ANEX) or Argonaut reactors (such as RRR). The individual reactors need not be further elaborated here. A survey of this category is given in Annex II, Tab. II.4.

4 PLANTS OF NUCLEAR FUEL SUPPLY AND WASTE MANAGEMENT

Annex III includes essential data and information on nuclear fuel supply and waste management in the form of tables, figures and enclosures. Figure III shows a survey map of the nuclear fuel supply and waste management sites.

On behalf of the Federal Environment Ministry, the Nuclear Waste Management Commission carried out a safety assessment (stress test) of the plants of nuclear fuel supply and waste management in Germany. The results of the stress test were published in March 2013 (part 1) and in October 2013 (part 2) and can be accessed on the website of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB): http://www.bmub.bund.de/N49919/.

4.1 URANIUM ENRICHMENT PLANTS

Gronau Uranium Enrichment Plant (UAG)

In the Gronau uranium enrichment plant (cf. Table III.1), natural uranium in the form of uranium hexafluoride (UF6) is enriched in centrifuge cascades to the point of a maximum concentration of the fissile U-235 isotope of 6 percent by weight (w/o).

The plant was commissioned in the middle of August 1985 with 400 Mg of uranium separative work per year (SW/a).

An application for extending the production capacity to 4,500 Mg UTA/a was filed in September 1998. The relevant licence was granted on 14 February 2005. It includes the construction and operation of a second uranium separating plant with a separation capacity of up to 2,700 Mg UTA/a with a maximum enrichment of 6%. The licence also includes the storage of 58,962 Mg of depleted uranium (tails) in oxidic form and 38,100 Mg as UF_6, of 10,000 Mg of natural uranium (feed) as UF_6 and 1,250 Mg of enriched uranium (product) with a maximum enrichment of 6% of uranium-235 as UF_6. Apart from completion of the uranium oxide storage facility, the final stage of completion of the extended facility has been reached. The UAG is operated by Urenco Deutschland GmbH with a licensed capacity of nominally 4,500 Mg UTA/a.

According to Urenco's own information, the re-enrichment of depleted uranium in Russia was terminated in 2009. The uranium hexafluoride produced in future would be converted into the triuranium octoxide (U_3O_8) – which is chemically more stable – by the French AREVA company (formerly COGEMA) in Pierrelatte, and subsequently be stored on the company premises in Gronau.

The construction of a storage hall with a capacity of 60,000 Mg U_3O_8 was launched in 2011.

4.2 FUEL ELEMENT FABRICATION PLANTS

Only one fuel element fabrication plant is still in operation in the Federal Republic of Germany. All other plants have already been entirely dismantled and released from regulatory control (cf. Tables III.2; III.3).

4.2.1 Fuel element fabrication plant in operation

ANF Fuel Element Fabrication Plant, Lingen

In the ANF Fuel Element Fabrication Plant uranium fuel elements with a maximum fraction of 5% of uranium-235 are produced for major use in light-water reactors. Uranium dioxide (UO_2) powder, uranium hexafluoride (UF_6) or externally fabricated UO_2 pellets are used as raw material. The fuel element fabrication process includes the following procedural steps: Conversion, pellet fabrication, fuel rod fabrication and fuel element fabrication.

Fuel element fabrication started in January 1979 with externally produced uranium pellets. In March 1987, the production of up to 400 Mg of UO_2 pellets annually was licensed with the 5th partial operation licence (start of production in 1988). The operation of the dry version with uranium-235 enriched to up to 5 % was started in June 1994. In June 1996, a second fuel rod production line and a building for the storage and handling of UO_2 pellets and powder were licensed. The currently licensed processing performance has been laid down to be 800 Mg/a for dry conversion and 650 Mg/a for other partial plants.

The licensed storage capacity of uranium hexafluoride is 275 Mg. A hall for the storage of UF_6 containers with licence according to § 7 AtG has been taken into operation.

On 26 June 2014 a licence pursuant to § 7 Atomic Energy Act was granted for the expansion of the storage areas for nuclear fuel by integrating the storage hall for the storage of radioactive waste that had previously been licensed pursuant to § 6 Atomic Energy Act.

4.2.2 Fuel element fabrication plants released from regulatory control

Siemens Fuel Element Fabrication Plant Hanau, Plant Section MOX-Processing

Since 1968 the facility served to produce mixed oxide (MOX) fuel elements on the basis of uranium dioxide/plutonium dioxide (UO_2/PuO_2), plutonium dioxide (PuO_2) or uranium dioxide (UO_2) fuel, mainly for light-water reactors.

Since the Hessian Environmental Ministry issued a decree according to § 19 AtG, the plant stopped operation in summer 1991 after an incident involving contamination had occurred. In April 1994, the operator decided not to re-commission the old plant but to run a clean-out programme.

The licensing procedure for the dismantling of the Siemens MOX facility was discussed in a hearing in March 2000 in Hanau, the dismounting of the first production facilities was licensed in December 2000. The 1st partial licence for the dismantling of the emptying facility was granted in May 2001, the 2nd partial licence in March 2003 and a 3rd partial licence on 3 January 2005. It provided for some buildings and parts of the open-air ground being already used conventionally. The fourth and concluding partial licence was granted on 16 March 2005.

Dismantling work concluded in July 2006 and the MOX processing plant section was released from regulatory control in September 2006.

The dismantling of the non-contaminated new facility which had to be carried out separately was licensed on 7 December 1998. The building designed against air crashes was emptied and is available for other use.

The facility premises can now be used conventionally as industrial site.

Siemens Fuel Element Fabrication Plant Hanau, Plant Section Uranium Processing

Since 1969, the plant served to produce uranium fuel elements with a maximum fraction of 5% uranium-235 for major use in light-water reactors. UF_6 was used as raw material.

Due to unfavourable overall boundary conditions at the Siemens site the production of uranium fuel elements stopped in October 1995. To prepare decommissioning, several single licences for the dismantling of plant components and for the removal of nuclear fuel were granted from 1996 to 1998. From 1999 to March 2001, three partial licences and several single licences for subsequent decommissioning were granted.

The finally approved decommissioning procedure included the dismantling of the production buildings and the remediation of the premises on the basis of the 10 µSv concept. (This means that it is justifiable to release the materials, the objects or the facility from radiation protection supervision if the release leads to radiation exposures that are only in the order of 10 µSv per calendar year for individuals.) After the controlled areas had been closed and the buildings dismantled one started remediating the premises. Since uranium had entered the soil and the groundwater as a result of the facility operation, it had also become necessary to remediate the soil, the existing sewers and the groundwater. After remediation work could be successfully concluded in January 2006, the facility was released from regulatory control in May 2006. Merely a groundwater remediation which had become necessary for chemico-toxic reasons and which is in the responsibility of the competent authority under water right is still continuing. The operation of the groundwater treatment plant was licensed according to § 7 StrlSchV.

Siemens Fuel Element Fabrication Plant, Plant Section Karlstein

Since 1966, the plant served to produce fuel elements made of uranium oxide with a fraction of maximum 4% of uranium-235.

In the scope of the decommissioning decision for the Siemens plant sections in Hanau the comparatively small plant in Karlstein was closed, too. The removal of all radioactive operational equipment was concluded. The Siemens Fuel Element Fabrication Plant, Plant Section Karlstein, was released from regulatory control in March 1999.

Non-nuclear operation carried on and is used for the fabrication of structural components for fuel elements (ANF Karlstein). Since 2001, the Karlstein site is a subsidiary of Framatome ANP, later renamed AREVA NP.

NUKEM-A Fuel Element Fabrication Plant, Hanau

Since 1962, the NUKEM company produced fuel elements for research and material test reactors; the fuel elements were made of uranium and thorium up to an enrichment degree of 94% of uranium 235.

A first licence for the dismantling of components in the area of the fuel element fabrication was granted on 5 December 1988. On 23 December 1988 NUKEM filed an application for the decommissioning of the entire NUKEM industrial premises. The licence for decommissioning was granted on 10 March 1993. Further licences were granted for the dismantling of the non-safety relevant plant components.

It had turned out that the so-called Monostahalle located on the Degussa premises (outside the ring fence of the NUKEM-A premises), which was meanwhile used again by Degussa, had to be included in the decommissioning procedure. Therefore, two additional licences for the dismantling of this complex of buildings were applied for and granted on 9 November 1999 and on 26 June 2001.

All buildings inside the ring fence have meanwhile been dismantled. In May 2006 the remediation of the soil concluded and the entire premises, with the exception of 1.000 m, were released from regulatory control. Until 2015 a groundwater remediation plant had been operated on the partial area under § 19 AtG. The radiological groundwater remediation stopped with notification of 20 July 2015 and the grounds were released from regulatory control.

Hochtemperatur-Brennelement Gesellschaft (HOBEG)

From 1972 to 1988, the facility of Hochtemperaturreaktor Brennelement GmbH (HOBEG) located on the Hanau premises was operated to produce ball-shaped fuel elements for high-temperature reactors. The capacity was up to 200,000 fuel elements per year. Altogether approximately 1 million fuel elements were fabricated. The HOBEG plant was initially operated with several single licences according to § 9 AtG. On 30 December 1974 these individual licences were combined to a temporary licence covering all individual licences. The facility was temporarily taken out of operation on 15 January 1988, and was decommissioned subsequently.

Between 5 December 1988 and 7 April 1995, altogether nine licences according to § 7 para. 3 AtG for the decommissioning of the facility were granted. The procedural components were dismantled and the major part of them was sold. The buildings and the surrounding terrain were decontaminated. Following relevant measurements, the remaining buildings and the associated terrain were cleared and released from regulatory control on 18 December 1995. Today, the terrain and the buildings are used by Nuclear Cargo & Service GmbH (DAHER-NCS).

4.3 STORAGE OF SPENT FUEL ELEMENTS

4.3.1 Storage in nuclear power plants

Spent fuel elements are initially stored in the nuclear power plants in the wet storage pools of the reactor facility and then in interim storage facilities near the site (cf. Table III.5 in Annex III).

In accordance with requirements imposed in the licences for the nuclear power plants, a capacity of one core load must basically be kept free in the wet storage pools to ensure that the reactor core can be entirely unloaded at any time. In general, the internal storage capacities cannot be used by several nuclear power plants. Exceptions were approved for the double unit facilities of Neckarwestheim and Philippsburg.

For the Obrigheim NPP the operation of an already constructed additional wet storage facility in the earthquake-protected emergency building outside the reactor building was approved in 1998. The first fuel elements were stored here in 1999 (cf. Chapter 4.3.2).

4.3.2 Storage in decentralised on-site interim storage facilities

Table III.5 gives a survey of the decentralised on-site interim storage facilities in Germany.

AVR – Jülich Cask Storage Facility

The AVR cask storage facility is a dry storage facility for spent ball-shaped fuel elements originating from the AVR Jülich in transport and storage casks of the CASTOR®THTR/AVR type.

The cask storage facility forms a part of waste storage hall II in the Department of Decontamination of Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH, formerly Jülich Research Center (FZJ).

On 17 June 1993 the BfS granted a nuclear licence pursuant to § 6 Atomic Energy Act (AtG) for the storage of maximum 300,000 spent AVR fuel elements for a period of 20 years. Storage operation was taken up on 23 August 1993. At the end of 2009, altogether 152 loaded casks of the CASTOR®THTR/AVR type were stored in the AVR cask storage facility.

In 2007, the FZJ GmbH initially applied for the licence for storage in Jülich to be extended given that the storage licence was limited until 30 June 2013. With letter of 29 April 2009 the FZJ declared that the extension would have to be effective for three years.

Furthermore, on 24 September 2009, the FZJ requested Gesellschaft für Nuklear-Service mgH (GNS) to submit an application to the BfS for being permitted to store the 152 casks in the GNS interim storage facility in Ahaus (TBL Ahaus). The FZJ requested Nuclear Cargo + Service GmbH (NCS, since 1 October 2015 named DAHER-NCS) on 4 October 2010 to apply for a transport licence for the transport to the TBL Ahaus. As a result, the FZJ asked on 16 July 2010 to suspend the licensing procedure for the extension of storage in Jülich.

In 2012 the FZJ changed its plans again and filed an application on 16 May 2012, for resuming the procedure for further storage of the AVR fuel elements in Jülich. On behalf of the FZJ the GNS applied on 11 January 2013 for the suspension of the procedure for the storage of the AVR fuel elements in Ahaus; the NCS also applied on 17 January 2013 for the suspension of the procedure for the transport to Ahaus.

On 15 December 2014 the FZJ announced that it now wished to pursue the option of a transport to the TBL Ahaus again. For this purpose the GNS resumed the licensing procedure for the storage of the fuel elements in the TBL Ahaus with letter of 6 January 2015. The NCS resumed the licensing procedure for the transport of the AVR fuel elements from Jülich to Ahaus on 21 July 2015.

Since the middle of 2012 the FZJ furthermore examines the feasibility of shipping the AVR fuel elements to the USA.

The storage licence pursuant to § 6 AtG meanwhile expired on 30 June 2013. On 27 June 2013, the Ministry of Economic Affairs, Energy, Industry, Middle Class and Trade of the federal state of North Rhine Westphalia (MWEIMH), being responsible as nuclear supervisory authority, ordered that the AVR fuel elements continue to be stored in the Jülich Interim Storage Facility. This decision was limited to six months and continued to entitle the FZJ GmbH to the nuclear fuels. It was followed by a corresponding decision of 17 December 2013 which was limited to seven months.

Once it was clear that proof of earthquake safety, which needs to be furnished by the applicant and is required for a licence pursuant to § 6 AtG, would be delayed indefinitely should the storage in Jülich be prolonged, the MWEIMH NRW imposed an injunction pursuant to § 19 para. 3 AtG according to which the nuclear fuels must be removed from the AVR cask storage facility with immediate effect and it must be guaranteed that the nuclear fuels remain with a person entitled to them pursuant to § 5 para. 1 sentence 1 AtG. At the same time the injunction regulates the further storage until evacuation and it is assumed that the licensing procedure pursuant to § 6 AtG will continue. The FZJ GmbH presented a detailed concept for the removal of the nuclear fuels from the AVR cask storage facility on 31 October 2014. The alternative options mentioned in the concept are shipping the AVR fuel elements to the USA, to the TBL Ahaus or to an interim storage facility on the premises of the Jülich Research Center, which would still have to be constructed.

On 1 September 2015, the nuclear competencies were combined at the Jülich site by integrating the “Geschäftsbereich Nuklearservice” (Department of Nuclear Service) of the FZJ GmbH in the AVR GmbH. Since 1 January 2016 the new company is listed under the name Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN).

Interim Storage Facility in the Obrigheim NPP

Based on licences dating from 1979 to 1983, Kernkraftwerk Obrigheim GmbH (KWO) constructed an interim storage facility for spent fuel elements from the KWO on the nuclear power plant premises. It is an external wet storage facility for 980 fuel elements (approx. 286 Mg of HM) which was erected in the emergency building until 1984. The operation licence of this storage facility comprises the storage of 980 fuel elements exclusively from the KWO and of core components. It was granted according to § 7 AtG on 26 October 1998.

Emplacement of fuel elements started in the middle 1999. Once the Obrigheim NPP had shut down on 11 May 2005, altogether 342 fuel elements were stored in the external wet storage facility until the end of 2007. On 22 April 2005, Kernkraftwerk Obrigheim GmbH submitted an application to the BfS for storage of the spent fuel elements in a dry storage facility (cf. the following section "On-site interim storage facilities").

On-site interim storage facilities

From 1998 to 2000, applications for the storage of nuclear fuel in the form of spent fuel elements in on-site interim storage facilities (SZL) were filed for altogether 13 sites by the NPP operators. The application for an on-site interim storage facility in Stade was withdrawn after one had decided to decommission the NPP.

The Federal Office for Radiation Protection (BfS) is the competent authority for granting nuclear licences according to § 6 AtG. Apart from the nuclear licence for the storage of nuclear fuel, the construction of the building especially requires a building licence according to the building regulations of the relevant federal state. In the licensing procedures relating to the applications of 1999 a joint Environmental Impact Assessment (EIA) was carried out. This was based on the European Directive 97/11/EG that was effective until 16 February 2012 and was replaced by the Directive 2011/92/EU and the Environmental Impact Assessment Act. Possible effects of the respective projects on man, animals, plants and their habitat, and on soil, water, air, and climate were examined.

In the context of the licensing procedures pursuant to § 6 para. 2 no. 4 AtG, the BfS has to examine in particular whether the required protection against disruptive actions or other interference by third parties (SEWD) is guaranteed. Since the terrorist attacks of 11 September 2001, air traffic is a prime target for terrorist attacks, despite of the known high safety standards. Despite the fact that no new findings have become known in the past years and more recently that indicate a concrete risk of stationary nuclear facilities, the BfS has examined the consequences of a targeted crash of a large passenger plane onto an interim storage facility, in addition to the consequences of terrorist attacks and acts of sabotage. This has been done in the context of examinations pursuant to § 6 para. 2 no. 4 AtG. As a result of its examinations, the BfS has noted that the evacuation-related intervention reference levels of 100 millisierverts (mSv) effective dose (required in the case of disaster control) would not be reached.

The on-site interim storage facilities are dry storage facilities for spent fuel elements placed into transport and storage casks that are kept in storage halls or tubes, respectively. In all already licensed storage facilities, CASTOR® V/19 or CASTOR® V/52 type casks are used initially. The granted licences for all on-site interim storage facilities applied for until 2000 permit the storage of spent fuel elements with a mass of heavy metal amounting to altogether 14,025 Mg on 1,435 storing positions for transport and storage casks of the CASTOR® type. Capacity had originally been dimensioned such that all spent fuel elements that would have accrued until nuclear power plant operation finally stopped (on the basis of the electricity volumes determined in 2002), could have been accepted until nuclear power plant operation had discontinued and could have been stored there, also beyond decommissioning, until a repository would be taken into operation. As the authorisation for power operation for altogether eight nuclear power plants expired on 6 August 2011 on the basis of the 13th Amendment to the Atomic Energy Act that became effective on 31 July 2011 and as, at the same time, the remaining operating times of the other nuclear power plants will end in 2022 at the latest, the storage capacities of the on-site interim storage facilities will no longer be exhausted by the storage of spent fuel elements accruing in future.

By the end of 2003, storage of spent fuel elements was granted for twelve on-site interim storage facilities (cf. Table II.5). The BfS initially granted partial licences for those parts of the application whose examination had been concluded, so that the applications filed between 1998 and 2000 have as yet not been decided. In 2015, the BfS continued the examinations in the context of modification licences for the on-site interim storage facilities. The focus was on examinations of the use of a modified type of transport and storage casks CASTOR® V/19 and CASTOR® V/52 and the new cask type TN 24 E, examinations of an upgrade of the cranes according to the increased requirements of the KTA Safety Standard 3902, and examinations in connection with an extension of the protection of the on-site interim storage facilities against disruptive actions or other intervention of third parties, see above. In the licensing procedures for modifications it was examined individually whether supplementary examinations had to be carried out for the Environmental Impact Assessment in individual cases.

In June 2013, the OVG Schleswig upheld the action against the licence for the Brunsbüttel on-site interim storage facility. The licence of November 2003 was unlawful and to be annulled since it did not fulfil the requirements set out in § 6 para. 2 no. 4 AtG. The defendant had wrongly determined and evaluated the necessary level of protection against terrorist impacts in the form of a targeted crash of a passenger plane as well as the risks of the scenario of a terrorist attack on the on-site interim storage facility with anti-tank weapons in the licensing procedure. The OVG Schleswig did not grant the right to further appeals. The Federal Republic of Germany - as the defendent - lodged a complaint against the denial of leave to appeal to the Federal Administrative Court (BVerwG). With decision of 8 January 2015 the BVerwG dismissed the complaint against the denial of leave to appeal in the decision of the OVG Schleswig of 19 June 2013. With the decision of the BVerwG the revocation of the licence for the SZL Brunsbüttel has become effective. Until recovery of a legal licence, the nuclear supervisory authority of the Federal State of Schleswig-Holstein gave order on 16 January 2015, to carry on storing the altogether nine stored CASTOR® casks in the SZL Brunsbüttel until January 2018. With letter of 16 November 2015, Kernkraftwerk Brunsbüttel GmbH & Co.

oHG filed an application to the BfS for being granted a new licence for the storage of nuclear fuels in the on-site interim storage facility Brunsbüttel.

Another legal proceeding is pending at the OVG Lüneburg concerning the licence for the Unterweser on-site interim storage facility.

Table 4.1 gives a survey of the respective first licences, the licensed masses of heavy metal (HM) and storing positions, start of construction and taking into operation (i.e. the first emplacement of a loaded cask) of the on-site interim storage facilities. Further details about the on-site interim storage facilities are given in Table III.5.

Table 4.1: On-site interim storage facilities (SZL)

On-site interim storage facility (SZL)	Granting the 1st licence according to § 6 AtG	Mass HM [Mg]	Storing positions TOTAL (Taken at the end of 2015)	Taken into operation
SZL Biblis	22.09.2003	1.400	135 (52)	18.05.2006
SZL Brokdorf	28.11.2003	1.000	100 (29)	05.03.2007
SZL Brunsbüttel	28.11.2003	450	80 (9)	05.02.2006
SZL Grafenrheinfeld	12.02.2003	800	88 (21)	27.02.2006
SZL Grohnde	20.12.2002	1,000	100 (27)	27.04.2006
SZL Gundremmingen	19.12.2003	1,850	192 (42)	25.08.2006
SZL Isar	22.09.2003	1,500	152 (35)	12.03.2007
SZL Krümmel	19.12.2003	775	80 (21)	14.11.2006
SZL Lingen	06.11.2002	1,250	125 (38)	10.12.2002
SZL Neckarwestheim	22.09.2003	1,600	151 (53)	06.12.2006
SZL Philippsburg	19.12.2003	1,600	152 (40)	19.03.2007
SZL Unterweser	22.09.2003	800	80 (27)	18.06.2007

On 22 April 2005, Kernkraftwerk Obrigheim GmbH submitted an application to the BfS for the storage of spent fuel elements in the Obrigheim on-site interim storage facility. On 1 January 2007, KWO GmbH as the applicant was replaced by EnBW Kernkraft GmbH (EnKK). Storage of altogether 342 spent fuel elements was applied for which came from the pressurised water reactor of the Obrigheim NPP that had already been shut down in May 2005 and is now under decommissioning. The fuel elements are currently stored in an already existing wet storage facility on the site (see above). On the premises of the Obrigheim NPP, the applicant intends to operate a separate on-site interim storage facility for the dry interim storage of spent fuel elements for 40 year at most. However, no further application documents have been presented by EnKK in the procedure since 2013.

Since 2013, the EnKK has been pursuing alternatively the storage of the 342 spent fuel elements from the Obrigheim NPP in the Neckarwestheim on-site interim storage facility. With letter of 10 December 2013 it filed a corresponding application to the BfS according to § 6 AtG. The EnKK concept for the storage of the spent fuel elements in altogether 15 casks of the CASTOR® 440/84 type is to be maintained.

The Neckarwestheim on-site interim storage facility is situated ca. 40 km from the Obrigheim site (air-line distance). In a transport study, the EnKK is currently examining on which transport route (road, rail, river Neckar) to use to take the CASTOR® casks to the Neckarwestheim on-site interim storage facility. The EnKK has come to the conclusion that transport on an inland vessel on the river Neckar should be prioritised. The so-called “Roll-on/Roll-off procedure” with a transport vehicle should be prioritised for loading/unloading the vessel. As an alternative, the EnKK also pursues direct transport by road. On behalf of the EnKK, the NCS GmbH filed a corresponding application to the BfS for a transport licence under § 4 AtG on 27 March 2014.

4.3.3 Storage in central interim storage facilities

A survey of the central interim storage facilities outside nuclear power plant sites is given in Table III.4. in Annex III to this report.

For the transport cask storage facilities of Ahaus, Gorleben, and the transport cask storage facility of the Interim Storage Facility North, investigations into the possible impacts of a targeted air crash were carried out in the scope of investigations into a possible subsequent requirement according to § 17 AtG. Expert

results have shown that in the case of an assumed targeted air crash the lives and health of the population in the vicinity would not be jeopardised by the release of considerable amounts of radioactive substances and that no drastic disaster control measures need to be taken.

Ahaus Transport Cask Storage Facility (TBL-A)

The Transport Cask Storage Facility Ahaus is a dry storage facility for spent fuel elements in transport and storage casks of the CASTOR® type.

The nuclear licence for the storage of fuel elements from light-water reactors according to § 6 AtG for a capacity of 1,500 Mg of heavy metal (HM) was granted on 10 April 1987, after a corresponding application had been filed on 2 August 1984. Storage operation started in June 1992.

On 17 March 1992, the TBL-A was granted a licence for the storage of spent ball-shaped fuel elements from the THTR-300 in transport and storage casks of the CASTOR® THTR/AVR type. By the end of April 1995, all 305 CASTOR® THTR/AVR casks containing the fuel elements from the THTR-300 were stored.

On the basis of a comprehensive new application a new licence was granted on 7 November 1997. It comprises the storage of maximum 3,960 Mg of HM in the previously licensed casks and in the new casks of the CASTOR® V/19, CASTOR® V/19 SN06, and CASTOR® V/52 types on 420 storing positions until 31 December 2036. The licence stipulates the maximum storable activity to be $2 \cdot 10^{20}$ Bq and the heat output limit of all casks in the hall to be 17 MW.

In addition to the 305 CASTOR® THTR/AVR casks already stored, 2 CASTOR® V/19 casks, 1 CASTOR® V/19 SN06 cask and 3 CASTOR® V/52 casks containing LWR fuel elements were transported to the Ahaus Transport Cask Storage Facility on 20 March 1998.

Following the conclusion of the appeal and review procedure, the storage licence for the TBL Ahaus is definitive.

On 9 November 2009 the Bezirksregierung Münster granted the licence pursuant to § 7 StrlSchV for the limited interim storage of radioactive waste from the operation and decommissioning of German nuclear power plants with a maximum total activity of 10^{17} Bq for a period of 10 years maximum. The operational and decommissioning waste is to be stored in the western half of the hall, placed in different casks made from concrete, cast-iron and steel. This waste is later on to be taken to the licensed federal Konrad repository, which is located near Salzgitter and is currently being converted.

Furthermore, altogether six modification licences pursuant to § 6 AtG were granted from 2000 until 2010 (cf. Table III.4).

On 20 December 2006, the GNS and the BZA filed an application according to § 6 AtG for the storage of high-pressure compacted intermediate-level radioactive waste (CSD-C – Colis Standard de Déchet Compactés) from the reprocessing of spent fuels in transport and storage casks of the TGC36 type. A new transport and storage cask of the TGC27 type is being developed for the storage of this CSD-C waste. From today's point of view one plans to store this waste in up to 150 casks.

With letter of 24 September 2009 the GNS and the BZA additionally applied for the storage of the AVR ball-shaped fuel elements from the Jülich AVR cask storage facility in the TBL Ahaus. This was done because the licence for the AVR cask storage facility expired in 2013 (cf. Chapter 4.3.2). The altogether 152 casks of the CASTOR® THTR/AVR type are to be stored in the eastern half of the hall beside the already stored 305 casks of the CASTOR®THTR/AVR type with fuel elements from the THTR. Upon request of the GNS of 11 January 2013, the procedure was suspended until further notice and resumed with letter dated 6 January 2015.

With letter of 30 September 2014, the GNS asked for reopening of proceedings under nuclear law for the storage of the spent fuel elements from the Heinz Maier-Leibnitz research neutron source of the Technical University of Munich in the TBL Ahaus. It is planned to store the fuel elements in ca. 21 casks of the new cask type CASTOR®MTR3 in storage facility area II of the TBL Ahaus. The storage of spent fuel elements from German research reactors applied for is part of the comprehensive joint application of the BZA and the GNS of 15 September 1995, for which a decision has so far only been made for the fuel elements of the Rossendorf research reactor with respect to research reactor fuel elements.

Gorleben Transport Cask Storage Facility (TBL-G)

The Gorleben Transport Cask Storage Facility is a dry storage facility for spent fuel elements from nuclear power plants with light-water reactors and for HAW vitrified waste containers from reprocessing in transport and storage casks.

Following application in September 1980, the nuclear storage licence according to § 6 Atomic Energy Act for a capacity of 1,500 Mg of heavy metal (HM) was granted on 5 September 1983. Storage operation started on 25 April 1995.

In a new licence of 2 June 1995, especially the storage of mixed-oxide (MOX) containing fuel elements and the storage of nuclear fuels in the form of waste as well as of nuclear fuel containing waste and other radioactive substances was permitted, in addition to the increase to altogether 3,800 Mg of HM and the storage of solidified high-level radioactive fission product solutions. The storable activity was limited to $2 \cdot 10^{20}$ Bq. Prior to this decision a public participation procedure was carried out on the basis of the amendment to § 6 AtG.

Until 2011, five casks containing spent fuel elements (1 CASTOR® Ic, 1 CASTOR® IIa, 3 CASTOR® V/19) and 108 casks containing HAW vitrified waste block canisters (1 TS 28 V and 74 CASTOR® HAW 20/28 CG, 21 CASTOR® HAW 28 M and 12 TN85) were stored in the TBL Gorleben.

More casks are expected to be returned from the British Sellafield Ltd. Reprocessing plant, ca. 21 casks of the CASTOR® HAW28M type containing HAW vitrified waste block canisters, and five casks containing solidified intermediate-level radioactive waste (MAW vitrified waste block canisters) from the reprocessing of spent fuel elements at AREVA NC in France in casks of the CASTOR® HAW28M type.

Following an Amendment to the Atomic Energy Act in combination with the Repository Site Selection Act (StandAG) of 23 July 2013, the storage of these casks in the TBL Gorleben has been ruled out. It is planned to distribute them to on-site interim storage facilities. In a position paper of the BMUB with the NPP operating utilities of 19 June 2015, the concept was presented of returning the wastes from reprocessing to the on-site interim storage facilities of Philippsburg, Brokdorf, Biblis and Isar. In a joint statement of the Bavarian State Government and the BMUB of 4 December 2015 it was stated that it is planned to store the five CASTOR casks arriving from France in the SZL Philippsburg. The CASTOR casks arriving from the UK are to be returned in three transports and evenly – seven each – distributed to the sites of Biblis, Brokdorf and Isar.

With letters of 5 December 2013 and 12 December 2013, the GNS and the BLG applied for extending the storage licence pursuant to § 7 para. 2 StrlSchV to the storage of other radioactive materials at the TBL-G. In the framework of this combined utilisation it is now planned to store in a part of the storage facility waste suitable for disposal which was conditioned previously on the site, in a still to be constructed attachment to the waste storage facility Gorleben.

Transport Cask Storage Facility in the Interim Storage Facility North Rubenow (ZLN)

The Transport Cask Storage Facility in the Interim Storage Facility North is a dry storage facility for spent fuel elements in transport and storage casks. It is situated in hall no. 8 of the Interim Storage Facility North on the premises of EWN. The ZLN mainly serves to store spent fuel elements, nuclear fuel, and other radioactive waste from the reactors of Rheinsberg and Greifswald.

On 5 November 1999, the licence according to § 6 AtG was granted, after a corresponding application had been filed in April 1993. The licence was granted for a capacity of maximum 585 Mg of HM in maximum 80 casks of the CASTOR® 440/84 type. The maximum storable activity inventory was limited to $7.5 \cdot 10^{18}$ Bq. Emplacement operation of CASTOR® casks started on 11 December 1999.

Until 2011, there were thus altogether 74 loaded CASTOR® casks in the ZLN (62 CASTOR® 440/84, 3 CASTOR® KRB-MOX, 5 CASTOR® HAW 20/28 SN 16 and 4 CASTOR® KNK).

An application of 30 June 2011 for licensing the expansion of the protection against disruptive measures and other third party intervention was withdrawn by the EWN with letter of 20 July 2015. The EWN is currently examining alternative approaches.

4.4 INTERIM STORAGE OF RADIOACTIVE WASTE AND NUCLEAR FUELS

4.4.1 Interim storage of radioactive waste

A survey of external waste interim storage facilities in Germany is given in Table III.6 in Annex III.

Apart from facilities on the nuclear power plant sites, the following facilities are currently available for storing the waste:

- the external storage hall Unterweser,
- the decentralised interim storage facility Biblis,
- the TBL Ahaus,
- the waste storage facility Gorleben (ALG),
- the EVU hall of the interim storage facility Mitterteich,

- the interim storage facilities of Nuclear + Cargo Service GmbH (NCS) in Hanau,
- the interim storage facility North (ZLN) near Greifswald,
- the interim storage facility Rossendorf (ZLR) and
- the interim storage facility of the Hauptabteilung Dekontaminationsbetriebe (HDB) in Karlsruhe.

Based on the licences for these interim storage facilities there are restrictions in delivery.

The major part of the radioactive waste produced by nuclear industry and research institutions is intermediately stored on the waste producers' sites. Radioactive waste produced in the medical field and by small waste producers is intermediately stored in Länder collecting depots.

In the Morsleben Repository for Radioactive Waste (ERAM) one drum with radium radiation sources and seven special containers with mainly Co-60 radiation sources are intermediately stored. The BfS plans to dispose of these radiation sources in the ERAM within the scope of its closure. The BfS filed the respective application for disposal of this waste on 12 September 2005.

4.4.2 Government custody of nuclear fuels

According to § 5 AtG, nuclear fuels (such as fresh fuel elements, fuel rods, and UO_2-pellets) must be kept in government custody if the operator does not have a valid licence. According to § 5 Atomic Energy Act, the authority competent for federal custody is the Federal Office for Radiation Protection.

Should, contrary to expectations, there be larger amounts of nuclear fuels to be kept in government custody, they are stored on site. Maintaining an own installation for this purpose is disproportionate.

For smaller amounts of nuclear fuel accruing which have to be kept in government custody according to § 5 AtG in future, storage space will be rented and containers and paraphernalia will be developed and purchased. The objective is to prepare largely maintenance-free container storage for emergencies.

A plutonium-beryllium neutron source (Pu-Be source) is still in government custody in the BfS branch office in Berlin Karlshorst.

4.5 REPROCESSING OF NUCLEAR FUELS

In the 60s of the 20th century, Germany started developing the technology used for the reprocessing of spent fuel elements. For this purpose the Karlsruhe reprocessing plant (WAK) was constructed as pilot plant. There were plans for the construction of a national waste management centre (Gorleben Nuclear Waste Management Centre) where interim storage, industrial reprocessing, and disposal were to be dealt with on one site.

After this plan and domestic reprocessing had been given up, the management of spent fuel elements from German nuclear power plants by interim storage and reprocessing in other EU Member States was accepted – by the decision of the federal government of 6 June 1989 – as it was part of the integrated waste management concept and thus of the proof of precautionary measures to dispose of radioactive waste. The construction of an industrial German reprocessing plant in Wackersdorf (WAW) was stopped in the same year and the spent fuel elements were taken to France (AREVA, La Hague) or England (BNFL, Sellafield) for reprocessing.

As a result of an Amendment to the Atomic Energy Act of 1994, direct disposal was put on a par with reprocessing as a waste management alternative, so that fuel elements were also intermediately stored in the Gorleben and Ahaus interim storage facilities for direct disposal later on.

Due to the Amendment to the Atomic Energy Act of 27 April 2002, a ban was imposed on transports to reprocessing plants abroad after 30 June 2005, in order to minimise the risk associated with reprocessing and transports to reprocessing plants. From this time on, the management of fuel elements has exclusively been restricted to direct disposal.

Karlsruhe Reprocessing Plant (WAK)

The WAK (cf. Table III.7) on the premises of the Research Center Karlsruhe (FZK) – today Karlsruhe Institute of Technology (KIT) – was a test facility for the reprocessing of spent fuels from research, prototype and power reactors. Apart from the objective to gain operational experience, development projects relating to a German reprocessing plant were carried out on an industrial scale. The WAK resumed operation in 1971 under the leadership of the WAK Betriebsgesellschaft mbH. The operation finally ended in 1991 following a decision to do without a large-scale reprocessing plant. During this period approximately 200 Mg of nuclear fuels originating from numerous reactors were reprocessed. The uranium and plutonium obtained in this process was taken to nuclear fuel supply companies for further processing.

An amount of 60 m^3 of high-level radioactive liquid waste concentrate (HAWC) with an activity of $7.7 \cdot 10^{17}$ Bq accrued from reprocessing, which was last stored inside the LAVA building (facility for the storage and evaporation of high-level radioactive waste liquids). The low-level and intermediate-level operational waste of the WAK was conditioned in the Karlsruhe Nuclear Research Center. After radioactive waste emplacement into the Asse mine stopped in 1978, additional conditioned operational waste remained with the WAK Rückbau- und Entsorgungs-GmbH.

Operation finally ended on 30 June 1991. At the end of 1991 the federal government, the Land of Baden-Württemberg and the utilities decided to decommission and dismantle the reprocessing plant. On 22 March 1993, the first partial decommissioning licence for the WAK was granted.

At the end of the reprocessing operation the plant consisted of

- The process building with the installations for the reprocessing of spent fuels,
- The storage buildings with containers and processing units for the interim storage of HAWC and intermediate-level liquid waste (MAW) as well as
- Facilities and buildings for media supply and technical infrastructure.

The objective is to dismantle all buildings completely and to achieve the state of "green field" by 2030. This overall objective is to be achieved in six technically independent steps.

The process building which had contained the reprocessing process installations has been nearly empty since 2006 (steps 1-3). The vitrification of the HAWC was completed in 2010. The adaptation of the HAWC storage facilities and the vitrification plant Karlsruhe (VEK, details see below) to the reduced overall operation has been achieved. Step 4 has thus been completed. Step 5 consists of the dismantling of the HAWC storage facilities and the VEK. The conventional dismantling of all buildings (step 6) will only be carried out after the entire plant has been released from regulatory control.

Prior to dismantling the storage facilities, the HAWC that was last stored in 2 containers in the LAVA building had to be conditioned in a way suitable for disposal and to be disposed of. For this special purpose the VEK was constructed. The first partial construction licence for the VEK was granted on 30 December 1998. The construction of the VEK started at the beginning of 2000. The second partial operation licence for hot (nuclear) operation was granted on 24 February 2009. Between September 2009 and June 2010 the approx. 60 m^3 of HAWC were processed in the VEK into 123 vitrified waste block canisters containing altogether 49 Mg of waste glass. Additional 17 waste block canisters were produced during the subsequent rinsing process, so that altogether 56 Mg of waste glass were produced. After having filled the 140th and last waste block canister, the operation of the Karlsruhe vitrification plant finally terminated on 25 November 2010; it has been in the post-operational phase since. The 140 waste block canisters were placed into 5 transport and storage casks of the CASTOR® HAW 20/28 type and were taken to the Interim Storage Facility North of EWN GmbH in Lubmin near Greifswald in February 2011 (cf. Chapter 4.3.3). The melting furnace has been emptied and shut down, the entire plant has been rinsed. All residual liquids in the process engineering components still existing after operation was stopped have dried meanwhile. On 28 April 2014 the operator was granted the 24th decommissioning licence for manually emptying the installations in the VEK that had already been taken out of operation. The major part of this work has been completed. An application for remote-controlled dismounting of the VEK process technology was filed on 24 March 2014.

Two emptied HAWC casks each are in the buildings “LAVA” (storage casks) and “HWL” (reserve casks) in thick-walled concrete cells which are only accessibly by remote-handling because of the high dose rate. For carrying out the remote-handling and for the residue logistics a new access building south to the HWL was constructed and taken into operation in May 2008. Despite having been rinsed several times after being emptied, solid HAWC residues were detected in the reserve cask (8aB21) and in the two LAVA casks. In the scope of the remote-handled dismantling of the HAWC storage casks which has been permitted by the 22nd decommissioning licence of 8 December 2010, these solid residues are to be recovered.

The 23rd decommissioning licence was granted on 14 December 2011. It includes the dismounting of the LAVA-high-active laboratory and the LAVA (hot) cells. The high-active laboratory has been dismantled in the meantime. The demolishing of the equipment in the LAVA cells has started.

On 12 December 2014, an application was filed for the demolishing of the residual equipment and releasing the controlled area. Furthermore, an application for the demolishing of the pipe duct LAVA-ELMA and releasing the controlled area ELMA was filed on 12 March 2015.

Wackersdorf Reprocessing Plant (WAW)

In 1982, the Deutsche Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH (DWK) filed an application for the construction of a reprocessing plant on the Wackersdorf site (Oberpfalz/Bavaria) to the Bavarian State Ministry of Rural Development and the Environment.

This application resulted from the decision made by the heads of the federal and Länder governments made in 1979, which considered reprocessing, including the recirculation of the utilisable nuclear fuels and the disposal of radioactive waste from the reprocessing process, to be feasible in terms of safety according to the state of the art of science and technology and demanded to rapidly construct a reprocessing plant. It was also a result from Lower Saxony Prime Minister Ernst Albrecht's (CDU) attitude: he considered the National Waste Management Centre in Gorleben not to be politically enforceable.

The first partial building licence was granted in September 1985. The Bavarian Administrative Court considered the development plan contrary to law in January 1988. Construction had started in December 1985. Modifications of the concept then made it necessary to develop a new safety report, to perform another public hearing and to examine the safety of the facility as a whole.

Offers made by COGEMA (now: AREVA) and later on by BNFL to take over the reprocessing of spent fuel elements from German nuclear power plants for the long term and to do this at reasonable prices, persuaded the German utilities to reconsider the Wackersdorf project and to give it up. The procedure was formally completed by the DWK withdrawing the building application in December 1989.

4.6 CONDITIONING OF FUEL ELEMENTS

Gorleben Pilot Conditioning Plant (PKA)

(Cf Table III.8 in Annex III)

In order to advance methods for direct disposal, a pilot conditioning plant for spent fuel elements and radioactive waste was erected at the Gorleben site. The plant is a multi-purpose facility, where, apart from fuel elements, all types of radioactive waste from nuclear facilities can be reloaded or conditioned in such a way that they are suitable for disposal. The plant has been designed for a capacity of 35 Mg of HM per year.

In January 1990, the first nuclear partial licence was granted for the erection of the building shells and the fence and earth wall surrounding the plant and the preliminary positive overall judgement of the plant concept.

With decision of 21 July 1994, the Lower Saxon Environment Ministry granted the second partial licence for the erection of the PKA. It concerns the entire technical and electro-technical part as well as the PKA's instrumentation and control.

The third partial licence, which includes the operation licence, was granted in December 2000. Until the federal government will nominate a repository site, PKA operation is restricted to repairing defective transport and storage casks on the basis of a collateral clause to the granted licence, in case repairs will become necessary at one of these casks stored at the same site in the TBL Gorleben. On 18 December 2001, the Lower Saxony Environment Ministry issued a subsequent requirement to the second partial licence of 21 July 1994 that certain systems and plant components be operated in "cold operation". This serves to maintain the PKA in its tested state and ensures that a defective cask can be accepted at any time.

Currently only those systems are being operated in the PKA that are required for repairing a cask and maintaining the plant (including periodic reviews) and the expertise of the staff.

4.7 DISPOSAL

A survey of radioactive waste repositories and decommissioning projects in the Federal Republic of Germany is given in Table III.9. The course of licensing procedures for radioactive waste repositories pursuant to § 9b Atomic Energy Act is shown in Fig. III.2.

4.7.1 Responsibilities regarding disposal

The legal basis for the disposal of radioactive waste is the Atomic Energy Act (AtG).

Following the decision of the federal government of 2011 concerning the phase-out of nuclear energy until 2022, the federation and the Länder agreed on extending the achieved consensus regarding the termination of power generation with nuclear energy (cf. Chapter 1.3) to the issue of high-level radioactive waste management which is still open. In order to place the search for a repository for high-level radioactive waste on a broad, political and social basis, the Bundestag and Bundesrat passed the Act Concerning the Search

and Selection of a Site for a Repository for Heat-Generating Radioactive Waste (Repository Site Selection Act – StandAG). It became effective on 27 July 2013. The StandAG provides for a legally binding, formal public participation and active public relations work in all phases of the repository site selection procedure.

The Federal Office for Radiation Protection as project sponsor is responsible for the implementation of the repository site-selection procedure according to StandAG, the construction, operation and decommissioning of repositories. A site-selection procedure for a repository for heat-generating radioactive waste is reinitiated and implemented on the basis of the Repository Site Selection Act.

Pursuant to § 9a para. 3 Atomic Energy Act the federation must establish facilities for the safekeeping and disposal of radioactive waste. The BfS is the responsible authority (§ 23 para. 1 no. 2 Atomic Energy Act). The BfS is part of the portfolio of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and is subject to the BMUB's functional and legal control in terms of the implementation of repository-related tasks. Since 2008, the Nuclear Waste Management Commission (ESK) has given advice to the Federal Environment Ministry in terms of nuclear waste management issues.

The BfS collaborates with the Federal Institute for Geosciences and Natural Resources (BGR), (the latter being part of the portfolio of the Federal Ministry of Economy and Technology (BMWi)) in geo-scientific and geo-technical issues associated with the planning, construction, operation and decommissioning of repositories. The collaboration is done on the basis of a corresponding agreement.

According to § 9 para. 3 Atomic Energy Act the federation or the BfS, respectively, may use the services of third parties to comply with its obligations. Under a contract of 1984, the German Company for the Construction and Operation of Repositories for Waste (DBE) has been tasked with the planning and construction of federal facilities for the long-term storage and disposal of radioactive waste. DBE's shares are held by the GNS mbH (75 %) and the EWN GmbH (25 %). Currently, the DBE as the plant-managing company commissioned by the BfS, is in charge of the construction of the Konrad repository, the decommissioning of the Morsleben repository and the transfer of the Gorleben mine into a state where it is kept open but not operated. The 100-% federally-owned Asse GmbH has been tasked with the operational management and the decommissioning of the Asse II mine. On behalf of the BfS, the company for the operation and decommissioning of the Asse II mine carries out tasks relating to the planning, construction and operation of federal facilities for the safekeeping and disposal of radioactive waste. Like the DBE, it is also a third party in the context of § 9a para. 3 sentence 2 Atomic Energy Act. The overall responsibility for the construction and operation of federal repositories is with the BfS. The DBE and the Asse-GmbH are supervised by the BfS. The BfS also initiates and co-ordinates facility-related research and development projects.

On behalf of the BMWi, large research institutions do basic research in the field of radioactive materials disposal and carry out facility-related research and development works on behalf of the BfS. Contractors are, among others, Helmholtz Zentrum München – German Research Center of Health and Environment (formerly GSF), Gesellschaft für Reaktorsicherheit mbH (GRS), the Karlsruhe Institute of Technology (KIT) and the former Jülich Research Center (FZJ), now Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN).

In 2013 the German Bundestag passed the law concerning the search and selection of a site for a repository for heat-generating radioactive waste (Repository Site Selection Act - StandAG). According to the StandAG, the site selection procedure is prepared by the "Commission High-level Radioactive Waste Storage" (Commission). This Commission is part of the Environment Committee of the German Bundestag and consists of 33 members comprising representatives from society, politics and science. In the public meetings, the Commission will e.g. deal with the question as to whether, for a proper waste management, other options than the immediate disposal of high-level radioactive waste in deep geological formations should be investigated scientifically. Furthermore, the Commission develops decision criteria for the selection procedure, criteria for correction possibilities (e.g. retrieval), requirements for the organisation and the performance of the selection process and the participation and information provided to the public. The Commission will conclude its work by presenting a report on the site selection procedure until the middle of 2016. Based on the suggestion of the BfS President regarding the reorganisation of responsibilities in the area of disposal, the Commission passed a position paper on the new organisation of the authority's structure. The objectives are creating clear responsibility structures, minimising interfaces and increasing efficiency. The disposal-related tasks of the project sponsor and operator which have so far been carried out by the BfS – supported by so-called administrative assistants in particular for operational management tasks (Asse-GmbH and DBE GmbH) – are planned to be combined in a federally owned operating company to be newly founded. Supervision, licensing and regulation of radioactive waste management is to be executed by

a central federal authority. The implementation and reorganisation of responsibilities described above is currently under preparation.

4.7.2 Repository and decommissioning projects

GORLEBEN mine (project)

The exploration of the Gorleben salt dome for its possible suitability to host a repository for all types of radioactive waste started in 1979.

The mining exploration of the Gorleben salt dome was terminated when the StandAG entered into force (cf. Chapter 4.7.1). Like any other eligible site, the Gorleben site will be included in the repository site-selection procedure in accordance with the criteria and requirements proposed by the "Commission High-level Radioactive Waste Storage" pursuant to the StandAG. Until a decision will be taken about the site and as to whether the Gorleben site will be discarded pursuant to the StandAG, the mine will be kept operable, ensuring compliance with all legal requirements and that the necessary maintenance measures are carried out required for its operation.

On 30 October 2013 an application was submitted to the mining authority for a main operating plan which contains only measures required to bring the mine into a state where it will be kept open, and then to keep it in that state. The approval of the main operating plan was granted by the mining authority on 18 December 2013 and limited until 30 September 2014.
On 29 July 2014 the BMUB and the Lower Saxon Ministry for the Environment, Energy and Climate Protection agreed as to how the Gorleben mine would have to be transferred into a state where it is just kept open. The two shafts and the parts of the infrastructure area necessary for mining reasons will continue to be operated. During a transitional phase, the mine openings, facilities and buildings no longer needed will be taken out of operation and, if necessary, dismantled. According to this agreement, the main operating plan including the transition measures was submitted to the LBEG on 30 September 2014 for approval. Until this approval will be available, the LBEG issued an information injunction pursuant to § 72 para. 1 BBergG, stating that works and measures would be tolerated that have been listed in the main operating plan and that have already been approved by licensed special operating plans. The new main operating plan was approved on 26 November 2014. The overall concept "Just keeping Gorleben open" as at 26 June 2015 forms the basis for transferring the Gorleben mine into a state where it is just kept open.

KONRAD repository

The Konrad mine in Salzgitter developed the iron ore deposit in depths between 800 m and 1,300 m. The deposit had been known since 1933. The Konrad 1 mine was constructed in 1957. For economic reasons, iron ore production already stopped in 1976. From 1977, the mine was initially investigated as to whether it would be basically suited to host a repository for radioactive waste. After these investigations had been concluded with a positive result, the then competent Federal Institute of Science and Metrology (Physikalisch-Technische Bundesanstalt, PTB) filed the application for the initiation of a plan-approval (licensing) procedure according to § 9b AtG on 31 August 1982. The plan provided for the disposal of up to 650,000 m^3 of radioactive waste with negligible heat generation. Subsequently, the estimations of the waste volume to be expected reduced considerably. Therefore, the volume licensed for disposal has been restricted to 303,000 m^3 of waste for the national need. The radioactive waste to be disposed of mainly accrues in the use of nuclear energy for electricity generation, in the decommissioning and dismantling of nuclear power plants and other nuclear installations. Other, comparatively small amounts of waste originate from radioisotope application in craft, research, medicine, the Federal Armed forces as well as from research and development works. The portion of radioactive waste with negligible heat generation in the entire waste package volume to be disposed of (not including possibly accruing waste from the ASSE II mine and uranium enrichment) is more than 90% but only about 0.1% of the total activity of all radioactive wastes.

The licensing procedure that had started in 1982 was completed through the plan-approval decision of 22 May 2002. In March 2006, the pending actions against the plan-approval decision were rejected by the Lüneburg Higher Administrative Court; revision was not admitted. The complaints against the non-admission of the revision to the decisions of the Higher Administrative Court filed by the claimants were rejected by the Federal Administrative Court with decision of 26 March 2007. The plan-approval decision is thus legally binding. Since then the Konrad mine has been converted into a repository. Until that time the federal government had given directive to not deal with planning documents while they were examined by the licensing authority and during the court proceedings. The mining licence of the competent mining authority which is required in addition to the nuclear plan-approval decision was granted with the approval of the main operating plan.

The necessary planning and constructions for implementing the project continued in 2015. Especially the over 500 collateral clauses in the plan-approval decision and the fact that the major part of the plans originate from the nineties make it necessary to comprehensively up-date the plans. The current remediation requirements of the existing facilities, today's market availability of licensed components, the status of the technical code, the requirements of the energy saving regulations and the provisions on sustainable and barrier-free building are taken into account. Among others, building permits become necessary through these comprehensive changes to the plans. In the context of the BfS' privileged status regarding the Konrad project that has been recognised by the federal state of Lower Saxony, the simplified building approval procedure pursuant to § 74 Lower Saxon Building Ordinance (NBauO) has been applied.
It has shown that the deadlines for the time the Konrad repository would be taken into operation that had been taken over from the nineties were incorrect and had created unrealistic expectations. The BfS has requested the DBE to develop an updated schedule for the completion of the Konrad mine which takes into account the most recent findings. The DBE presented an updated schedule for the construction of the Konrad repository in January 2016, which provides for the construction to be completed (completion of commissioning phase B) at the end of September 2022. According to information by the DBE, the occurrence of project risks may lead to a change of the schedule.

The BfS has requested the DBE to complete the construction by the end of September 2022 or, if possible, earlier and to inform the BfS if support is needed.

A latent schedule-related project risk is the updating of plans for the buildings and installations to today's standards. Although Konrad is an old iron mine that is being converted and although the mine will be accessed via the existing shafts, the emplacement chambers and additional mine rooms underground will be excavated all new. Geotechnical calculations are carried out parallel to the conversion work in order to get the exact dimensions of the new mine rooms. Already existing results have already led to considerable adjustments of the conversion and thus to delays. Meanwhile the emplacement transport gallery as horizontal connection between shaft and emplacement chambers has been driven and 80% of the emplacement chambers planned for commissioning have been produced. On the surface, the necessary buildings on the Konrad 1 premises continue to be built. The access road to the Konrad 2 mine premises has been completed. Here, clearance for construction of the buildings has been achieved and preliminary infrastructure works are carried out.

The plans for the repository are adapted to the current technical rules and regulations. In the scope of the nuclear licensing procedure, all necessary safety-related proofs for the Konrad repository have been furnished. Currently there is no concrete knowledge of possible safety deficiencies. Nonetheless, the BfS as the operator of the facility, must pursue the state of the art of science and technology. Therefore, the BfS will check the safety-related requirements according to the state of the art in science and technology even before the facility will be taken into operation. There will also be further checks according to the state of the art for the operational and for the closure phase.

MORSLEBEN Repository for Radioactive Waste (ERAM)

Through the Unification Treaty of 1990, the Federal Republic of Germany has become responsible for the Morsleben Repository for Radioactive Waste (ERAM) which was established in the former potash and rock salt mine of Bartensleben by the former GDR government. Until 1998, except for the period from 1991 to 1994 when emplacement operations had discontinued, it was used for the disposal of low-level and intermediate-level radioactive waste with mainly short half-lives. Through the legal transfer the Federal Office for Radiation Protection has been the holder of the permanent operation licence since 1990.

In the ERAM, altogether ca. 14,432 m^3 of low-level and intermediate-level radioactive waste with a total activity of ca. $1.8 \cdot 10^{14}$ Bq was disposed of from 1971 until February 1991 (referring to 1 July 1991) and ca. 22,320 m^3 of low-level and intermediate-level radioactive waste with a total activity at the time of emplacement of ca. $9.1 \cdot 10^{13}$ Bq from January 1994 until September 1998. Furthermore, radiation sources and one container with radium with a total activity at the time of emplacement of ca. $2.9 \cdot 10^{15}$ Bq were stored intermediately in the ERAM.

On 21 May 1999, the BfS announced that for safety reasons, the emplacement of radioactive waste in the ERAM would not be resumed after operations were stopped by court order in September 1998. On the basis of the Amendment to the Atomic Energy Act of 2002, the provisions of § 57 a Atomic Energy Act were modified to the extent that the permanent operation licence for the ERAM of 22 April 1986 continues to be effective for an indefinite period as plan-approval decision in the context of § 9 b Atomic Energy Act, except for the regulations relating to the acceptance and disposal of further radioactive waste. The acceptance for disposal of radioactive waste from third parties has been ruled out since.

On 9 May 1997, the BfS limited the application for further operation of the ERAM to the scope of its decommissioning. The application was filed to the Ministry for Agriculture and the Environment (MLU) of Saxony-Anhalt on 13 October 1992. In the context of the plan-approval procedure for decommissioning, the radioactive waste intermediately stored until that time and the operational radioactive waste accruing during decommissioning operation is to be disposed of while the ERAM is being decommissioned.

Given that the emplacement of radioactive waste has permanently ended and the procedure for the decommissioning applied for is pending, it is planned to change repository operation to keeping the mine open. For this purpose, an appropriate plan for converting the ERAM and keeping it operable was submitted to the competent licensing authority of the federal state of Saxony-Anhalt in 2003. However, fundamental questions have arisen about what has to be done, so that the procedure has been suspended until further notice since 11 June 2014.

To improve the geo-mechanical state in the central part of the ERAM, altogether 27 rock salt mining districts were stabilised with ca. 935,000 m^3 of salt concrete between 2003 and 2011. With this measure the mining security objective has been achieved.

Plans in the plan-approval procedure for the decommissioning of the ERAM aim at keeping the protection goals both in the context of radiation protection and mining law. Even if the release of radionuclides from a sealed repository cannot be entirely prevented in the long term, only so small amounts of these radionuclides may reach the biosphere that the protection goals will be complied with in the long run.

A key component of the decommissioning concept is the wide backfilling of major parts of the underground installations and shafts with building materials that have a sealing and stabilising effect. The emplacement areas in the repository's eastern field and western-southern field are additionally sealed with building materials and structures that have been especially developed for the conditions. This is done at selected sites in the access galleries. Altogether more than 4 million cubic metres of salt concrete will have to be filled into the ERAM for the planned backfilling measures. Likewise, the several-hundred-metre-deep shafts will be sealed with especially developed structures to complete the works.

From October to December 2009, the necessary documents were displayed to the public in the scope of public participation of the plan-approval procedure "Decommissioning of the ERAM". The public hearing relating to the objections to the project was held in October 2011.

Subsequent to the hearing, the Federal Environment Ministry tasked the Waste Management Commission (ESK) with the preparation of an opinion on the question as to whether the proof of long-term safety (LZSN) for the ERAM complied with the state of the art of science and technology in terms of methodology. The ESK statement was published on 31 January 2013 and includes six main requirements to supplement the long-term safety assessments. According to the current methodological guidance, adaptations of the decommissioning concept have to be examined, too.

Furthermore, large-scale tests underground relating to the sealing structures in rock salt and in anhydrite and the in-depth planning have shown that more investigations and planning adjustments are necessary with regard to building material, building concept and the required safety proof.

In 2015, parallel to the handling of the ESK recommendations, basic strategic considerations were made on the state of the decommissioning project, the boundary conditions and the further approach. The results confirm the need for the professional adjustments to the state of the art of science and technology and advanced changed organisational procedures in the management of the licensing procedure.

Due to the change in plans regarding the sealing and the comprehensive works associated with the ESK recommendations, a large number of the already submitted documents needs to be revised, taking into account already available examination results of the MLU. Once the documents have been revised, it must be decided whether another public participation will be necessary.

Asse II mine

The Asse II mine near Wolfenbüttel is an about 100-year-old potash and rock salt mine where over 125,000 drums containing radioactive wastes were disposed of between 1967 and 1978. Between 1965 and 1995, Helmholtz Zentrum München used the mine on behalf of the Federal Ministry of Research to test the handling and storage of radioactive waste in a repository. Today, the Asse mine faces two major problems: On the one hand, saline solutions enter the mine, on the other hand the stability of the mine openings is endangered. In September 2008, the ministries involved agreed to treat the Asse mine as a repository in future. At the beginning of 2009, the Federal Office for Radiation Protection (BfS) took over operatorship for the Asse II mine from Helmholtz Zentrum München.

The BfS is tasked with the immediate decommissioning of the Asse mine and to retrieve the wastes prior to decommissioning (§ 57b AtG; "Lex Asse"). No practical experiences from comparable projects can be used for retrieving the radioactive wastes. The monitoring and handling of influent solutions into the mine and the stabilisation of the mine openings increase the project's complexity and the need for recovering the wastes as soon as possible.

The operations that are necessary to keep the mine operable and the fact-finding are carried out on the basis of the NMU nuclear licences according to § 7 StrlSchV and according to § 9 AtG granted in July and, respectively, in April 2011. Furthermore, the approvals pursuant to Mining Law (main/special operating plans) are effective.

Retrieval: Since "Lex Asse" became effective, the justification of retrieval no longer needs to be evaluated. Against this background, the fact-finding was evaluated presenting the future approach on retrieval at concept design level. Retrieval operation is thus to start at emplacement chambers (ELK) where atmosphere and local state of the rock are known. The licensing and implementing experiences gained here can be applied to retrieval in sealed and completely backfilled emplacement chambers (principle: from simple to complex). The concept plan is currently being updated.

Fact finding: According to the evaluation of the fact-finding, the current step 1 of the fact-finding (drilling into two selected emplacement chambers) will be continued and completed according to plan. One will do without the test-wise opening and recovery of single packages (steps 2 and 3). So far emplacement chamber 7/750 pillar above the emplacement chamber have been explored using five drillings with a length of up to 58 m. More drillings into the roof and the pillars of emplacement chamber 7/750 are being prepared. Executive planning for the exploration of emplacement chamber 12/750 have started from the 700-m level.

Shaft 5: Although it is planned to check the possibility and boundary conditions of retrieval via shaft 2 according to the evaluation result, it is fact that, in the long run, a new shaft with underground infrastructure areas is obligatory for retrieval operations.

Three drillings to explore the shaft site, one 900-m deep exploration drilling from the surface to the east of the premises and two underground drillings on the 574-m level (length of borehole 370-m and 293-m) have been completed so far. An additional drilling on the 574-m level and two drillings from the 700-m level are under preparation. A decision about the suitability of the currently planned shaft site can only be taken once the exploration works have concluded.

Interim storage facilities: Prior to the beginning of retrieval operations, a conditioning plant and a ready interim storage facility for the waste must be available. The criteria-based selection process for the interim storage facility site is under preparation.

Site exploration / site monitoring: Combining drilling information for the site exploration in a spatial geological model requires a seismic exploration. Therefore, the BfS prepares a large-scale, high-resolution, 3-D seismic examination on the mountain range. In May 2015 one started to get the access permissions for premises from 700 owners. Currently the basic examination of the 3-D seismic is under way.

The state of the rock and the solutions flowing into the Asse II mine are continuously monitored. Currently, about 12.5 m^3 solution are collected in the mine daily. At the main collecting point on the 658-m level a volume of ca. 11.5 m^3/day is currently collected. In front of emplacement chamber 8 on the 750-m level, ca. 13 l/day of contaminated solutions from the overburden is currently collected. The solutions had been in contact with the wastes. The flow paths of the solutions in salt rock are not known.

Emergency preparedness / stabilisation: A prerequisite for the further operation of the Mine and the retrieval of the wastes are the stabilisation of the mine openings and the precautionary measures to minimise the consequences of the drowning of the Asse II mine.

The rock deformations are to be reduced by stabilising the mine's southern flank which shows a high excavation ratio (backfilling of roof clefts). So far 59 out of 89 of the roof clefts have been backfilled with ca. 60,000 m^3 of Sorel concrete (as of December 2015). These and further backfilling measures in the entire mine workings reduce convergence-active cavities where solution might accumulate and be pressed out of the rock.

As precautionary measures to minimise the consequences in case of the mine drowning, two sealing structures were completed in the summer of 2015 in the western part of the 750-m level. Furthermore, supporting backfill was brought into the northern area of the 750-m level. For 2016 sealing structures in the southern area of the 750-m level are prepared (main cross-cut to the south, 2nd southern lateral road to the west).

Counterflooding with magnesium chloride solution is prepared as emergency measure in case of drowning. Counterflooding requires larger equipment for receiving and discharging solutions (AFL II). This is currently set up in the eastern part of the premises.

Mining and special measures: A permanent task in the partial project Mining and special measures consists in maintaining the serviceability of mine and machines. Furthermore, it must be ensured that influent solutions ready to be released are removed and reused. For this purpose one must find a new way in 2016 to dispose of the solutions which have so far been taken to a mine that is being flooded. To avoid bottlenecks and for redundant energy supply, an electrical system has been set up on the premises in 2015 which may take up operation early in 2016.[1]

[1] After copy deadline: The electrical system started operation in March 2016.

ANNEXES - SURVEY

ANNEX I – NUCLEAR POWER PLANTS

As of 31.12.2015

Table I.1: Licensing and regulatory authorities of the federal government and the federal states for the storage of nuclear fuels according to § 6 AtG and for facilities according to § 7 AtG

	Authority for licences according to § 6 AtG	**Regulatory authority according to § 19 in conjunction with § 6 AtG**
Federal Republic of Germany	Federal Office for Radiation Protection	Länder supervisory authorities
Land	**Licensing authority for facilities according to § 7 AtG**	**Regulatory authority according to § 19 in conjunction with § 6 AtG and § 7 AtG**
Baden-Württemberg (BW)	Ministry of the Environment, Climate Protection and the Energy Sector, in agreement with the Ministry for Finances and Economy and the Ministry of the Interior	Ministry of the Environment, Climate Protection and the Energy Sector
Bavaria (BY)	Bavarian State Ministry of the Environment and Consumer Protection	
Berlin (BE)	Berlin Senate Department for Urban Development and the Environment	
Brandenburg (BB)	Ministry of Justice and for Europe and Consumer Protection	
Bremen (HB)	Senator for the Environment, Building, Traffic in consultation with the Senator for Health	
Hamburg (HH)	Authority for Urban Development and Environment	
Hesse (HE)	Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection	
Mecklenburg-Vorpommern (MV)	Ministry of the Interior and Sport	
Lower Saxony (NI)	Lower Saxon Ministry for the Environment, Energy and Climate Protection	
North Rhine –Westphalia (NW)	Ministry of Economic Affairs, Energy, Industry, Middle Class and Trade of the Land of North Rhine-Westphalia	
Rhineland-Palatinate (RP)	Ministry of Economy, Climate Protection, Energy and Regional Planning	
Saarland (SL)	Ministry for the Environment, Energy and Traffic	
Saxony (SN)	Saxon State Ministry for the Environment and Agriculture	
Saxony-Anhalt (ST)	Ministry for Agriculture and Environment	
Schleswig-Holstein (SH)	Ministry for a Turnaround in Energy Policy, Agriculture, the Environment and Rural Areas Schleswig-Holstein	
Thuringia (TH)	Ministry for Agriculture, Forestry, Environment and Nature Conservation	

Table I.2: Nuclear power plants in operation

Name of facility and site	Operator	Type	Capacity gross [MW_e]	Capacity net [MW_e]	1st partial licence	Initial criticality
GKN 2 Neckarwestheim BW	EnBW Kernkraft GmbH (EnKK)	PWR	1,400	1,310	09.11.1982	29.12.1988
KKP 2 Philippsburg BW	EnBW Kernkraft GmbH (EnKK)	PWR	1,468	1,402	06.07.1977	13.12.1984
KKI 2 Essenbach BY	E.ON Kernkraft GmbH	PWR	1,485	1,410	12.07.1982	15.01.1988
KRB-II-B Gundremmingen BY	Kernkraftwerk Gundremmingen GmbH	BWR	1,344	1,284	16.07.1976	09.03.1984
KRB-II-C Gundremmingen BY	Kernkraftwerk Gundremmingen GmbH	BWR	1,344	1,288	16.07.1976	26.10.1984
KWG Grohnde NI	E.ON Kernkraft GmbH	PWR	1,430	1,360	08.06.1976	01.09.1984
KKE Lingen NI	Kernkraftwerke Lippe-Ems GmbH	PWR	1,406	1,335	04.08.1982	14.04.1988
KBR Brokdorf SH	E.ON Kernkraft GmbH	PWR	1,480	1,410	25.10.1976	08.10.1986

Table I.3: Nuclear power plants finally shut down

Name of facility and site	Operator	Type	Capacity gross [MW_e]	Initial criticality	Final shutdown	Application for decommissioning
GKN 1 Neckarwestheim BW	EnBW Kernkraft GmbH (EnKK)	PWR	840	26.05.1976	06.08.2011	24.04.2013
KKP 1 Philippsburg BW	EnBW Kernkraft GmbH (EnKK)	BWR	926	09.03.1979	06.08.2011	24.04.2013
KKG Grafenrheinfeld BY	E.ON Kernkraft GmbH	PWR	1,345	09.12.1981	27.06.2015	28.03.2014
KKI 1 Essenbach BY	E.ON Kernkraft GmbH	BWR	912	20.11.1977	06.08.2011	04.05.2012
KWB A Biblis HE	RWE Power AG	PWR	1,225	16.07.1974	06.08.2011	06.08.2012
KWB B Biblis HE	RWE Power AG	PWR	1,300	25.03.1976	06.08.2011	06.08.2012
KKU Esenshamm NI	E.ON Kernkraft GmbH	PWR	1,410	16.09.1978	06.08.2011	04.05.2012
KKB Brunsbüttel SH	Kernkraftwerk Brunsbüttel GmbH & Co. oHG	BWR	806	23.06.1976	06.08.2011	01.11.2012
KKK Krümmel SH	Kernkraftwerk Brunsbüttel GmbH & Co. oHG	BWR	1,402	14.09.1983	06.08.2011	24.08.2015

Table I.4: Nuclear power plants under decommissioning

Name of facility and site	Operator	Type	Gross capacity [MW_e]	Initial criticality	Final shut-down	Status
KKR Rheinsberg BB	Energiewerke Nord GmbH	PWR	70	11.03.1966	01.06.1990	Dismantling licence 28.04.1995 ff. Last licence of 04.09.2013
KNK II Eggenstein-Leopoldshafen BW	Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs-GmbH	FBR	21	10.10.1977	23.08.1991	Dismantling licence 26.08.1993 ff.
MZFR Eggenstein-Leopoldshafen BW	Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs-GmbH	PWR	57	29.09.1965	03.05.1984	Dismantling licence 17.11.1987 ff.
KWO Obrigheim BW	EnBW Kernkraft GmbH (EnKK)	PWR	357	22.09.1968	11.05.2005	1st SG 28.08.2008 2nd SG 24.10.2011 3rd Dismantling licence 30.04.2013
KRB A Gundremmingen BY	Kernkraftwerk Gundremmingen GmbH	BWR	250	14.08.1966	13.01.1977	Dismantling licence 26.05.1983 ff.
KGR 1 Lubmin MV	Energiewerke Nord GmbH	PWR	440	03.12.1973	18.12.1990	Licence of 30.06.1995 ff. for decommissioning/dismantling entire plant
KGR 2 Lubmin MV	Energiewerke Nord GmbH	PWR	440	03.12.1974	14.02.1990	Licence of 30.06.1995 ff. for decommissioning/dismantling entire plant
KGR 3 Lubmin MV	Energiewerke Nord GmbH	PWR	440	06.10.1977	28.02.1990	Licence of 30.06.1995 ff. for decommissioning/dismantling entire plant
KGR 4 Lubmin MV	Energiewerke Nord GmbH	PWR	440	22.07.1979	02.06.1990	Licence of 30.06.1995 ff. for decommissioning/dismantling entire plant
KGR 5 Lubmin MV	Energiewerke Nord GmbH	PWR	440	26.03.1989	30.11.1989	Licence of 30.06.1995 ff. for decommissioning/dismantling entire plant

Name of facility and site	Operator	Type	Gross capacity [MW_e]	Initial criticality	Final shut-down	Status
KKS Stade NI	Kernkraft Stade GmbH & Co. oHG	PWR	672	08.01.1972	14.11.2003	Licence decommissioning/dismantling Phase 1 - 7.09.2005 Phase 2 - 15.02.2006 Phase 3 - 14.05.2009 Phase 4 - 04.02.2011
KWL Lingen (Ems) NI	Kernkraftwerk Lingen GmbH	BWR	252	31.01.1968	05.01.1977	Licence for SE 21.11.1985; lic.for dismantling of 21.12.2015
AVR Jülich NW	Jülicher Entsorgungsgesellschaft für Nuklearanlagen (JEN) mbH	HTR	15	26.08.1966	31.12.1988	1st SG for SE 09.03.1994, Licence for complete dismantling 31.03.2009, modification licence of 18.01.2013
KWW Würgassen NW	E.ON Kernkraft GmbH	BWR	670	22.10.1971	26.08.1994	1st SG 14.04.1997 ff.
THTR Hamm-Uentrop NW	Hochtemperatur-Kernkraftwerk GmbH	HTR	308	13.09.1983	29.09.1988	Licence for operation of SE 21.05.1997
KMK Mülheim-Kärlich RP	RWE Power AG	PWR	1,302	01.03.1986	09.09.1988	Licence decommissioning /dismismantling Phase 1a 16.07.2004, Supplement 23.02.2006, Licence 3b of 16.09.2014 for reducing the size of the premises Licence 3c of 31.01.2014 for release and clearance of areas – conclusion, Licence 2b for dism.of components and component parts of the primary circuit of 08.10.2015

Table I.5: Nuclear power plants released from regulatory control

Name of facility and site	Operator	Type	Gross capacity [MW_e]	Initial criticality	Final shut-down	Status / Release from regulatory control
SSR Karlstein BY	Karlsruhe Institute of Technology (KIT), formerly Forschungszentrum Karlsruhe GmbH	SSR	25	14.10.1969	20.04.1971	Entirely dismantled/May 1998
KKN Niederaichbach BY	Karlsruhe Institute of Technology (KIT), formerly Forschungszentrum Karlsruhe GmbH	PTR	106	17.12.1972	31.07.1974	Entirely dismantled/August 1994
VAK Karlstein BY	Versuchsatomkraftwerk Kahl GmbH	BWR	16	13.11.1960	25.11.1985	The buildings and the plant site were released from regulatory control on 17.05.2010; dismantling completed on 24.09.2010.

Table I.6: Stopped nuclear power plant projects

Name of facility and site	Operator	Type	Gross capacity [MW_e]	Notes
KGR 6 **Lubmin** **MV**	Energiewerke Nord GmbH	PWR	440	Final shut-down 30.11.1989 Licence of 30.06.1995 ff. for decomm./dismantl. entire plant
KGR 7 **Lubmin** **MV**	Energiewerke Nord GmbH	PWR	440	Project stopped
KGR 8 **Lubmin** **MV**	Energiewerke Nord GmbH	PWR	440	Project stopped
SNR 300 **Kalkar** **NW**	Schnell-Brüter-Kernkraftwerksgesellschaft mbH	FBR	327	Project stopped 20.03.1991
Stendal A **Stendal** **ST**	Altmark Industrie GmbH	PWR	1,000	Project stopped
Stendal B **Stendal** **ST**	Altmark Industrie GmbH	PWR	1,000	Project stopped

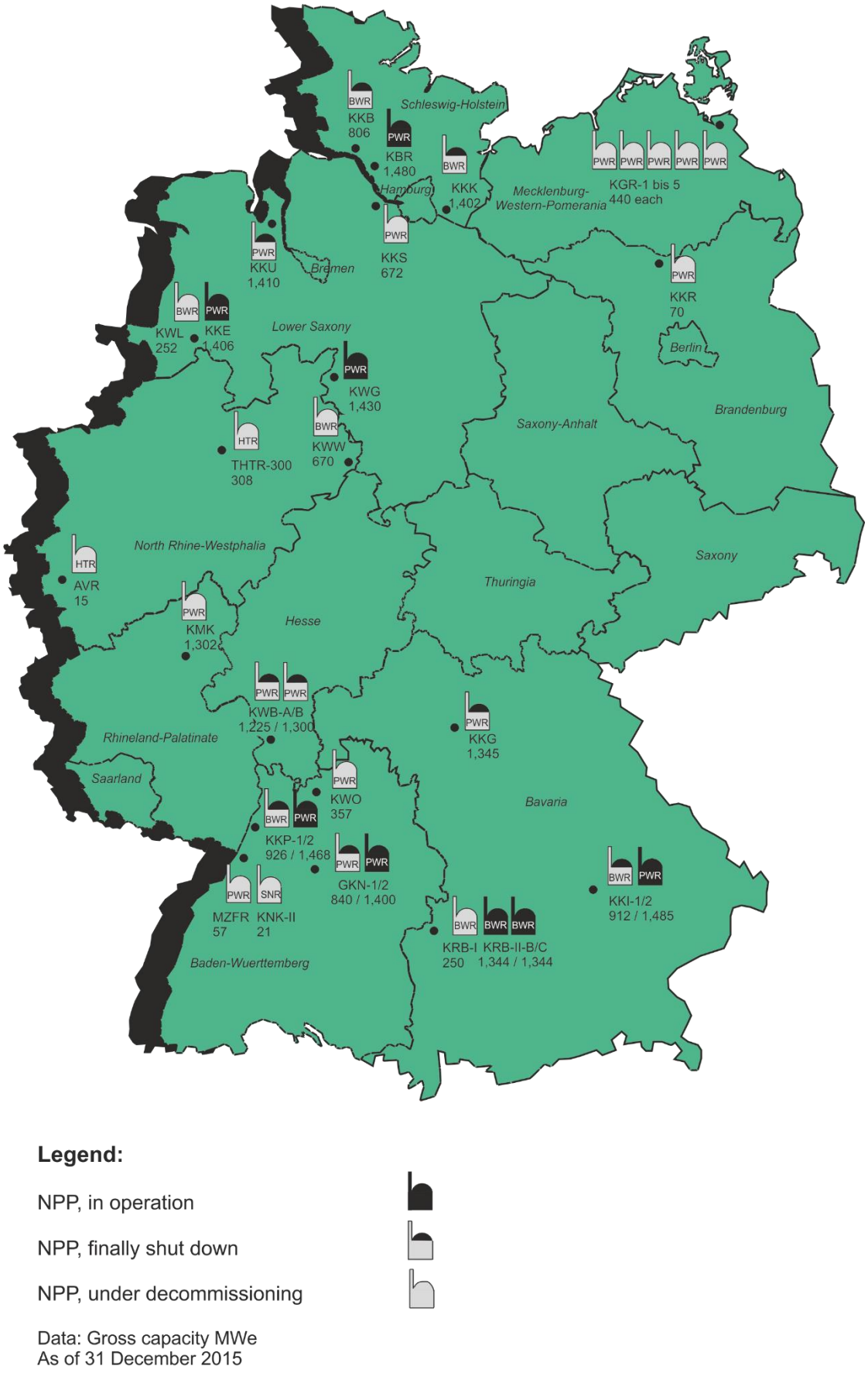


Fig. I: Nuclear power plants in the Federal Republic of Germany

ANNEX II – RESEARCH REACTORS

As of 31.12.2015

Table II.1: Research reactors in operation

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Status
BER II **Berlin** **BE**	Helmholtz-Zentrum Berlin für Materialien und Energie GmbH	Pool, MTR	10	$1 \cdot 10^{14}$	09.12.1973	In operation
SUR Stuttgart **Stuttgart** **BW**	University of Stuttgart, Institutes for Nuclear Energy and Energy Systems	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	24.08.1964	In operation
SUR Ulm **Ulm** **BW**	Hochschule Ulm, Laboratory for Radiation Measurement and Reactor Technology	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$5 \cdot 10^{6}$	01.12.1965	In operation
SUR Furtwangen **Furtwangen** **BW**	Hochschule Furtwangen	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	28.06.1973	In operation
FRM-II **Garching** **BY**	Technische Universität München (TUM)	Pool, Compact core	20	$8 \cdot 10^{14}$	02.03.2004	In operation
FRMZ **Mainz** **RP**	Universität Mainz Institut für Kernchemie	Pool, Triga Mark II	0,1	$4 \cdot 10^{12}$	03.08.1965	In operation
AKR-2 **Dresden** **SN**	Technische Universität Dresden, Institute for Energy Technology	Training Reactor AKR 2	$2 \cdot 10^{-6}$	$3 \cdot 10^{7}$	22.03.2005 (AKR-1: 28.07.1978)	In operation

Table II.2: Research reactors finally shut down

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
SUR Hannover Hannover NI	Leibniz Universität Hannover, Institute of Nuclear Engineering and Non-Destructive Testing	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	09.12.1971	Since 2008 free from nuclear fuel	Application for decommissioning of 22.10.2013
SUR Aachen Aachen NW	Rheinisch-Westfälische Technische Hochschule (RWTH)	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	22.09.1965	In 2002	Application for decommissioning of 2010
FRG-1 Geesthacht SH	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	Pool, MTR	5	$1 \cdot 10^{14}$	23.10.1958	Final shut-down on 28.06.2010	Application of 21.03.2013
FRG-2 Geesthacht SH	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	Pool, MTR	15	$2 \cdot 10^{14}$	16.03.1963	28.01.1993	Licence for taking out of operation and partial dismantling of 17.01.1995, application for dismantling of FRG-1 and still existing plant components of FRG-2 of 21.03.2013

Table II.3: Research reactors under decommissioning

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
FR 2 Eggenstein-Leopoldshafen BW	Wiederaufarbeitungs-anlage Karlsruhe Rückbau- und Entsorgungs-GmbH	Tank type D_2O reactor	44	$1 \cdot 10^{14}$	07.03.1961	21.12.1981	Decommissioning licence of 03.07.1986 ff., Safe Enclosure since 20.11.1996
FRM Garching BY	Technische Universität München (TUM)	Pool, MTR	4	$7 \cdot 10^{13}$	31.10.1957	28.07.2000	Decommissioning licence of 03.04.2014
FRN Oberschleißheim BY	Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt GmbH	Pool, Triga Mark III	1	$3 \cdot 10^{13}$	23.08.1972	16.12.1982	Decommissioning licence of 30.05.1983, Safe Enclosure since 24.05.1984
FRMB Braunschweig NI	Physikalisch Technische Bundesanstalt Braunschweig (PTB)	Pool, MTR	1	$6 \cdot 10^{12}$	03.10.1967	19.12.1995	Decommissioning licence of 02.03.2001, facility released from regulatory control by 28.07.2005, except for interim storage facility
FRJ-2 (DIDO) Jülich NW	Jülicher Entsorgungsgesellschaft für Nuklearanlagen (JEN) mbH, former Jülich Research Center (FZJ)	Tank type D_2O reactor	23	$2 \cdot 10^{14}$	14.11.1962	02.05.2006	Decommissioning licence of 20.09.2012
RFR Rossendorf SN	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Tank type WWR-S(M)	10	$1 \cdot 10^{14}$	16.12.1957	27.06.1991	Decommissioning licence of 30.01.1998 ff, second modification of 4th licence of 01.02.2005 on 09.01.2014

Table II.4: Research reactors released from regulatory control

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
Research reactors > 50 kW_{th}							
TRIGA HD I **Heidelberg** **BW**	Deutsches Krebsforschungszentrum (DKFZ)	Pool, Triga Mark I	0.25	$1 \cdot 10^{13}$	26.08.1966	31.03.1977	Released from regulatory control on 13.12.2006, within the scope of the clearance procedure the plant was conventionally dismantled in 2009 and the premises were completely remediated.
TRIGA HD II **Heidelberg** **BW**	Deutsches Krebsforschungszentrum (DKFZ)	Pool TRIGA Mark I	0.25	$1 \cdot 10^{13}$	28.02.1978	30.11.1999	Released from regulatory control on 13.12.2006
FRF 2 **Frankfurt** **HE**	Johann Wolfgang Goethe Universität Frankfurt	Modified TRIGA	1	$3 \cdot 10^{13}$ (designed)	No criticality	Not operated	Released from regulatory control on 31.10.2006
FRH **Hannover** **NI**	Hannover Medical School	Pool TRIGA Mark I	0.25	$9 \cdot 10^{12}$	31.01.1973	18.12.1996	Released from regulatory control on 13.03.2008
FRJ-1 (MERLIN) **Jülich** **NW**	Forschungszentrum Jülich GmbH (FZJ)	Pool MTR	10	$1 \cdot 10^{14}$	24.02.1962	22.03.1985	Released from regulatory control on 23.11.2007
OH **Geesthacht** **SH**	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	FDR Ship reactor	38	$3 \cdot 10^{13}$	26.08.1968	22.03.1979	Released from regulatory control on 01.09.1982, storage of reactor pressure vessel according to StrlSchV
Research reactors < or = 50 kW_{th}							
BER I **Berlin** **BE**	Helmholtz-Zentrum Berlin für Materialien und Energie GmbH	Homoge-neous reactor	$5 \cdot 10^{-2}$	$2 \cdot 10^{12}$	24.07.1958	Summer 1972	23.04.1974 Dec.completed
SUR Berlin **Berlin** **BE**	Technische Universität Berlin	Siemens Training Reactor SUR 100	$1 \cdot 10^{-7}$	$5 \cdot 10^{6}$	26.07.1963	15.10.2007	16.04.2013 Released from regulatory control

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
SNEAK Eggenstein-Leopoldshafen BW	Karlsruhe Research Center	Homoge-neous reactor	$1 \cdot 10^{-3}$	$7 \cdot 10^{6}$	15.12.1966	11/1985	06.05.1987 (notice of assessment)
SUAK Eggenstein-Leopoldshafen BW	Karlsruhe Research Center	Fast sub-critical system	No capacity		Commis-sioning 20.11.1964	07.12.1978	
STARK Eggenstein-Leopoldshafen BW	Karlsruhe Research Center	Argonaut	$1 \cdot 10^{-5}$	$1 \cdot 10^{8}$	11.01.1963	03/1976	1977 Released from regulatory control
SUR Karlsruhe Eggenstein-Leopoldshafen BW	Karlsruhe Research Center	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	07.03.1966	09/1996	26.06.1998 Released from regulatory control
AEG Zero Energy Reactor Karlstein BY	Kraftwerk Union	Tank type/critical system	$1 \cdot 10^{-4}$	$1 \cdot 10^{8}$	23.06.1967	1973	21.12.1981 Decommissioning completed
AEG Prüfreaktor PR 10 Karlstein BY	Kraftwerk Union	Argonaut	$1.8 \cdot 10^{-4}$	$3 \cdot 10^{10}$	27.01.1961	1976	22.02.1978 Decommissioning completed
SAR Garching BY	Technische Universität München	Argonaut	$1 \cdot 10^{-3}$	$2 \cdot 10^{11}$	23.06.1959	31.10.1968	20.03.1998 Decommissioning completed
SUA München Garching BY	Technische Universität München	Sub-critical Assembly	No capacity		Commis-sioning 06/1959	1968	20.03.1998 Decommissioning completed
SUR München Garching BY	Technische Universität München	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	28.02.1962	10.08.1981	20.03.1998 Decommissioning completed

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
SUR Bremen **Bremen** **HB**	Hochschule Bremen	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	10.10.1967	17.06.1993	03/2000 Decommissioning completed
SUR Hamburg **Hamburg** **HH**	Fachhochschule Hamburg	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	15.01.1965	08/1992	12/1999 Decommissioning completed
FRF 1 **Frankfurt** **HE**	Johann Wolfgang Goethe Universität Frankfurt	Homoge-neous reactor	$5 \cdot 10^{-2}$	$1 \cdot 10^{12}$	10.01.1958	19.03.1968	31.10.2006 Released from regulatory control
SUR Darmstadt **Darmstadt** **HE**	Technische Hochschule Darmstadt	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	23.09.1963	22.02.1985	29.11.1996 Decommissioning completed
ADIBKA **Jülich** **NW**	Jülich Research Center	Homoge-neous reactor	$1 \cdot 10^{-4}$	$3 \cdot 10^{8}$	18.03.1967	30.10.1972	1977 Decommissioning completed
KAHTER **Jülich** **NW**	Jülich Research Center	Critical Assembly	$1 \cdot 10^{-4}$	$2 \cdot 10^{8}$	02.07.1973	03.02.1984	06/1988 Decommissioning completed
KEITER **Jülich** **NW**	Jülich Research Center	Critical Assembly	$1 \cdot 10^{-6}$	$2 \cdot 10^{7}$	15.06.1971	1982	06/1988 Decommissioning completed
ANEX **Geesthacht** **SH**	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	Critical Assembly	$1 \cdot 10^{-4}$	$2 \cdot 10^{8}$	05/1964	05.02.1975	01/1980 Decommissioning completed
SUR Kiel **Kiel** **SH**	Fachhochschule Kiel	Siemens training reactor SUR-100	$1 \cdot 10^{-7}$	$6 \cdot 10^{6}$	29.03.1966	11.12.1997	02.04.2008 Released from regulatory control

Name of facility and site	Operator	Type	Thermal power [MW_{th}]	Thermal neutron flux [$cm^{-2}s^{-1}$]	Initial criticality	Out of operation	Status
RAKE Rossendorf SN	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Tank type/critical assembly	$1 \cdot 10^{-5}$	$1 \cdot 10^{8}$	03.10.1969	26.11.1991	28.10.1998 Released from regulatory control
RRR Rossendorf SN	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Argonaut	$1 \cdot 10^{-3}$	$2 \cdot 10^{11}$	16.12.1962	25.09.1991	11.05.2000 Released from regulatory control
ZLFR Zittau SN	Hochschule Zittau/Görlitz Department of mechanical engineering	Tank type WWR-M	$1 \cdot 10^{-5}$	$2 \cdot 10^{8}$	25.05.1979	24.03.2005	03.05.2006 Released from regulatory control

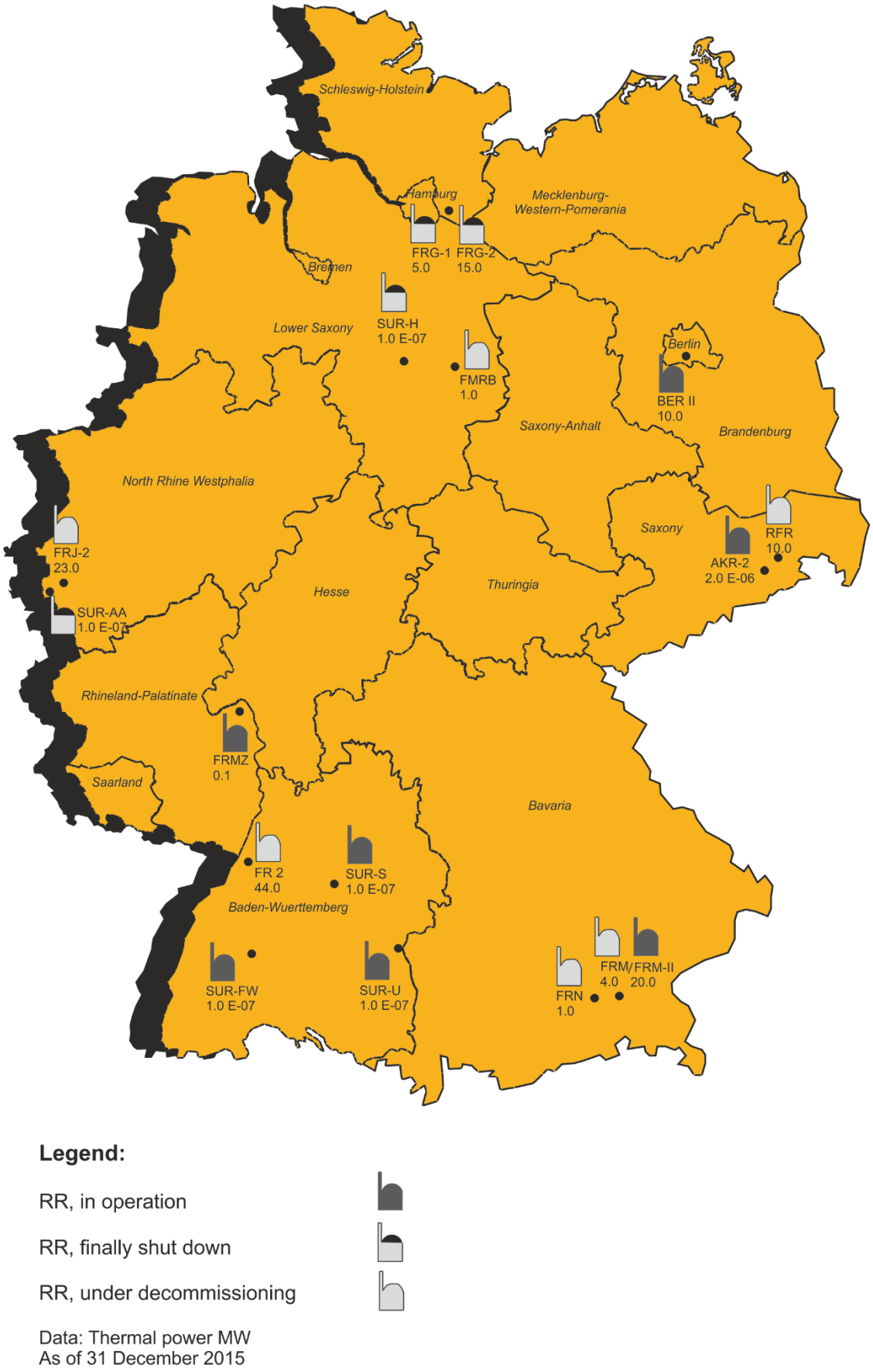


Fig. II: Research reactors in the Federal Republic of Germany

ANNEX III – PLANTS OF NUCLEAR FUEL SUPPLY AND WASTE MANAGEMENT

As of 31.12.2015

Table III.1: Uranium enrichment plants

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
GRONAU Uranium enrichment plant (UAG) **NW**	Uranium enrichment	4,500 Mg of uranium separative work per year (SW/y) according to notification of 14.02.2005	3rd partial licence of 04.06.1985 (operation licence) 9th partial licence of 31.10.1997; capacity increase to 1,800 t UTA/a Notification no. 7/Ä2 of 27.11.1998 2nd modification licence for two more separating halls, Notification no. 7/6 of 14.02.2005 on increase of production capacity to 4,500 Mg of SW/y	The licence of 14.02.2005 also comprises the handling of depleted and enriched uranium (up to max. 6% U-235). The expanded plant has been under construction since the middle of 2008 and is commissioned gradually. The plant is operated with a nominal capacity of 4,500 Mg SW/a. The storage hall with a capacity of up to 60,000 Mg U_3O_8 was completed in 2014.

Table III.2: Fuel element fabrication plants in operation

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
ANF fuel element fabrication plant Lingen NI	Fabrication of mainly LWR fuel elements of low-enriched uranium dioxide	Handling and processing of annually altogether 800 Mg of uranium in the form of uranium powder or uranium pellets with up to 5 % U-235-fraction	Operation licence of 18.01.1979, 7th Partial operation licence of 08.06.1994 (operation of conversion plant with enriched uranium) 07.03.1997: Capacity increase of fuel element fabrication by 250 Mg of externally fabricated uranium pellets per year 11.01.2005: Increase of uranium powder throughput rate to 650 Mg/a 02.12.2009: Increase of capacity to 800 Mg/a 12.06.2014: Expansion of storage areas for nuclear fuel	On its premises, ANF stores certain types of radioactive waste determined for disposal according to § 6 AtG originating from its own fuel element fabrication and UF_6 for third parties. A hall for the storage of UF_6 containers has been taken into operation.

Table III.3: Fuel element fabrication plants released from regulatory control

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
SIEMENS fuel element fabrication plant, plant section Karlstein **BY**	Fabrication of fuel elements of low-enriched uranium dioxide	Annual throughput of 400 Mg of UO_2 up to max. 4.0 % U-235 fraction	Operation licence according to § 9 AtG: 02.09.1966 Operation licence according to § 7 AtG: 30.12.1977 Licence according to § 7 AtG for dismantling of plant components: 16.08.1994 and 18.03.1996 Released from regulatory control March 1999	Fuel element fabrication has been discontinued; conventional fabrication of ends only (ANF Karlstein).
SIEMENS fuel element fabrication plant Hanau Plant section: MOX processing **HE**	Fabrication of MOX fuel elements of plutonium and uranium mainly for use in LWR	Throughput of about 35 Mg HM/a, expansion to 120 Mg of HM/a was planned	Operation licence according to § 9 AtG: 16.08.1968. Last comprehensive licence according to § 9 AtG of 30.12.1974 6th Partial building licence acc. to § 7 AtG of 12.03.1991 Several partial licences for removing the fuel from the production line and dismantling of the plant for MOX fuel from 1997 to 2005 Released from regulatory control Sept. 2006	In April 1994, the operator decided to not re-commission the old plant. The fabrication facilities have been dismantled. Government custody has been terminated. Dismantling work completed in July 2006.
SIEMENS fuel element fabrication plant Hanau Plant section: Uranium processing **HE**	Fabrication of LWR fuel elements of low-enriched uranium	Throughput 1,350 Mg U/a	Operation licence according to § 9 AtG: 22.07.1969 Operation licence according to § 7 AtG: 31.08.1990 Several individual and partial licences for removing the fuel of the production line and for dismantling the facility from 1996 to 2001 Released from regulatory control May 2006	Fabrication of uranium fuel elements stopped in October 1995. Dismantling work incl. remediation of the premises was completed in January 2006. The plant was released from regulatory control. Groundwater decontamination still continues (licence according to § 7 StrlSchV).

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
NUKEM-A Fuel Element Fabrication Plant Hanau-Wolfgang HE	Fabrication of fuel elements of enriched uranium and thorium for research reactors	100 kg U-235 enrichment up to 20 %; 1,700 kg U-235 enrichment between 20 % and 94 %; 100 Mg natural uranium; 100 Mg depleted uranium; 200 Mg thorium	Operation licence according to § 9 AtG: 30.07.1962 Several licences for decommissioning, dismantling and remediation of the site between 1988 and 2001 Released from regulatory control in May 2006, except for a partial area of 1.000 m^2 for further groundwater decontamination. Radiological groundwater remediation pursuant to § 19 AtG completed on 20.07.2015.	Operation licence discontinued on 15.01.1988; by 31.12.1988 the fuel was removed from the production line Dismantling works and soil remediation have been completed. The plant has been released from regulatory control with effect of 20.07.2015.
Hochtemperatur-Brennelement Gesellschaft (HOBEG) Hanau HE	Fabrication of ball-shaped fuel elements for HTR on the basis of uranium (up to 94 % of uranium-235) and thorium	200,000 fuel elements/a 11.7 Mg HM (during operation time)	Operation licence according to § 9 AtG: 30.12.1974. 9 licences for dismantling and decommissioning between 05.12.1988 and 07.04.1995. On 18.12.1995 released from regulatory control.	The facility was temporarily taken out of operation on 15.01.1988, and was decommissioned later on. The components relating to process engineering were dismantled. Decontamination of premises and building has been completed. Premises and buildings are used by Nuclear Cargo & Service GmbH.

Table III.4: Central fuel element interim storage facilities

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Transport cask storage facility in the interim storage facility North (ZLN) **Rubenow (near Greifswald)** **MV**	Storage of spent fuel elements from the Rheinsberg and Greifswald reactors in transport and storage casks (dry storage).	585.4 Mg in max. 80 storage containers Max. storable activity: $7.5 \cdot 10^{18}$ Bq	According to § 6 AtG of 05.11.1999 1st modification of 14.03.2001 2nd modification of 07.07.2003 3rd modification of 19.12.2005 4th modification of 17.02.2006 5th modification of 17.12.2008 6th modification of 24.02.2009 7th modification of 30.04.2010	On 31.12.2015, 74 casks were stored in the ZLN: - 62 CASTOR® 440/84 - 3 CASTOR® KRB-MOX - 4 CASTOR® KNK. - 5 CASTOR® HAW 20/28 CG.
Gorleben Transport Cask Storage Facility (TBL-G) **NI**	Storage of spent fuel elements in transport and storage casks and of solidified HAW fission product solutions and other radioactive waste (dry storage).	3,800 Mg HM or 420 cask storing positions; Max. storable activity: $2 \cdot 10^{20}$ Bq	05.09.1984 according to § 6 AtG New licence of 02.06.1995 for spent fuel elements and vitrified fission product solutions 1st modification of 01.12.2000 2nd modification of 18.01.2002 3rd modification of 23.05.2007 4th modification of 29.01.2010	On 31.12.2015, altogether 113 casks were stored in the TBL-G, of these - 5 casks with spent fuel elements, of these - 1 CASTOR® Ic - 1 CASTOR® IIa, - 3 CASTOR® V/19 and 108 casks with HAW vitrified waste block canisters, of these - 1 TS 28 V, - 74 CASTOR® HAW 20/28 CG, - 21 CASTOR® HAW28M - 12 TN85.

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Ahaus Transport Cask Storage Facility (TBL-A) **NW**	Storage of spent fuel elements in transport and storage casks of the CASTOR® type (dry storage).	420 cask storing positions (LWR), Capacity up to altogether max. 3,960 Mg HM Max. storable activity: $2 \cdot 10^{20}$ Bq	10.04.1987 acc. to § 6 AtG amended version of the storage licence of 07.11.1997 (increase of the mass of heavy metal and licence for further cask types) 1st modification of 17.05.2000, 2nd modification of 24.04.2001, 3rd modification of 30.03.2004 4th modification of 04.07.2008 5th modification of 22.12.2008 6th modification of 26.05.2010	In April 1995 the emplacement of 305 CASTOR® THTR/AVR casks with fuel elements of the THTR-300 was terminated. On 20.03.1998, additionally - 2 CASTOR® V/19 - 1 CASTOR® V/19 SN06 and - 3 CASTOR® V/52 with LWR-fuel elements were taken to the TBL-A. In 2005, 18 CASTOR® MTR 2 casks were stored which were transported from Rossendorf to Ahaus

Table III.5: On-site interim storage facilities

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
On-site interim storage facility Neckarwestheim Gemmrigheim BW	Storage of spent fuel elements from units GKN 1 and GKN 2 of the Neckar Joint NPP	1,600 Mg of heavy metal in up to 151 transport and storage casks with up to $8.3 \cdot 10^{19}$ Bq activity and 3.5 MW heat release	According to § 6 AtG of 22.09.2003 1st modification of 22.03.2006 2nd modification of 28.09.2006 1st supplement of 03.09.2007 2nd supplement of 18.02.2010 3rd modification of 11.05.2010 4th modification of 13.12.2013 5th modification of 16.04.2014	Start of construction 17.11.2003 First emplacement 06.12.2006 At the end of 2015 53 casks were stored in the interim storage facility
On-site interim storage facility Philippsburg BW	Storage of spent fuel elements from units 1 and 2 of the Philippsburg NPP	1,600 Mg of heavy metal in up to 152 transport and storage casks with up to $1.5 \cdot 10^{20}$ Bq activity and 6.0 MW heat release	According to § 6 AtG of 19.12.2003 1st modification of 05.10.2006 2nd modification of 21.12.2006 3rd modification of 13.06.2014 4th modification of 18.12.2014	Start of construction 17.05.2004 First emplacement 19.03.2007 At the end of 2015 40 casks were stored in the interim storage facility
Interim storage facility Obrigheim NPP BW	Storage of spent fuel elements and core components from the Obrigheim NPP (wet storage)	980 fuel elements (ca. 286 Mg HM)	26.10. 1998 acc. to § 7 AtG	Since the end of 2007 342 fuel elements have been in the fuel pool
On-site interim storage facility Grafenrheinfeld BY	Storage of spent fuel elements from the Grafenrheinfeld NPP	800 Mg of heavy metal in up to 88 transport and storage casks with up to $5 \cdot 10^{19}$ Bq activity and 3.5 MW heat release	According to § 6 AtG of 12.02.2003 Order for immediate enforcement of 10.09.2003 1st modification of 31.07.2007 2nd modification of 06.10.2011 3rd modification of 03.11.2011	Start of construction 22.09.2003 First emplacement 27.02.2006 At the end of 2015 21 casks were stored in the interim storage facility

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
On-site interim storage facility Gundremmingen BY	Storage of spent fuel elements from units B and C of the Gundremmingen NPP	1,850 Mg of heavy metal in up to 192 transport and storage casks with up to $2.4 \cdot 10^{20}$ Bq activity and 6.0 MW heat release	According to § 6 AtG of 19.12.2003 Order for immediate enforcement of 28.07.2004 1st modification of 02.06.2006 2nd modification of 07.01.2014	Start of construction 23.08.2004 First emplacement 25.08.2006 At the end of 2015 42 casks were stored in the interim storage facility
On-site interim storage facility Isar Niederaichbach BY	Storage of spent fuel elements from Isar 1 and Isar 2 NPPs	1,500 Mg of heavy metal in up to 152 transport and storage casks with up to $1.5 \cdot 10^{20}$ Bq activity and 6.0 MW heat release	According to § 6 AtG of 22.09.2003 Order for immediate enforcement of 28.05.2004 1st modification of 11.01.2007 2nd modification of 29.02.2008 3rd modification of 16.11.2011 4th modification of 07.02.2012	Start of construction 14.06.2004 First emplacement 12.03.2007 At the end of 2015 35 casks were stored in the interim storage facility
On-site interim storage facility Biblis HE	Storage of spent fuel elements from units A and B of the Biblis NPP	1,400 Mg of heavy metal in up to 135 transport and storage casks with up to $8.5 \cdot 10^{19}$ Bq activity and 5.3 MW heat release	According to § 6 AtG of 22.09.2003 1st modification of 20.10.2005 1st supplement of 20.03.2006 2nd modification of 27.03.2006 3rd modification of 16.06.2014 4th modification of 22.07.2014	Start of construction 01.03.2004 First emplacement 18.05.2006 At the end of 2015 52 casks were stored in the interim storage facility
On-site interim storage facility Grohnde NI	Storage of spent fuel elements from the Grohnde NPP	1,000 Mg of heavy metal in up to 100 transport and storage casks with up to $5.5 \cdot 10^{19}$ Bq activity and 3.75 MW heat release	According to § 6 AtG of 20.12.2002 Order for immediate enforcement of 19.09.2005 1st modification of 17.04.2007 2nd modification of 23.05.2012 3rd modification of 25.06.2012	Start of construction 10.11.2003 First emplacement 27.04.2006 At the end of 2015 27 casks were stored in the interim storage facility

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
On-site interim storage facility Lingen (Emsland) Bramsche NI	Storage of spent fuel elements from the Emsland NPP	1,250 Mg of heavy metal in up to 125 transport and storage casks with up to $6.9 \cdot 10^{19}$ Bq activity and 4.7 MW heat release	According to § 6 AtG of 06.11.2002 with order for immediate enforcement 1st supplement of 31.07.2007 1st modification of 01.02.2008 2nd modification of 19.12.2014	Start of construction 18.10.2000 First emplacement 10.12.2002 At the end of 2015, 38 casks were stored in the interim storage facility
On-site interim storage facility Unterweser Rodenkirchen NI	Storage of spent fuel elements from the Unterweser NPP	800 Mg of heavy metal in up to 80 transport and storage casks with up to $4.4 \cdot 10^{19}$ Bq activity and 3.0 MW heat release	According to § 6 AtG of 22.09.2003 Order for immediate enforcement of 05.02.2007 1st modification of 27.05.2008 2nd modification of 05.01.2012 3rd modification of 18.12.2012	Start of construction 19.01.2004 First emplacement 18.06.2007 At the end of 2015 27 casks were stored in the interim storage facility
AVR cask storage facility in the FZJ Jülich NW	Storage of spent AVR fuel elements in transport and storage casks of the CASTOR® type	Up to 300,000 AVR fuel elements in max. 158 CASTOR® THTR/AVR casks	Notification according to § 6 AtG of 17.06.1993 1st modification of 27.04.1995 2nd modification of 07.07.2005	Since 2009, 152 casks of the CASTOR® THTR/AVR type have been stored in the interim storage facility.
On-site interim storage facility Krümmel (near Geesthacht) SH	Storage of spent fuel elements from the Krümmel NPP	775 Mg of heavy metal in up to 80 transport and storage casks with up to $9.6 \cdot 10^{19}$ Bq activity and 3.0 MW heat release	According to § 6 AtG of 19.12.2003 1st modification of 16.11.2005 Order for immediate enforcement of 28.04.2006 2nd modification of 17.10.2007 3rd modification of 09.07.2014	Start of construction 23.04.2004 First emplacement 14.11.2006 At the end of 2015 21 casks were stored in the interim storage facility
On-site interim storage facility Brokdorf SH	Storage of spent fuel elements from the Brokdorf NPP	1,000 Mg of heavy metal in up to 100 transport and storage casks with up to $5.5 \cdot 10^{19}$ Bq activity and 3.75 MW heat release	According to § 6 AtG of 28.11.2003 1st modification of 24.05.2007 2nd modification of 19.07.2012 3rd modification of 29.08.2012	Start of construction 05.04.2004 First emplacement 05.03.2007 At the end of 2015 29 casks were stored in the interim storage facility

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
On-site interim storage facility Brunsbüttel SH	Storage of spent fuel elements from the Brunsbüttel NPP	450 Mg of heavy metal in up to 80 transport and storage casks with up to $6.0 \cdot 10^{19}$ Bq activity and 2.0 MW heat release	According to § 6 AtG of 28.11.2003 Order for immediate enforcement of 28.10.2005 1st modification of 14.03.2008 2nd modification of 21.07.2014	Start of construction 07.10.2003 First emplacement 05.02.2006 At the end of 2015, 9 casks were stored in the interim storage facility

Table III.6: External waste interim storage facilities

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Hauptabteilung Dekontaminationsbetriebe (HDB) Karlsruhe BW	Storage of non-heat generating wastes from FZK, WAK, ITU, federal state collecting depot BW as well as to a limited extent also for third parties	Handling (conditioning and interim storage) of radioactive residues and nuclear fuel containing wastes up to a total activity of $4.5 \cdot 10^{17}$ Bq	Handling licence according to § 9 AtG of 25 November 1983, replaced by licence according to § 9 AtG of 29 June 2009	In operation since December 1964.
Interim storage facility of the utilities Mitterteich BY	Interim storage of waste with negligible heat generation from Bavarian nuclear facilities	40,000 waste packages (200-l, 400-l, or cast-iron casks)	Handling licences according to § 3 StrlSchV of 07.07.1982	In operation since July 1987.
On-site interim storage facilities Biblis HE	Interim storage of other radioactive substances in the scope of a combined utilisation of the on-site interim storage facility	Up to a total activity of $1 \cdot 10^{17}$ Bq	Handling licence according to § 7 StrlSchV of 13.12.2006	In operation since June 2008.
NCS interim storage facility Hanau HE	Interim storage of waste with negligible heat generation mainly produced by the nuclear industry	1,250 Konrad containers (KC) and 800 m^2 floor space	Handling licence according to § 7 StrlSchV of 11.06.2002 Handling licence according to § 3 StrlSchV of 02.04.1982	In operation since October 2002. In operation since 1982.
Interim storage facility North (ZLN) Rubenow MV	Interim storage of operational and decommissioning waste of the Greifswald and Rheinsberg NPPs with interim storage of the dismantled large components	165,000 m^3	Handling licence according to § 3 StrlSchV of 20.02.1998	In operation since March 1998.
Waste storage facility Unterweser NI	Storage of waste with negligible heat generation from the Unterweser and Stade NPPs	200-l and 400-l drums, concrete casks, steel-plate casks, concrete containers, cast-iron casks with a total activity of up to $1.85 \cdot 10^{15}$ Bq	Handling licences according to § 3 StrlSchV of 24.06.1981, 29.11.1991, and 06.11.1998	In operation since autumn of 1981.

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Waste storage facility Gorleben (drum storage facility) NI	Storage of waste with negligible heat generation from NPPs, medicine, research, and crafts	200-l, 400-l-drums, type-III concrete casks, type-I-II cast-iron casks, type-I-IV casks with a total activity of up to $5 \cdot 10^{18}$ Bq	Handling licences according to § 3 StrlSchV of 27.10.1983, 13.10.1987, and 13.09.1995	In operation since October 1984.
Waste storage facility Ahaus NW	Storage of radioactive wastes from NPPs	Konrad containers, 20 containers and plant components, total activity limit for storage area I of $1 \cdot 10^{17}$ Bq	Handling licence according to § 7 StrlSchV of 09.11.2009	In operation since July 2010.
interim storage facilities Rossendorf (RFR) SN	Interim storage of operational and decommissioning wastes of the research site	Total storage volume of 2,770 m^3 (gross)	Handling licence according to § 3 StrlSchV of 10.02.1999	In operation since February 1999.

Table III.7: Reprocessing plants

Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Karlsruhe Reprocessing Plant (WAK) Eggenstein-Leopoldshafen, BW	Experimental plant for reprocessing and technology development	0.175 Mg HM/day; ca. 40 Mg UO_2/a	Operation WAK: 1st partial operation licence according to § 7 AtG of 02.01.1967 Decommissioning WAK: 1st decommissioning licence, March 1993 21st decommissioning licence and dismantling of the WAK (step 4) of 23.04.2010 for deregulation after end of vitrification 22nd decommissioning licence acc. to § 7 AtG of 08.12.2010 for remote-handled disassembly of the HAWC storage casks in the HWL and in the LAVA. 23rd decomm. Licence of 14.12.2011 for the disassembly of the LAVA High-Active Laboratory and the LAVA (Hot) Cells 24th Decomm. Licence of 28.04.2014 for the premature manual disassembly in the VEK Operation VEK: 1st partial operating licence (TBG) for the VEK of 20.12.2005 (inactive commissioning) 2nd Partial operating licence for the VEK of 24.02.2009 (nuclear [hot] commissioning)	The plant was in operation from 1971 to 1990. During this period approximately 200 Mg of nuclear fuels originating from test and power reactors were reprocessed. Decommissioning and dismantling with the objective of “Greenfield” until 2030 have made progress. The installations of the process building have been largely removed. A vitrification plant (VEK) for 60 m^3 of HAWC was constructed and operated until November 2010. The HAWC was entirely vitrified, producing 140 vitrified waste block canisters (56 Mg), which were placed into 5 transport and storage casks of the CASTOR® HAW 20/28 type. Since February 2011, the CASTOR® casks have been stored in the Interim Storage Facility North of the EWN GmbH. Thus essential prerequisites have been created for the dismantling of the VEK and the HAWC storage facilities.

Table III.8: Conditioning plants for fuel elements

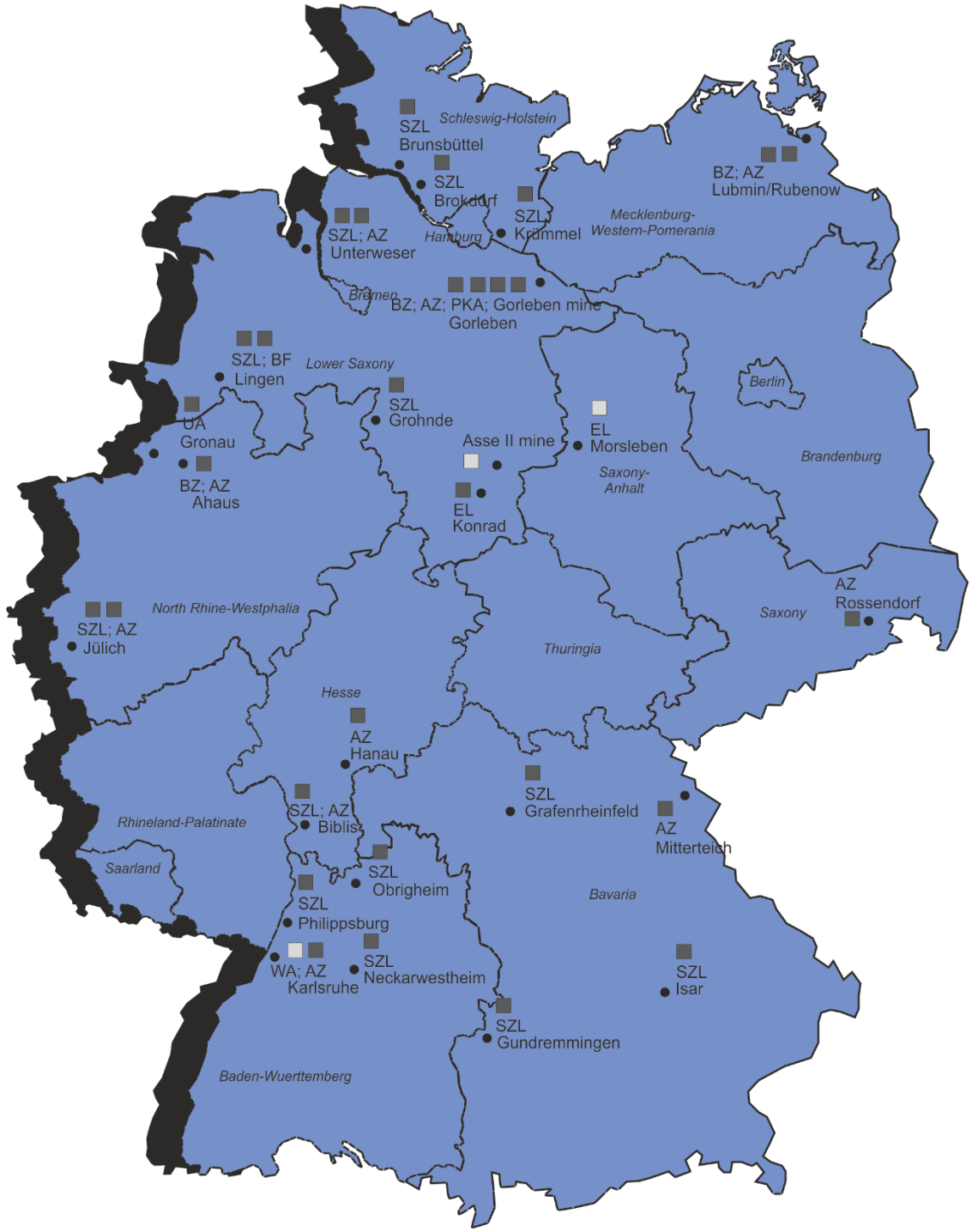
Name of facility and site	Purpose of the facility	Capacity according to licence	Licence	Notes
Pilot conditioning plant (PKA) Gorleben, NI **NI**	Repair of defective casks, conditioning of radioactive residues and waste (among others, spent fuel elements, fuel rods and fuel element mounting parts) for interim storage and disposal	Heavy metal throughput applied for: 35 Mg/a Capacity of operational buffer storage facility: 12 Mg HM	Acc. to § 7 AtG 1st partial licence of 30.01.1990 2nd partial licence of 21.07.1994 (Subsequently imposed obligation of 18.12.2001) 3rd partial licence: 19.12.2000 (includes operation licence)	According to the 3rd partial licence the use of the plant is initially restricted to the repair of defective storage casks. An additional requirement to the 2nd partial licence ensures that one is ready to accept defective casks at any time.

Table III.9: Disposal and decommissioning projects

Name of facility and site	Purpose of the facility	Amounts disposed of / activity	Licence	Notes
Gorleben mine Gorleben, NI	Proof that the site is suitable for the disposal of all types of radioactive waste		The application for a plan-approval decision according to § 9b AtG was filed in 1977. The mine was kept open on the basis of the licensed main operating plan acc.to § 52 BBergG for keeping the Gorleben mine open for the period from 01.10.2014 until 30.09.2016 (mine operating plan keeping mine open).	The geological host formation is rock salt. Once the StandAG had become effective in 2013, the mining exploration of the Gorleben salt dome was officially terminated (cf. chapter 4.7.1).
Konrad repository Salzgitter, NI	Disposal of radioactive waste with negligible heat generation		Application according to § 9b AtG in 1982 (plan-approval application) Withdrawal of the application for immediate enforcement with BfS letter of 17.07.2000. The plan-approval decision was granted on 22.05.2002. After appeal procedures were exhausted after actions had been filed against the plan-approval decision, it has become effective on 26.03.2007 and can be implemented. Pending constitutional complaints have not been admitted nor have they been accepted for decision. On 15.01.2008 the main operating plan was approved by the competent mining authority.	The geological host formation is Coral Oolith (iron ore) underneath a barrier from the Jurassic which is impermeable to water.

Name of facility and site	Purpose of the facility	Amounts disposed of / activity	Licence	Notes
ASSE II mine Remlingen, NI	Research and development works for the disposal of radioactive and chemo-toxic waste, Disposal of low-level and intermediate-level radioactive waste	Between 1967 and 1978 ca. 124,500 LAW- and ca. 1,300 MAW packages were emplaced. Total activity according to today's knowledge $2.89 \cdot 10^{15}$ Bq (01.01.2010), 20 % of which is contributed by MAW packages.	Licences according to § 3 StrlSchV as amended on 15.10.1965. Storage licence for nuclear fuels according to § 6 AtG. Licence according to § 7 StrlSchV granted on 08.07.2010 for the handling of other radioactive substances outside the emplacement chambers up to the 100-fold of exemption limit. Licence according to § 9 AtG for the handling of nuclear fuels and other radioactive materials in the context of fact-finding step 1 of 21.04.2011. Further licence acc.to § 7 StrlSchV of 20.09.2011 for the handling of sealed and open radioactive materials (radiation protection laboratory).	The geological host formation is rock salt. Since 01.01.2009 the BfS is the operator of the Asse II mine. Conversion to operation according to nuclear law. Since the "LEX Asse" became effective in April 2013, it is planned to retrieve the radioactive wastes before the facility will be decommissioned, if this poses an acceptable risk.

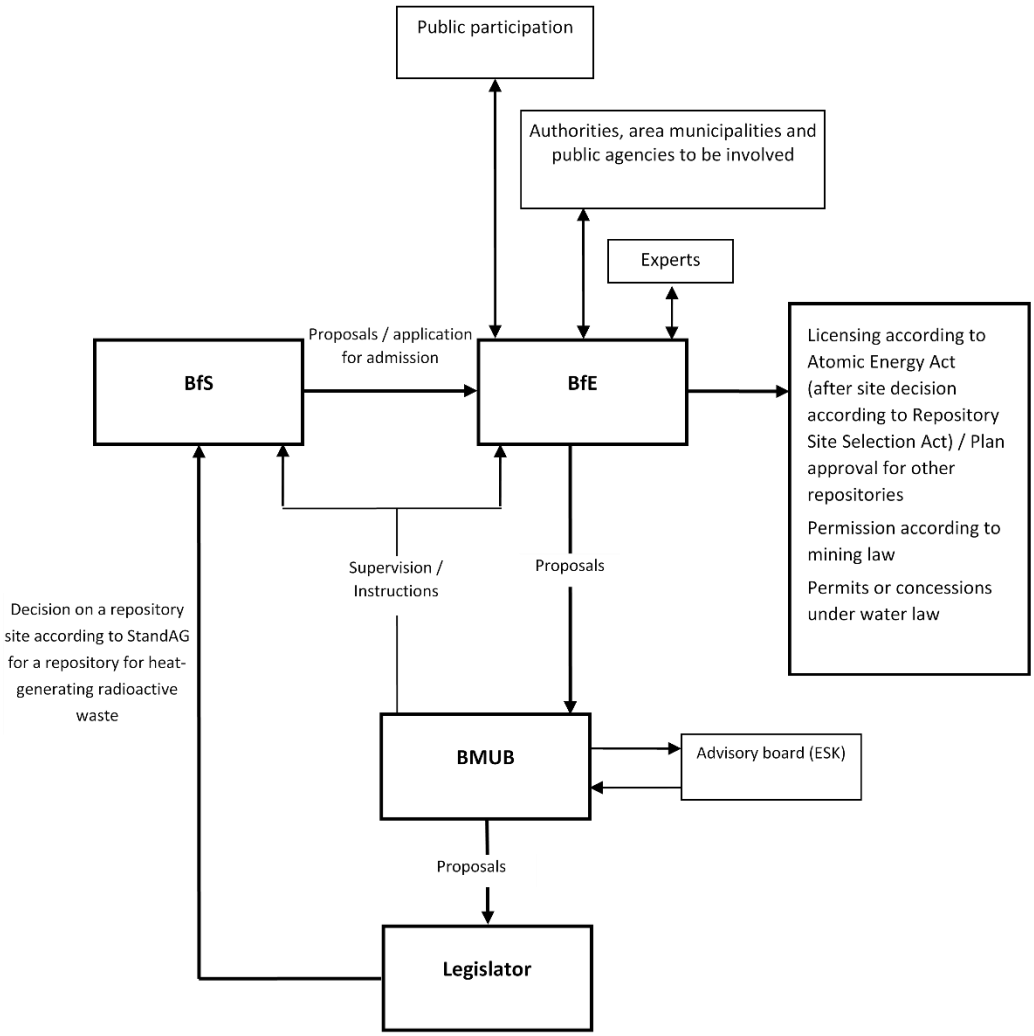
Name of facility and site	Purpose of the facility	Amounts disposed of / activity	Licence	Notes
Morsleben Repository for Radioactive Waste (ERAM) **ST**	Disposal of low-level and intermediate-level radioactive waste with mainly short-lived radionuclides	Disposal of altogether 36,753 m^3 of low-level and intermediate-level radioactive waste, total activity of all radioactive waste stored is in the order of magnitude of less than $3.3 \cdot 10^{14}$ Bq, the activity of the alpha-emitters is in the order of magnitude of 10^{11} Bq (as of 31.12.2010). Furthermore, waste with an activity of ca. $1.8 \cdot 10^{14}$ Bq has been stored intermediately (as on 31.12.2013).	22.04.1986: Continuous operating licence (DBG) granted. According to § 57a AtG it continued to be effective until 30.06..2005; through amendment to the AtG in 2002, the DBG is effective for an unlimited period of time as plan-approval decision, except for the regulations relating to the acceptance of further radioactive waste or its emplacement for the purpose of disposal. 12.04.2001: Declaration of the BfS to waive the acceptance of further radioactive waste for disposal	The geology of the emplacement areas is determined by potash and rock salt formations. On 25.09.1998 emplacement operation stopped. Conversion of the mine and keeping it open were applied for on 10.07.2003. The procedure has been suspended since 11.06.2014. Decommissioning was applied for on 09.05.1997. Following the public hearing in October 2012, the MLU examines the objections in terms of their relevance to the plan-approval decision. The ESK recommendation of 31.01.2013 regarding the state of the art of science and technology in the proof of long-term safety exists.



Legend:

AZ	Rad. waste interim storage facility	SZL	On-site interim storage facility
BF	Fuel element fabrication plant	UA	Uranium enrichment plant
BZ	Central interim storage facility	WA	Reprocessing plant
EL	Radioactive waste repositiory		
PKA	Pilot conditioning plant	■	In operation/ under construction
As of 31 December 2015		□	Under decommissioning

Fig. III.1: Plant sites of nuclear fuel supply and waste management



Legend:

BMUB Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

BfS Federal Office for Radiation Protection

BfE Federal Office for the Regulation of Nuclear Waste Management

ESK Nuclear Waste Management Commission

Fig. III.2: Licensing procedures for radioactive waste repositories pursuant to § 9a AtG

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Kontakt:
Bundesamt für Strahlenschutz
Postfach 10 01 49
38201 Salzgitter
Telefon: + 49 (0)3018 333 0
Telefax: + 49 (0)3018 333 1885
Internet: www.bfs.de
E-Mail: ePost@bfs.de
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