Bundesamt für
kerntechnische
Entsorgungssicherheit

2018 Status Report on the Use of Nuclear Energy in Germany

Department of Nuclear Safety and Supervision in Nuclear Waste Management

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SUMMARY

This report, which was correct on 31 December 2018, provides a summary of the use of nuclear energy in Germany. The report lists the main data concerning all the nuclear power plants, research reactors and the facilities for nuclear fuel supplies and waste management. Seven nuclear power plant units were operating on the reporting date (31 December 2018). Electricity generation using nuclear power in 2018 amounted to approx. 76.0 TWh (2017: 76.3 TWh) in 2018. The share of nuclear energy in the total gross electricity generation amounted to 11.8% (2017: 11.7%)[1].

The report contains a summary of the main operating results and information about the licences granted under the Atomic Energy Act during the year under review for the nuclear power plants. The report also provides a brief description of the current status of nuclear power plants that have been shut down or decommissioned or projects that have been halted. For research reactors, the report presents the main specifications regarding their type, key data (thermal output, thermal neutron flux) and the purpose of using the units. It also provides a summary of the licence and operating history and the current operational status. In the case of the facilities for supplying and disposing of nuclear fuels, it offers details about the intended purpose and output. The report also presents the licence history and the current operating and licensing status. As regards waste management, the report describes the new statutory structures and the supervision activities. The information is summarised in table form at the end of the report. The report is updated and published every year.

[1] Provisional estimates/source: BDEW March 2019

LIST OF ABBREVIATIONS

ADIBKA	Burn-up measurement of differential fuel elements with a critical assembly
AGEB	Energy Balances Working Group
AKR-2	Training reactor at Dresden University of Technology
ANEX	Facility for zero power experiments
ANF (AREVA)	Advanced Nuclear Fuels GmbH, French industrial company, main line of business: nuclear technology
AtG	Atomic Energy Act
AVR	Jülich experimental nuclear power plant
BB	Brandenburg
BDEW	German Association of Energy and Water Industries
BE	Berlin
BER II	Berlin Experimental Reactor II
BfE	Federal Office for the Safety of Nuclear Waste Management
BfkEG	Act to Establish a Federal Office for the Safety of Nuclear Waste Management
BfS	Federal Office for Radiation Protection
BGE	Bundesgesellschaft für Endlagerung mbH
BGZ	Gesellschaft für Zwischenlagerung mbH
BLG	Brennelementlager Gorleben GmbH
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (since March 2018)
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Reactor Safety (renamed BMUB in December 2013; renamed BMU again in March 2018 by an organisational directive)
BNFL	British Nuclear Fuels Ltd
Bq	Becquerel
BUND	Bund für Umwelt und Naturschutz Deutschland e.V.
BVerwG	Federal Administrative Court
BW	Baden-Württemberg
BWR	Boiling water reactor
BY	Bavaria
BZA	Brennelement-Zwischenlager-Ahaus-GmbH
CASTOR®	Cask for Storage and Transport of Radioactive Material
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
CLAB	Centralt mellanlager för använt bränsle, 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, Standard package for waste compacted under high pressure
DAHER-NCS	Nuclear Cargo + Service GmbH
DIDO	Heavy-water-moderated and cooled research reactor at the Jülich Research Centre
DKFZ	German Cancer Research Centre
DNT	DAHER Nuclear Technologies GmbH
DWK	Deutsche Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH
ELK	Storage chamber
ELMA	Extended storage facility for intermediate-level radioactive waste
EnBW	Energiewerke Baden-Württemberg AG
EnKK	EnBW Kernkraft GmbH
E.ON	E.ON Kernkraft GmbH
ERAM	Morsleben repository for radioactive waste
EVU	Electric power utility
EWN	Energiewerke Nord GmbH, EWN Entsorgungswerk für Nuklearanlagen GmbH since 2 Feb. 2017
FDR	Advanced pressurised water reactor
FMRB	Research and measurement reactor in Braunschweig
FR 2	Karlsruhe 2 research reactor
FRF 1	Frankfurt 1 research reactor
FRF 2	Frankfurt 2 research reactor

FRG-1	Geesthacht 1 research reactor
FRG-2	Geesthacht 2 research reactor
FRH	Research reactor at Hanover Medical School
FRJ-1	Jülich 1 research reactor
FRJ-2	Jülich 2 research reactor
FRM	Munich research reactor
FRM-II	Munich II research reactor, high-flux neutron source
FRMZ	TRIGA Mark II research reactor at the University of Mainz
FRN	Neuherberg research reactor
FZJ	Forschungszentrum Jülich GmbH
FZK	Forschungszentrum Karlsruhe GmbH
GDR	German Democratic Republic
GKN 1	Neckarwestheim unit 1 nuclear power plant
GKN 2	Neckarwestheim unit 2 nuclear power plant
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	Bremen
HDR	Grosswelzheim hot steam reactor
HE	Hesse
HEU	Highly enriched uranium
HH	Hamburg
HKG	Hochtemperatur-Kernkraftwerk GmbH
HMGU	Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt GmbH
HOBEG	Hochtemperatur-Brennelement Gesellschaft
HTR	High-temperature reactor
HWL	High-active waste store
JEN	Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH
K	Kelvin
KAHTER	Critical facility for high-temperature reactors
KBR	Brokdorf nuclear power plant
KEITER	Critical experiment on an 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
KKG-BELLA	On-site storage facility for fuel elements
KKI 1	Isar 1 nuclear power plant
KKI 2	Isar 2 nuclear power plant
KKK	Krümmel nuclear power plant
KKN	Niederaichbach nuclear power plant
KKP 1	Philippsburg unit 1 nuclear power plant
KKP 2	Philippsburg unit 2 nuclear power plant
KKR	Rheinsberg nuclear power plant
KKS	Stade nuclear power plant
KKU	Unterweser nuclear power plant
KKW	Nuclear power plant
KMK	Mülheim-Kärlich nuclear power plant
KNK II	Compact sodium-cooled core reactor facility, Karlsruhe
KRB A	Gundremmingen unit A nuclear power plant
KRB-II-B	Gundremmingen unit B nuclear power plant
KRB-II-C	Gundremmingen unit C nuclear power plant

KWB A	Biblis unit A nuclear power plant
KWB B	Biblis unit B nuclear power plant
KWG	Grohnde joint nuclear power plant
KWL	Lingen nuclear power plant
KWO	Obrigheim nuclear power plant
KWU	Siemens AG, power plant department
KWW	Würgassen nuclear power plant
LAVA	Facility for storing and evaporating high-level radioactive waste liquids
LAW	Low-active waste
LEU	Low-enriched uranium
LUnA	Storage facility for low-level and intermediate-level radioactive waste
LWR	Light water reactor
MERLIN	Medium-energy research light-water-moderated industrial nuclear reactor at the Jülich Research Centre (FZJ)
MEU	Medium-enriched uranium
MOX	Mixed oxide (fuel)
MTR	Materials testing reactor
MV	Mecklenburg-Vorpommern
MW_e	Megawatt of electrical power
MWEIMH NRW	Ministry of Economic Affairs, Energy, Industry, the Medium-Sized Economy and Trade in the State of North Rhine-Westphalia (Ministry of Economic Affairs, Innovation, Digitalisation and Energy in the State of North Rhine-Westphalia since 30 June 2017)
MWh	Megawatt hour
MW_{th}	Megawatt of thermal power
mvK	With a modified cage
MZFR	Multi-purpose research reactor, Karlsruhe
NCS	Nuclear Cargo + Service GmbH, therefore NCS since 1 October 2015
NI	Lower Saxony
NMU	Lower Saxony Ministry for the Environment, Energy, Construction and Climate Protection
NUKEM	NUKEM GmbH Alzenau
NW	North Rhine-Westphalia
OH	Otto Hahn
oHG	General partnership
OVG	Higher Administrative Court
ö.H.	Funded by public sector
PE	PreussenElektra GmbH
PFB	Planning approval decision
PKA	Pilot conditioning plant
PTB	Physikalisch-Technische Bundesanstalt
PuO_2	Plutonium dioxide
PWR	Pressurised water reactor
RAKE	Rossendorf Directive for Critical Experiments
RBZ-N	Residual material processing centre at Neckarwestheim
RBZ-P	Residual material processing centre at Philippsburg
RFR	Rossendorf research reactor
RP	Rhineland-Palatinate
RRR	Rossendorf ring zone reactor
RWE	Rheinisch-Westfälische Elektrizitätsgesellschaft
SAAS	State board for atomic Safety and radiation protection (in former GDR)
SAL-N	On-site storage facility for low-level and intermediate-level radioactive waste at Neckarwestheim
SAL-P	On-site storage facility for low-level and intermediate-level radioactive waste at Philippsburg
SAR	Siemens Argonaut reactor
SE	Safe enclosure
SG	Decommissioning licence
SH	Schleswig-Holstein
SL	Saarland
SM	Heavy metal (HM)

SMUL	Saxon State Ministry for the Environment and Agriculture
SN	Saxony
SNEAK	Fast zero-power reactor
SFR	Sodium-cooled fast reactor
ST	Saxony-Anhalt
StandAG	Site Selection Act
STARK	Fast thermal Argonaut reactor
StrlSchG	Radiation Protection Act
SUA	Siemens subcritical assembly
SUR	Siemens training reactor
SZL	On-site storage facility
TBH-KBR	Transport preparation building at Brokdorf nuclear power plant
TBL	Transport cask storage facility
TBL-A	Transport cask storage facility at Ahaus
TBL-G	Transport cask storage facility at Gorleben
TH	Thuringia
THTR-300	Thorium high-temperature reactor, Hamm-Uentrop
TRIGA	Training, Research and Isotope Production facility of General Atomic
TRIGA HD I	TRIGA HD I research reactor, Heidelberg
TRIGA HD II	TRIGA HD II research reactor, Heidelberg
TSG	Partial decommissioning licence
TUM	Technical University of Munich
TWh	Terawatt hour
U-235	Uranium isotope 235
U_3O_8	Triuranium octoxide
UAG	Gronau uranium enrichment facility
UF_6	Uranium hexafluoride
UO_2	Uranium dioxide
UTA	Uranium separation work
VAK	Kahl experimental nuclear power plant
VDEW	Verband der Elektrizitätswirtschaft (e.V.)
VEK	Karlsruhe vitrification plant
VGB	Technische Vereinigung der Großkraftwerksbetreiber (e.V.)
VKTA	Strahlenschutz, Analytik und Entsorgung Rossendorf (e.V.)
WAK	Dismantling project for the Karlsruhe WAK reprocessing plant
WAW	Wackersdorf reprocessing plant
WENRA	Western European Nuclear Regulators Association
WWER	Water-cooled, water-moderated energy reactor (Russian type PWR)
WWR-S (M)	Water-cooled, water-moderated Russian reactor; S represents series production and M modification (RFR: changes to the core and fuel)
ZLN	Rubenow Interim Storage Facility North

1 ELECTRICAL POWER GENERATION IN GERMANY

1.1 GENERAL ISSUES

Approx. 646.8 TWh of electrical energy were generated in Germany in 2018 (2017: 653.6 TWh; please note: gross generation excluding any power feed, i.e. without any electricity exchange balance). Gross power generation in Germany declined by about 1% compared to the previous year (see Table 1.1).

Table 1.1: Shares of energy sources in the overall gross electricity generation in percent

***	2016		2017		2018*	
	TWh	%	**TWh**	%	**TWh**	%
Nuclear energy	84.6	13.0	76.3	11.7	76.0	11.8
Lignite	149.5	23.0	148.4	22.7	145.5	22.5
Black coal	112.2	17.2	92.9	14.2	83.2	12.9
Oil	5.8	0.9	5.6	0.9	5.2	0.8
Natural gas	81.3	12.5	86.7	13.3	84.4	12.9
Renewables, including	189.8	29.2	216.2	33.1	226.4	35.0
Wind	80.1	12.3	105.6	16.2	111.5	17.2
Water	20.5	3.2	20.2	3.1	16.6	2.6
Biomass	45.0	6.9	45.0	6.9	45.7	7.1
Solar power	38.1	5.9	39.4	6.0	46.2	7.1
Waste (only the renewable share)	5.9	0.9	6.0.	0.9	6.2	1.0
Geothermal power	0.2	****	0.2	****	0.2	****
Others (total) **	27.3	4.2	27.5	4.2	27.0	4.1
TOTAL	650.6	100.0	653.6	100.0	646.8	100.0

* All the figures from 2018 are provisional. Differences between the provisional (estimated) figures and the final figures are possible.

** The “Others” energy source category is specified as pump storage, domestic waste (non-regenerative part) and industrial waste in the specifications provided by the BDEW.

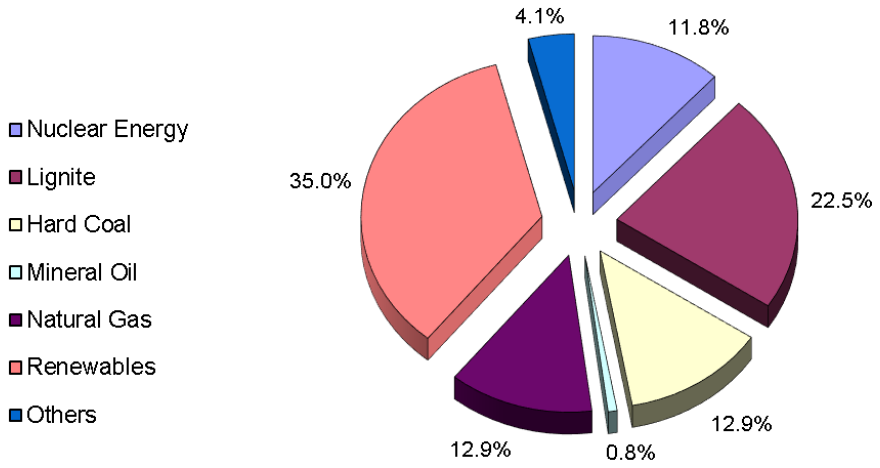
*** All the figures have been rounded

**** Very low figure and not specified here

[Sources: AGEB, BDEW, correct in March 2019]

Some of the shares of the individual energy sources in the gross electricity generation figures are significantly different from the previous year. Water power declined by 18% due to the extremely dry weather. Wind generated 5.6% more. Solar power about 17% more due to the extremely sunny summer.

The share of nuclear energy in the total gross electricity generation in 2018 remained about the same as in 2017 (2017: 11.7%; 2018: 11.8% - source: BDEW). No nuclear power plant units were finally shut down during the year under review. The total gross output from nuclear power plants in operation amounted to 10,013 MWe at midnight on 31 December 2018 (see Table 2.1).



The figures specified in the graphic are provisional. Differences between the provisional (estimated) figures and the final figures are possible.

Fig. 1: Shares of the energy sources in the total gross electricity generated in 2018 (base figure: 646.8 TWh)

1.2 THE RENEWABLE ENERGY ACT

The increased use of renewable energy sources forms part of the German climate protection strategy. It is embedded in the Renewable Energy Act (EEG), which became law for the first time in 2000 and has been constantly developed since then. The share of renewable energy sources in electricity production was stipulated in the amended version of the EEG in 2014. According to this, its share is to rise to 40-45% by 2025, to 55-60% by 2035 and to at least 80% by 2050. In order to manage the increase in a better way, a mandatory expansion corridor has been set. The 2017 EEG heralded the next phase of the turnaround in energy. It is the central tool for achieving an effective annual quantity control system and introducing more renewable energy sources to the market.

1.3 PHASE-OUT OF ELECTRICITY PRODUCTION THROUGH NUCLEAR ENERGY

The use of nuclear power to generate electricity commercially is being halted in Germany – in phases. The last nuclear power plants are due to be shut down in 2022.

The end of the operating terms for the individual nuclear power plants is stipulated in the Atomic Energy Act. Once a nuclear power plant has been finally shut down, the post-operational phase starts, while work is performed to prepare for its complete decommissioning.

1.3.1 Effects of the reactor accident in Fukushima

The German government decided in a moratorium dated 14 March 2011 to disconnect all the nuclear power plants in Germany that had been operative up to and including 1980 from the grid for a temporary period of three months and run them down as a result of the reactor accident at the Fukushima Daiichi nuclear power plant in Japan on 11 March 2011. This affected the Biblis A and Biblis B, Neckarwestheim 1, Brunsbüttel, Isar 1, Unterweser and Philippsburg 1 nuclear power plants. The Biblis B and Brunsbüttel nuclear power plants were already disconnected from the grid at this time – and the Krümmel nuclear power plant too.

The Reactor Safety Commission conducted a safety check on the eight nuclear power plants that were shut down and the nine still operating. Its results and the general social dialogue involving the “Safe Energy Supplies” ethics commission led to a reassessment of the risks of using nuclear power in Germany. The German government decided to end the use of nuclear power to commercially generate electricity in the country.

1.3.2 Current nuclear energy legislation in Germany

The 13th Law to Amend the Atomic Energy Act dated 31 July 2011 stipulated that the final nuclear power plants in Germany would be shut down at the end of 2022.

When the new Atomic Energy Act became law on 6 August 2011, further authorisation for power operations at the eight nuclear power plants – Biblis A and B, Neckarwestheim 1, Brunsbüttel, Isar 1, Unterweser, Philippsburg 1 and Krümmel – expired. The plants were therefore finally shut down. Decommissioning was applied for. Seven nuclear power plant had received their first decommissioning licence by 31 December 2018. The Grafenrheinfeld nuclear power plant was finally disconnected from the grid on 27 June 2015 and a first decommissioning licence was granted for it on 11 April 2018. Power operations for the Gundremmingen B nuclear power plant ended on 31 December 2017. This means that there have still been seven German nuclear power plants in operation since 1 January 2018.

The Atomic Energy Act stipulates the following dates for the end of their term or finally shutting down the remaining nuclear power plants that are still operating:

31 December 2019 Philippsburg 2 nuclear power plant

31 December 2021 Grohnde, Gundremmingen C and Brokdorf nuclear power plants

31 December 2022 Isar 2, Emsland and Neckarwestheim 2 nuclear power plants.

1.3.3 Quantities of electricity generated in Germany

The German government and the energy supply companies had already agreed a certain quantity of electricity for each nuclear power plant in June 2000, which the individual facility could still generate related to 1 January 2000 (consensus agreement). This created an operating period of roughly 32 years for each nuclear power plant and it was stipulated in the Atomic Energy Act in April 2002. The German government decided in 2010 to extend the period of operation of the nuclear power plants, which had started to generate power up to and included 1980, by eight years or the term of the younger nuclear power plants by 14 years. In line with this, the Atomic Energy Act, which was amended in December 2010, allocated additional electricity volumes to the individual nuclear power plants. Inspired by the reactor accident at Fukushima Daiichi, the German government decided to stop using nuclear energy to generate electricity commercially. The Atomic Energy Act alone, which was then amended in August 2011, again contains the electricity volumes stipulated in the earlier Atomic Energy Act in April 2002 for each individual nuclear power plant. The extension of operating terms stipulated in December 2010 was reversed and the additional electricity volumes cancelled.

The amendment to the Atomic Energy Act in August 2011 stipulated a specific shut-down date for each individual nuclear power plant in law for the first time. The Atomic Energy Act also lists the electricity volumes that can still be generated related to 1 January 2000 in column 2 of Annex 3 related to Section 7 Paragraph 1a (cf. also column 2 of the table in Figure 2); once this quantity has been generated, any authorisation to operate the plant expires. According to the Atomic Energy Act, it is possible to transfer electricity volumes from one nuclear power plant to another. They can be completely or partially transferred from one – normally an older and smaller nuclear power plant – to a different unit. It is also possible to transfer the remaining quantities of electrical power from the nuclear power plants that were shut down on 6 August 2011 according to the Atomic Energy Act (Biblis A, Neckarwestheim 1, Biblis B, Brunsbüttel, Isar 1, Unterweser, Philippsburg 1 and Krümmel). Any transfer from a newer to an older nuclear power plant requires approval by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in agreement with the Chancellor's Office and the Federal Ministry of Economics and Technology. In this case, the BMU insists that a comparative safety analysis is conducted for both the nuclear power plants involved. Any transfers of electricity volumes must be communicated to the Federal Office for the Safety of Nuclear Waste Management (BfE) and are taken into consideration when registering the electricity volumes.

1.3.4 Tasks for the Federal Office for the Safety of Nuclear Waste Management

The "Act on Realignment of the Organisational Structures of Radioactive Waste Disposal" became law on 30 July 2016. It envisages pooling most of the state tasks for licensing and supervising nuclear technology, storage, the site selection procedure and supervising disposal operations in a new public authority, the Federal Office for the Safety of Nuclear Waste Management (BfE).

The BfE therefore took over the task of logging and documenting the net electricity volumes generated by German nuclear power plants from the Federal Office for Radiation Protection (BfS) on 30 July 2016.

The energy supply companies measure the amounts of electricity generated and have been reporting this data every month to the BfS since May 2002 or now to the BfE; they arrange an annual check on the measurement equipment by independent expert organisations and authenticate the amounts of electricity reported by an auditing company. The audit reports from the experts and auditors are submitted to the BfE.

The BfE announces the amounts of electricity that have been generated, transferred and still remain in the Federal Gazette. This announcement is made once a year. Figure 2 reports the electricity volumes on 31 December 2018; it was published on 1 April 2019 in the Federal Gazette as an annual figure for 2018 and the latest version can be viewed on the BfE website at https://www.base.bund.de/DE/kt/kta-deutschland/laufzeiten/laufzeiten.html (in German only).

If the remaining quantity of electricity creates an expected term of less than six months, figures are published every month.

Announcement acc. to 7 para. 1c Atomic Energy Act (AtG) - annual statement 2018 -

Electricity volumes [GWh net] produced, transferred from 1 January 2000 to 31 December 2018 and residual volumes acc. to 7 para. 1a annex 3 column 2 AtG

Nuclear Power Plant	Residual Electricity volume as of 1 January 2000	Net Electricity Volume produced from 1 January 2000 until 31 December 2015	Net Electricity Volume produced in 2016	Net Electricity Volume produced in 2017	Net Electricity Volume produced in 2018	Electricity Volume (Production rights) transferred until 31 December 2018	Residual Electricity Volume
1	2	3	4	5	6	7	8
Philippsburg 2[11)]	198610.00	168027.62	9697.04	7380.93	10323.15	8454.24	11635.50
Grohnde	200900.00	169671.74	8415.91	9133.02	10339.24		3340.09
Gundremmingen C[4) 5) 8) 9)]	168350.00	159275.76	8918.29	9462.04	9874.20	41000.00	21819.71
Brokdorf	217880.00	176484.02	10938.01	5480.41	9838.25		15139.31
Isar 2	231210.00	182181.00	11338.88	10901.56	11477.22		15311.34
Emsland[12)]	230070.00	175051.53	10539.68	10751.52	10915.03	17700.00	40512.24
Neckarwestheim 2	236040.00	168062.13	10687.24	9880.28	9099.37		38310.98
Sum	**1483060.00**	**1198753.80**	**70535.05**	**62989.76**	**71866.46**		**146069.17**
Stade[1)]	23180.00	18394.47				-4785.53	0.00
Obrigheim[2)]	8700.00	14199.89				5499.89	0.00
Mülheim-Kärlich[3) 4) 8) 9) 12)]	107250.00					-67683.28	39566.72
Neckarwestheim 1	57350.00	57350.00					0.00
Isar 1	78350.00	76325.88					2024.12
Biblis A[1) 8)]	62000.00	64591.29				2591.29	0.00
Biblis B[3) 7) 8)]	81460.00	81737.52				277.52	0.00
Brunsbüttel	47670.00	36670.33					10999.67
Unterweser[5) 6) 7) 8) 9)]	117980.00	106777.14				-8800.00	2402.86
Philippsburg 1[2) 11)]	87140.00	73185.87				-13954.13	0.00
Grafenrheinfeld [6)]	150030.00	150283.19				500.00	246.81
Krümmel	158220.00	69974.89					88245.11
Gundremmingen B[4) 5) 7) 10)]	160920.00	160381.79	9517.68	9173.06		19200.00	1047.47
Total	**2623310.00**	**2108626.06**	**80052.73**	**72162.82**	**71866.46**		**290601.93**

The Column 6 "Net Electricity Volume produced in 2018" contains the values examined by certified accountants according to § 7 para. 1a AtG

[1)] The residual 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 (column 7).

[2)] Transfer of 5499.89 GWh from the Philppsburg 1 nuclear power plant to the Obrigheim nuclear power plant on 23 January 2003 and on 11 May 2005 (column 7).

[3)] Transfer of 8100.00 GWh from the residual electricity volume of the nuclear power plant under decommissioning Mühlheim-Kärlich to the Biblis B nuclear power plant on 30 June 2010 (column 7).

[4)] Transfer of 8400.00 GWh to the Gundremmingen B nuclear power plant and 1500.00 GWh to the Gundremmingen C nuclear power plant from the residual electrity volume of the nuclear power plant under decommissioning Mühlheim-Kärlich on 28 May 2015 (column 7).

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

[6)] Transfer of 500.00 GWh from the residual electricity volume of the shut-down nuclear power plant Unterweser to the Grafenrheinfeld nuclear power plant on 05 June 2015 (column 7).

[7)] Transfer of 8000.00 GWh to the Gundremmingen B nuclear power plant: 6000.00 GWh from the Biblis B nuclear power plant and 2000.00 GWh from the Unterweser nuclear power plant on 27 January 2017 (column 7).

[8)] Transfer of 8000.00 GWh to the Gundremmingen C nuclear power plant: 2194.24 GWh from the Biblis A nuclear power plant, 1822.48 GWh from the Biblis B nuclear power plant , 1983.28 GWh from the Mülheim-Kärlich nuclear power plant and 2000.00 GWh from the Unterweser nuclear power plant on 27 January 2017 (column 7).

[9)] Transfer of 31000.00 GWh to the Gundremmingen C nuclear power plant: 30000.00 GWh from theMülheim-Kärlich nuclear power plant and 1000.00 GWh from the Unterweser nuclear power plant on 10 January 2018 (column 7).

[10)] In accordance to the atomic energy act § 7 para. 1a No 3 the Gundremmingen B nuclear power plant was shut down on 31 December 2017.

[11)] Transfer of 8454.24 GWh from the residual electricity volume of the Philippsburg 1 nuclear power plant to the Philippsburg 2 nuclear power plant on 20 March 2018 (column 7).

[12)] Transfer of 17700.00 GWh from the residual electricity volume of the nuclear power plant under decommissioning Mülheim-Kärlich to the Emsland nuclear power plant on 15 October 2018 (column 7).

Fig. 2: Electricity volumes of the German nuclear power plants, transfer of production rights and documentation of residual electricity volumes (annual report for 2018, Federal Gazette: 1 April 2019)

2 NUCLEAR POWER PLANTS

This was the status regarding nuclear power plants in Germany on the reporting date of 31 December 2018:

7 nuclear power plants were operating,

2 nuclear power plants had been finally shut down[2],

24 nuclear power plants were under decommissioning,

3 nuclear power plants had been completely decommissioned and released from the Atomic Energy Act and

6 nuclear power plants projects had been halted.

Table 2.1: Nuclear power plants in Germany in 2018 (correct on: 31 December 2018)

Status	Pressurised water reactor (PWR)		Boiling water reactor (BWR)		Others		Total	
	Number	MWe (gross)	Number	MWe (gross)	Number	MWe (gross)	Number	MWe (gross)
Operating	6	8,669	1	1,344	—	—	7	10,013
Finally shut down	0	0	2	2,746	—	—	2	2,746
Under decommissioning	15	10,778	6	3,816	3	344	24	14,938
Completely dismantled	—	—	1	16	2	131	3	147
Project halted	5	3,320	—	—	1	327	6	3,647

The individual nuclear power plants are described in line with their operating status in chapters 2.1 – 2.5 and in the relevant tables in Annex I.

Figure I at the end of the report in Annex I provides a summary of the sites of all the nuclear power plants in Germany. The operating times of the nuclear power plants in Germany are also presented in the following figure since their first criticality date.

[2] After going to print: the first licence to decommission and dismantle the Gundremmingen nuclear power plant was granted on 19 March 2019.

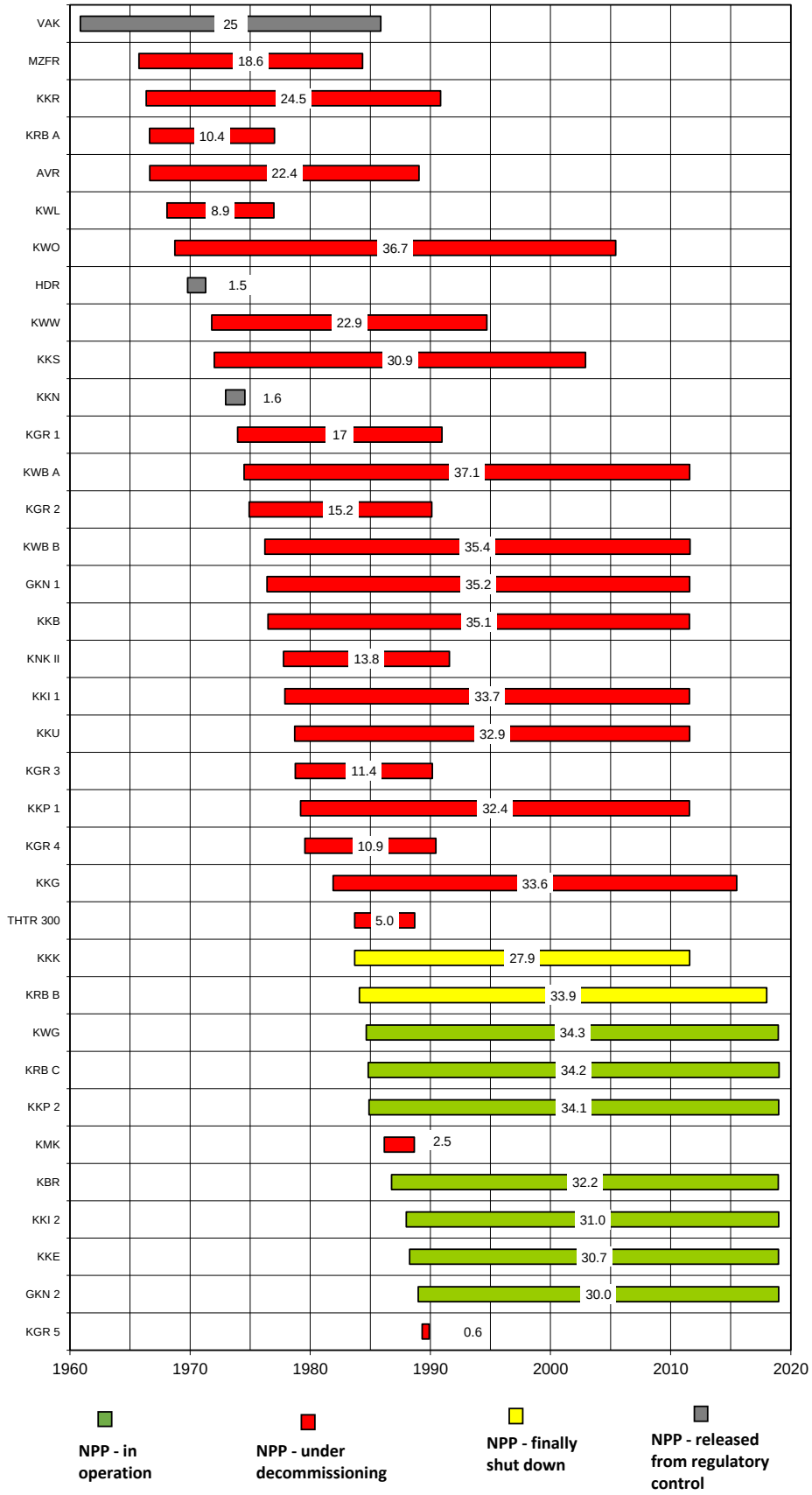


Fig. 3: Operating times for the nuclear power plants in Germany in years since first criticality
Correct on 31 December 2018

2.1 NUCLEAR POWER PLANTS IN OPERATION

Seven nuclear power plants were still operating in the 2018 reporting year. Table I.2 in Annex I contains a list of the nuclear power plants in operation in the year under review with their main key data.

2.1.1 Availability and reportable events

Table 2.2. lists the availability and the reportable events of German nuclear power plants during the last 10 years. The Federal Office for the Safety of Nuclear Waste Management (BfE) took over the task as the Incident Registration Centre from the Federal Office for Radiation Protection (BfS) on 30 July 2016. It now publishes annual and monthly reports on reportable events. These reports contain the events reported according to the Nuclear Safety Officer and Reporting Ordinance at nuclear power plants and research reactors in Germany; they are registered by the Incident Registration Centre at the BfE.

You can obtain details and further information about reportable events on the Internet from the BfE home page at https://www.bfe.bund.de/EN/ns/events/events_node.html

Table 2.2: Average availability and total number of reportable events at nuclear power plants

Year	Time availability* [%]	Working availability* [%]	Energy utilisation* [%]	Number of reportable events
2018	90.9	89.7	86.2	76
2017	82.0	80.2	76.3	54
2016	88.9	88.4	84.4	70
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

*Source: Technical Association of Energy Plant Operators (VGB)

2.1.2 Plant and licensing status

The following section provides a brief description of the nuclear power plants in operation with some information about the licences granted during the reporting period by the responsible authorities under the Atomic Energy Act according to Table I.1 (Annex I) – in line with Section 7 of the Act. Current licensing procedures are also mentioned if they are particularly important for the plant and licensing status.

The terrorist attacks on 11 September 2001 in the USA focused attention on nuclear facilities as possible targets. Although no special risk for nuclear facilities exists according to the security authorities, German nuclear power plants are included in the packages of measures needing to be protected against terrorist attacks by commercial aircraft. The goal is, firstly, to make any interference in air traffic harder and, secondly, reduce any possible effects. The whole package not only includes internal measures at power plants, which could be implemented immediately, but also applications to make it harder for terrorists to hit their target if they deliberately try to do so with an aircraft (camouflage through artificial nebulisation). Licences according to Atomic Energy Act Section 7 have already been granted and implemented for some plants.

Baden-Württemberg

Neckarwestheim unit 2 nuclear power plant (GKN 2)

Neckarwestheim 2 is a fourth-generation pressurised water reactor (PWR), a convoy unit, and was commissioned in 1988 with output measuring 1,316 MW_e. The current reactor output of 1,400 MW_e is the result of several thermal and electrical changes to output.

The Neckarwestheim 2 nuclear power plant is the youngest operating in Germany, having been commissioned in December 1988. The Neckarwestheim 2 nuclear power plant will lose its licence for power operations on 31 December 2022 at the latest.

EnBW Kernkraft GmbH (EnKK) applied for decommissioning and dismantling GKN 2 according to Section 7 Paragraph 3 of the Atomic Energy Act on 18 July 2016. The application was updated in a letter dated 15 May 2017. The project was announced on 22 June 2018 and the documents were put on public display between 2 July and 3 September 2018. The public hearing took place on 27 November 2018.

The Ministry for the Environment in Baden-Württemberg granted the handling licences for low-level and intermediate-level radioactive waste at a new on-site storage facility (SAL-N) and in a residual waste processing centre at Neckarwestheim on 17 December 2018. The applications in line with Section 7 of the Radiation Protection Ordinance were made in April 2014.

Philippsburg Unit 2 nuclear power plant (KKP 2)

The Philippsburg 2 nuclear power plant is a third-generation pressurised water reactor (PWR), a pre-convoy unit. The facility was commissioned in 1984 with output measuring 1,349 MW_e. The electrical performance of the facility was gradually increased to a figure of 1,468 MW_e through several increases in thermal and electrical output. The Philippsburg 2 nuclear power plant will lose its licence for power operations on 31 December 2019 at the latest.

EnKK applied to decommission and dismantle KKP 2 according to Section 7 Paragraph 3 of the Atomic Energy Act on 18 July 2016. The application was updated in a letter dated 15 May 2017. The documents were put on public display between 9 April and 8 June 2018. The public hearing took place on 25 and 26 September 2018.

The Ministry for the Environment in Baden-Württemberg granted the handling licences for low-level and intermediate-level radioactive waste at a new on-site storage facility (SAL-N) and in a residual waste processing centre at Philippsburg on 17 December 2018. The applications in line with Section 7 of the Radiation Protection Ordinance were made in April 2014.

Bavaria

Isar Unit 2 nuclear power plant (KKI 2)

The Isar unit 2 nuclear power plant is a convoy unit with a fourth-generation pressurised water reactor. It was commissioned as the first of the three convoy facilities (Neckarwestheim 2, Emsland) with power output measuring 1,370 MW_e in 1988. The current reactor output measuring 1,485 MW_e is the result of two increases in thermal and several in electrical output. This means that KKI 2 is currently Germany's most efficient nuclear power plant unit. The Isar 2 nuclear power plant will lose its licence for power operations on 31 December 2022 at the latest.

An "application for a licence to handle radioactive substances in the transport preparation building according to Section 7 of the Radiation Protection Ordinance" was made for the Isar site on 12 April 2018.

The licence holder changed on 1 July 2016 through the change of operating name to E.ON Kernkraft GmbH. The current licence holder for KKI 2 is PreussenElektra GmbH (PE).

Gundremmingen unit C nuclear power plant (KRB II C)

The Gundremmingen nuclear power plant was designed as a double-unit with structurally identical units – KRB-II-B and KRB-II-C. Type 72 boiling water reactors (BWR), which each produced output measuring 1,310 MW_e were commissioned in 1984, operated in both units. The current reactor output from unit C is 1,344 MW_e. KRB II C will lose its licence for power operation on 31 December 2021 at the latest. Unit B was already permanently shut down according to the Atomic Energy Act on 31 December 2017. RWE Nuclear GmbH was added as one of the licence holders to the licences granted under the Atomic Energy Act for the Gundremmingen nuclear power plant according to Section 7 Paragraph 1 of the Act on 8 December 2017 (15th amended licence). As a result, RWE Power AG has been released from any responsibility under the Atomic Energy Act.

As part of making better use of the fuel elements, RWE applied on 27 August 2015 to operate the facility with ATRIUM 11 recharged fuel elements up to an enrichment of nominally 4.6 w/o U-235 in the mixing core. The 16th amended licence was granted for Unit C of the Gundremmingen nuclear power plant to use ATRIUM 11 fuel elements according to Section 7 of the Atomic Energy Act on 22 January 2018.

Lower Saxony

Grohnde nuclear power plant (KWG)

The Grohnde nuclear power plant is a third-generation PWR (pre-convoy) and was commissioned in 1984 with output measuring 1,365 MW_e. One thermal and two electrical capacity increases led to the current reactor output of 1,430 MW_e. An application to decommission and dismantle the facility in the first demolition phase was made according to Section 7 Paragraph 3 of the Atomic Energy Act on 26 October 2017. The construction of a transport preparation building was applied for according to Section 7 of the Radiation Protection Ordinance on 30 November 2017. The Grohnde nuclear power plant will lose its licence for power operations on 31 December 2021 at the latest.

KWG only had a residual electricity volume that would suffice for a probable residual period of less than 6 months on 31 October 2018, according to Section 7 Paragraph 1c of the Atomic Energy Act. The BfE

therefore arranged an announcement on this in the Federal Gazette according to the aforementioned statutory stipulation for the first time on 24 December 2018.

Due to a change in operating name at E.ON Kernkraft GmbH, the licence holder changed on 1 July 2016. The current licence holder for KWG is PreussenElektra GmbH (PE).

Emsland nuclear power plant (KKE)

The Emsland facility is a fourth-generation PWR and therefore one of the three convoy units in Germany. The facility was commissioned in 1988 with electrical output measuring 1,316 MW_e. The current reactor output of 1,406 MW_e is the result of one thermal and several electrical capacity increases. The last increase in performance by 6 MW took place in May 2014 by replacing the high-pressure turbine. Kernkraftwerke Lippe-Ems GmbH applied to decommission and dismantle the facility according to Section 7 Paragraph 3 of the Atomic Energy Act on 22 December 2016. The Emsland nuclear power plant will lose its licence for power operations on 31 December 2022 at the latest.

RWE has pooled its nuclear energy division in RWE Nuclear GmbH since 1 January 2018. RWE Nuclear GmbH holds 87.5% of the shares in the Emsland nuclear power plant.

Schleswig-Holstein

Brokdorf nuclear power plant (KBR)

The Brokdorf nuclear power plant is a third-generation PWR (pre-convoy). The facility was commissioned with output measuring 1,380 MW_e in 1986. The reactor output is currently 1,480 MW_e. This is the result of two thermal and several electrical capacity increases.

Due to a change in operating name at E.ON Kernkraft GmbH, the licence holder changed on 1 July 2016. The current licence holder for KBR is PreussenElektra GmbH (PE).

An application was made to the licensing authority to decommission and dismantle the Brokdorf nuclear power plant in the first dismantling phase according to Section 7 Paragraph 3 of the Atomic Energy Act on 1 December 2017. The Brokdorf nuclear power plant will lose its licence for power operations on 31 December 2021 at the latest.

A licence application according to Section 7 of the Radiation Protection Ordinance to handle radioactive substances and residual substances in a transport preparation building that still needs to be constructed (TBH-KBR) was made on 8 December 2017.

2.2 NUCLEAR POWER PLANTS FINALLY SHUT DOWN

This chapter presents the nuclear power plants that have been finally shut down, but have still not obtained a licence for decommissioning.

Table I.3 of Annex I contains the most important data on the nuclear power plants in this category.

Bavaria

Gundremmingen Unit B nuclear power plant (KRB-B)

The Gundremmingen nuclear power plant was designed as a double-unit facility with identical units – KRB-II-B and KRB-II-C. Type 72 boiling water reactors (BWR), which were each commissioned with output measuring 1,310 MW_e in 1984, operated in both units. The reactor output at unit B was most recently 1,344 MW_e because of several electrical capacity increases.

The operator applied for dismantling of plant components in unit B on 11 December 2014.[3] KRB-II-B was permanently shut down according to the Atomic Energy Act on 31 December 2017. The reactor was defueled. The fuel elements are located in the fuel element storage pool.

Unit C will lose its licence for power operations on 31 December 2021 at the latest.

RWE Nuclear GmbH was added to the licences granted under the Atomic Energy Act for the Gundremmingen nuclear power plant according to Section 7 Paragraph 1 of the Act on 8 December 2017 (15th amended licence). As a result, RWE Power AG has been released from any responsibility under the Atomic Energy Act.

Schleswig-Holstein

Krümmel nuclear power plant (KKK)

[3] After going to print: the first licence to decommission and dismantle Gundremmingen nuclear power plant was granted on 19 March 2019.

Krümmel nuclear power plant was the most powerful type 69 BWR. The facility was commissioned in 1983 with output measuring 1,316 MW_e. The reactor output was 1,402 MW_e at the end of its power operations.

Following a transformer fire in June 2007, the facility was shut down. After being briefly started up in June 2009, another short circuit occurred in a machine transformer. Since that time, KKK has been at a standstill.

As a result of the change in the Atomic Energy Act in 2011, the facility halted its power operations for good (cf. chapter 1.3.2). The reactor was defueled. Krümmel nuclear power plant is largely free of fuel elements. There are still 12 fresh fuel elements and 154 individual fuel rods in the spent fuel pool. 60 fuel elements are in the dry storage facility.

An application was made by the operator to decommission and dismantle Krümmel nuclear power plant on 24 August 2015. A scoping meeting was held on 27 June 2016 as part of conducting the environmental impact assessment. The application to decommission the facility was formulated more precisely on 29 September 2017. The dismantling of the reactor pressure vessel, the biological shield, other activated parts of the unit and areas surrounding the fuel element storage pool were also included.

An application was made on 13 December 2016 for a licence according to Section 7 of the Radiation Protection Ordinance to handle radioactive substances in a storage facility for radioactive waste and residual materials, which needs to be built.

The documents for both the aforementioned plans were exhibited between 24 July and 24 September 2018. The public hearing took place on 11 and 12 December 2018.

2.3 NUCLEAR POWER PLANTS UNDER DECOMMISSIONING

24 nuclear power plant units were under decommissioning in Germany during the year under review (cf. Table I.4 in Annex I). The thorium high-temperature reactor at Hamm-Uentrop is the last German nuclear power plant that is being operated in safe enclosure. The other nuclear power plants being dismantled with the objective of “green field”.

Baden-Württemberg

Neckarwestheim unit 1 nuclear power plant (GKN 1)

The Neckarwestheim 1 nuclear power plant is a second-generation PWR and was commissioned with output measuring 855 MW_e in 1976. The electrical reactor output amounted to 840 MW_e at the end. The facility was run down on 16 March 2011 on the instructions of the German government. The licence for power operation expired on 6 August 2011 when the Atomic Energy Act was amended (cf. chapter 1.3.2). The fuel elements were transported to unit II. The last transport operation took place in April 2018. Since then, the facility has been free of fuel elements and fuel rods.

The first decommissioning and dismantling licence was applied for on 24 April 2013. The decommissioning and dismantling licence for Neckarwestheim unit 1 was granted on 3 February 2017. This put an end to the post-operational phase. GKN 1 has been one of the facilities under decommissioning since then. Dismantling has started. The second dismantling licence was applied for in a letter dated 21 December 2017. The documents were exhibited publicly between 3 September and 5 November 2018.

The Environment Ministry in Baden-Württemberg granted the handling licences for low-level and intermediate-level radioactive waste at a new on-site storage facility and in a residual material processing centre at Neckarwestheim on 17 December 2018. The applications in line with Section 7 of the Radiation Protection Ordinance were made in April 2014.

Philippsburg unit 1 nuclear power plant (KKP 1)

The Philippsburg 1 nuclear power plant, like Isar 1, Brunsbüttel and Krümmel, is a type 69 boiling water reactor (BWR) and was commissioned in 1979 with output measuring 900 MW_e. The electrical output when the reactor was shut down in 2011 was 926 MW_e. The licence for power operations expired when the Atomic Energy Act was amended on 6 August 2011 (cf. chapter 1.3.2). All the fuel elements and fuel rods had been taken to the KKP on-site storage facility by the end of 2016. KKP 1 has been free of fuel elements and fuel rods since then.

An application for the first decommissioning and dismantling licence was made on 24 April 2013, according to Section 7 Paragraph 3 of the Atomic Energy Act. The decommissioning and dismantling licence for the Philippsburg unit 1 nuclear power plant was granted on 7 April 2017. This put an end to the post-operational phase. KKP 1 has been one of the facilities under decommissioning since then. Dismantling has started. The 2nd dismantling licence was applied for in a letter dated 21 December 2017.

The Environment Ministry in Baden-Württemberg granted the handling licences for low-level and intermediate-level radioactive waste at a new on-site storage facility and in a residual material processing centre

(RBZ-P) at Philippsburg on 17 December 2018. The applications in line with Section 7 of the Radiation Protection Ordinance were made in April 2014.

Karlsruhe multi-purpose research reactor (MZFR)

The multi-purpose research reactor with a heavy-water-cooled pressure vessel reactor (57 MW_e) was operated from 1965 until 1984. Apart from generating electricity, it also supplied heat to the Kernforschungszentrum Karlsruhe through its combined heat and power facility. After having been finally shut down, it was decided to dismantle the facility directly and completely. The spent fuel elements were reprocessed at the Karlsruhe Reprocessing Plant (WAK). Decommissioning has been taking place since then in the partial steps approved under the Atomic Energy Act (partial decommissioning licences).

The 8th decommissioning licence dated 31 January 2007 allowed the dismantling of the activated part of the biological shield, the dismantling of all the systems and equipment, decontamination and the dismantling of all the building structures. The remotely-operated dismantling work at the MZFR ended in 2011 with the demolition of the activated concrete. The work is now focusing on preparing the reactor building for demolition. The reactor building is being decontaminated and cleared while the structure is still standing.

Obrigheim nuclear power plant (KWO)

The Obrigheim nuclear power plant (KWO), a pressurised water reactor with output measuring 357 MW_e, went critical on 22 September 1968 for the first time and started power operations in 1969. After 36 years in service, KWO was finally shut down on 11 May 2005 after its licence for power operations expired according to Section 7 Paragraph 1a of the Atomic Energy Act.

Dismantling is due to take place in four independent licence stages. The nuclear fuel has been removed from the core. The fuel elements were transported to the Neckarwestheim on-site storage facility in 15 CASTOR® casks between 27 June and 19 December 2017. The facility has been free of nuclear fuel since then.

The first decommissioning and dismantling licence to finally and permanently halt operations was granted on 28 August 2008. Among other things, the 2nd decommissioning and dismantling licence, granted on 24 October 2011, regulates the dismantling of unit parts and assigned assistance systems in the control area (including the reactor cooling system and steam generator) and the operating procedures for continuing the decommissioning process.

The 3rd dismantling licence to demolish the lower part of the reactor pressure vessel, the reactor pressure vessel fittings, the biological shield and individual structural unit parts in the reactor building was granted on 30 April 2013. The dismantling of the reactor pressure vessel fittings has been completed. The lower part of the reactor pressure vessel has been demolished. The reactor basin has been dismantled and packaged. Work to demolish the biological shield and the fuel element pool is continuing at the moment.

The 4th and final dismantling stage was applied for on 3 November 2015 and approved on 14 May 2018. The licence covers the dismantling of residual structural, machine and electrical parts of the equipment, processing the residual materials that occur during this procedure and treating any radioactive waste that accrues. The dismantling work should include decontaminating buildings, parts of buildings, rooms, parts of rooms and other structural parts of the facility.

Karlsruhe compact sodium-cooled reactor (KNK II)

The KNK II experimental power plant was used to develop the breeder technology. The facility received a 21 MW_e sodium-cooled fast breeder reactor and was commissioned in 1977. The reactor was finally shut down after the experimental programme concluded on 23 August 1991.

The decommissioning concept envisages the dismantling of the unit in ten stages. The first licence for decommissioning the facility was granted on 26 August 1993. The unit has been free of nuclear fuel since 26 May 1994; it was initially transported to Cadarache (F) and is now kept in the North Storage Facility.

After the dismantling of the primary shielding was completed as part of the 9th decommissioning licence, the dismantling of the biological shield is now being prepared. The existing enclosure was dismantled and replaced by a dismantling caisson (protective housing). The first start-ups of the equipment are already taking place. The training and testing programme to dismantle the biological shield is also in progress.

The 10th decommissioning licence was applied for in April 2016. This regulates the dismantling of the remaining parts of the unit and the demolition of buildings. The documents are being examined.

The goal of decommissioning is to release the unit from the Atomic Energy Act and create a “green field”.

Bavaria

Gundremmingen Unit A nuclear power plant (KRB A)

The Gundremmingen A unit (BWR) was commissioned with output measuring 250 MW_e in August 1966. Typical of this facility was an internal water/steam separating and steam-drying facility in the reactor, which was used in a BWR for the first time. Following an incident in 1977, the operator decided in 1980 to no longer repair the unit for economic reasons, but shut it down for good. The last fuel elements had been removed from the facility by 1989 and were taken for reprocessing. The decommissioning licence according to Section 7 Paragraph 3 of the Atomic Energy Act was granted on 26 May 1983. The complete dismantling work of the facility is taking place in three phases on the basis of the licences granted under the Atomic Energy Act. The dismantling work is well advanced. The systems and components in the machine building and reactor building, which are no longer required, have been dismantled. The reactor building has been decontaminated, but has not yet been released from supervision under the Atomic Energy Act.

The former technical building (without the reactor building) in unit A has been used as a technology centre since 1 January 2015. Decontamination work and waste treatment work for the two units – KRB-II-B and KRB-II-C – are being performed there.

A change in the co-licence ownership was applied for according to Section 7 of the Atomic Energy Act Paragraph 1 for Gundremmingen nuclear power plant on 31 July 2017 and was approved on 8 December 2017. RWE Nuclear GmbH was added as one of the licence holders to the licences granted under the Atomic Energy Act for the Gundremmingen nuclear power plant according to Section 7 Paragraph 1 of the Act (15th amended licence). As a result, RWE Power AG has been released from any responsibility under the Atomic Energy Act.

Isar Unit 1 nuclear power plant (KKI 1)

The Isar I nuclear power plant is a type 69 BWR and was commissioned in 1977 with electrical output measuring 907 MW_e. The final electrical reactor output measured 912 MW_e. KKI 1 has been permanently shut down since 17 March 2011. The licence for power operations expired when the Atomic Energy Act was amended on 6 August 2011 (cf. chapter 1.3.2). The reactor core has been completely defueled and the fuel elements are located in the storage pool.

An application to decommission and dismantle KKI 1 according to Section 7 Paragraph 3 of the Atomic Energy Act was made on 4 May 2012. The 1st decommissioning and dismantling licence for the Isar unit 1 nuclear power plant was granted on 17 January 2017. This put an end to the post-operational phase and KKI was transferred to the decommissioning phase. The licence was challenged in the courts. The legal challenge from BUND Naturschutz in Bayern e.V. on 8 February 2017 against the decommissioning and dismantling licence was rejected by the 22nd Senate of the Bavarian Administrative Court in its ruling on 20 December 2018.

Loading operations are currently continuing with the aim of removing the fuel elements from the fuel element storage pool. An application for a licence to handle radioactive substances in the transport preparation building according to Section 7 of the Radiation Protection Ordinance" was made for the Isar site on 12 April 2018.

The licence holder changed on 1 July 2016 through the change of operating name at E.ON Kernkraft GmbH. The current licence holder for KKI 1 is PreussenElektra GmbH (PE).

Grafenrheinfeld nuclear power plant (KKG)

The Grafenrheinfeld nuclear power plant is a third-generation PWR (pre-convoy unit) and was commissioned in 1981 with output measuring 1,299 MW_e. The reactor output was finally 1,345 MW_e and this resulted from two electrical capacity increases.

The operator applied to decommission and dismantle the facility on 28 March 2014. The unit had already been removed from the grid early by the operator on 27 June 2015. The 1st decommissioning licence according to Section 7 Paragraph 3 of the Atomic Energy Act was granted on 11 April 2018. BUND Naturschutz in Bayern e. V. challenged this licence in the courts on 4 June 2018.

The Grafenrheinfeld nuclear power plant is in the first of two dismantling phases. The reactor has been defueled and the fuel elements have been taken to the fuel element storage pool. Work to load the fuel elements into CASTOR® casks is taking place and transport the units to the on-site storage facility for fuel elements at the moment. A start was made on building the planned transport preparation building for low-level to intermediate-level residual materials in July 2018.

The licence holder changed on 1 July 2016 through the change of operating name at E.ON Kernkraft GmbH. The current licence holder for KKG is PreussenElektra GmbH (PE).

Brandenburg

Rheinsberg nuclear power plant (KKR)

The Rheinsberg nuclear power plant with output measuring 70 MW_e (WWER reactor type) went into service in 1966. It was used for the own reactor development work in the GDR. The generated electrical power was fed into the national grid. The facility was finally shut down in 1990 after 24 years. The site has been free of nuclear fuel since 9 May 2001; the fuel elements were taken to the North Storage Facility. There are plans to dismantle the facility completely. The 1st decommissioning licence was granted on 28 April 1995. The decommissioning work is being gradually completed in partial stages with the appropriate licences.

The reactor pressure vessel was transported to the North storage facility near Greifswald on 30 October 2007. This has significantly reduced the activity inventory at the facility.

The operator applied for the issue of a modification licence I/95 on 3 July 2013 to decommission and partly dismantle KKR according to Section 7 of the Atomic Energy Act. This deals with the concept of long-term storage. The operator withdrew the application in a letter dated 22 September 2015. A revised concept to further dismantle KKR was presented to the licensing authority on 27 August 2015. EWN submitted the "concept for the ongoing procedure" in a letter dated 13 January 2016. This envisages completing the direct demolition work by 2025.

The core removal from the different rooms in the reactor building and the building for special water processing is taking place at the moment. Further demolition work on the infrastructure in the hot cell occurred during the reporting period. Decontamination work to eliminate hot spots in the special drainage system is continuing at the moment.

Hesse

Biblis nuclear power plant - units A (KWB A) and B (KWB B)

The Biblis A and B units are two of the eight nuclear power plants that had to finally halt their power operations based on the amendment to the Atomic Energy Act in 2011 (cf. chapter 1.3.2).

Biblis A with a second-generation PWR was commissioned with output measuring 1,204 MW_e in 1974. The final electrical reactor output was 1,225 MW_e. Biblis nuclear power plant was designed as a double-unit plant. Unit B, also a second-generation PWR, began operating in 1976 with electrical output measuring 1,300 MW_e. This output was the same to the end of its working life. Applications in line with the Atomic Energy Act (Section 7 Paragraph 3) to decommission and dismantle units A and B at Biblis were made on 6 August 2012. The 1st decommissioning and dismantling licence for Biblis nuclear power plant units A and B was granted on 30 March 2017. This ended the post-operational phase and started the decommissioning phase. BUND Hessen e.V. contested the licence for unit A in the courts. The licence holder declared that it was using the licences on 1 June 2017.

Applications were made for further licences for both nuclear power plant units according to Section Paragraph 3 of the Atomic Energy Act on 22 January 2018. The applications related to dismantling the reactor pressure vessel, the biological shield and the equipment to enclose the outer security area.

The primary cycle decontamination has been completed for both units.

Preparations to remove the steam generators are taking place at the nuclear power plant site at the moment. There are plans to partially dismantle them on site. EWN will then further dismantle them at Lubmin at a later date. The current dismantling work involves creating the demolition infrastructure.

Unit A has been free of nuclear fuel since November 2016. The same occurred at unit B on 23 September 2018. The fuel elements were taken to the Biblis on-site storage facility. The faulty rods still in unit B are due to be loaded into CASTOR® casks during the 2nd quarter of 2019 and taken to the on-site storage facility.

The licence to build a storage facility for radioactive waste and residual materials from operating and decommissioning KWB (LAW store 2) was granted according to Section 7 of the Radiation Protection Ordinance for the temporary storage of low-level and intermediate-level radioactive waste that accrues during the dismantling work at the nuclear power plant site on 5 April 2016. Construction work started in October 2016. The storage facility is due to go into service in 2019.

An application to change the owner of the Biblis nuclear power plant was made on 31 July 2017 according to Section 7 Paragraph 1 of the Atomic Energy Act and approved on 15 December 2017. RWE Nuclear GmbH has taken over the licences under the Atomic Energy Act and RWE Power AG has been released from any responsibility under the Atomic Energy Act since the beginning of 2018. Because the nuclear energy operations at RWE Power AG have been effectively hived off, RWE Nuclear GmbH has been the sole licence and facility owner at the Biblis nuclear power plant since April 2018.

Mecklenburg-Vorpommern

Greifswald nuclear power plant, unit 1 – 5 (KGR)

Greifswald nuclear power plant was built based on a decision by the government of the former GDR in 1955 to use nuclear energy to generate electric power. Of the eight PWR units at KGR, each producing 440 MW_e (Russian WWERs – reactor W-230 and W-213), unit 1 went into service in 1973. Units 2 – 4 were commissioned in 1974, 1977 and 1979. Units1 – 4 were shut down in 1990 after a safety review by GRS (Gesellschaft für Anlagen- und Reaktorsicherheit mbH) and the State Board for Atomic Safety and Radiation Protection (SAAS) in the former GDR. It was also decided to decommission unit 5, which went critical for the first time in 1989 and the supervisory body at the time, SAAS, interrupted the start-up. Unit 5 is connected to unit 6 through the double-unit design. Units 6 – 8 were still being built then (cf. chapter 2.5 too).

Greifswald nuclear power plant has been free of nuclear fuel since 22 May 2006.

The 1st licence to decommission the complete facility and dismantle parts of it was granted according to Section 7 Paragraph 3 of the Atomic Energy Act on 30 June 1995. More licences and modification licences to decommission and dismantle the unit have been granted since then. EWN GmbH applied according to Section 7 Paragraphs 1 and 3 of the Atomic Energy Act on 8 July 2016 to dismantle structural parts of the North II waste air chimney that are no longer required (units 3 and 4) and the air duct between the special building 2 and chimney 2. The licence was granted on 9 May 2018. A further application for the issue of a licence to decommission and dismantle/demolish the structural parts of the North II special building, including the linking bridge to the North II apparatus building and the filling point/rotation thin-layer evaporator unit (GA08.7), was made in a letter dated 5 June 2018.

EWN applied for the licence to dismantle the building according to Section 12 of the Radiation Protection Act in a letter dated 28 September 2018. Large components from the dismantling work at the Greifswald and Rheinsberg nuclear power plants will be broken up in the future dismantling building and packaged so that they are ready for disposal.

Lower Saxony

Stade nuclear power plant (KKS)

Stade nuclear power plant, a PWR with output measuring 672 MW_e, operated between 1972 and 2003. It was finally shut down on 14 November 2003. The operator at the time, E.ON, applied to directly dismantle the facility in a letter dated 23 July 2001. The fuel elements were transported to France for reprocessing at the end of April 2005. The demolition work is planned in five phases. Phase four was approved on 4 February 2011 – this involves the ongoing demolition of the facility and measures to clear buildings and ground surfaces. Demolition and waste management work took place during the year under review. A crane was installed in the containment section and it will help dismantle the inner building structures in the safety vessel. The dismantling of the old reactor building crane started during the year under review.

Contamination was discovered on the floor of the containment section during the dismantling work in January 2014. It is assumed that this contamination stems from the power operational phase. The find meant that the relevant concrete area cannot not be cleared through removal of contaminants from the existing building structure after general decontamination, but must be dismantled. Depending on the level of activity, the building rubble will have to be disposed of as radioactive waste or cleared for elimination at waste tips or without any restrictions according to Section 29 of the Radiation Protection Ordinance. A concept on how to proceed has been submitted.

Lingen nuclear power plant (KWL)

The Lingen plant, a BWR with output measuring 252 MW_e, was commissioned in 1968. The facility was shut down in January 1977 after 9 years of power operations because of damage to the steam converters in order to insert new units. Further serious damage was discovered and the operator decided in March 1979 to decommission the nuclear part and use the existing steam turbine with a high-temperature gas turbine powered by natural gas that would be newly installed. Based on the licence dated 21 November 1985, the facility has been operated in safe enclosure (SE) since 1988. The fuel elements were transported to Sellafield (GB) before the start of SE operations. The adjacent Emsland nuclear power plant has been monitoring the SE.

Kernkraftwerk Lingen GmbH announced in December 2007 that it had withdrawn the application to continue the safe enclosure operations. The operator applied to dismantle the facility according to Section 7 Paragraph 3 of the Atomic Energy Act on 15 December 2008. Dismantling of the remaining facility is due to take place in three partial projects. The licence for the first approval stage (partial project 1) to dismantle the Lingen nuclear power plant was granted on 21 December 2015. It covers the dismantling of all the non-contaminated and contaminated parts of the facility, if they are not required for the ongoing dismantling operations and further demolition. A second licensing stage (partial project 2), to be applied for later, is due to cover the dismantling of the reactor pressure vessel and its fittings, the biological shield, the residual demolition work,

decontamination and the release of the facility from supervision under the Atomic Energy Act. The third partial project covers the conventional demolition of the building. The removal of the steam generators is being prepared.

RWE Nuclear GmbH has become party to the licences under the Atomic Energy Act since the start of 2018 and RWE Power AG has been released from its responsibilities under the same act. The operator of KWL, Kernkraftwerk Lingen GmbH, is a subsidiary of RWE Nuclear GmbH.

Unterweser nuclear power plant (KKU)

Unterweser nuclear power plant was commissioned with output measuring 1,300 MW_e in 1978. It is a second-generation PWR unit. Its electrical reactor output was 1,410 MW_e at the end. Power operations expired on 6 August 2011 through the 13th amendment to the Atomic Energy Act (cf. chapter 1.3.2). The fuel elements were removed from the reactor core and have been stored at the on-site storage facility. The power plant is therefore free of fuel elements. The waste management of fuel element rods still in the plant is continuing.[4]

An application to decommission and dismantle KKU was made according to Section 7 Paragraph 3 of the Atomic Energy Act on 4 May 2012 and it was supplemented in a letter dated 20 December 2013 that the dismantling of KKU should start with fuel elements still in the facility. The 1st licence notice for the Unterweser nuclear power plant for decommissioning and dismantling (I/2018) was granted on 5 February 2018. The licence covers the permanent and final halting of power operations as well as measures for the remaining operations.

An application according to Section 7 of the Radiation Protection Ordinance to build a storage facility for radioactive waste to accommodate low-level and intermediate-level radioactive waste was made to the state authority on 20 June 2013. The licence notice was granted on 5 December 2018. The storage facility is due to have been built by October 2019 and then start operating.

Due to the change in operating name at E.ON Kernkraft GmbH, the licence holder changed on 1 July 2016. The current licence holder for KKU is PreussenElektra GmbH (PE).

North Rhine-Westphalia

Experimental nuclear reactor (AVR)

The AVR experimental nuclear reactor was an experimental reactor that was exclusively developed in Germany. It was commissioned in 1966 with its 15 MW_e pebble-bed, high-temperature reactor (HTR) and helped the development work, which had begun in Germany, on this type of reactor with ball-shaped fuel elements made of graphite, in which coated particles with uranium and thorium were located. It was finally shut down at the end of 1988 when the THTR-300 prototype reactor (308 MW_e) in Hamm-Uetrop was decommissioned, marking the end of development work on this technology in Germany. During its operating period, the AVR fed about 1,500 GWh of electrical energy into the public grid. The licence to decommission, defuel the reactor core, dismantle parts of the facility and create safe enclosure was granted on 9 March 1994. The defueling of the ball fuel elements into the central interim storage facility on the site of the Jülich Research Centre was completed in June 1998, apart from no more than 197 remaining items. The remaining ball fuel elements cannot be recovered at a reasonable cost and with adequate radiation protection measures until the reactor vessel has been dismantled.

After EWN GmbH took over what was then AVR GmbH in 2003, the operator decided to change the dismantling concept. Safe enclosure was ended and an application was made for direct demolition. The licence to fully demolish the plant was granted on 31 March 2009. The reactor vessel was removed from the reactor building and transported to the reactor vessel storage facility built at the site on 23 May 2015. The licence to operate the storage facility was granted on 1 March 2010. This storage facility is exclusively used to store the AVR reactor vessel and is designed for storage lasting between 30 and 60 years.

The dismantling work for components in the primary circuit has been completed. The preparations for the concrete dismantling work in the protection vessel are well advanced. A demolition robot will be used for the dismantling work.

Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN) was founded on 1 September 2015. It now handles the nuclear departments at the Jülich Research Centre and Arbeitsgemeinschaft Versuchsreaktor (AVR) GmbH.

[4] Entry after going to print: the Unterweser nuclear power plant has been clear of nuclear fuel since 21 February 2019.

Würgassen nuclear power plant (KWW)

The Würgassen nuclear power plant, a boiling water reactor with output measuring 670 MW_e, operated between 1971 and 1994. Because of the cracks found on the reactor's core shroud during a scheduled overhaul, the operator decided to decommission the facility for good. It has been free of nuclear fuel since October 1996; the fuel elements were taken to La Hague (F) for reprocessing.

The 1st decommissioning licence was granted on 14 April 1997. Another three decommissioning licences have been granted for the plant since then. The nuclear demolition work was successfully completed in 2014. The clearance procedure according to Section 29 of the Radiation Protection Ordinance for the control area buildings and parts of the operating site continued during the year under review. Storage operations for radioactive waste – exclusively low-level and intermediate-level radioactive waste from the demolition and operations at the facility – also continued. The technical infrastructure has been adapted to the requirements.

Hamm-Uentrop thorium high-temperature reactor (THTR-300)

The THTR-300, equipped with a helium-cooled, pebble-bed, high-temperature reactor (308 MW_e), went into service in 1983. A decision to finally decommission the facility was taken in 1989, after it had been shut down for its scheduled annual overhaul on 29 September 1988. The German government, the state of North Rhine-Westphalia, the HKG operating company and its shareholders signed a general agreement to phase out the remainder of the THTR-300 project on 13 November 1989. The 1st partial licence for decommissioning, defueling the reactor core and dismantling parts of the facility was granted on 22 October 1993. Since that time, the ball fuel elements have been removed from the reactor core and taken to the Ahaus fuel element storage facility in CASTOR® casks. The reactor core has been defueled since 1995. The licence to operate "safe enclosure" (maintenance operations) was granted on 21 May 1997. The facility has been in safe enclosure mode since October 1997 and this is envisaged to last for a period of approx. 30 years.

Rhineland-Palatinate

Mülheim-Kärlich (KMK)

The Mülheim-Kärlich nuclear power plant, a PWR with output measuring 1,302 MW_e, went into service in March 1986. After the Federal Administrative Court cancelled the 1st partial licence, it has been shut down since 9 September 1988.

RWE Power AG had withdrawn the applications according to Section 7 of the Atomic Energy Act for the issue of the 1st partial licence to construct and operate KMK, if they had not been approved, and the partial licence for permanent operations in letters dated 21 June 2001. The spent fuel elements were transported to La Hague (F) for reprocessing. New fuel elements, which were set to refuel the reactor, were returned to the manufacturer in Belgium.

The demolition of the KMK facility is taking place in three independent stages. Stage 1 covers the final decommissioning of the facility. Stage 2 will involve the dismantling of the equipment in the primary circuit. Stage 3 envisages the release of the buildings and the site from the Atomic Energy Act. The demolition of the released buildings will then take place according to building law regulations.

The demolition measures continued in the year under review based on the licence granted on 16 July 2004 for demolition phase 1a and the modification licence for licence 1a granted on 23 February 2006.

The application for demolition phase 2b to demolish the two steam generators, the reactor pressure vessel with its core fittings and the activated areas in the biological shield received a positive response on 8 October 2015. The dismantling of the steam generators started in October 2018. It is planned to disassemble them in the control area.

The notification dated 31 January 2014 according to Section 7 Paragraph 3 of the Atomic Energy Act regulates the release and clearance of floor areas and the equipment located on them (licence 3c). Based on the "3a East" and "3b West" licences, which have now been completed, the facility's site was reduced to a size of 6 ha. This area is required for the ongoing demolition of the rest of the unit. A final licence under the Atomic Energy Act 3d is designed to regulate the clearance of the buildings in the control area and release the site from supervision under the act.

An application was made on 31 July 2017 to change the co-licence ownership according to Section 7 Paragraph 1 of the Atomic Energy Act for the Mülheim-Kärlich nuclear power plant; it was approved on 8 November 2017. RWE Nuclear GmbH has become party to the licences under the Atomic Energy Act since the beginning of 2018 and RWE Power AG has been released from any responsibility under the same act.

Schleswig-Holstein

Brunsbüttel nuclear power plant (KKB)

Brunsbüttel nuclear power plant, the oldest type 69 BWR unit, obtained its 1st operating licence on 22 June 1976. The reactor output of 806 MW_e was not changed since it went into service.

Brunsbüttel is one of the eight nuclear power plants in Germany that were finally shut down because of a change to the German Atomic Energy Act in 2011 (cf. chapter 1.3.2). The facility is free of any nuclear fuel.

The Schleswig-Holstein Ministry Energy granted the licence to decommission and dismantle KKB in response to the application dated 1 December 2012 according to Section 7 Paragraph 3 of the Atomic Energy Act on 21 December 2018. The dismantling of the reactor pressure vessel is being prepared as part of the disposal work.

An application to handle radioactive substances in a storage facility for radioactive waste and residual materials, which will be built, was made in line with Section 7 of the Radiation Protection Ordinance on 5 May 2014.

2.4 NUCLEAR POWER PLANTS RELEASED FROM THE ATOMIC ENERGY ACT

Three nuclear power plants in Germany have been completely dismantled so far and released from supervision under the Atomic Energy Act. Annex I, Table I.5 lists the major data on these facilities.

Bavaria

Grosswelzheim super-heated steam reactor (HDR)

The Grosswelzheim super-heated steam reactor with output measuring 25 MW_e served as the prototype and experimental plant for developing this reactor design and was commissioned in 1969. After only 18 months in operation, it was finally shut down because of distortion on the cladding tubes on the new kind of boiling water super-heater fuel elements. The spent fuel elements were reprocessed at WAK. The reactor building and the fitted systems were used to perform non-nuclear experiments on the behaviour of nuclear power plant equipment in severe accidents (e.g. earthquakes) between 1974 and 1991. Approval to decommission the reactor was given on 16 February 1983. The facility has been completely dismantled.

It was released from the Atomic Energy Act in mid-May 1998. The remaining dismantling work of a conventional nature had been completed by mid-October 1998.

Niederaichbach nuclear power plant (KKN)

The Niederaichbach nuclear power plant, a prototype power plant with output measuring 106 MW_e, stood out because it used natural uranium and a heavy-water-moderated pressure tube reactor with CO_2 gas cooling. The pressure tube system sought to prevent the need for any thick-walled pressure vessels for LWR reactors and use reactors of almost any size.

The licence to start operations was granted on 11 December 1972. The reactor first went critical on 17 December 1972. Technical problems and the design of the light water reactor, which had already been implemented at this time, contributed to the owner's decision to shut down the reactor for good. Development work on this reactor type therefore came to an end. The decommissioning of KKN was decided when it was shut down on 31 July 1974. The nuclear power plant therefore only operated at full power for 18.3 days. The licence to transfer the unit to safe enclosure was granted on 21 October 1975 and the licence for "safe enclosure" was granted on 20 October 1981. The fuel elements were transported to CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives) in France. The complete demolition of the facility was approved on 6 June 1986. The decommissioning of KKN was completed on 17 August 1995 and the nuclear power plant was released from the Atomic Energy Act. The ground slabs in the reactor and the tomb building have remained in the soil, as it would have been necessary to lower the groundwater to fully remove them. The remaining floor slabs and underground pipes have been removed. This was the first nuclear power plant in the world with notable capacity to have been decommissioned so that the site could be handed over as a "green field". This enabled Germany to demonstrate for the first time the feasibility of completing complete technical disposal and the associated licence procedure under the Atomic Energy Act.

Kahl experimental power plant (VAK)

The Kahl experimental nuclear power plant with 16 MW_e was the first nuclear power plant to generate electrical power in Germany. It went into service in 1960. The facility was shut down in 1985 because the operator indicated that all the envisaged scientific and operational experiments had been completed. The 1st partial decommissioning licence was granted in a notification dated 5 May 1988. The fuel elements had been removed from the unit by 1989 and were taken to Karlsruhe (WAK) for reprocessing. Spent MOX fuel elements, which could not be reprocessed at WAK, were transported to Sweden to be stored and kept at the Central Interim Storage Facility for Spent Fuel Elements (CLAB).

The buildings and the plant site were released from supervision under the Atomic Energy Act on 17 May 2010. The dismantling activities involving conventional demolition work were completed on 24 September 2010.

2.5 NUCLEAR POWER PLANT PROJECTS HALTED

Below is a list of nuclear power plant units that were planned, but their completion was halted after building work had started. Table I.5 in Annex I provides a list of these projects.

Mecklenburg-Vorpommern

Greifswald (KGR) nuclear power plant, Units 6 - 8

The building and assembly work on units 6 – 8 (440 MW_e, Russian design PWR – WWER, reactor W-213) at Greifswald nuclear power plant was halted in 1990.

Unit 6 is used for visitor tours as a technical exhibition to demonstrate the reactor technology. The turbine building in units 5 – 8 was completely cleared and is being used for industrial purposes now (cf. chapter 2.3 too). Non-contaminated equipment from units 7 and 8 was transported to unit 5 and dismantled there. Tools and equipment for remotely dismantling reactor components were tested there.

North Rhine-Westphalia

Kalkar sodium-cooled fast breeder reactor (SNR 300)

The SNR 300 with output measuring 327 MW_e, a sodium-cooled fast breeder reactor, was built between 1973 and 1991, largely completed and prepared for operations. Even before the fuel elements that had been manufactured were inserted, a decision was made in 1991 to forego starting the plant. The systems that had been built were subsequently dismantled, scrapped or sold. The site was handed over to Kern-Wasser-Wunderland Freizeitpark GmbH by transfer of ownership on 1 April 1996 and has been commercially used since then. The fuel elements were initially kept in state custody by the Federal Office for Radiation Protection and later transported to France for processing.

Saxony-Anhalt

Stendal nuclear power plant

Construction of a nuclear power plant with four units was planned near Stendal. A decision was taken in 1979 to build pressure water reactors of the Russian WWER design, each with output measuring 1,000 MW_e, at the site. The former State Board for Atomic Safety and Radiation Protection in the GDR (SAAS) granted the 1st construction licence for two units on 10 September 1982. The building and assembly work that was started on units A and B at the Stendal nuclear power plant was halted in 1990 after delays lasting several years. Some of the buildings and facilities were demolished or are being used elsewhere.

3 RESEARCH REACTORS

Research reactors are nuclear facilities that are not used to generate electricity commercially. They are used for scientific experiments at research centres and universities etc.

In the Federal Republic of Germany altogether 46 research reactors have to be considered of which currently (correct on 31 December 2018):

7 research reactors in operation,

3 research reactors finally shut down,

7 research reactors decommissioned and

29 research reactors where decommissioning has been completed. They have been released from the Atomic Energy Act.

The following chapters contain information about German research reactors in line with their operational and licence status. The most important information on German research reactors are listed in the tables in Annex II. Figure II provides a summary of the sites where units still exist.

3.1 RESEARCH REACTORS IN OPERATION

Altogether seven research reactors in all were in operation in Germany (as on 31 December 2018).These include three research reactors with a continuous thermal power output of more than 50 kW_{th} and four training reactors (homogeneous zero power reactors) with a continuous thermal power output of no more than 2 W_{th}. The most important data on the research reactors operating can be found in Annex II, Table II.1, in addition to the following information.

Berlin experimental reactor II (BER II)

The BER II is a pool-type reactor with MTR fuel elements. The thermal output measures 10 MW_{th} and the thermal neutron flux is approx. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor was commissioned on 9 December 1973 and is mainly used for pure and applied research with beamline experiments and to generate radioactive isotopes.

Extensive expansion work on the unit took place between 1985 and 1989 to double the original thermal output from 5 MW_{th} to 10 MW_{th} and increase the thermal neutron flux almost ten-fold to approx. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. To reduce proliferation risk BER II was converted from high-enriched (HEU) to low-enriched uranium (LEU). Permission was granted on 14 June 1994 to operate BER II with LEU fuel elements or during transition period with mixed HEU and LEU fuels. Following a series of mixed fuel loads, a purely LEU core was built up for the first time and commissioned on 7 February 2000.

In the year 2018 the reactor was in normal operation. After the operator applied to decommission and dismantle the Berlin experimental reactor BER II on 24 April 2017, further preparations for this were continued in 2018. Two status meetings were held with the licensing and supervising authority, where the major process sequences were discussed for the decommissioning licence procedure. The authority also requested to conduct an environmental impact assessment according to the Environmental Impact Assessment Act to decommission and dismantle BER II and suggested furthermore that public participation should be initiated. A dialogue group was formed consisting of representatives from local politics, initiatives and environmental associations, local residents and representatives of the Helmholtz Centre in Berlin. The dialogue group's discussions have been taking place regularly since the spring of 2018. The research reactor will be finally shut down by 31 December 2019.

Revision of the operator documents for periodical safety review and participation in a topical peer review from WENRA (Western European Nuclear Regulators Association) on the subject of aging management continued in 2018.

Munich high-flux neutron source in Garching (FRM-II)

The FRM-II is the newest research reactor commissioned in Germany. It is a light-water-cooled pool-type reactor with a compact core with highly enriched uranium (HEU) as its fuel and heavy water as the moderator. With a thermal neutron flux of $8 \cdot 10^{14}$ $1/cm^2 \cdot s$, the unit is the most intensive German neutron source for beamline experiments and radiation for scientific, industrial and medical purposes – with a comparatively low thermal output of 20 MW_{th}.

The nuclear commissioning and operation at the unit were regulated by the operating licence granted on 2 May 2003. The reactor went critical for the first time on 2 March 2004. Routine operations with the unit started on 25 April 2005.

Based on the operating licence dated 2 May 2003 and an agreement between the federal government and the Free State of Bavaria, it was originally intended to convert the reactor from HEU to a fuel with a reduced

degree of enrichment of no more than 50% uranium-235 (MEU) by 31 December 2010 at the latest. However, due to unexpected delays in the international technical/scientific development of new high-density fuels, it was impossible to meet this target. An adaptation of the original federal/state agreement from 30 May 2003 was made on 22 October 2010 and this now stipulated conversion by 31 December 2018 at the latest. It has not yet been possible to practically conduct the conversion work. A new agreement is currently being prepared between the federal government and the state of Bavaria.

In the year 2018 the plant was in normal operation. During a maintenance break from 7 October 2017 until 22 January 2018, a plug on beamline 6 was replaced in addition to changing the fuel element and conducting inspection works. The new modified protection plug is required for the planned ultra-cold neutron source to connect the neutron conductor to the experiments.

Checks on operator documents regarding periodical safety reviews and participation in WENRA's topical peer review on the subject of aging management continued in 2018.

TRIGA Mark II research reactor at the University of Mainz (FRMZ)

The FRMZ is a TRIGA Mark II open pool-type reactor. It is a light-water-cooled and moderated reactor with homogenous fuel moderator elements consisting of LEU and zirconium hydride. Nuclear commissioning of the unit was on 3 August 1965. The thermal output in continuous operations measures 100 kW_{th} and the thermal neutron flux $4 \cdot 10^{12}$ 1/cm^2•s. The reactor can also be operated with a peak output of 250 MW_{th} in pulsed operations for 30 ms and a thermal neutron flux of $8 \cdot 10^{15}$ 1/cm^2•s. The unit is operated for nuclear physical research purposes and is particularly suitable for investigating short-lived radionuclides with rabbit systems because of the high neutron flux density that can be obtained for short periods with pulsed operations.

An extensive modification of the reactor's circuits was performed on the basis of a licence dated 28 July 1992.

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

In the year 2018 the reactor was in normal operation. The FRMZ voluntarily took part in WENRA's topical peer review on the subject of aging management. The process started in 2017 and continued in 2018.

Nuclear training reactor at Dresden University of Technology (AKR-2)

The AKR-2 is a homogenous, solid-moderated, zero-power reactor. The fuel plates consist of a homogenous mixture consisting of low-enriched uranium oxide (enrichment < 20% U-235) as the fuel and polyethylene as the moderator material. The reactor core is surrounded by a reflector made of graphite. The maximum thermal output during continuous operations is 2 W_{th} and the thermal neutron flux is approx. $3 \cdot 10^7$ 1/cm^2•s. The AKR-2 was commissioned on 22 March 2005 and replaced the old AKR-1 unit, which was operated at Dresden University of Technology from July 1978 until March 2004. The AKR-2 is mainly used for training and teaching purposes, but is also a tool for research work on domestic and international projects.

In the year 2018 the reactor was in normal operation.

Siemens training reactors (SUR) 100

There are still three Siemens training reactors operating in Germany (at Furtwangen, Stuttgart and Ulm). The reactor core in the SUR units consists of U_3O_8 with low-level U-235 enrichment (< 20%) as a fuel and polyethylene is used as the moderator. Both materials are pressed together in cylindrical fuel plates in the form of a homogenous mixture. A graphite reflector surrounds the reactor core on all sides. The SUR units were mainly commissioned in Germany in the 1960s and 1970s. The thermal reactor output measures 100 mW_{th} and the thermal neutron flux in the central experimental channel is normally $5 \cdot 10^6$ 1/cm^2•s. The details can be found in Table II.1. The SUR units are mainly used as practical training devices for instruction and teaching in the field of nuclear technology.

In the year 2018 all SURs were in normal operation.

3.2 RESEARCH REACTORS FINALLY SHUT DOWN

Three research reactors were registered under the heading "Finally shut down" on 31 December 2018. No decommissioning licence had been granted for these reactors yet. The main data on these reactors is listed in Table II.2 in Annex II of the report.

Geesthacht 1 research reactor (FRG-1)

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

FRG-1 was originally used to conduct research into nuclear ship propulsion. It was mainly deployed for material research with beamline experiments as well as isotope production and conducting neutron activation analyses at a later date.

The FRG-1 was operated with the new FRG-2 reactor in a joint reactor building, but different operating pools from 1963 onwards. Because a joint operating licence was granted later on 6 September 1967, both reactors should be viewed as one reactor unit in licence terms; this also applied even after the issue of the licence to take the unit out of service and dismantle parts of the FRG-2 on 17 January 1995 (see FRG-2 section).

FRG-1 was continually upgraded during the course of its 40 operating years. Conversion from HEU to LEU occurred in February 1991 on the basis of a modification licence dated 4 May 1988 – a first for a German research reactor. In addition to reducing the proliferation risk, it was possible to increase the thermal neutron flux by using much denser fuel.

The FRG-1 was finally shut down on 28 June 2010. Since that time, the unit has been in its post-operational phase under its ongoing valid operating licence. The final spent fuel elements were shipped to the USA on 24 July 2012. The reactor has been free of nuclear fuel since the end of July 2012. The experimental devices at the research reactor have been taken to Delft (Netherlands) and St. Petersburg (Russia) for further use on research units.

An application to decommission and dismantle FRG-1 and the research reactor unit (consisting of FRG-1 and unit parts that still existed from FRG-2) and release the unit from supervision under the Atomic Energy Act was made on 21 March 2013. The dismantling of the research reactor is set to take place under a single decommissioning and dismantling licence according to Section 7 Paragraph 3 of the Atomic Energy Act. The application to decommission the FRG-1 research reactor and dismantle the research reactor unit and the hot laboratory was submitted in greater detail on 6 September 2016. The public hearing took place on 21 March 2017. The reactor pressure vessel from the nuclear vessel “Otto Hahn”, which is stored at the research centre site, was included in the procedure when submitting the decommissioning application in greater detail and is to be dismantled in a building that still needs to be built. The procedure is already well advanced. Licence documents are currently being examined or revised.

An application was made for the issue of a licence according to Section 7 of the Radiation Protection Ordinance to handle radioactive materials to operate a storage facility for low-level and intermediate-level radioactive waste (transport preparation building) at the site of the research reactor on 6 September 2016.

Geesthacht 2 research reactor (FRG-2)

FRG-2 like FRG-1 is an open pool-type MTR reactor; the thermal output was 15 MW_{th} and the maximum thermal neutron flux was approx. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. It was commissioned as a material testing reactor on 16 March 1963 and used for irradiation tests to further develop nuclear power plant components and reactor safety.

The FRG-2 was operated with FRG-1 in a joint reactor building, but with different reactor pools. Since a joint operating licence came into force on 6 September 1967, both the reactors were viewed as one reactor from a licensing point of view. This licence also allowed an increase in the thermal output of FRG-2 from 5 MW_{th} to 15 MW_{th}. The reactor was operated continually with HEU during its 30-year operating period.

Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH (GKSS) applied to take FRG-2 out of service on 28 January 1993 because of the decline in orders for material tests with irradiation in agreement with the Federal Ministry for Research and Technology (now the Federal Ministry of Education and Research) and industry – and partially dismantle the reactor. The licence was granted on 17 January 1995. The fuel elements had been transported to the USA by 20 September 2000.

An application to decommission and dismantle FRG-1 and the research reactor unit (consisting of FRG-1 and the parts of FRG-2 that still existed) and release the unit from supervision under the Atomic Energy Act was made on 21 March 2013. The dismantling of the research reactor unit is due to take place through a single decommissioning and dismantling licence according to Section 7 Paragraph 3 of the Atomic Energy Act. The application to decommission the FRG-1 research reactor and dismantle the research reactor unit and the hot laboratory were submitted in greater detail on 6 September 2016 (cf. FRG-1). The public hearing took place on 21 March 2017. The procedure is already well advanced. The licence documents are being checked or revised at the moment.

Siemens training reactor in Aachen (SUR-AA)

The Siemens training reactor in Aachen was operated by the RWTH Aachen University. It was manufactured by Siemens-Schuckertwerke AG in 1963 and went critical for the first time on 22 September 1965.

The thermal reactor output was 100 mW_{th} and the thermal neutron flux was approx. $6 \cdot 10^6$ $1/cm^2 \cdot s$. The research reactor was used for training and practice purposes for nuclear training and was also used to conduct

experiments for degree courses and graduate diploma dissertations. The reactor was shut down in 2002. The fuel plates consisting of enriched uranium-235 were taken to the Technical University of Munich for conditioning and disposal in 2008. The operator submitted the application to decommission and dismantle the unit to the responsible state authority in 2010. The licence procedure is continuing. An environmental impact assessment and public participation are not necessary because of the reactor's low performance.

3.3 RESEARCH REACTORS UNDER DECOMMISSIONING

Seven research reactors were under decommissioning in Germany at the end of 2018. Table II.3 in Annex II contains the most important data on units in this category.

Karlsruhe 2 research reactor (FR 2)

The FR 2 was an enclosed tank reactor operated with low-enriched uranium (2%) and moderated and cooled with heavy water. This was the first German reactor unit developed and built according to a national concept. With 44 MW_{th}, it was the most powerful German research reactor in terms of thermal output. With its thermal neutron flux of $1 \cdot 10^{14}$ $1/cm^2 \cdot s$, the FR 2 was used as a source of neutrons for beamline experiments for fundamental research and for irradiation experiments for develop fuel rods and produce isotopes for medical purposes.

The nuclear launch of the reactor took place on 7 March 1961 with natural uranium. The unit was converted to fuel elements with low-enriched uranium (2%) to increase the original thermal neutron flux from $3.9 \cdot 10^{13}$ $1/cm^2 \cdot s$ to $1 \cdot 10^{14}$ $1/cm^2 \cdot s$ in 1966. The maximum thermal output from the reactor then increased from 12 MW_{th} to 44 MW_{th} (licence dated 26 January 1966).

The FR 2 was finally shut down for economic reasons on 21 December 1981 after an operating period of 20 years. The fuel elements had been handed over to WAK for reprocessing by 22 October 1982. The first of several partial licences to decommission, partially demolish and ensure safe enclosure for at least 30 years was granted on 3 July 1986. The reactor unit as the remaining part of the facility has been in a state of safe enclosure since 20 November 1996. The reactor building has been used for a permanent exhibition on the history of nuclear technology since 1997.

Following safe enclosure, there are plans to dismantle the site to finally remove the reactor unit. The planning work is taking place now. The Baden-Württemberg Ministry of the Environment, Climate Protection and the Energy Sector is the responsible licensing authority.

Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs- GmbH, which has been responsible for the unit since 2009, has been operating under its new business name, Kerntechnische Entsorgung Karlsruhe GmbH, since 3 February 2017.

Munich research reactor (FRM)

The FRM is a pool-type reactor with an American design and thermal output measuring 4 MW_{th} and a thermal neutron flux of $7 \cdot 10^{13}$ $1/cm^2 \cdot s$. The unit was commissioned as the first reactor in Germany on 31 October 1957. It was used to provide beamline experiments and radiation, e.g. to generate radioisotopes, verify elements and for tumour therapy.

The unit went into service with LEU and thermal output measuring 1 MW_{th} in 1957, but had already been converted to HEU by 1960. During the course of its operating life, its thermal neutron flux rate was increased from an original figure of $1 \cdot 10^{13}$ $1/cm^2 \cdot s$ to $7 \cdot 10^{13}$ $1/cm^2 \cdot s$; the thermal output was raised from 2.5 MW_{th} to 4 MW_{th} in 1968 and a beryllium reflector was installed in 1982. The core has been operated as a mixed core since 1991 and gradually converted from HEU to MEU.

The Technical University of Munich applied to decommission the unit on 14 December 1998 so that it could transfer it to an adjacent unit in what was the new FRM-II at that time (chapter 3.1) in a later procedural stage. The reactor was finally shut down on 28 July 2000 and the remaining 47 fuel elements were transported to the USA. The licence according to Section 7 of the Atomic Energy Act to dismantle the FRM reactor in Garching was granted on 3 April 2014. The first stage of dismantling work has been completed. No further dismantling work can take place in the reactor building until the ventilation system has been renewed. The FRM dome, known as the Garching nuclear egg, is subject to a preservation order.

Neuherberg research reactor (FRN)

The FRN was a TRIGA Mark III pool reactor with homogenous fuel moderator elements consisting of LEU and zirconium hydride. The permanent thermal output from the unit measured 1 MW_{th} and the thermal neutron flux was $3 \cdot 10^{13}$ $1/cm^2 \cdot s$. When operated with pulses, the reactor was able to provide output peaks of up to 2,000 MW_{th} for a short time – for approx. 10 ms. The unit went into service on 23 August 1972 and was used to produce isotopes and conduct beamline experiments in medical/biological research.

The reactor was finally shut down on 16 December 1982. The fuel elements were removed under the operating licence and disposed of in the USA. The decommissioning licence dated 30 May 1983 covered the decommissioning of the unit and the dismantling of unit parts and achieving safe enclosure for the shielding unit with the former reactor pool. A separate licence notice dated 24 May 1984 allowed the unit to be kept in a state of safe enclosure.

Braunschweig research and measuring reactor (FMRB)

The FMRB was a light-water-cooled and moderated pool-type reactor with two separated fissile material zones consisting of HEU, which were connected in neutron/physical terms via a heavy-water tank containing 400 litres. The reactor first went critical on 3 October 1967. The thermal output was 1 MW_{th} and the thermal neutron flux $6 \cdot 10^{12}$ $1/cm^2 \cdot s$. The unit was used by the Physikalisch-Technische Bundesanstalt (PTB) as a source of neutrons for radiation and beamline experiments, particularly in the field of neutron metrology and dosimetry as well as for condensed matter physics.

The reactor was taken out of service for economic reasons on 19 December 1995. The fuel elements that still existed were transported to the USA on 28 August 1996. The decommissioning licence for the unit was granted on 2 March 2001. The unit had been completely dismantled by the middle of 2004. The radioactive waste and residual materials that accrued during operations and demolition had been conditioned and taken to the specially constructed storage facility in the rooms of the FMRB by May 2005 and this is still subject to supervision under the Atomic Energy Act. The remaining reactor building and other building areas and floor surfaces had been gradually released from the scope of the Atomic Energy Act by 28 July 2005 and the PTB can now use them for other purposes without any restrictions. The site where the PTB operates the storage facility was transferred to Bundesanstalt für Immobilienaufgaben (BIMA) by an act of law on 1 January 2012.

Siemens training reactor in Hanover (SUR-H)

The SUR-H, a training reactor with thermal output measuring 100 mW_{th} and a thermal neutron flux of $6 \cdot 10^6$ $1/cm^2 \cdot s$, was operated at the Leibniz University Hannover at the Institute for Nuclear Technology and Non-Destructive Testing Procedures. The design of the SUR reactors is described in chapter 3.1. The licence to build and operate the SUR-H was granted by the Lower Saxony Social Ministry on 11 October 1971. The reactor operated from 1971 until 2008. The fuel plates were removed according to the operating licence in 2008 and passed to the Technical University of Munich, the Institute for Radiochemistry, in Garching for conditioning and disposal. The start-up source was removed in 2013 and was given to Eckert & Ziegler Nuclitec GmbH for further use. The application to decommission and dismantle the Siemens SUR 100 Hannover training reactor was made on 22 October 2013. The responsible licensing authority granted the licence to decommission and dismantle the research reactor according to Section 7 Paragraph 3 of the Atomic Energy Act on 4 September 2017.

Jülich research reactor (FRJ-2)

The FRJ-2 (DIDO, derived from D_2O) was a heavy-water-cooled and moderated, enclosed tank reactor operated by HEU with an English design. The reactor with thermal output measuring 23 MW_{th} and a thermal neutron flux of $2 \cdot 10^{14}$ $1/cm^2 \cdot s$ was used for beamline experiments and radiation to produce isotopies and analyse neutron activation.

The nuclear launch of the unit took place on 14 November 1962. An initial output increase from 10 MW_{th} to 15 MW_{th} was conducted in 1967 by making full use of existing reserves. A second output increase to 23 MW_{th} followed in 1972 by means of conversion and upgrading measures.

The FRJ-2 was finally shut down on 2 May 2006. The spent fuel elements were transported to the USA under the operating licence. The North Rhine-Westphalian state authority granted the licence to decommission and dismantle the reactor unit on 20 September 2012.

The Jülich Research Centre, which was responsible at that time, established an external centre at the FRM-II research reactor in Garching (chapter 3.1) to continue its scientific work. The Jülich Centre for Neutron Sciences operates the Maier-Leibnitz Centre there in conjunction with the Technical University of Munich and the Helmholtz Centre.

The decommissioning licence was transferred to Arbeitsgemeinschaft Versuchsreaktor GmbH, which is based at Jülich, on 1 September 2015. The company has been operating as “Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH (JEN)” since 1 January 2016. This now covers the nuclear operations at the Jülich Research Centre and Arbeitsgemeinschaft Versuchsreaktor GmbH.

Rossendorf research reactor (RFR)

The RFR was a light-water-moderated and cooled tank reactor with a Russian design (WWR-S(M)). The thermal capacity at the end measured 10 MW_{th} and the thermal neutron flux was approx. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. The

unit mainly served as a source of neutrons for isotope production, activation analyses and material research – but also for training purposes in the GDR's nuclear energy programme.

The reactor was commissioned with LEU on 16 December 1957 and with thermal output measuring 2 MW_{th}; this had been gradually increased to 10 MW_{th} by 1967, partly through switching from LEU to MEU.

The licence to operate the reactor was covered by temporary approval notices and was extended for the last time on 8 October 1990 until 30 June 1991 by the responsible legal authority at that time. The reactor was finally shut down on 27 June 1991. After taking over responsibility as the new authority in nuclear law with supervisory powers according to Section 19 Paragraph 3 of the Atomic Energy Act, the Saxon State Ministry for the Environment and Agriculture (SMUL) ordered a halt to the unit's operations aimed at nuclear fission. It granted the order on 28 June 1991.

The spent fuel elements were taken to the transport cask storage facility at Ahaus in 18 CASTOR® casks between 30 May 2005 and 13 June 2005.

Several partial licences were granted to decommission and dismantle the unit from 30 January 1998 onwards. The licence according to Section 7 Paragraph 3 of the Atomic Energy Act for the second modification of the fourth licence 4653/18 VKTA 04/2 was granted on 9 January 2014. The modification involves the extension of the previous scope of the licence to cover the total demolition of the remaining unit in radiation protection conditions. The operator applied for the unit to be released from the Atomic Energy Act on 21 June 2018.

3.4 RESEARCH REACTORS RELEASED FROM THE ATOMIC ENERGY ACT

Decommissioning had been completed for six research reactors with permanent thermal output measuring more than 50 kW_{th} and for 23 research reactors with thermal output measuring less than or exactly 50 kW_{th} in Germany by 31 December 2018. They are then released from the scope of the Atomic Energy Act. Table II.4 in Annex II of this report provides a summary of this.

TRIGA HD I research reactor in Heidelberg (TRIGA HD I)

The TRIGA HD I was a TRIGA Mark I pool-type reactor with homogeneous fuel moderator elements consisting of LEU and zirconium hydride. The reactor's thermal performance measured 250 kW_{th} and its thermal neutron flux was $1 \cdot 10^{13}$ $1/cm^2 \cdot s$. The unit went into service as a radiation source for nuclear medical applications on 26 August 1966.

The reactor was finally shut down on 31 March 1977 because a second research reactor (TRIGA HD II, see below) had been constructed at the German Cancer Research Centre in Heidelberg (DKFZ). The fuel elements were transferred to the new reactor for further use there. The licence to decommission the unit, granted on 30 June 1980, covered the demolition of the components and the safe enclosure of the reactor tank and the biological shield and this was completed on 11 December 1980. As the intention was to demolish the building, the DKFZ submitted an application on 25 April 2003 to dismantle the rest of the unit and this was approved on 16 January 2006. The dismantling of the facility and the clearance of the building structure were completed during the first half of 2006. The TRIGA HD I was released from supervision under the Atomic Energy Act on 13 December 2006. The facility was demolished in a conventional manner in 2009 as part of the clearance procedure and the site has been completely redeveloped.

TRIGA HD II research reactor in Heidelberg (TRIGA HD II)

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

The unit was taken out of service on 30 November 1999 because isotope production had been taken over by an accelerator at the DKFZ and reactor use was expected to decline. The fuel elements were transported to the USA for disposal on 1 June 2001. A licence to decommission and completely dismantle the research reactor was granted according to Section 7 Paragraph 3 of the Atomic Energy Act on 13 September 2004. The unit was completely demolished during 2005 and released from the scope of the Atomic Energy Act on 13 December 2006.

Frankfurt 2 research reactor (FRF 2)

The FRF 2 was a light-water cooled and moderated reactor of the modified TRIGA type with homogeneous fuel moderator elements consisting of LEU and zirconium hydride. The reactor was installed in the remaining buildings (reactor hall and reactor unit) of the previous FRF 1 reactor, which had been dismantled, on the basis of the construction licence dated 10 January 1973. The FRF 1 was operated as an L54 homogeneous

fuel solution reactor with thermal output measuring 50 kW_{th} from 10 January 1958 to 19 March 1968. The FRF 2 was designed as a neutron source for basic research in nuclear physics and in solid-state physics as well as for activation analyses and producing isotopes. The Hessian Minister of Education decided on 11 July 1980 not to grant an operating licence and nuclear operations were waived for the reactor, which was ready for use.

The licence to decommission the FRF 2 and dismantle the unit components was granted on 25 October 1982. Those reactor fuel elements that had not been used were taken to a foreign research reactor facility (TRIGA MARK II in Ljubljana) in 1981. The residual activity in the unit resulted exclusively from the former operations of the FRF 1 and was in a state of safe enclosure after the unit had been partially demolished. After the reactor building had been used as a storage facility for low-level radioactive waste produced by the University of Frankfurt, the dismantling of the remaining structures of the FRF – consisting of FRF 1 and FRF 2 – was approved on 28 December 2004. The facility was released from supervision under the Atomic Energy Act on 31 October 2006, after the activated concrete structures had been dismantled and the remaining building structures and the facility site had been measured and declared free of contaminants.

Research reactor at Hanover Medical School (FRH)

The FRH was a TRIGA Mark I pool-type reactor with homogeneous fuel moderator elements consisting of LEU and zirconium hydride. The thermal output of the reactor measured 250 kW_{th} and the thermal neutron flux was approx. $9 \cdot 10^{12}$ $1/cm^2 \cdot s$. The nuclear start-up of the reactor took place on 31 January 1973. Its use as a source of neutrons mainly covered neutron activation analyses and the production and activation of short-lived radionuclides for medical/biological applications.

Due to changes in production processes for radiopharmaceuticals and a fall in demand for the reactors' use, it was finally shut down on 18 December 1996. The fuel elements were transported to the USA on 9 July 1999. An application to decommission and dismantle plant components was made on 22 February 2002 and approved on 8 May 2006. The unit had been completely demolished and declared clear of contaminants by August 2007. State supervision of the facility according to Section 19 of the Atomic Energy Act ended on 13 March 2008.

Jülich 1 research reactor (FRJ-1)

The FRJ-1 (MERLIN, Medium Energy Research Light Water Moderated Industrial Nuclear Reactor) was a pool-type reactor with an English design operated with HEU and with MTR type fuel elements. The thermal output at the end measured 10 MW_{th} and the thermal neutron flux was approx. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor started operating on 23 February 1962 and was used for radiation and beamline experiments.

The unit was extensively converted to increase the neutron flux from $6 \cdot 10^{13}$ $1/cm^2 \cdot s$ to the last available level of $1.1 \cdot 10^{14}$ $1/cm^2 \cdot s$ in 1971. Among other things, this involved using new fuel elements with a higher U-235 mass and modifications to the primary and secondary circuits for the removal of the thermal output that had doubled from 5 MW_{th} to 10 MW_{th}.

The FRJ-1 was shut down on 22 March 1985. According to the operational licence, the fuel elements had been removed from the unit and transported to the USA and Great Britain by October 1992. The licence to decommission the unit was granted on 8 June 1995. Dismantling work on the unit took place gradually on the basis of further partial and additional licences. Approval to decontaminate the reactor building and its extensions and meet the requirements for clearance from contaminants with the aim to release the unit from supervision was granted by the licence dated 29 November 2004. This work was completed during the course of 2007 and the plant was released from supervision under the Atomic Energy Act on 23 November 2007. The reactor building and its extensions were then dismantled in line with conventional regulations, so that it was possible to achieve a "green field" state during the course of 2008.

"Otto Hahn" nuclear ship (OH)

The "Otto Hahn" was the only nuclear ship operated in Germany and was formally classified as a research reactor. An "advanced pressurised water reactor" with low-enriched uranium dioxide and a maximum enrichment level of 5.42% for U-235 and thermal output measuring 38 MW_{th} was used as the power source.

The principal task of the "Otto Hahn" was to gain operational experience with nuclear-powered ships for civil use. The "Otto Hahn" went into service as a nuclear ship on 11 October 1968 and was taken out of service on 22 March 1979. A licence was granted to decommission the "Otto Hahn" according to Section 7 of the Atomic Energy Act in connection with Sections 3 and 4 of the Radiation Protection Ordinance (old version) on 1 December 1980. The reactor vessel was removed in June 1981 at the port of Hamburg and transported to Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH (GKSS), where it has been stored since in a specially built shaft construction (concrete shaft) for a follow-up investigation programme. After the reactor had been removed, the ship was decontaminated and declared free of contaminants and released from supervision under the Atomic Energy Act on 1 September 1982. The reactor pressure vessel

from the “Otto Hahn” nuclear ship, which is stored at the premises of what is now the Helmholtz Centre in Geesthacht, was included in the procedure for decommissioning the FRG 1 and dismantling the research reactor unit according to Section 7 of the Atomic Energy Act in response to the application dated 6 September 2016. It is planned to disassemble the reactor pressure vessel in a building that still needs to be constructed.

The fuel elements had been delivered to WAK for reprocessing by the autumn of 1979, apart from 49 spent and three unspent fuel elements. 52 fuel rods initially remained with the ship’s former operator and were transported to the French CEA research centre (Commissariat à l’Energie Atomique et aux Energie Alternatives) in Cadarache in July 2010. They were taken from there to the North Storage Facility as part of a consolidated transport, along with approximately 2,500 other fuel elements from the Karlsruhe Research Centre, in December 2010.

Research reactors with output measuring 50 kW_{th} or less

There are 23 reactors among the research reactors with output measuring 50 kW_{th} or less, which have already been dismantled or released from supervision under the Atomic Energy Act. One of these units, (SUAK), was not licensed according to Section 7 of the Atomic Energy Act, but Section 9. Different reactor concepts were used for the reactors. Some of them were training reactors (e.g. SUR-KI), reactors with a fuel solution (e.g. ABDIKA), critical assemblies (such as ANEX) or Argonaut reactors (e.g. RRR). There is no need to provide more details about the individual reactors here. A summary of this category can be found in Annex II, Tab. II. 4.

4 FACILITIES FOR NUCLEAR SUPPLIES AND WASTE MANAGEMENT

Annex III includes important data and information on nuclear fuel supplies and waste management in the form of tables, figures and annexes. Figure III provides a summary of the nuclear fuel supply and waste management sites.

The Nuclear Waste Management Commission acting on behalf of the Federal Environment Ministry performed a safety assessment (stress test) of the nuclear supplies and waste management facilities in Germany. The results of the stress test were published in March 2013 (part 1) and in October 2013 (part 2) and can be found on the website of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): https://www.bmu.de/download/esk-stresstest-von-anlagen-und-einrichtungen-der-nuklearen-ver-und-entsorgung/ (only available in German).

4.1 URANIUM ENRICHMENT PLANTS

Gronau uranium enrichment plant (UAG)

Natural uranium in the form of uranium hexafluoride (UF_6) is enriched in centrifuge cascades up to a maximum concentration of the fissile U-235 isotope of 6% at the Gronau uranium enrichment centre (cf. Table III.1).

The facility went into service in the middle of August 1985 with 400 Mg of uranium separation work per year (UTA/a).

An application to extend the production capacity to 4,500 Mg of UTA/a was made in September 1998. The licence for this was granted on 14 February 2005. It covers the construction and operation of a second uranium separation facility with a separation capacity of up to 2,700 Mg of UTA/a and a maximum enrichment level of 6%. The licence also includes storing 58,962 Mg of depleted uranium (tails) in oxidic form and 38,100 Mg as UF_6, 10,000 Mg of natural uranium (feed) as UF_6 and 1,250 Mg of enriched uranium (product) with a maximum enrichment level of 6% for uranium-235 as UF_6. The expansion work here has been completed. The uranium oxide storage facility is finished, but is not yet being used. The UAG is operated by Urenco Deutschland GmbH with a licensed capacity of a nominal 4,500 Mg of UTA/a.

According to Urenco's own information, the company halted the re-enrichment of depleted uranium in Russia in 2009. The uranium hexafluoride that accrues in future will be converted into triuranium octoxide (U_3O_8) – which is chemically more stable – by the French AREVA firm (formerly COGEMA) in Pierrelatte and then stored at the company's site in Gronau.

The construction of a storage building able to hold up to 60,000 Mg of U_3O_8 was completed in 2014. The storage facility was not yet in operation at the end of 2018. Storage is not expected to start before 2019.

4.2 FUEL ELEMENT FACTORIES

Only one fuel element factory is still operating in Germany (correct on 31 December 2018). All the other facilities have already been entirely dismantled and released from supervision under the Atomic Energy Act (cf. Tables III.2; III.3).

4.2.1 Fuel element factory in operation

ANF fuel assembly fabrication plant, Lingen

Uranium fuel elements with a maximum fraction of 5% of uranium-235 are produced mainly for use in light-water reactors at the ANF fuel element factory. Uranium dioxide (UO_2) powder, uranium hexafluoride (UF_6) or UO_2 pellets, which are produced externally, are used as the raw material. The process of making fuel elements includes the following procedural steps: conversion, pellet production, fuel rod production and fuel element production.

Fuel element production started in January 1979 with uranium pellets that were supplied from outside. The production of up to 400 Mg of UO_2 pellets annually was licensed through the 5th partial operating licence in March 1987 (start of production in 1988). The facility started dry conversion with uranium-235 enriched up to 5% in June 1994. A second fuel rod production line and a building for storing and handling UO_2 pellets and powder were approved in June 1996. The processing work that is currently licensed has been set at 800 Mg/a for dry conversion and at 650 Mg/a for other parts of the facility.

The licensed storage capacity for uranium hexafluoride is 275 Mg. A building to store UF_6 containers has started operating in line with the licence according to Section 7 of the Atomic Energy Act.

A licence according to Section 7 of the Atomic Energy Act was granted to expand the storage areas for nuclear fuel by integrating the facility for storing radioactive waste, which had previously been licensed according to Section 6 of the Atomic Energy Act.

4.2.2 Fuel element factories released from the Atomic Energy Act

Siemens fuel element factory in Hanau, MOX processing section

The facility was used 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, from 1968 onwards.

The Hessian Ministry of the Environment issued an order to halt operations according to Section 19 of the Atomic Energy Act following an incident involving contamination; it has therefore been at a standstill since the summer of 1991. The operator decided in April 1994 not to re-start the old unit, but to completely use the fuel in the reactor.

The licensing procedure to dismantle the Siemens MOX unit was discussed at a hearing in Hanau in March 2000 and the dismantling of the first production facilities was approved in December 2000. The 1st partial licence to dismantle the emptied unit was granted in May 2001, the 2nd partial licence in March 2003 and a 3rd partial licence on 3 January 2005. It allowed some buildings and parts of the open-air site to be used for conventional purposes. The 4th and concluding partial licence was granted on 16 March 2005.

Dismantling work on the unit finished in July 2006 and the MOX processing section was released from supervision under the Atomic Energy Act in September 2006.

Dismantling the non-contaminated new facility, which had to be carried out separately, was approved on 7 December 1998. The fission product storage facility designed to withstand air crashes was emptied and is now available for other use.

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

Siemens fuel element factory in Hanau, uranium processing section

The unit had been used to produce uranium fuel elements with a maximum fraction of 5% of uranium-235, mainly for use in light-water reactors, since 1969. UF_6 was used as the raw material.

Siemens halted the production of uranium fuel elements at the site in October 1995 because of generally unfavourable conditions there. To prepare for decommissioning, several individual licences to dismantle plant components and remove nuclear fuel were granted between 1996 and 1998. Three partial licences and several individual licences for subsequent decommissioning work were granted between 1999 and March 2001.

The decommissioning procedure that was finally approved included dismantling the factory buildings and cleaning up the site 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 they only create radiation exposure that is about 10 µSv per calendar year for individuals in the population.) After the controlled areas had been closed and the buildings demolished, a start was made on cleaning up the site. Since uranium had entered the soil and the groundwater as a result of operating the facility, it was also necessary to clean up the soil, the existing sewers and the groundwater. After it was possible to complete the clean-up work in January 2006, the facility was released from supervision under the Atomic Energy Act in May 2006. The groundwater processing unit from Siemens AG was taken out of service in November 2012. The groundwater was checked at several measuring points until September 2016 to monitor the uranium content. The processing unit licensed according to Section 7 of the Radiation Protection Ordinance was kept on hand during the monitoring process and was not dismantled until the procedure had been concluded at the end of 2016.

Siemens fuel element factory, Karlstein section

The plant had been used to manufacture fuel elements made of uranium oxide with a maximum fraction of 4% of uranium-235 since 1966.

As part of the decision to decommission the Siemens units in Hanau, the comparatively small one in Karlstein was closed too. The disposal of all the radioactive operational equipment has been completed. The Siemens fuel element factory, Karlstein section, was released from supervision under the Atomic Energy Act in March 1999.

Non-nuclear operations continued and are used to manufacture structural components for fuel elements (ANF Karlstein). The Karlstein factory has been a subsidiary of Framatome ANP, later renamed AREVA NP, since 2001.

NUKEM-A fuel element factory in Hanau

The NUKEM company had produced fuel elements for research and material test reactors from uranium and thorium up to an enrichment degree of 94% for uranium 235 since 1962.

A first licence to dismantle parts of the unit in the area where the fuel elements were made was granted on 5 December 1988. NUKEM applied to decommission the entire NUKEM industrial premises on 23 December 1988. The decommissioning licence was granted on 10 March 1993. Further licences followed to dismantle the factory components that were not relevant to safety.

It turned out that the so-called Monosta building located on the Degussa site (outside the ring fence of the NUKEM-A premises), which was being used by Degussa again, had to be included in the decommissioning procedure. Therefore, applications were made for two additional licences to dismantle this building complex and they were granted on 9 November 1999 and 26 June 2001.

All the buildings inside the ring fence have now been demolished. The clean-up of the soil was concluded in May 2006 and the entire site, apart a small area measuring 1,000 m^2, was released from supervision under the Atomic Energy Act. A groundwater clean-up unit was operated on the small area according to Section 19 of the Atomic Energy Act until 2015. The radiological clean-up of the groundwater halted on the basis of an official notice dated 20 July 2015 and the site was released from supervision under the Atomic Energy Act.

Hochtemperatur-Brennelement-Gesellschaft (HOBEG)

The unit operated by Hochtemperaturreaktor Brennelement GmbH (HOBEG) at the nuclear site in Hanau was operated to manufacture ball-shaped fuel elements for high-temperature reactors from 1972 until 1988. The unit produced as many as 200,000 fuel elements each year. Overall, about 1 million fuel elements were produced. The HOBEG unit was initially operated with several individual licences in line with Section 9 of the Atomic Energy Act. These were combined to form a temporary licence covering all of them on 30 December 1974. The facility was temporarily shut down on 15 January 1988 and was later mothballed.

Altogether nine licences to decommission the facility were granted according to Section 7 Paragraph 3 of the Atomic Energy Act between 5 December 1988 and 7 April 1995. The process-related components were dismantled and most of them sold. The buildings and the surrounding terrain were decontaminated. Following appropriate measurements, the remaining buildings and the associated site were cleared and released from supervision under the Atomic Energy Act on 18 December 1995. The site and the buildings are now used by Nuclear Cargo & Service GmbH (DAHER-NCS).

4.3 STORING SPENT FUEL ELEMENTS

4.3.1 Storage at nuclear power plants

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

In line with conditions imposed in the licences for the nuclear power plants, capacity amounting to one core load must basically be kept vacant in the wet storage pools to ensure that the reactor core can be entirely defueled at any time. In general, the internal storage capacities cannot be used by several nuclear power plants. Exceptions have been approved for the double unit facilities at Neckarwestheim and Philippsburg.

Operations at an additional wet storage facility, which had already been built in 1984 according to Section 7 of the Atomic Energy Act, in the earthquake-proof emergency building outside the reactor building at the Obrigheim nuclear power plant were approved on 26 October 1998. The licence to operate this external storage facility covers the storage of 980 fuel elements (approx. 286 Mg of HM) exclusively from Obrigheim nuclear power plant and nuclear components. The first fuel elements were stored there in mid-1999. After Obrigheim nuclear power plant was shut down on 11 May 2005, 342 fuel elements in all were stored in the external wet storage facility until the end of 2007. All the 342 existing Obrigheim nuclear power plant fuel elements were loaded into 15 CASTOR® 440/84 mvK casks in 2017 and were taken for storage to the Neckarwestheim on-site storage facility (cf. chapter 2.3 too).

Of the reactors taken out of service in 2011, all have now applied for a decommissioning licence (cf. chapter 1.3.2 and chapter 3.2). The Biblis A and Philippsburg 1 units were free of nuclear fuel in 2017 and the Brunsbüttel reactor unit in 2018. The fuel elements in the wet storage pools were completely packed into casks there and placed in the on-site storage facility.

4.3.2 Storage at local on-site storage facilities

The Federal Office for Radiation Protection (BfS) was responsible for granting licences to store nuclear fuels according to Section 6 of the Atomic Energy Act until 29 July 2016. When the Act on the Realignment of the

organisational structures of radioactive waste disposal became law, the responsibility for completing licensing procedures according to Section 6 of the Atomic Energy Act was transferred to the Federal Office for the Safety of Nuclear Waste Management (BfE).

AVR cask storage facility in Jülich

The AVR cask storage facility is a dry storage unit for spent ball-shaped fuel elements originating from the AVR Jülich in CASTOR® THTR/AVR transport and storage casks. It forms part of the waste storage building II in the decontamination department at Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH, formerly Forschungszentrum Jülich (FZJ) GmbH.

The BfS granted a nuclear licence according to Section 6 of the Atomic Energy Act to store no more than 300,000 spent AVR fuel elements for a period of 20 years on 17 June 1993. Storage operations started on 23 August 1993. Altogether, 152 full CASTOR® THTR/AVR casks have been stored at the AVR cask storage facility since 2009.

FZJ GmbH initially applied for an extension to the licence for storage at Jülich because the storage licence was only effective until 30 June 2013. FZJ declared in a letter dated 29 April 2009 that the extension should last for three years.

FZJ also requested Gesellschaft für Nuklear-Service mbH (GNS) to submit an application to the BfS on 24 September 2009 for permission to store the 152 casks at the GNS interim storage facility at the Ahaus transport cask storage facility. FZJ requested Nuclear Cargo + Service GmbH (NCS, known as DAHER-NCS since 1 October 2015), on 4 October 2010 to apply for a transport licence according to Section 4 of the Atomic Energy Act for transport operations there.

FZJ has also been examining the possibility of transporting the AVR fuel elements to the USA since the middle of 2012.

As the storage licence in line with Section 6 of the Atomic Energy Act expired on 30 June 2013, what was then the North Rhine-Westphalia Ministry for Economic Affairs, Energy, Industry, the Medium-Sized Sector and Trade in its function as the supervisory authority under the Atomic Energy Act initially ordered the continuing storage of the AVR fuel elements at the AVR cask storage facility, according to Section 19 Paragraph 3 of the Atomic Energy Act. This order was restricted to six months and entitled FZJ GmbH to continue owning the nuclear fuels. This was followed by an appropriate order on 17 December 2013, restricted to seven months.

Once it was clear that proof of earthquake safety, which needs to be provided by the applicant and is required for a licence according to Section 6 of the Atomic Energy Act, would be delayed indefinitely if storage at Jülich was prolonged, the North Rhine-Westphalia Ministry for Economic Affairs, Energy, Industry, the Medium-Sized Sector and Trade imposed an injunction in line with Section 19 Paragraph 3 of the Atomic Energy Act on 2 July 2014, stating that the nuclear fuels had to be removed from the AVR cask storage facility immediately and assurance should be given that the nuclear fuels would remain with an organisation entitled to handle them in line with Section 5 Paragraph 1 Sentence 1 of the Atomic Energy Act. The order also regulated further storage until their removal and assumed that the licensing procedure in line with Section 6 of the Atomic Energy Act would continue. FZJ GmbH presented a detailed concept to remove the nuclear fuels from the AVR cask storage facility on 31 October 2014. The alternative options mentioned in the concept involved shipping the AVR fuel elements to the USA, to the Ahaus transport cask storage facility or to a storage facility on the premises of the Jülich Research Centre, which would have to be constructed from scratch.

The licence was granted to store the AVR fuel elements at the Ahaus transport cask storage facility on 21 July 2016. The town of Ahaus and a private person have initiated court proceedings against this licence with the Higher Administrative Court in the state of North Rhine-Westphalia. The case is still pending there. The licensing procedure for transporting the AVR fuel elements from Jülich to Ahaus has still not been completed.

On-site storage facilities

The operators of nuclear power plants applied to store nuclear fuels in the form of spent fuel elements at on-site storage facilities at 13 sites between 1998 and 2000. The application for this kind of facility at Stade was withdrawn again after the decision to decommission the nuclear power plant.

Apart from the licence to store nuclear fuel under the Atomic Energy Act, it is also necessary to obtain a building licence to erect a structure according to the building regulations in the federal state concerned. A common environmental impact assessment was performed in the licencing procedures related to the applications from 1999 onwards. This was based on European Directive 97/11/EC, which applied until 16 February 2012, and was replaced by Directive 2011/92/EU and the Environmental Impact Assessment Act. The possible effects of each project on human beings, animals, plants and their habitat, and on soil, water, air, and the climate were examined.

As part of the licensing procedures in line with Section 6 Paragraph 2 No. 4 of the Atomic Energy Act, checks particularly needed to be made on whether the necessary protection against any disruptive action or other interference by third parties was guaranteed. Ever since the terrorist attacks of 11 September 2001, air traffic has been a prime target for terrorist attacks, despite the familiar high safety standards. Even if no new findings have come to light in recent years or currently indicate a specific risk for stationary nuclear facilities, checks were not only made for terrorist and sabotage acts, but also the effects of a deliberate crash by a large passenger plane on a storage facility, according to Section 6 Paragraph 2 No. 4 of the Atomic Energy Act. As a result of the checks, it was discovered that the intervention reference levels of 100 millisieverts (mSv) for civil protection as the effective dose for any evacuation would not be reached in any scenario that was studied.

The on-site storage facilities are dry storage facilities for spent fuel elements in transport and storage casks that are kept in storage halls or tunnel tubes. CASTOR® V/19 or CASTOR® V/52 casks are being used initially at all the storage facilities that have already been licensed. The licences granted for all on-site storage facilities, for which applications had been made by 2000, permit the storage of spent fuel elements with a heavy metal mass totalling 14,025 Mg at 1,435 storage points for CASTOR® transport and storage casks. The capacity was originally designed in such a way that all the spent fuel elements that would have accrued until the nuclear power plant operations finally halted (based on the electricity quantities set in 2002), could have been accommodated at the on-site storage facilities and could have been stored there, even after the decommissioning of the nuclear power plants, until a disposal facility started operating. As the authorisation for power operations at eight nuclear power plants expired on 6 August 2011 on the basis of the 13th Amendment to the Atomic Energy Act, which took effect on 31 July 2011, and as the remaining operating times of the other nuclear power plants will end in 2022 at the latest, full use will no longer be made of the storage capacities at the on-site facilities to store spent fuel elements that accrue in future.

Storage of spent fuel elements had been authorised for twelve on-site storage facilities by the end of 2003 (cf. Table III.5). The Federal Office for Radiation Protection, which was responsible at the time, had initially granted partial licences for those parts of the application that had been fully checked, with the result that the processing of the applications made in 1998 – 2000 has not yet been completed. The checks in the context of modification licences for the on-site storage facilities continued in 2018. The licence procedures firstly concerned the use of new types of containers, the possibility of using alternative loading options for the spent fuel elements and loading special fuel rods (e.g. faulty fuel rods) into special receptacles for storage in the container. Secondly, the checks on refitting the on-site storage facilities for safety reasons continued as part of the licensing procedures. The procedures for storing special fuel rods in receptacles at the on-site storage facilities at Biblis, Unterweser and Krümmel were completed in 2018. The licence for the new loading options for the CASTOR® V/19 transport and storage casks was granted for the on-site storage facility at Grafenrheinfeld. The procedure for refitting the on-site storage facilities at Grafenrheinfeld and Neckarwestheim for safety reasons was also completed in 2018. The modification licence involved individual checks on whether additional investigations were necessary for an environmental impact assessment.

With regard to returning the waste from reprocessing in France and Great Britain, the relevant applications to store the vitrified waste were made for the on-site storage facilities at Philippsburg, Brokdorf, Biblis and Isar on 29 September 2017. The five CASTOR® HAW28M casks returning from France with vitrified intermediate-level radioactive waste were to be stored at the on-site storage facility at Philippsburg. The vitrified high-level radioactive waste from reprocessing spent fuel elements at Sellafield is to be stored in as many as seven CASTOR® HAW28M casks at the sites in Biblis, Brokdorf and Isar, in line with the application.

Schleswig Higher Administrative Court upheld the legal action against the licence for the Brunsbüttel on-site storage facility in June 2013. The licence dated November 2003 was unlawful and needed to be cancelled, since it did not fulfil the requirements set out in Section 6 Para. 2 No. 4 of the Atomic Energy Act. 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 a terrorist attack scenario at the on-site storage facility with anti-tank weapons in the licensing procedure. Schleswig Higher Administrative Court did not grant the right to any appeal. The Federal Republic of Germany - the defendant - lodged a complaint against the denial of leave to appeal with the Federal Administrative Court (BVerwG). In its ruling dated 8 January 2015, the latter rejected the complaint against the denial of leave to appeal in the ruling made by Schleswig Higher Administrative Court on 19 June 2013. The decision by the Federal Administrative Court means that the revocation of the licence for the Brunsbüttel on-site storage facility is legally binding. To prevent a situation where nine CASTOR® casks would be stored at the on-site storage facility in Brunsbüttel without a licence, the nuclear authority in the federal state of Schleswig-Holstein under the Atomic Energy Act granted a decree on 16 January 2015, which was effective until an enforceable storage licence for the stored nuclear fuel was granted in line with Section 6 of the Atomic Energy Act, but at the latest by 16 January 2018. This decree obliges the storage facility operator, Kernkraftwerk Brunsbüttel GmbH & Co. oHG, to

be responsible for immediately ensuring licensed storage of the nuclear fuel. In its letter dated 16 November 2015, Kernkraftwerk Brunsbüttel GmbH & Co. oHG applied to the Federal Office of Radiation Protection, the then responsible body, to issue a new licence to store nuclear fuels at the on-site storage facility at Brunsbüttel. The nuclear regulatory authority ordered that the remaining 517 spent fuel elements still in the reactor pressure vessel at the Brunsbüttel nuclear power plant should be loaded into CASTOR® casks on 24 November 2016. The eleven casks in all were filled between the end of 2016 and the middle of 2017 and have been stored at the on-site storage facility at Brunsbüttel since then until a new licence is granted. As it was not possible to complete the licence procedure by 16 January 2018 according to Section 6 of the Atomic Energy Act, the nuclear regulatory authority ordered the storage of the nuclear fuel at the on-site storage facility at Brunsbüttel for a further two years until 31 January 2020 in a ruling dated 20 December 2017.

Further legal proceedings are pending at the Lower Saxony Higher Administrative Court concerning the licence for the Unterweser on-site storage facility dated 22 September 2003.

Beyond this, several private persons have lodged proceedings with the Bavarian Administrative Court with the aim of annulling the storage licence granted on 19 December 2003 for the on-site storage facility at Gundremmingen. The plaintiffs mainly base their case on what they believe is inadequate protection at the on-site storage facility against terrorist attacks. The case is currently still pending at the Bavarian Administrative Court.

Table 4.1 provides a list of the respective first licences, the licensed masses of heavy metal (HM) and storage positions as well as when the on-site storage facilities started operating (i.e. the first storage of a full cask). Further details about the on-site storage facilities are provided in Table III.5.

Table 4.1: On-site storage facilities (SZL)

On-site storage facilities (SZL)	Issue of the 1st licence according to Section 6 of the Atomic Energy Act	HM mass [Mg]	Total storage positions (used by end of 2018)	Commissioning date
SZL Biblis	22.09.2003	1,400	135 (101)	18.05.2006
SZL Brokdorf	28.11.2003	1,000	100 (33)	05.03.2007
SZL Brunsbüttel*	28.11.2003	450	80 (20)	05.02.2006
SZL Grafenrheinfeld	12.02.2003	800	88 (30)	27.02.2006
SZL Grohnde	20.12.2002	1,000	100 (34)	27.04.2006
SZL Gundremmingen	19.12.2003	1,850	192 (60)	25.08.2006
SZL Isar	22.09.2003	1,500	152 (59)	12.03.2007
SZL Krümmel**	19.12.2003	775	65 (41)	14.11.2006
SZL Lingen	06.11.2002	1,250	125 (47)	10.12.2002
SZL Neckarwestheim	22.09.2003	1,600	151 (81)	06.12.2006
SZL Philippsburg	19.12.2003	1,600	152 (62)	19.03.2007
SZL Unterweser	22.09.2003	800	80 (39)	18.06.2007

* The licence for storage at the on-site storage facility at Brunsbüttel has been cancelled.

** The 4th modification licence for the on-site storage facility at Krümmel to extend the protection against disruptive action or other intervention by third parties has reduced the number of storage spaces from 80 to 65 and cut the overall heat output from 3.0 MW to 2.28 MW.

4.3.3 Storage at central facilities

Table III.4 in Annex III of this report provides a summary of the central storage sites outside nuclear power plant sites.

In the case of the transport cask storage facilities at Ahaus, Gorleben and the transport cask storage facility at the North Storage Facility, investigations into the effects of a deliberately induced plane crash were performed as part of the investigation into a possible additional condition according to Section 17 of the Atomic Energy Act. The experts' results showed that no risk to life and health as a result of the release of a considerable amount of radioactive substances could be expected from a deliberately caused plane crash, as asserted, and that no radical disaster control measures were necessary.

The transport cask storage facilitys at Ahaus and Gorleben were operated by GNS Gesellschaft für Nuklear-Service mbH, a firm for energy supply companies, until 30 July 2017. The storage facilities at the sites in

Ahaus and Gorleben have been operated by the newly founded BGZ Gesellschaft für Zwischenlagerung mbH since 1 August 2017. The switch in licence ownership was approved by the BfE (Federal Office for the Safety of Nuclear Waste Management) with the 9th modification licence for the transport cask storage facility at Ahaus and the 5th modification licence for the transport cask storage facility at Gorleben. BGZ is an independent company, organised under private law, and its costs are covered by the fund to finance nuclear disposal. The sole shareholder in BGZ is the Federal Republic of Germany, represented by the Federal Ministry for the Environment.[5]

Ahaus transport cask storage facitity (TBL-A)

The Ahaus transport cask storage facility was originally designed exclusively as a dry storage facility for spent fuel elements in CASTOR® transport and storage casks. The Ahaus transport cask storage facility consists of a storage area I (western storage area) and a storage area II (eastern storage area).

The licence under the Atomic Energy Act to store fuel elements from light-water reactors according to Section 6 of the Act for a capacity of 1,500 Mg of heavy metal (HM) was granted on 10 April 1987, after an appropriate application was filed on 2 August 1984. Storage operations started in June 1992.

The Ahaus transport cask storage facility has a licence to store spent ball-shaped fuel elements from the THTR 300 in CASTOR® transport and storage casks; this was granted on 17 March 1992. All 305 CASTOR® THTR/AVR casks with the fuel elements from the THTR-300 had been put in storage there by the end of April 1995.

A new licence was granted on 7 November 1997 on the basis of an extensive new application. It covers the storage of max. 3,960 Mg of HM in the previously licensed casks and in the new CASTOR® V/19, CASTOR® V/19 SN06, and CASTOR® V/52 casks at 420 storing positions in storage areas I and II until 31 December 2036. The licence stipulates the maximum storable activity to be $2 \cdot 10^{20}$ Bq and the upper limit for the heat output limit of all the casks in the hall at 17 MW.

In addition to the 305 CASTOR® THTR/AVR casks already in storage, two CASTOR® V/19 casks, one CASTOR® V/19 SN06 cask and three CASTOR® V/52 casks containing LWR fuel elements were transported to the Ahaus transport cask storage facility on 20 March 1998.

The regional authorities in Münster granted the licence for the limited storage of other radioactive substances according to Section 7 of the Radiation Protection Ordinance from operating and decommissioning German nuclear power plants with a max. total activity of 10^{17} Bq for a period of no more than 10 years, starting with the storage of the first radioactive substances; this was granted on 9 November 2009. The limited period ends on 20 July 2020. The radioactive waste can be stored in various casks made of concrete, cast-iron and steel in the western half of the building (storage area I). This waste will later be taken to the licensed federal Konrad disposal site, which is located near Salzgitter and is currently being built.

It is not possible to have any joint, simultaneous use of storage area I to store nuclear fuel in the context of the storage licence according to Section 6 of the Atomic Energy Act. GNS applied to store other radioactive substances in storage area I beyond the previous 10-year period to the regional authorities in Münster on 29 August 2016.

Altogether eight modification licences according to Section 6 of the Atomic Energy Act were also granted (cf. Table III.4) between 2000 and 2016.

They approved, among other things, the refitting of the Ahaus transport cask storage facility for safety reasons through the 7th modification licence dated 8 February 2016. As the licence for the AVR cask storage facility expired in 2013 (cf. chapter 4.3.2), the storage of the AVR stocks at the Ahaus transport cask storage facility was also licensed by the 8th modification licence dated 21 July 2016. Based on this licence, the 152 CASTOR® THTR/AVR casks can be stored in the eastern half of the building (storage area II) beside the 305 CASTOR®THTR/AVR casks already being stored there with fuel elements from the THTR.

GNS and BZA made an application according to Section 6 of the Atomic Energy Act to store high-pressure compacted intermediate-level radioactive waste (CSD-C - Colis Standard de Déchets Compactés) from reprocessing spent nuclear fuels in TGC36 transport and storage casks on 20 December 2006. A new TGC27 transport and storage cask has been under development since 2012 to store this CSD-C waste. This waste is to be stored in as many as 150 casks.

[5] After going to print: The twelve storage facilities at the nuclear power plant sites were taken over by BGZ on 1 January 2019. BGZ will be responsible for taking over operations at twelve storage facilities with low-level and medium-level waste at the nuclear power plant sites in a further step on 1 January 2020. As a result, responsibility for storing (conditioned) radioactive waste from the energy supply companies will be centrally handled by BGZ in future.

In a letter dated 30 September 2014, GNS asked for the reopening of the licence procedure under the Atomic Energy Act to store spent fuel elements from the Heinz-Maier Leibniz research neutron source at Munich University of Technology at the Ahaus transport cask storage facility. The fuel elements are due to be stored in about 21 new CASTOR® MTR3 casks in the storage area II. The storage of spent fuel elements from German research reactors, which has been applied for, is part of the extensive joint application from BZA and GNS dated 15 September 1995; a ruling has only been granted for the research reactor fuel elements from the Rossendorf research reactor so far.

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 HAW vitrified waste receptacles from reprocessing in transport and storage casks.

Following the application made in September 1980, the storage licence according to Section 6 of the Atomic Energy Act was granted for a capacity of 1,500 Mg of HM on 5 September 1983. Storage operations started on 25 April 1995.

In a new licence granted on 2 June 1995, permission was provided to not only store 3,800 Mg of HM in all and vitrified high-level radioactive fission product solutions, but also particularly to store fuel elements containing mixed oxide (MOX) and nuclear fuels in the form of waste and waste containing nuclear fuels and other radioactive substances. The storable activity was restricted to $2 \cdot 10^{20}$ Bq. Public participation was arranged before this decision was made, based on the change to Section 6 of the Atomic Energy Act.

The 6th modification licence dated 21 June 2018 granted permission to refit the Gorleben transport cask storage facility.

Five casks with spent fuel elements (1 CASTOR® Ic, 1 CASTOR® IIa, 3 CASTOR® V/19) and 108 casks with HAW vitrified waste receptacles (1 TS 28 V, 74 CASTOR® HAW 20/28 CG, 21 CASTOR® HAW 28 M und 12 TN85) had been put into storage at the Gorleben transport cask storage facility by 2011.

Originally, a further 21 or so CASTOR® HAW28M casks with HAW vitrified waste receptacles from the British reprocessing facility, Sellafield Ltd, and another five casks with vitrified intermediate-level waste (MAW vitrified waste receptacles) from the reprocessing of spent fuel elements at AREVA NC in France were to be stored in CASTOR® HAW28M casks at the Gorleben transport cask storage facility.

Following an amendment to the Atomic Energy Act in combination with the Site Selection Act (StandAG) on 23 July 2013, storage of these casks at the Gorleben transport cask storage facility was ruled out legally. There are plans to distribute the casks to on-site interim storage facilities. A benchmark paper published by the Federal Ministry for the Environment with the energy supply companies operating the nuclear power plants dated 19 June 2015 presented the concept of returning the waste from reprocessing to the on-site interim storage facilities at Philippsburg, Brokdorf, Biblis and Isar. A joint statement by the Bavarian State Government and the Federal Ministry for the Environment dated 4 December 2015 stated that the five CASTOR® casks arriving from France should be stored at the on-site interim storage facility at Philippsburg. The CASTOR® casks arriving from the UK were to be returned in three transport operations and distributed evenly to the sites at Biblis, Brokdorf and Isar – each accommodating seven of them (cf. chapter 4.3.2 too).

In letters dated 5 December 2013 and 12 December 2013, GNS and BLG, the operators of the Gorleben transport cask storage facility, applied to extend the storage licence according to Section 7 Para. 2 of the Radiation Protection Ordinance to store other radioactive substances at their site. As part of this combined usage, the intention is to store disposable waste in one section of the storage area, which will first be conditioned at the site in an extension building at the Gorleben waste storage facility; the latter still has to be built.

Transport cask storage facility at interim storage facility North at Rubenow (ZLN)

The transport cask storage facility at the interim storage facility North is a dry storage unit for spent fuel elements in transport and storage casks. It is located in hall no. 8 of the interim storage facility North at the EWN site. It is mainly used to accommodate spent fuel elements, nuclear fuels and other radioactive waste from the reactors at Rheinsberg and Greifswald.

The licence according to Section 6 of the Atomic Energy Act was granted on 5 November 1999, after an appropriate application was made in April 1993. Approval was given for a max. capacity of 585 Mg of HM in no more than 80 CASTOR® 440/84 casks. The maximum activity that could be stored was restricted to $7.5 \cdot 10^{18}$ Bq. A start was made on storing the CASTOR® casks on 11 December 1999.

74 full CASTOR® casks (62 CASTOR® 440/84, 3 CASTOR® KRB-MOX, 5 CASTOR® HAW 20/28 CG SN 16 and 4 CASTOR® KNK) had been put into storage at the interim storage facility North by 2011.

EWN withdrew an application dated 30 June 2011 to license the expansion of the protection against any disruptive measures and other third-party intervention in a letter dated 20 July 2015. EWN has been examining

alternative procedures since then. EWN provided information in December 2017 that it was planning to construct a replacement storage facility for the 74 casks by 2024. The replacement storage facility is to be built to the north-east of the interim storage facility North at the EWN site Rubenow. EWN announced that the new application for the replacement storage facility would probably be made to the BfE during 2019.

4.4 STORING RADIOACTIVE WASTE AND STATE COSTUDY OF NUCLEAR FUELS

4.4.1 Storing radioactive waste

Table III.6 in Annex III contains a list of external waste storage sites in Germany.

The following facilities are currently available for the waste, in addition to facilities at the sites:

- the external storage building at Unterweser,
- the local on-site storage facility at Biblis,
- the Ahaus transport cask storage facility,
- the Gorleben waste storage facility,
- the EVU- building at the Mitterteich storage facility,
- the Nuclear + Cargo Service GmbH storage facility at Hanau,
- the interim storage facility near Greifswald,
- the Rossendorf interim storage facility and
- the interim storage facility at Hauptabteilung Dekontaminationsbetriebe (HDB) in Karlsruhe.

There are restrictions on deliveries to these storage sites in the licences.

Radioactive waste from the nuclear industry and research institutes is mainly stored by those causing the waste. Radioactive waste from medical and small users is stored at state collection points.

One drum with radium radiation sources and seven special casks, mainly with Co-60 sources, are intermediately stored at the Morsleben repository for radioactive waste (ERAM). There are plans to dispose of these sources of radiation at ERAM as part of the decommissioning process. The operator at the time, the Federal Office for Radiation Protection (BfS), applied for the disposal of this waste in 2005. Bundesgesellschaft für Endlager took over the responsibility for operating the disposal site at Morsleben from BfS in April 2017.

4.4.2 State custody of nuclear fuels

In the interests of end-to-end state controls for the location of nuclear fuels, Section 5 Para. 4 of the Atomic Energy Act stipulates that the state must store any nuclear fuels, where it is impossible to find or consult a person authorised to own them. This can particularly be the case if nuclear fuels are found or confiscated during border checks. The responsible body for state custody has been the Federal Office for the Safety of Nuclear Waste Management (BfE) since 30 July 2016; it took over this task from the previous responsible body, the Federal Office for Radiation Protection (BfS).

As a precaution, storage areas at the interim storage facility North near Lubmin have been rented for smaller volumes of nuclear fuels that need to be kept in state custody according to Section 5 Paragraph 4 of the Atomic Energy Act. However, these storage areas are currently not being used.

If larger amounts of nuclear fuels need to be kept in state custody, contrary to expectations, they would initially be stored at the local site. The Federal Office for the Safety of Nuclear Waste Management would then adopt measures to ensure that the storage of the nuclear fuels at the local site meets the requirements for storing nuclear fuels according to Section 6 of the Atomic Energy Act.

4.5 REPROCESSING NUCLEAR FUELS

Germany started to develop the technology to reprocess spent fuel elements during the 1960s. The Karlsruhe reprocessing plant (WAK) was constructed as a pilot plant for this purpose. There were plans to construct a national waste management centre (Gorleben Nuclear Waste Management Centre) where storage, industrial reprocessing and disposal were handled at one site.

After this plan and domestic reprocessing were abandoned, the German government accepted that spent fuel elements from German nuclear power plants would be disposed of through storage and reprocessing in other EU member states – through its decision on 6 June 1989; this was part of the integrated disposal concept and therefore provided proof of the precautionary measures for waste management. The construction of an industrial German reprocessing plant at Wackersdorf (WAW) was halted in the same year and the spent

fuel elements were transported to France (AREVA, La Hague) or to England (BNFL, Sellafield) for reprocessing.

After the Atomic Energy Act was amended in 1994, direct disposal was placed on a par with reprocessing as a waste management alternative, so that fuel elements were also stored at the Gorleben and Ahaus storage facilities for direct disposal at a later time.

To minimise the risks associated with reprocessing or transporting waste for reprocessing, transport operations to reprocess waste abroad were prohibited after 30 June 2005 through the amendment to the Atomic Energy Act on 27 April 2002. The waste management of fuel elements was exclusively restricted to direct disposal from this time onwards.

The dismantling of the Karlsruhe reprocessing plant (WAK)

WAK (cf. Table III.7) at the Karlsruhe Research Centre site – now the Karlsruhe Institute of Technology – was a test facility for reprocessing spent nuclear substances from research, prototype and power reactors. Apart from gaining operating experience, development projects for a German reprocessing unit were conducted on an industrial scale. WAK started operating in 1971 under the management of WAK Betriebsgesellschaft mbH. After the decision to forego a large-scale technical reprocessing unit, operations were finally halted in 1991. During this period, approx. 200 Mg of nuclear fuels from a variety of reactors were processed. The uranium and plutonium obtained in this process were taken to nuclear fuel supply companies for further processing.

About 60 m^3 of high-level radioactive liquid waste concentrate (HAWC) with an activity of $7.7 \cdot 10^{17}$ Bq accrued from operating the reprocessing unit and it was last stored inside the LAVA building (facility for storing and evaporating high-level radioactive waste liquids). The low-level and intermediate-level operational waste from WAK was conditioned at the Kernforschungszentrum Karlsruhe. After the storage of radioactive waste at Asse mine was halted in 1978, additional conditioned operational waste is still at the WAK site. WAK Rückbau- und Entsorgungs-GmbH changed its name to Kerntechnische Entsorgung Karlsruhe GmbH (KTE) in February 2017.

Operations were finally halted on 30 June 1991. The German government, the state of Baden-Wurttemberg and the energy supply companies decided to decommission and dismantle the reprocessing plant at the end of 1991. The 1st partial decommissioning licence for WAK was granted on 22 March 1993.

At the end of the reprocessing operations, the unit consisted of

- the process building with the reprocessing equipment for spent nuclear fuels,
- the storage buildings with containers and process units for storing HAWC and intermediate-level liquid waste (MAW) and
- facilities and buildings to supply media and the technical infrastructure.

The goal is to dismantle all the buildings completely and achieve a “green field” state by 2030. This overall goal is to be achieved in six technically independent stages.

The process building, which had contained the reprocessing equipment, has been almost completely empty since 2006 (stages 1-3). The vitrification of the HAWC was completed in 2010. Adapting the HAWC storage facilities and the Karlsruhe vitrification plant (VEK, see details below) to the reduced overall operations has taken place. Stage 4 has therefore been completed. Stage 5 involves dismantling the HAWC storage facilities and the VEK. The conventional dismantling of all the buildings (stage 6) will only be carried out after the entire plant has been released from supervision under the Atomic Energy Act.

Prior to dismantling the storage buildings, the HAWC that was last stored in 2 containers in the LAVA building had to be conditioned to make it suitable for disposal and removed. The VEK was built for this purpose. The 1st partial construction licence for the VEK was granted on 30 December 1998. Construction work on the VEK started at the beginning of 2000. The 2nd partial operational licence for hot (nuclear) operations was granted on 24 February 2009. The approx. 60 m^3 of HAWC were processed at the VEK into 123 vitrified waste receptacles containing 49 Mg of waste glass between September 2009 and June 2010. Additional 17 waste receptacles accrued during the subsequent rinsing process, so that altogether 56 Mg of waste glass were produced. When the 140th and final waste receptacle was filled on 25 November 2010, operations at the Karlsruhe vitrification plant finally halted; it has been in the post-operational phase since then. The 140 waste receptacles were placed in 5 CASTOR®HAW 2028 transport and storage casks and were taken to the interim storage facility North operated by EWN GmbH in Lubmin near Greifswald in February 2011 (cf. chapter 4.3.3). The melting furnace has been emptied and shut down and the entire plant has been rinsed. All the remaining liquids in the process engineering components still existing after operations were halted have now dried out. The operator received the 24th decommissioning licence to manually remove the installa-

tions from the VEK, which had already been shut down, on 28 April 2014. Most of this work has been completed. The application to manually dismantle the media and energy supplies to the VEK was granted on 26 June 2017. This work is now at an advanced stage. The 26th decommissioning licence to remotely dismantle the VEK process technology was granted on 6 July 2018.

Two emptied HAWC casks are in the “LAVA” (storage cask) and “HWL” (reserve casks) buildings in thick-walled concrete cells that are only accessible remotely because of the high dose rate. A new access building south of the HWL was constructed and put into operation in May 2008 to perform the remote operations and handle the residual material logistics. Despite having been rinsed several times, solid HAWC residue was detected in the reserve cask (81B21) and in two LAVA casks after they were emptied. This solid residue will be recovered when the HAWC storage receptacles are remotely dismantled; this was approved by the 22nd decommissioning licence on 8 December 2010. The remote-controlled dismantling of the first HAWC cask (81B31) at the HWL was completed in 2018.

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

An application was made to demolish the residual equipment and abolish the HWL controlled area on 12 December 2014. An application to dismantle the LAVA-ELMA pipe duct and abolish the ELMA controlled area was also made on 12 March 2015.

Wackersdorf reprocessing plant (WAW)

Deutsche Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH (DWK) applied to construct a reprocessing plant on the Wackersdorf site (Upper Palatinate/Bavaria) to the Bavarian State Ministry of Rural Development and the Environment in 1982.

This application resulted from the decision made by the heads of the federal and state governments in 1979, which considered reprocessing, including the return of the usable nuclear fuels and the disposal of radioactive waste from the reprocessing process, to be feasible in safety terms according to the current findings and technology, and requested the rapid construction of a reprocessing plant. One consequence of this was that the Lower Saxony State Premier, Ernst Albrecht (CDU), considered that it would be politically feasible to establish the National Disposal Centre in Gorleben.

The 1st partial building licence was granted in September 1985. The Bavarian Administrative Court ruled that the development plan was illegal in January 1988. Construction had started in December 1985. Modifications to the concept then made it necessary to draw up a new safety report, hold another public hearing and examine the safety of the facility as a whole.

Offers made by COGEMA (now: AREVA) and later by BNFL to handle the reprocessing of spent fuel elements from German nuclear power plants in the long term and do so at reasonable prices persuaded the German power companies to reconsider the Wackersdorf project and abandon it. The procedure was formally completed when DWK withdrew its building application in December 1989.

4.6 CONDITIONING FUEL ELEMENTS

Pilot conditioning plant at Gorleben (PKA)

(cf. Table III.8 in Annex III too)

In order to advance methods for direct disposal, a pilot conditioning plant for spent fuel elements and radioactive waste was built at the Gorleben site. The unit is a multi-purpose facility, where, apart from fuel elements, all kinds of radioactive waste from nuclear facilities can be transhipped or conditioned so that it is suitable for disposal. The plant is designed to handle 35 Mg of HM per annum.

The 1st partial licence under the Atomic Energy Act to erect the building shells and the fence and earth wall surrounding the facility as well as the preliminary positive overall evaluation of the plant concept was granted in January 1990.

In its ruling dated 21 July 1994, the Lower Saxony Environment Ministry granted the 2nd partial licence to construct the pilot conditioning facility. It covers the entire technical and electrical part as well as the control technology at the facility.

The 3rd partial licence, which includes the operating licence, was granted in December 2000. Until the federal government names its disposal site, operations at the pilot conditioning facility in Gorleben are restricted to repairing faulty transport and storage casks on the basis of an ancillary clause to the licence that has been granted, in case repairs are necessary for one of the casks stored on the same site at the transport cask storage facility in Gorleben. The Lower Saxony Environment Ministry imposed a subsequent condition to the 2nd partial licence dated 21 July 1994 on 18 December 2001 that certain systems and plant components

should be operated “cold". This ensures that the facility is maintained in its test state and that a faulty cask can be accepted at any time. The Lower Saxony Ministry for the Environment, Energy and Climate Protection allowed a change in the licence holder through the modification licence 1/2017 dated 1 August 2017. BGZ (Gesellschaft für Zwischenlagerung mbH) is taking over, while GNS (Gesellschaft für Nuklear-Service mbH) is bowing out.

Only those systems that are necessary to repair a cask and maintain the plant (including recurring checks) and the staff members’ expertise are operating at the pilot conditioning facility.

4.7 DISPOSAL

The “Act to Reform the Organisational Structure When Disposing of Nuclear Waste” took effect on 30 July 2016. This law envisages pooling most of the state tasks for licensing and supervising nuclear technology, storage, the site selection and supervising disposal in one new public body, the Federal Office for the Safety of Nuclear Waste Management (BfE).

The law also envisages establishing a state-owned company for the operational tasks of searching for a site, building and operating the disposal facility and the Asse II mine and the Gorleben mine, i.e. Bundesgesellschaft für Endlagerung mbH (BGE).

The National Civil Society Board was also constituted in December 2016. Its task is to provide mediatory and independent support for the selection of a site to dispose of high-level radioactive waste.

The parties involved have started their work to select a disposal site for high-level radioactive waste, as envisaged in the Site Selection Act.

4.7.1 Statutory principles for disposal

The main legal principles for disposing of radioactive waste are the following:

- The Act on the peaceful utilisation of nuclear energy and the protection against its hazards (Atomic Energy Act - AtG)
- The Act to Search for and Selection of a Site for a Disposal Facility for High-Level Radioactive Waste (Site Selection Act - StandAG)
- The Act on the Realignment of the Organisational Structures of Radioactive Waste Disposal
- The Act to Establish a Federal Office for the Safety of Nuclear Waste Management (BfkEG)
- The Act Regulating the Transfer of Obligations for Financing and to Act for the Management of radioactive Waste from the Operators of Nuclear Power Stations (Waste Management Transfer Act)
- The Act on the Protection against the Harmful Effect of Ionising Radiation (Radiation Protection Act - StrlSchG)

The Act on the peaceful utilisation of nuclear energy and the protection against its hazards (Atomic Energy Act - AtG)

According to Section 9a Paragraph 3 of the Atomic Energy Act, the federal government must establish facilities to store and dispose of radioactive waste. The federal government has to delegate its tasks to a third party, which must be organised under private law. Its sole shareholder is the federal government. The federal government delegates the necessary sovereign powers to this third party by entrusting them to it. In this sense, the third party is subject to supervision by the federal government. The third party commissioned to perform the tasks basically performs the resulting duties itself.

The Act to Search for and Selection of a Site for a Disposal Facility for High-Level Radioactive Waste (Site Selection Act - StandAG)

Following the federal government’s decision in 2011 to abandon nuclear energy by 2022, the federal government and the states agreed to extend their consensus on terminating power generation with nuclear energy (cf. Chapter 1.3) to the issue of disposing of high-level radioactive waste; this has still not been resolved. In order to place the search for a disposal site for high-level radioactive waste on a broad, political and social basis, both houses of the German parliament passed the Act to Search for and Selection of a Site for a Disposal Facility for High-Level Radioactive Waste (Site Selection Act - StandAG). This came into effect on 27 July 2013. It provides for legally binding, formal public participation and active public relations work in all phases of the site selection procedure. It also contains the principles and approach for a science-based and transparent procedure when searching for a site to dispose of particularly high-level radioactive waste so that it ensures the best possible safety for a period of one million years. The Act stipulates decision-making tools, technical criteria and requirements for this. This procedure aims to find a disposal site by 2031. The

Gorleben salt dome will be included in the site selection procedure like any other site that appears appropriate.

The disposal site selection procedure was preceded by the work of the “Storage of high-level radioactive waste” commission, which was set up at the German parliament. The commission issued its final report on the fundamental issues related to the disposal site selection procedure at its meeting on 27 June 2016. This report formed the basis for the amendment to the StandAG. The Act to Further Developing the Act to Search for and Selection of a Site for a Disposal Facility for Heat-Generating Radioactive Waste and further acts were announced on 15 May 2017 and most parts of them became law on 16 May 2017. Section 21 Paragraph 2 Sentence 3 – 5 of the StandAG, which governs the safeguarding of potentially suitable areas, became law on 16 August 2017. This aims to prevent any disadvantageous changes to areas that are viewed as possibly being suitable for the disposal facility during the early phase of the process.

Act on Realignment of the Organisational Structures of Radioactive Waste Disposal

The “Act on the Realignment of the Organisational Structures of Radioactive Waste Disposal became law on 30 July 2016. On this basis, the organisations and authorities are being restructured for tasks such as the search for a disposal site for high-level radioactive waste or the organisational structures at existing departments are being improved. The aim of the law is to guarantee a clear assignment of responsibilities and tasks in the field of radiation protection and disposal.

The state tasks of supervision and licensing in the field of nuclear technology, storage, site selection and supervising disposal have been pooled in one public authority, the Federal Office for the Safety of Nuclear Waste Management (BfE).

An independent state company has been established for the operational tasks in searching for a site, building and operating the disposal facility and of the Asse II mine – i.e. Bundesgesellschaft für Endlagerung mbH (BGE). The Federal Republic of Germany is the sole shareholder, represented by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). BGE also execute the tasks defined in the Site Selection Act as the project delivery organisation (understood as implementer) in the site selection procedure. BGE will particularly make suggestions for the selection of site regions and the sites to be explored as well as site- specific investigation programmes and test criteria. BGE is conducting the above-ground and underground investigations for the regions or sites still to be determined as well as the respective preliminary safety investigations. The BGE will than suggest a repository site to the BfE. The decision will be finally determined by a federal law.

The National Civil Society Board has also been established as another committee alongside the supervisory body (BfE) and the implementer (BGE) through the “Act to Reform the Organisational Structure When Disposing of Nuclear Waste”. The board was constituted in December 2016 and is to support the site selection procedure and adopt an intermediary role. The board has its own business office.

The Act to Establish a Federal Office for the Safety of Nuclear Waste Management (BfkEG)

The Federal Office for the Safety of Nuclear Waste Management (BfE), which was established according to Section 1 of the “Act to Establish a Federal Office for the Safety of Nuclear Waste Management” (BfkEG) dated 23 July 2013 (Federal Gazette I p. 2563) was set up on 1 September 2014, initially as the Federal Office for Nuclear Disposal. Based on the “Act on the Realignment of the Organisational Structures of Radioactive Waste Disposal” the name was changed to the “Federal Office for the Safety of Nuclear Waste Management (BfE)”. Various tasks have been assigned to the office since the end of 2016 and it has been undergoing development since then. The BfE is an independent and senior federal body and is directly subject to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The latter exercises the administrative, legal and specialist supervision of the BfE. According to Section 2 of the Act to Establish a Federal Office for the Safety of Nuclear Waste Management, the BfE handles the German government’s administrative tasks in the field of licensing federal facilities to safeguard and dispose of radioactive waste, which have been assigned to it by the Atomic Energy Act, the Site Selection Act or other federal laws or on the basis of these laws. The BfE therefore handles the tasks of a supervisory body, which were assigned to various federal and state authorities in the past. The BfE handles the tasks both of a supervisory body (monitoring the site selection procedure and overseeing the construction, operations and decommissioning of disposal facilities), the licensing authority (checking and approving transport operations, storage and waste management), and is a specialist authority (to further develop the regulations, provide advice and specialist support to the BMU in the field of nuclear safety). The BfE also manages public participation in the site selection procedure. The Act to Establish a Federal Office for the Safety of Nuclear Waste Management also stipulates that the BfE should conduct its own scientific research to fulfil its tasks.

The Act Regulating the Transfer of Obligations for Financing and to Act for the Management of radioactive Waste from the Operators of Nuclear Power Stations (Waste Management Transfer Act)

The "Act on the Organisational Restructuring in the Field of Radioactive Waste Disposal" and its Article 2, the "Regulating the Transfer of Obligations for Financing and to Act for the Management of radioactive Waste from the Operators of Nuclear Power Stations (Waste Management Transfer Act) became law on 27 January 2017. This now also transfers the responsibility for storing radioactive waste and later delivering it to a disposal facility from the operators of the nuclear power plants (causing the waste) to the state's own Gesellschaft für Zwischenlagerung mbH (BGZ), which is governed by private law.

The Act on the Protection against the Harmful Effect of Ionising Radiation (Radiation Protection Act - StrlSchG)

The Radiation Protection Act transfers Directive 2013/59/Euratom into national law. It determines rules for the protection of individuals and – if the long-term protection of human health is involved – of the environment from the damaging effects of ionising radiation. The act was approved by both houses of the German parliament as Article 1 of the Act to Reform the Law on the Protection against the Harmful Effect of Ionising Radiation on 27 June 2017. The federal right to radiation protection, which was previously based on the Atomic Energy Act and the Radiation Protection Precautions Act, gained its own independent and unified basis through this act. Regulations, which were previously part of the Radiation Protection Ordinance and the X-Ray Ordinance, were subsequently brought together. Many regulations for disposing of radioactive waste were updated and adapted to the latest scientific standards.

4.7.2 How the site selection procedure for a disposal facility for high-level radioactive waste is proceeding

Phase 1 of the site selection procedure is currently taking place, where BGE mbH will initially publish the identified subareas in an interim report. All regions with potentially favourable geological conditions for safe disposal have to be listed. Regions, which are generally not suited for the safe disposal of radioactive waste, will be excluded from the further steps of the site selection procedure. Subsequently, BGE will suggest site regions for surface-based investigation. From 2017 on, BGE requested all the available data sets on the underground conditions from the geological services of the federal states and is currently evaluating them with regard to exclusion criteria according to Section 22 of the Site Selection Act. In 2018, BGE started the data enquiries with the geological services of the federal states regarding the minimum requirements according to Section 23 of the Site Selection Act. BGE has announced that it will present its first results with the *subareas interim report* during the third quarter of 2020.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is currently developing the ordinances related to Section 26 of the Site Selection Act (*Safety Requirements for Building, Operating and Decommissioning of the Facility for the Disposal of Radioactive Waste*) and Section 27 of the Site Selection Act (*Preliminary Safety Analyses in the Site Selection Procedure*). The Federal Office for the Safety of Nuclear Waste Management (BfE) is supporting the BMU in this task to guarantee the consistency of the calculation basis needed so that the BfE and the Federal Office for Radiation Protection (BfS) can perform dose estimations.

As part of safeguarding all potentials regions according to Section 21 of the Site Selection Act, 804 projects were checked by the BfE in 2018. Approval has not been denied to any project so far.

The BfE organised the first status conference on disposal in Berlin on 8 and 9 November 2018. About 200 participants discussed the current state and the technical, social and scientific challenges associated with the site selection procedure. The target groups were: involved or interested institutions, scientists, citizens' initiatives and the interested members of the general public. According to Section 6 of the Site Selection Act, the BfE made the information platform available in 2017. On this platform all the major documents and papers on the selection procedure are being published continuously. This also includes the appropriate documents from the implementer (BGE). The mobile disposal facility exhibition, which is being made available as a local, "visiting" information service, reached about 10,000 people at 10 sites in all during 2018.

4.7.3 Responsibilities during supervision and licensing of facilities for the disposal of radioactive waste

The "Act on the Realignment of the Organisational Structures of Radioactive Waste Disposal" envisages pooling most of the state tasks of licensing and supervising nuclear technology, storage, the site selection procedure and monitoring the disposal operations in a new public authority, the Federal Office for the Safety

of Nuclear Waste Management (BfE). As a result, the BfE became the central licensing and supervisory body under the Atomic Energy Act and is independent of the disposal facility operator.

To ensure that the regulations under the Atomic Energy Act are followed during disposal of radioactive waste, the following licensing and supervisory system now applies in Germany:

- The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) bears the overall political responsibility in the field of disposal. The ministry supervises the Federal Office for the Safety of Nuclear Waste Management (BfE) within its specialist and legal supervisory powers and is the shareholder in Bundesgesellschaft für Endlagerung mbH (BGE).
- The BfE is the supervisory body under the Atomic Energy Act with regard to the Konrad and Morsleben disposal facilities, and to the Asse II mine.
- The BfE is also the licensing authority for the Konrad and Morsleben projects, but transitional regulations exist here: the previous responsibility of the states ends for the Konrad disposal site once it is put into service and the Morsleben disposal site when the current planning approval process for decommissioning is concluded. The state of Lower Saxony will remain the permanent licensing authority for the Asse II mine.

4.7.4 Repositories and decommissioning projects

KONRAD disposal facility

The Konrad mine in Salzgitter opened up the iron ore deposits at a depth of between about 800 m and 1,300 m, which had been known about since 1933. Iron ore was mined here between 1957 and 1976. Operations were halted for economic reasons in 1976 and the mine was initially examined to determine its possible geoscientific suitability to accommodate radioactive waste from 1977 onwards. Following the positive conclusion of these investigations, the then responsible Physikalisch-Technische Bundesanstalt applied to initiate a planning approval procedure according to Section 9b of the Atomic Energy Act on 31 August 1982. The plan envisaged disposing of up to 650,000 m^3 of radioactive waste with negligible heat generation. Based on current estimates of the expected volume of waste, the volume approved for disposal was restricted to 303,000 m^3 for national needs. The radioactive waste needing to be disposed of particularly accrues when using nuclear power to generate electricity, decommissioning and dismantling nuclear power plants and other nuclear facilities. The waste from using radioisotopes in industry, research, medicine, the German armed forces and in the field of research and development work accounts for further shares, but they are comparatively insignificant.

The planning approval procedure, which started in 1982, was concluded by the planning approval decision on 22 May 2002. The Higher Administrative Court in Lüneburg rejected the pending legal cases against this decision in March 2006; no appeal was allowed. The Federal Administrative Court rejected the complaints by the plaintiffs against the non-allowance of any appeal in its ruling dated 26 March 2007. The planning approval decision is therefore legally binding. Since that time, Konrad mine has been under conversion to create a disposal facility. The mining licence from the responsible mining authority required in addition to the planning approval decision under the Atomic Energy Act was granted with the approval of the main operating plan.

The necessary planning and building work to implement the project continued in 2018. The current redevelopment requirements at the existing facilities, today's market availability of licensed components, the status of the technical regulations, the stipulations in the Energy Saving Order and the provisions for sustainable and barrier-free building work are being taken into consideration. Negotiations are currently taking place between BGE and the state of Lower Saxony so that the simplified building approval procedure according to Section 74 of the Lower Saxony Building Order can also apply to BGE as recognised by the state of Lower Saxony for the BfS' project-related privileges.

BGE submitted updated plans to construct the Konrad disposal facility on 13 March 2018; this envisages the completion of the building work (conclusion of commissioning phase B) during the first half of 2027.

The Konrad mine may involve the conversion of an old iron ore mine into a disposal facility and access will take place through the existing shafts; however, the storage chambers and adjoining areas in the mine underground need to be newly constructed and the shafts renewed. The storage transport route as a horizontal link between the shaft and the storage chambers has now been constructed and the storage chambers envisaged for putting the mine into service have been completed. Above ground, the necessary buildings are continuing to be built on the shaft site of Konrad 1. A start to constructing the first buildings at the Konrad 2 shaft site has been made.

As part of the licensing procedure under the Atomic Energy Act, all the necessary safety evidence has been provided for the Konrad disposal facility. There is no specific knowledge about any possible safety shortfalls at the moment. Nevertheless, Bundesgesellschaft für Endlagerung mbH (BGE) (since 25 April 2017, previously BfS) as the operator has the task of making use of the latest scientific and technical findings. The planning work for the disposal facility is now being checked and adapted, if necessary, in the light of the latest scientific and technical findings and the latest technical regulations. Further checks will also take place for the operating and sealing process in line with the latest findings.

MORSLEBEN repository for radioactive waste (ERAM)

The Federal Republic of Germany took over responsibility for the Morsleben repository for radioactive waste (ERAM), which was established by the GDR-government in the former Bartensleben potash and rock salt mine, through the Unification Treaty signed in 1990. Apart from an interruption to storage between 1991 and 1994, it was used to store low-level and intermediate-level radioactive waste, mainly with short half-life periods, until 1998. The holder of the permanent operating licence had been the Federal Office for Radiation Protection (BfS) as a result of the legal transfer in 1990. The operator tasks for the Morsleben disposal facility were transferred to Bundesgesellschaft für Endlagerung mbH (BGE) on 25 April 2017.

Approx. 14,432 m^3 of low-level and intermediate-level radioactive waste in total was put into storage at Morsleben between 1971 and February 1991 and about 22,320 m^3 of low-level and intermediate-level radioactive waste between January 1994 and September 1998. Radiation sources and a container with radium waste are also being stored at Morsleben.

The BfS announced on 21 May 1999 that, for safety reasons, no more radioactive waste would be put into storage at Morsleben after operations were interrupted by a court order in September 1998. On the basis of the amendment to the Atomic Energy Act in 2002, the provisions laid down in Section 57a of the Atomic Energy Act were modified to the extent that the permanent operating licence at Morsleben dated 22 April 1986 continued to be valid for an indefinite period as a planning approval decision in the sense of Section 9b of the Atomic Energy Act, except for the regulations relating to accepting and disposing of further radioactive waste. No radioactive waste has been accepted from third parties for disposal since then.

The application made by the BfS on 13 October 1992 to what is now the Ministry for the Environment, Agriculture and Energy (MULE) in the State of Saxony-Anhalt to continue using the Morsleben site was restricted by the BfS to decommissioning the site on 9 May 1997. The planning approval procedure for decommissioning is not only designed to achieve decommissioning, but also the disposal of the radioactive waste stored at Morsleben at this time and the disposal of any operating radioactive waste that occurs during the decommissioning process.

BGE is currently doing extensive work to supplement the planning approval documents in line with the recommendations of the Nuclear Waste Management Commission and the additional demands made by the experts from the Saxony-Anhalt Ministry for the Environment, Agriculture and Energy (MULE).

The main element in the decommissioning concept involves the extensive backfilling of the underground spaces and shafts with stabilising and sealing building materials. The storage areas in the eastern and west-south areas of the disposal facility are also being deliberately sealed with building materials and structures especially developed for these circumstances at selected points along the access routes and are therefore being isolated from the other areas of the mine. Overall, more than 4 million cubic metres of salt concrete will have to be installed in the Morsleben site for the envisaged backfilling work. The shafts that are several hundred metres deep will also have to be sealed with specially developed structures to conclude the work.

The licensing authority is responsible for deciding whether public participation is necessary again because of the changes to the process documents.

ASSE II mine

Asse II mine near Wolfenbüttel is a potash and rock salt mine that is about 100 years old and approx. 47,000 m^3 of radioactive waste was put into storage there in about 125,000 drums between 1967 and 1978. The Helmholtz Centre in Munich had used the mine between 1965 and 1995 on behalf of the Federal Ministry of Research to test the handling and storage of radioactive waste at a disposal facility. The ministries involved agreed in September 2008 that Asse should be treated as a disposal site in future. The Federal Office for Radiation Protection (BfS) replaced the Helmholtz Centre in Munich as the operator at Asse at the beginning of 2009. Responsibility for operations passed from the BfS to Bundesgesellschaft für Endlager mbH (BGE) on 25 April 2017.

As water is entering the mine from the surrounding area and the stability of the mine building is threatened too, the so-called “Lex Asse” (Section 57b of the Atomic Energy Act), the “Act to Accelerate the Retrieval of Radioactive Waste and Decommission Asse II Mine” became law on 24 April 2013. The new law creates an important legal basis for retrieving the radioactive waste. Through simplified procedures and the opportunity

of conducting work in parallel, the Lex Asse enables the work to be completed much faster. The general public's right to receive extensive information is also strengthened.

The operations necessary to keep the mine open and the work to gather facts are based on the licences from the Lower Saxony Ministry for the Environment, Energy, Construction and Climate Protection (NMU) according to Section 7 of the Radiation Protection Ordinance and Section 9 of the Atomic Energy Act, which have been available since July 2010 and April 2011. The Mining Act, particularly the requirement for operating plans, has to be followed too.

The conditions for continuing to operate the mine involve stabilising the mine building and taking precautions to minimise the consequences of any flooding of Asse II mine. The deformation of the rock is being reduced by stabilising the large number of chambers on the southern side of the mine (backfilling of roof clefts). The emergency plans envisage various measures to considerably reduce any spread of radionuclides from the waste in the storage chamber into the biosphere and human beings.

Once Section 57b of the Atomic Energy Act, "Lex Asse", became law, the BfS examined the procedure and the processes in a fact-finding mission, as the previous procedure consumed a great deal of time. Stage 1 in the fact-finding process (drilling two selected storage chambers, ELK 7/750 and 12/750) is being completed. It is foregoing the original plans of opening and recovering individual packages (stages 2 and 3) as samples. The retrieval of the waste from the accessible storage chambers on the ground 725 m down is being brought forward. The storage chambers, where the atmosphere and the local rock conditions are known, are to be tackled as early as possible with the mining technology that still has to be decided. BGE mbH is currently continuing to develop the plans for retrieval.

Before the retrieval work can start, a conditioning plant and a storage facility must be put into service for the waste. The criteria-based selection process for finding the storage site has begun.

ANNEXES – LIST

ANNEX I – NUCLEAR POWER PLANTS

Correct on 31 December 2018

Table I.1: The federal and state governments' licensing and supervisory bodies for storing nuclear fuels according to Section 6 of the Atomic Energy Act and Annexes according to Section 7 of the Atomic Energy Act

	The authority for licences according to Section 6 of the Atomic Energy Act	The supervisory authority according to Section 19 and Section 6 of the Atomic Energy Act
	Federal Office for the Safety of Nuclear Waste Management	State supervisory bodies
Federal state	**Licensing authority for units according to Section 7 of the Atomic Energy Act**	**Supervisory body according to Section 19 and Sections 6 and 7 of the Atomic Energy Act**
Baden-Württemberg (BW)	Ministry for the Environment, Climate and Energy in agreement with the Ministry for Finances and Economic and the Interior Ministry	Ministry for the Environment, Climate and Energy in Baden-Württemberg
Bavaria (BY)	Bavarian State Ministry for the Environment and Consumer Protection	
Berlin (BE)	Senate Department for the Environment, Transport and Climate Protection	
Brandenburg (BB)	Ministry of Justice and Europe and Consumer Protection in the State of Brandenburg	
Bremen (HB)	Senator for the Environment, Building, Transport in conjunction with the Senator for Health	
Hamburg (HH)	Authority for the Environment and Energy	
Hesse (HE)	Hesse Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection	
Mecklenburg-Vorpommern (MV)	Ministry for Internal Affairs and Europe	
Lower Saxony (NI)	Lower Saxony Ministry for the Environment, Energy, Building and Climate Protection	
North Rhine-Westphalia (NW)	Ministry of Economic Affairs, Innovations, Digitalisation and Energy in the State of North Rhine-Westphalia	
Rhineland-Palatinate (RP)	Ministry for the Environment, Energy, Nutrition and Forestry	
Saarland (SL)	Ministry for the Environment and Consumer Protection	
Saxony (SN)	Saxon State Ministry for the Environment and Agriculture	
Saxony-Anhalt (ST)	Ministry for the Environment, Agriculture and Energy	
Schleswig-Holstein (SH)	Ministry for the Energy Revolution, Agriculture, the Environment, Nature and Digitalisation in the State of Schleswig-Holstein	
Thuringia (TH)	Ministry for the Environment, Energy and Nature Conservation	

Table I.2: Nuclear power plants in operation

No.	Name	Abbreviation	Reactor type	Output MW_e	First criticality date	In power operations	Operator	Location
1	Neckarwestheim 2[1]	GKN 2	PWR	1,400	29.12.1988	1989	EnBW Kernkraft GmbH (EnKK)	Neckarwestheim (BW)
2	Philippsburg 2[2]	KKP 2	PWR	1,468	13.12.1984	1985	EnBW Kernkraft GmbH (EnKK)	Philippsburg (BW)
3	Gundremmingen C	KRB II C	BWR	1,344	26.10.1984	1985	Kernkraftwerk Gundremmingen GmbH	Gundremmingen (BY)
4	Isar 2	KKI 2	PWR	1,485	15.01.1988	1988	PreussenElektra GmbH	Essenbach (BY)
5	Emsland[3]	KKE	PWR	1,406	14.04.1988	1988	Kernkraftwerk Lippe-Ems GmbH	Lingen (NI)
6	Grohnde[4]	KWG	PWR	1,430	01.09.1984	1985	PreussenElektra GmbH	Grohnde (NI)
7	Brokdorf[5]	KBR	PWR	1,480	08.10.1986	1986	PreussenElektra GmbH	Brokdorf (SH)

[1] Application according to Section 7 Paragraph 3 of the Atomic Energy Act for decommissioning and dismantling on 18 July 2016

[2] Application according to Section 7 Paragraph 3 of the Atomic Energy Act for decommissioning and dismantling on 18 July 2016

[3] Application according to Section 7 Paragraph 3 of the Atomic Energy Act for decommissioning and dismantling on 22 December 2016

[4] Application according to Section 7 Paragraph 3 of the Atomic Energy Act for decommissioning and dismantling of the unit in the first dismantling phase dated 26 October 2017

[5] Application according to Section 7 Paragraph 3 of the Atomic Energy Act for decommissioning and dismantling of the unit in the first dismantling phase dated 1 December 2017

Table I.3: Nuclear power plants finally shut down

No.	Name	Abbrevia-tion	Reactor type	Output MW_e (gross)	First criti-cality date	In power opera-tions	Shut-down	Application for decom-missioning	Operator	Location
1	Gundremmingen B	KRB II B	BWR	1,344	09.03.1984	1989	31.12.2017	11.12.2014[1]	Kernkraftwerk Gundremmingen GmbH	Gundremmingen (BY)
2	Krümmel	KKK	BWR	1,402	14.09.1983	1984	06.08.2011	24.8.2015	Kernkraftwerk Krümmel GmbH & Co. oHG	Krümmel (SH)

[1] After going to print: the first licence to decommission and dismantle the Gundremmingen nuclear power plant was granted on 19 March 2019.

Table I.4: Nuclear power plants under decommissioning

No.	Name	Abbre-viation	Reactor type	Output MW_e (gross)	First criti-cality date	In power operations	Taken out of service	Decommis-sioning started	Operator	Location
1	Rheinsberg (ö.H.)[1]	KKR	PWR / WWER	70	11.03.1966	06.05.1966	01.06.1990	28.04.1995	Energiewerke Nord GmbH (EWN)	Rheinsberg (BB)
2	Compact sodium-cooled core unit (ö.H.)	KNK II	SFR	21	10.10.1977	1979	23.08.1991	26.08.1993	Wiederaufarbeitungs-anlage Karlsruhe Rückbau- und Entsorgungs-GmbH (Unternehmen der EWN GmbH)	Eggenstein-Leopoldshafen (BW)
3	Multi-purpose research reactor (ö.H.) Heavy-water-moderated and heavy-water-cooled pressure vessel reactor with natural uranium	MZFR	PWR / D_2O	57	29.09.1965	1966	03.05.1984	17.11.1987	Wiederaufarbeitungs-anlage Karlsruhe Rückbau- und Entsorgungs-GmbH (Unternehmen der EWN GmbH)	Eggenstein-Leopoldshafen (BW)
4	Obrigheim	KWO	PWR	357	22.09.1968	1969	11.05.2005	28.08.2008	EnBW Kernkraft GmbH (EnKK)	Obrigheim (BW)
5	Neckarwestheim 1	GKN 1	PWR	840	26.05.1976	1979	06.08.2011	03.02.2017	EnBW Kernkraft GmbH (EnKK)	Neckarwestheim (BW)
6	Philippsburg-1	KKP 1	BWR	926	09.03.1979	1980	06.08.2011	07.04.2017	EnBW Kernkraft GmbH (EnKK)	Philippsburg (BW)
7	Isar 1	KKI 1	BWR	912	20.11.1977	1979	06.08.2011	17.01.2017	PreussenElektra GmbH	Essenbach (BY)
8	Gundremmingen A	KRB A	BWR	250	14.08.1966	1967	13.01.1977	26.05.1983	Kernkraftwerk Gundremmingen GmbH	Gundremmingen (BY)
9	Grafenrheinfeld	KKG	PWR	1.345	09.12.1981	1982	27.06.2015	11.04.2018	PreussenElektra GmbH	Grafenrheinfeld (BY)
10	Biblis-A	KWB A	PWR	1.225	16.07.1974	1975	06.08.2011	30.03.2017	RWE Power AG	Biblis (HE)
11	Biblis-B	KWB B	PWR	1.300	25.03.1976	1977	06.08.2011	30.03.2017	RWE Power AG	Biblis (HE)

[1] ö.H.: Funded by the public sector

No.	Name	Abbre-viation	Reactor type	Output MW_e (gross)	First criti-cality date	In power operations	Taken out of service	Decommis-sioning started	Operator	Location
12	Greifswald-1 (ö.H.) In the case of units KGR 1 – 5, mention should also be made of the fact that the construction of unit 6 was well advanced, but did not go critical. However, unit 6 is part of the nuclear facility and therefore part of what needs to be dismantled by EWN GmbH.	KGR 1	PWR / WWER	440	03.12.1973	1974	18.12.1990	30.06.1995	Energiewerke Nord GmbH (EWN)	Lubmin (MV)
13	Greifswald-2 (ö.H.)	KGR 2	PWR / WWER	440	03.12.1974	1975	14.02.1990	30.06.1995	Energiewerke Nord GmbH (EWN)	Lubmin (MV)
14	Greifswald-3 (ö.H.)	KGR 3	PWR / WWER	440	06.10.1977	1978	28.02.1990	30.06.1995	Energiewerke Nord GmbH (EWN)	Lubmin (MV)
15	Greifswald-4 (ö.H.)	KGR 4	PWR / WWER	440	22.07.1979	1979	02.06.1990	30.06.1995	Energiewerke Nord GmbH (EWN)	Lubmin (MV)
16	Greifswald-5 (ö.H.)	KGR 5	PWR / WWER	440	26.03.1989	-	30.11.1989	30.06.1995	Energiewerke Nord GmbH (EWN)	Lubmin (MV)
17	Lingen 268 MWe was the electric output at the generator, including the fossil additional component; electrical output from nuclear power generation: 252 MWe.	KWL	BWR	252	31.01.1968	1968	05.01.1977	21.11.1985; 30.03.1988 SE 21.12.2015 (dismantling the unit)	Kernkraftwerk Lingen GmbH	Lingen (NI)
18	Stade	KKS	PWR	672	08.01.1972	1972	14.11.2003	07.09.2005	PreussenElektra GmbH	Stade (NI)
19	Unterweser	KKU	PWR	1,410	16.09.1978	1979	06.08.2011	05.02.2018	PreussenElektra GmbH	Esenshamm (NI)
20	Jülich experimental reactor (ö.H.)	AVR	HTR	15	26.08.1966	1969	31.12.1988	09.03.1994	JEN mbH (an EWN GmbH company), formerly AVR GmbH	Jülich (NRW)
21	Thorium high-temperature reactor (ö.H.)	THTR-300	HTR	308	13.09.1983	1987	29.09.1988	22.10.1993, 10/1997 SE	HKG	Hamm-Uentrop (NRW)
22	Würgassen	KWW	BWR	670	22.10.1971	1975	26.08.1994 Operator's decommis-sioning decision on 29.05.95	14.04.1997	PreussenElektra GmbH	Würgassen (NRW)

No.	Name	Abbre-viation	Reactor type	Output MW_e (gross)	First criti-cality date	In power operations	Taken out of service	Decommis-sioning started	Operator	Location
23	Mülheim-Kärlich	KMK	PWR	1302	01.03.1986	1987	09.09.1988	16.07.2004	RWE Power AG	Mülheim-Kärlich (RP)
24	Brunsbüttel	KKB	BWR	806	23.06.1976	1977	06.08.2011	21.12.2018	Kernkraftwerk Brunsbüttel GmbH & Co. oHG	Brunsbüttel (SH)

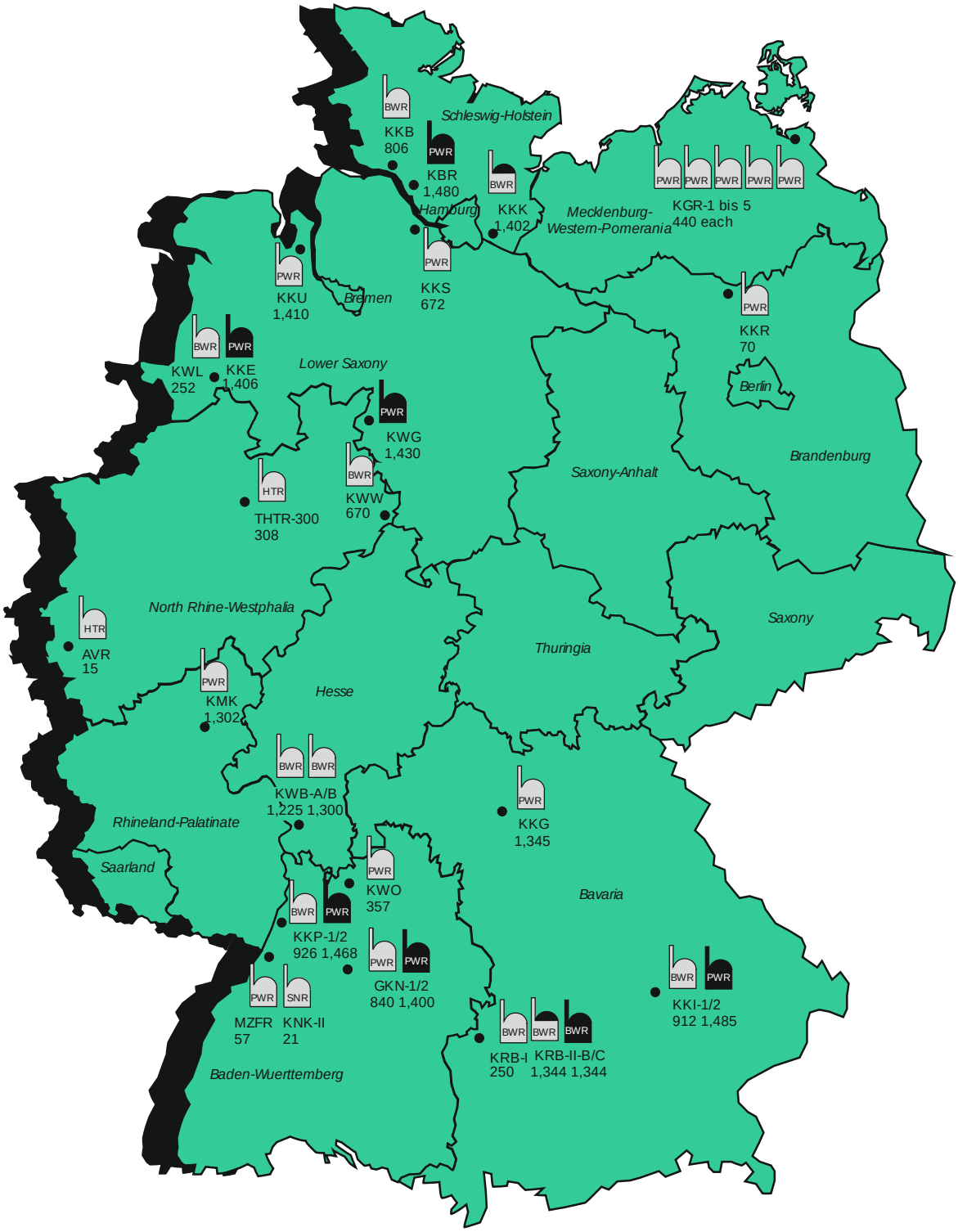
(ö.H.) Funded by the public sector

Table I.5: Nuclear power plants released from the Atomic Energy Act

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	in power operations	Taken out of service	Decommissioning started | ended	Operator	Location
1	Grosswelzheim hot steam reactor (ö.H.)	HDR	HDR (hot steam reactor)	25	14.10.1969	1970	20.04.1971	16.02.1983/ Released from the Atomic Energy Act: 14.05.1998 Dismantled: 15.10.1998	Karlsruhe Institute of Technology (KIT), formerly Forschungszentrum Karlsruhe GmbH	Karlstein (BY)
2	Niederaichbach (ö.H.) Heavy-water-moderated pressure tube reactor with $C0_2$ gas cooling	KKN	DRR / D_2O-moderator	106	17.12.1972	1973	31.07.1974	21.10.1975/ Released from the Atomic Energy Act: 17.08.1994 Dismantled: 17.08.1995	Karlsruhe Institute of Technology (KIT), formerly Forschungszentrum Karlsruhe GmbH	Niederaichbach (BY)
3	Kahl experimental nuclear power plant	VAK	BWR	16	13.11.1960	1962	25.11.1985	05.05.1988/ Released from the Atomic Energy Act: 17.05.2010 Dismantled: 24.09.2010	VAK	Karlstein (BY)

Table I.6: Nuclear power plant projects halted

No.	Name	Abbreviation	Operator	Type	Output gross [MWe]	Comments
1	Greifswald-6	KGR 6	Energiewerke Nord GmbH	PWR	440	Finally shut down: 30 Nov. 1989 General decommissioning/dismantling of the complete facility: 30 June 1995 ff.
2	Greifswald-7	KGR 7	Energiewerke Nord GmbH	PWR	440	Project halted
3	Greifswald-8	KGR 8	Energiewerke Nord GmbH	PWR	440	Project halted
4	Kalkar fast sodium-cooled reactor	SFR 300	Schnell-Brüter-Kernkraftwerksgesellschaft mbH	SFR	327	Project halted 20.03.1991
5	Stendal nuclear power plant unit A	Stendal A	Altmark Industrie GmbH	PWR	1,000	Project halted
6	Stendal nuclear power plant unit B	Stendal B	Altmark Industrie GmbH	PWR	1,000	Project halted



Legend:

NPP, in operation

NPP, under decommissioning

NPP, finally shut down

Data: Gross capacity MWe
As of 31 December 2018

Fig. I: Nuclear power plants in Germany

ANNEX II – RESEARCH REACTORS

Correct on 31 December 2018

Table II.1: Research reactors in operation

No.	Name	Abbrevia-tion	Type/reactor type; output	First criti-cality date	Operator	Location
1	Berlin experimental reactor II	BER-II	Pool-type / MTR ; 10 MW_{th}	09.12.1973	Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, formerly Hahn Meitner Institute	Berlin (BE)
2	SUR Furtwangen	SUR-FW	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	28.06.1973	Hochschule Furtwangen University	Furtwangen (BW)
3	SUR Stuttgart 1969: conversion and relocation to a different building	SUR-S	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	24.08.1964 / 12.06.1969	University of Stuttgart, Institute for Nuclear Energy and Energy Systems	Stuttgart (BW)
4	SUR Ulm	SUR-U	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	01.12.1965	Ulm University of Applied Sciences, Laboratory for Radiation Measurement Technology and Reactor Technology	Ulm (BW)
5	High-flow neutron source Munich/Garching	FRM-II	Pool-type / compact core with D_20 moderator; 20 MW_{th}	02.03.2004	Technical University of Munich	Garching (BY)
6	Research reactor Mainz	FRMZ	Pool-type / TRIGA MARK-II; 0.1 MW_{th}	03.08.1965	University of Mainz, Institute of Nuclear Chemistry	Mainz (RP)
7	Training nuclear reactor Licence was restricted until 30 June 2005 according to Section 57a of the Atomic Energy Act; 2004 converted to AKR-2. First criticality date as AKR-2: 22.03.05	AKR/ AKR-2	Homogenous (S) / SUR type; 2.0E-06 MW_{th}	28.07.1978 / 22.03.2005	Technical Univeersity of Dresden, Institute of Power Engineering	Dresden (SN)

Table II.2: Research reactors finally shut down

Nr.	Name	Abbreviation	Type/reactor type; output	First criti-cality date	Taken out of service	Application for de-commissioning	Operator	Location
1	Siemens training reactor Aachen	SUR-AA	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	22.09.1965	Unit has been free of nuclear fuels since 2008	Application made in 2010	RWTH Aachen University, Institute of Power Systems and Power Economics	Aachen (NRW)
2	Geesthacht-1 research reactor	FRG-1	Pool-type / MTR; 5 MW_{th}	23.10.1958	28.06.2010	21.03.2013[1]	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	Geesthacht (SH)
3	Geesthacht-2 research reactor	FRG-2	Pool-type / MTR; 15 MW_{th}	16.03.1963	28.01.1993 Application to take unit out of service 7.01.1995 Generally taken out of service and parts dismantled	21.03.2013 Application to dismantle the re-search reactor unit (consisting of the FRG-1 and the parts of the FRG-2 that still exist)	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH	Geesthacht (SH)

[1] The application to decommission and dismantle FRG-1 and dismantle the research reactor unit and the hot laboratory were made more precise on 6 September 2016. The reactor pressure vessel from the nuclear research ship “Otto Hahn” located on the site of the research reactor unit (consisting of FRG-1 and the remaining parts of FRG-2) are to be included in the process.

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Table II.3: Research reactors under decommissioning

No.	Name	Abbreviation	Type/reactor type; output	First criti-cality date	Taken out of service	Decommissioning started	Operator	Location
1	Research reactor-2	FR-2	Tank / D_2O; 44 MW_{th}	07.03.1961	21.12.1981	03.07.1986 (SG) | 20.11.1996 SE	Wiederaufarbeitungs-anlage Karlsruhe Rückbau- und Entsorgungs-GmbH (an EWN GmbH company)	Eggenstein-Leopoldshafen (BW)
2	Research reactor Munich	FRM	Pool-type / MTR; 4 MW_{th}	31.10.1957	28.07.2000	03.04.2014 (SG)	Technical University of Munich	Garching (BY)
3	Research reactor Neuherberg	FRN	Pool-type / TRIGA MARK-III; 1 MW_{th}	23.08.1972	16.12.1982	30.05.1983 (SG) | 24.05.1984 SE	Helmholtz Zentrum München – Deutsches Forschungszentrum für Gesundheit und Umwelt (GmbH)	Oberschleißheim (BY)
4	Research and measurement reactor Braunschweig	FMRB	Pool-type / MTR; 1 MW_{th}	03.10.1967	19.12.1995	02.03.2001 (SG) I 28.07.2005 (Unit re-leased from the Atomic Energy Act apart from the storage facility)	Physikalisch-Technische Bundesanstalt	Braunschweig (NI)
5	Siemens training reactor Hanover	SUR-H	Homogenous (S)/ SUR-100; 1.0E-07 MW_{th}	09.12.1971	The unit has been free of nuclear fuels since 2008	04.09.2017 (SG)	Leibniz University Hanover, Institute of Nuclear Technology and Non-Destructive Test Procedures	Hannover (NI)
6	DIDO	FRJ-2	Tank / D_20; 23 MW_{th}	14.11.1962	02.05.2006	20.09.2012 (SG)	JEN mbH (an EWN GmbH company), formerly Forschungszentrum Jülich GmbH	Jülich (NRW**)**
7	Rossendorf research reactor	RFR	Tank / WWR-SM; 10 MW_{th}	16.12.1957	27.06.1991	30.01.1998 (SG)	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Rossendorf (SN)

SG Decommissioning licence

SE Safe enclosure

Table II.4: Research reactors released from the Atomic Energy Act

Nr.	Name	Abbreviation	Type/reactor type; output	First criti-cality date	Taken out of service	Decommissioning started | ended	Operator	Location
1	Fast zero power assembly	SNEAK	Homogenous (S); 1.0E-03 MW_{th}	15.12.1966	11/1985	03.06.1986 (SG) | 06.05.1987	Kernforschungszent-rum Karlsruhe GmbH (now KIT)	Eggenstein-Leopoldshafen (BW)
2	Fast subcritical assembly Licence according to Section 9 of the Atomic Energy Act	SUAK	Fast subcritical assembly; 0 MW_{th}	20.11.1964 Commis-sioning	07.12.1978		Kernforschungszent-rum Karlsruhe GmbH (now KIT)	Eggenstein-Leopoldshafen (BW)
3	Fast thermal Argonaut reactor	STARK	Argonaut; 1.0E-05 MW_{th} Modified fast thermal Argonaut reactror	11.01.1963	03/1976	1976 (SG) | 1977	Kernforschungszent-rum Karlsruhe GmbH (now KIT)	Eggenstein-Leopoldshafen (BW)
4	Siemens training reactor Karlsruhe	SUR-KA	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	07.03.1966	09/1996	25.11.1996 (SG) | 26.06.1998	Forschungszentrum Karlsruhe GmbH (now KIT)	Eggenstein-Leopoldshafen (BW)
5	TRIGA Heidelberg I	TRIGA HD I	Pool-type / TRIGA MARK-I; 0.25 MW_{th}	26.08.1966	31.03.1977	30.06.1980 (SG), 11.12.1980 (SE), 16.01.2006 (AG) | 13.12.2006 Unit demolished and the site completely cleaned up (2009)	German Cancer Research Centre	Heidelberg (BW)
6	TRIGA Heidelberg II	TRIGA HD II	Pool-type / TRIGA MARK-I; 0.25 MW_{th}	28.02.1978	30.11.1999	13.09.2004 (SG) I 13.12.2006	German Cancer Research Centre	Heidelberg (BW)
7	AEG zero power reactor, thermal-critical assembly	TKA	Tank / thermal critical assembly; 1.0E-04 MW_{th}	23.06.1967	1973	28.09.1981 (SG) | 21.12.1981	Kraftwerk Union AG	Karlstein (BY)
8	AEG test reactor	PR-10	Argonaut; 1.80E-04 MW_{th}	27.01.1961	1976	27.07.1976 (SG) | 22.02.1978	Kraftwerk Union AG	Karlstein (BY)
9	Siemens Argonaut reactor	SAR	Argonaut; 1.0E-03 MW_{th}	23.06.1959	31.10.1968	08.01.1992 (AG) | 20.03.1998	Technical University of Munich	Garching (BY)
10	Siemens subcritical assembly SUA was part of the SUR Munich	SUA	Subcritical assembly; 0 MW_{th}	06/1959 Commis-sioning	1968	31.10.1968 (SG) 28.08.1992 (AG) | 20.03.1998	Technical University of Munich	Garching (BY)
11	Siemens training reactor Munich	SUR-M	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	28.02.1962	10.08.1981	28.08.1992 (AG) | 20.03.1998	Technical University of Munich	Garching (BY)

Nr.	Name	Abbreviation	Type/reactor type; output	First criti-cality date	Taken out of service	Decommissioning started | ended	Operator	Location
12	Berlin experimental reactor	BER I	Homogenous (L) / L-54(L); 0.05 MW_{th}	24.07.1958	Sommer 1972	15.02.1974 (Cancellation of licence to operate) | 23.04.1974	Hahn Meitner Institute (now: Helmholtz Centre for Materials and Energy in Berlin)	Berlin (BE)
13	Siemens training reactor Berlin	SUR-B	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	26.07.1963	15.10.2007	01.12.2008 (SG) | 16.04.2013	Technical University of Berlin, Institute for Energy Technology, Department of Nuclear Technology	Berlin (BE)
14	Siemens training reactor Bremen	SUR-HB	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	10.10.1967	17.06.1993	05.06.1997 (SG) 27.07.1999 (AG) | 03/2000	Bremen University of Applied Sciences	Bremen (HB)
15	Siemens training reactor Hamburg	SUR-HH	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	15.01.1965	08/1992	31.03.1999 (SG) | 12/1999	Hamburg University of Applied Sciences	Hamburg (HH)
16	Frankfurt -1 research reactor	FRF 1	Homogenous (L) / L-54(L); 0.05 MW_{th}	10.01.1958	19.03.1968	1970 (AG) | 31.10.2006	Johann Wolfgang Goethe University	Frankfurt (HE)
17	Frankfurt -2 research reactor	FRF-2	Pool-type / modified TRIGA; 1 MW_{th}	no criticality	not operated	25.10.1982 (SG) I 31.10.2006	Johann Wolfgang Goethe University	Frankfurt (HE)
18	Siemens training reactor Darmstadt	SUR-DA	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	23.09.1963	22.02.1985	23.11.1989 (SG) 02.08.1990 (AG) | 29.11.1996	Technical University of Darmstadt	Darmstadt (HE)
19	TRIGA Hanover	FRH/TRIGA MHH	Pool-type / TRIGA Mark-I; 0.25 MW_{th}	31.01.1973	18.12.1996	08.05.2006 (SG) | 13.03.2008	Hanover Medical School	Hannover (NI)
20	MERLIN research reactor	FRJ-1	Pool-type / MTR; 10 MW_{th}	24.02.1962	22.03.1985	08.06.1995 (SG) 23.11.2007	Forschungszentrum Jülich GmbH	Jülich (NRW)
21	Burn-up measurement of differential fuel elements with a critical assembly	ADIBKA	Homogenous (L) / L77A; 1.0E-04 MW_{th}	18.03.1967	30.10.1972	07.07.1977 (SG) | 12/1977	Hochtemperatur-Reaktorbau GmbH	Jülich (NRW)
22	Critical assembly for high-temperature reactors	KAHTER	Critical assembly; 1.0E-04 MW_{th}	02.07.1973	03.02.1984	09.11.1987 (SG) | 06/1988	Jülich Nuclear Research Facility	Jülich (NRW)
23	Critical experiment for in-core thermionic reactor	KEITER	Critical assembly; 1.0E-06 MW_{th}	15.06.1971	1982	18.03.1982 (SG) | 06/1988	Jülich Nuclear Research Facility	Jülich (NRW)
24	Rossendorf assembly for critical experiments	RAKE	Tank / critical assembly; 1.0E-05 MW_{th}	03.10.1969	26.11.1991	19.08.1997 (SG) | 28.10.1998	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Rossendorf (SN)

Nr.	Name	Abbreviation	Type/reactor type; output	First criti-cality date	Taken out of service	Decommissioning started | ended	Operator	Location
25	Rossendorf ring zone reactor	RRR	Argonaut; 1.0E-03 MW_{th}	16.12.1962	25.09.1991	31.03.1999 (SG) | 11.05.2000	VKTA-Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Rossendorf (SN)
26	Zittau teaching and research reactor Licence according to Section 57a of the Atomic Energy Act restricted until 30 June 2005	ZLFR	Tank / WWR-M; 1.0E-05 MW_{th}	25.05.1979	24.03.2005 Last operating date	01.07.2005 (SG) I 03.05.2006	Zittau/Görlitz University of Applied Sciences, Engineering Department	Zittau (SN)
27	Facility for homopolar power experiments	ANEX	Critical assembly; 1.0E-04 MW_{th}	05/1964	05.02.1975	19.03.1979 (AG) | 01/1980	GKSS Forschungszentrum Geesthacht GmbH	Geesthacht (SH)
28	"Otto Hahn“ nuclear vessel Responsible supervisory body in Hamburg under the Atomic Energy Act	OH	PWR / ship’s reactor; 38 MW_{th} Assigned to FR in Germany	26.08.1968	22.03.1979	01.12.1980 (SG) | 01.09.1982	GKSS Forschungszentrum Geesthacht GmbH	Geesthacht (SH)
29	Siemens training reactor Kiel	SUR-KI	Homogenous (S) / SUR-100; 1.0E-07 MW_{th}	29.03.1966	11.12.1997	19.03.2008 (SG) | 02.04.2008	Kiel University of Applied Sciences	Kiel (SH)

AG Dismantling licence

SG Decommissioning licence

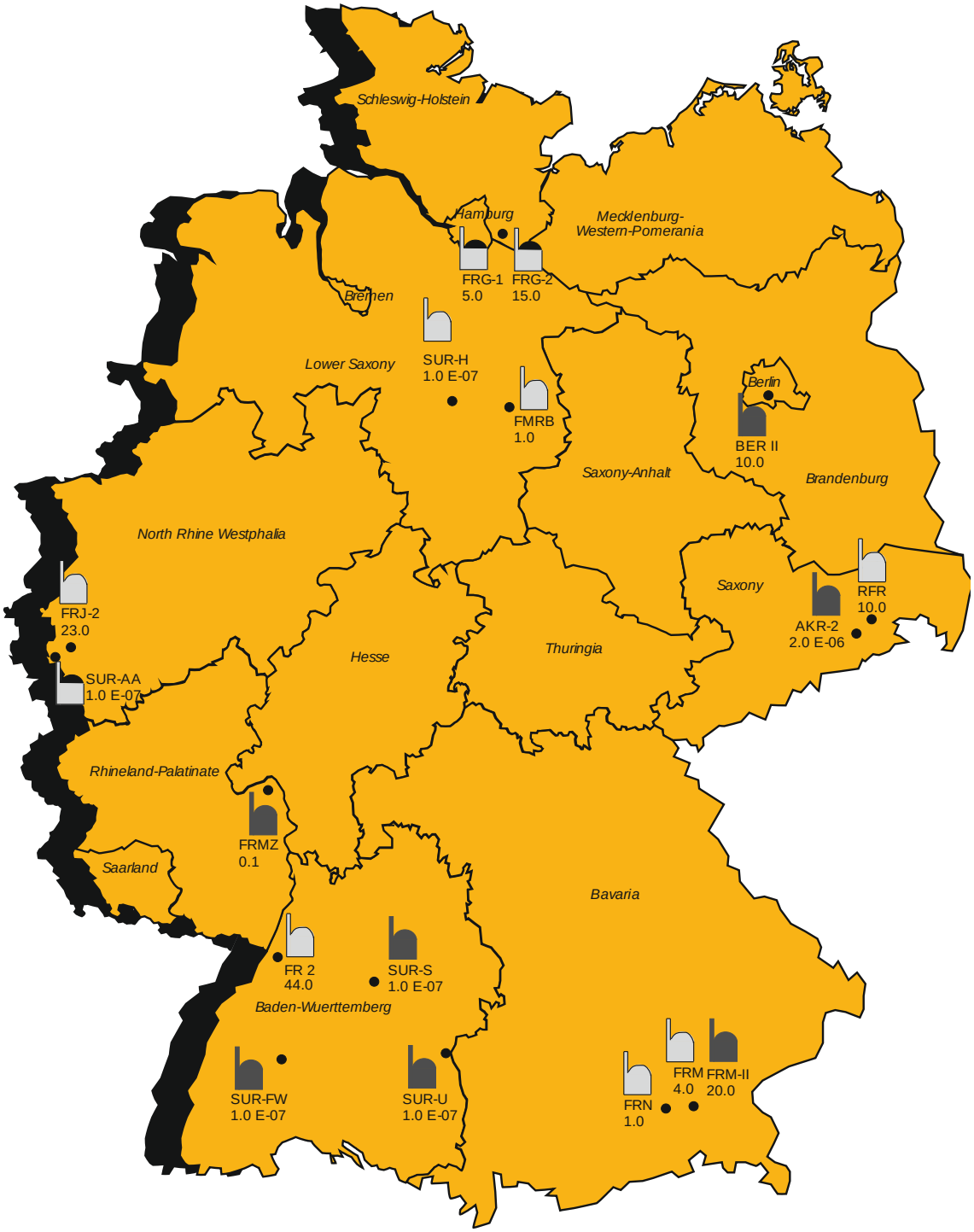


Fig. II: Research reactors in Germany

ANNEX III – FACILITIES FOR NUCLEAR SUPPLIES AND WASTE MANAGEMENT

Correct on 31 December 2018

Table III.1: Uranium enrichment plants

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Uranium enrichment plant in Gronau (UAG) Gronau (NW)	To enrich uranium	4,500 Mg of uranium separation work per annum (UTA/a) according to notification dated 14 February 2005	3rd Partial licence dated 4 June 1985 (operating licence); 9th Partial licence dated 31 Oct. 1997 extending capacity to 1,800 Mg of UTA/a; notification no. 7/Ä2 dated 27 Nov. 1998 2nd modification licence for 2 further separation buildings; notification no. 7/6 dated 14 Feb. 2005 to increase the production capacity to 4,500 Mg of UTA/a	The licence dated 14 February 2005 also covers dealings with depleted and enriched uranium (up to max. 6% of U-235). The extended facility has been under construction since mid-2008 and gradually commissioned. The facility is operated with a nominal capacity of 4,500 Mg of UTA/a. The construction of a storage building with a capacity for up to 60,000 Mg of U_3O_8 was completed in 2014, but had not yet been commissioned by the end of 2018.

Table III.2: Fuel element factories in operation

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	ANF fuel assembly fabrication plant Lingen Lingen (NI)	To mainly manufacture LWR fuel elements from low enriched uranium dioxide	Handling and processing 800 Mg of uranium in the form of uranium powder or uranium pellets with up to 5% of U-235 per annum	Operating licence dated 18 January 1979, 7th partial operating licence dated 8 June 1994 (operating the conversion unit with enriched uranium) 7 March 1997: capacity increase in fuel element production by 250 Mg of uranium tablets delivered from outside per annum; 11 Jan. 2005: increase in the uranium powder throughput to 650 Mg/a 2 Dec. 2009: increase in the capacity to 800 Mg/a 12 June 2014: expanding the storage areas for nuclear fuels	ANF stores the radioactive waste intended for disposal according to Section 6 of the Atomic Energy Act at a waste storage facility. The raw material UF_6 is kept in special containers in a separate storage building.

Table III.3: Fuel element factories released from the Atomic Energy Act

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	SIEMENS fuel element factory Karlstein section Karlstein (BY)	To manufacture fuel elements from low enriched uranium dioxide	Annual quantity of 400 Mg of UO_2 up to max. 4.0% of U-235	Operating licence according to Section 9 of the Atomic Energy Act dated 2 September 1966 Operating licence according to Section 7 of the Atomic Energy Act dated 30 Dec. 1977 Licence according to Section 7 of the Atomic Energy Act to dismantle parts of the facility dated 16 Aug. 1994 and 18 March 1996 Released from the Atomic Energy Act in March 1999	Fuel element production has been halted; only manufactures conventional structural parts now (ANF Karlstein).
2	SIEMENS fuel element factory in Hanau MOX processing section Hanau (HE)	To manufacture MOX fuel elements mainly for LWRs from plutonium and uranium	Capacity approx. 35 Mg HM/a, Envisaged expansion to 120 Mg HM/a	Operating licence according to Section 9 of the Atomic Energy Act dated 16 Aug.1968 Last extensive licence according to Section 9 of the Atomic Energy Act dated 30 Dec. 1974 6th partial building licence according to Section 7 of the Atomic Energy Act dated 12 March 1991 Several partial licences to run down and dismantle the facility for MOX fuel between 1997 and 2005. Released from the Atomic Energy Act: Sept. 2006	The operator decided in April 1994 to not put the old unit back into service again. The units that had been completed have been demolished. No state supervision is required now. The demolition work was completed in July 2006.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
3	SIEMENS fuel element factory in Hanau Uranium processing section Hanau (HE)	To manufacture LWR fuel elements from low enriched uranium	Capacity 1,350 Mg of U/a	Operating licence according to Section 9 of the Atomic Energy Act dated 22 July 1969 Operating licence according to Section 7 of the Atomic Energy Act dated 31 Aug. 1990 Several individual and partial licences to run down and dismantle the unit between 1996 and 2001 Released from the Atomic Energy Act: May 2006	Production of uranium fuel elements halted from October 1995 onwards. The demolition work including the clean-up of the site was completed in January 2006. The facility was released from the Atomic Energy Act. Cleaning the groundwater (generally according to Section 7 of the Radiation Protection Ordinance) has been completed.
4	Fuel element factory NUKEM-A Hanau-Wolfgang (HE)	To manufacture fuel elements from enriched uranium and thorium for research reactors	100 kg of U-235 enrichment up to 20%; 1,700 kg of U-235 enrichment between 20% and 94%; 100 Mg of natural uranium; 100 Mg of depleted uranium; 200 Mg of thorium	Operating licence according to Section 9 of the Atomic Energy Act dated 30 July 1962 Several licences to dismantle, decommission and clean up the site between 1988 and 2001 Released from the Atomic Energy Act in May 2006 – apart from a partial area of 1,000 m^2 for further groundwater cleaning. Radiological groundwater cleaning according to Section 19 of the Atomic Energy Act completed on 20 July 2015.	Operating licence dated 15 January 1988 suspended; all the fuel in the facility had been used by 31 December 1988. The dismantling work and the radiological clean-up of the soil have been completed. Supervision under the Atomic Energy Act was concluded with the notification dated 20 July 2015.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
5	Hochtemperatur-Brenn-element-Gesellschaft (HOBEG) Hanau (HE)	To manufacture ball-shaped fuel elements for HTRs on the basis of uranium of up to 94% of U-235) and thorium	200,000 fuel elements/a 11.7 Mg of HM (during the operating period)	Operating licence according to Section 9 of the Atomic Energy Act dated 30 Dec. 1974. Nine licences to dismantle and decommission between 5 December 1988 and 7 April 1995. Released from the Atomic Energy Act on 18 Dec. 1995.	The facility was temporarily taken out of service on 15 January 1988, then decommissioned. Process technology components were dismantled. Decontamination of the site and building structures has been completed. The site and building are used by Nuclear Cargo & Service GmbH.

Table III.4: Central fuel element storage facilities

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Transport cask storage facility at the North Storage Facility (ZLN) Rubenow (near Greifswald), MV	To store spent fuel elements from the Rheinsberg and Greifswald reactors in transport and storage casks (dry storage)	585.4 Mg of HM in max. 80 storage casks Max. storable activity: $7{,}5 \cdot 10^{18}$ Bq	According to Section 6 of the Atomic Energy Act dated 5 November 1999 1st amendment on 14 March 2001 2nd amendment on July 2003 3rd amendment on 19 Dec. 2005 4th amendment on 17 Feb. 2006 5th amendment on 17 Dec. 2008 6th amendment on 24 Feb. 2009 7th amendment on 30 April 2010	74 casks have been at the site since 2011: - 62 CASTOR® 440/84 - 3 CASTOR® KRB-MOX - 4 CASTOR® KNK - 5 CASTOR® HAW 20/28 CG SN 16.
2	Transport cask storage facility at Gorleben (TBL-G) NI	To store spent fuel elements in transport and storage casks and vitrified HAW fission products solutions and other radioactive substances (dry storage)	3,800 Mg of HM or 420 cask spaces; max. storable activity $2 \cdot 10^{20}$ Bq	According to Section 6 of the Atomic Energy Act on 5 September 1983, order of immediate enforcement on 6 September 1988 New licence dated 2 June 1995 for spent fuel elements and vitrified fission product solutions 1st amendment on 1 Dec. 2000 2nd amendment on 18 Jan. 2002 3rd amendment on 23 May 2007 4th amendment on 29 Jan. 2010 5th amendment on 1 Aug. 2017 6th amendment on 21 June 2018	113 casks have been in storage at Gorleben since 2011: - 5 casks with spent fuel elements - 1 CASTOR® Ic - 1 CASTOR® IIa, - 3 CASTOR® V/19 and 108 casks with HAW vitrified waste receptacles - 1 TS 28 V, - 74 CASTOR® HAW 20/28 CG, - 21 CASTOR® HAW28M - 12 TN85.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
3	Transport cask storage facility at Ahaus (TBL-A) NW	To store spent fuel elements in CASTOR® transport and storage casks (dry storage)	420 cask spaces (LWR), capacity up to a max. total of 3,960 Mg of HM; max. storable activity: $2 \cdot 10^{20}$ Bq	On 10 April 1987 according to Section 6 of the Atomic Energy Act New version of the storage licence on 7 November 1997 (increasing the mass of heavy metal and licence for more cask types) 1st amendment on 17 May 2000 2nd amendment on 24 April 2001 3rd amendment on 30 March 2004 4th amendment on 4 July 2008 5th amendment on 22 Dec. 2008 6th amendment on 26 May 2010 7th amendment on 8 Feb. 2016 8th amendment on 21 July 2016 9th amendment on 1 Aug. 2017	305 CASTOR® THTR/AVR storage casks with fuel elements from the THTR-3300 had been put into storage in April 1995. An additional - 2 CASTOR® V/19 - 1 CASTOR® V/19 SN06 und - 3 CASTOR® V/52 casks with LWR fuel elements were moved to Ahaus on 20 March 1998. 18 CASTOR® MTR 2 casks were put into storage in 2005 and were transported from Rossendorf to Ahaus.

Table III.5: Local on-site storage facilities

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Neckarwestheim on-site storage facility Gemmrigheim, BW	To store spent fuel elements from the GKN 1 and GKN 2 units at the joint Neckar nuclear power plant	1.600 Mg of heavy metal in as many as 151 transport and storage casks with up to $8.3 \cdot 10^{19}$ Bq of activity and 3.5 MW of thermal release	As per Section 6 of the Atomic Energy Act on 22 Sept. 2003 1st amendment on 22.03.2006 2nd amendment on 28.09.2006 1st supplement on 3 Sept. 2007 2nd supplement on 18 Feb. 2010 3rd amendment on 11 May 2010 4th amendment on 13 Dec. 2013 5th amendment on 16 April 2014 6th amendment on 9 Aug. 2016 7th amendment on 26 April 2017 8th amendment on 24 Aug. 2017 9th amendment on 17 Dec. 2018	Start of building work: 17 Nov. 2003 First storage: 6 Dec. 2006 81 casks were in storage at the end of 2018.
2	Philippsburg on-site storage facility BW	To store spent fuel elements from units 1 and 2 at the Philippsburg nuclear power plant	1.600 Mg of heavy metal in as many as 152 transport and storage casks with up to $1.5 \cdot 10^{20}$ Bq of activity and 6.0 MW of thermal release	As per Section 6 of the Atomic Energy Act on 19 Dec. 2003 1st amendment on 5 Oct. 2006 2nd amendment on 21 Dec. 2006 3rd amendment on 13 June 2014 4th amendment on 18 Dec. 2014 5th amendment on 24 Feb. 2016	Start of building work: 17 May 2004 First storage: 19 March 2007 62 casks were in storage at the end of 2018.
3	On-site storage facility at the Obrigheim nuclear power plant BW	To store spent fuel elements and nuclear components from the Obrigheim nuclear power plant (wet storage)	980 fuel elements (approx. 286 Mg of HM)	As per Section 7 of the Atomic Energy Act on 26 Oct. 1998	342 spent fuel elements were transported to the on-site storage facility at Neckarwestheim between June and December 2017.
4	On-site storage facility at Grafenrheinfeld BY	To store spent fuel elements from the Grafenrheinfeld nuclear power plant	800 Mg of heavy metal in as many as 88 transport and storage casks with up to $5 \cdot 10^{19}$ Bq of activity and 3.5 MW of thermal release	As per Section 6 of the Atomic Energy Act on 12.02.2003 Immediate enforcement ordered on 10 Sept. 2003 1st amendment on 31 July 2007 2nd amendment on 6 Oct. 2011 3rd amendment on 3 Nov. 2011 4th amendment on 26 April 2018 5th amendment on 15 Nov. 2018	Start of building work: 22 Sept. 2003 First storage: 27 Feb. 2006 30 casks were in storage at the end of 2018.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
5	On-site storage facility at Gundremmingen BY	To store spent fuel elements from units B and C at the Gundremmingen nuclear power plant	1,850 Mg of heavy metal in as many as 192 transport and storage casks with up to $2.4 \cdot 10^{20}$ Bq of activity and 6.0 MW of thermal release	As per Section 6 of the Atomic Energy Act on 19 Dec. 2003 Immediate enforcement ordered on 28 July 2004 1st amendment on 2 June 2006 2nd amendment on 7 Jan. 2014 3rd amendment on 27 Feb. 2015 4th amendment on 27 Oct. 2015 5th amendment on 14 Dec. 2017	Start of building work: 23.08.2004 First storage: 25 Aug. 2006 60 casks were in storage at the end of 2018.
6	On-site storage facility at Isar Niederaichbach BY	To store spent fuel elements from the Isar 1 and Isar 2 nuclear power plants	1,500 Mg of heavy metal in as many as 152 transport and storage casks with up to $1{,}5 \cdot 10^{20}$ Bq of activity and 6.0 MW of thermal release	As per Section 6 of the Atomic Energy Act on 22 Sept. 2003 Immediate enforcement ordered on 28 May 2004 1st amendment on 11 Jan. 2007 2nd amendment on 29 Feb. 2008 3rd amendment on 16 Nov. 2011 4th amendment on 7 Feb. 2012 5th amendment on 20 June 2016 6th amendment on 28 July 2016 7th amendment on 9 Aug. 2017	Start of building work: 14.06.2004 First storage: 12 March 2007 59 casks were in storage at the end of 2018.
7	On-site storage facility at Biblis HE	To store spent fuel elements from units A and B at the Biblis nuclear power plant	1,400 Mg of heavy metal in as many as 135 transport and storage casks with up to $8{,}5 \cdot 10^{19}$ Bq of activity and 5.3 MW of thermal release	As per Section 6 of the Atomic Energy Act on 22 Sept. 2003 1st amendment on 20 Oct. 2005 1st supplement on 20 March 2006 2nd amendment on 27 March 2006 3rd amendment on 16 June 2014 4th amendment on 22 July 2014 5th amendment on 22 Sept. 2015 6th amendment on 7 April 2016 7th amendment on 14 Dec. 2017 8th amendment on 14 June 2018	Start of building work: 01.03.2004 First storage: 18 May 2006 101 casks were in storage at the end of 2018.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
8	On-site storage facility at Grohnde NI	To store spent fuel elements from the Grohnde nuclear power plant	1,000 Mg of heavy metal in as many as 100 transport and storage casks with up to $5.5 \cdot 10^{19}$ Bq of activity and 3.75 MW of thermal release	As per Section 6 of the Atomic Energy Act on 20 Dec. 2002 Immediate enforcement ordered on 19 Sept. 2005 1st amendment on 17 April 2007 2nd amendment on 23 May 2012 3rd amendment on 25 June 2012	Start of building work: 10 Nov. 2003 First storage: 27 April 2006 34 casks were in storage at the end of 2018.
9	On-site storage facility at Lingen (Emsland) Bramsche NI	To store spent fuel elements from the Emsland nuclear power plant	1,250 Mg of heavy metal in as many as 125 transport and storage casks with up to $6.9 \cdot 10^{19}$ Bq of activity and 4.7 MW of thermal release	As per Section 6 of the Atomic Energy Act on 6 Nov. 2002 and immediate enforcement ordered 1st supplement on 31.07.2007 1st amendment on 1 Dec. 2008 2nd amendment on 19 Dec. 2014 3rd amendment on 7 Aug. 2015	Start of building work: 18 Oct. 2000 First storage: 10 Dec. 2002 47 casks were in storage at the end of 2018.
10	On-site storage facility at Unterweser Rodenkirchen NI	To store spent fuel elements from the Unterweser nuclear power plant	800 Mg of heavy metal in as many as 80 transport and storage casks with up to $4.4 \cdot 10^{19}$ Bq of activity and 3.0 MW of thermal release	As per Section 6 of the Atomic Energy Act on 22 Sept. 2003 Immediate enforcement ordered on 5 Feb. 2007 1st amendment on 27 May 2008 2nd amendment on 5 Jan. 2012 3rd amendment on 18 Dec. 2012 4th amendment on 11 Aug. 2016 5th amendment on 2 Nov. 2017 6th amendment on 26 July 2018	Start of building work: 19 Jan. 2004 First storage: 18 June 2007 39 casks were in storage at the end of 2018.
11	AVR cask storage facility at FZJ Jülich NW	To store spent AVR fuel elements in CASTOR® transport and storage casks	Up to 300,000 AVR fuel elements in max. 158 CASTOR® THTR/AVR - casks	Notification according to Section 6 of the Atomic Energy Act on 17 June 1993 1st amendment on 27 April 1995 2nd amendment on 7 July 2005 The storage licence expired on 30 June 2013.	152 CASTOR® THTR/AVR casks have been in the store since 2009.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
12	On-site storage facility at Krümmel (near Geesthacht), SH	To store spent fuel elements from the Krümmel nuclear power plant	775 Mg of heavy metal in as many as 65 transport and storage casks with up to $9.6 \cdot 10^{19}$ Bq of activity and 2.28 MW of thermal release The number of spaces was reduced from 80 to 65 and the thermal output from 3.0 to 2.28 MW through the 4th amendment.	As per Section 6 of the Atomic Energy Act on 19 Dec. 2003 1st amendment on 16 Nov. 2005 Immediate enforcement ordered on 28 April 2006 2nd amendment on 17 Oct. 2007 3rd amendment on 9 July 2014 4th amendment on 18 April 2016 5th amendment on 4 July 2016 6th amendment on 18 Dec. 2018	Start of building work: 23 April 2004 First storage: 14 Nov. 2006 41 casks were in storage at the end of 2018.
13	On-site storage facility at Brokdorf SH	To store spent fuel elements from the Brokdorf nuclear power plant	1000 Mg of heavy metal in as many as 100 transport and storage casks with up to $5.5 \cdot 10^{19}$ Bq of activity and 3.75 MW of thermal release	As per Section 6 of the Atomic Energy Act on 28.11.2003 1st amendment on 24 May 2007 2nd amendment on 19 July 2012 3rd amendment on 29 Aug. 2012	Start of building work: 5 April 2004 First storage: 5 March 2007 33 casks were in storage at the end of 2018.
14	On-site storage facility at Brunsbüttel SH	To store spent fuel elements from the Brunsbüttel nuclear power plant	450 Mg of heavy metal in as many as 80 transport and storage casks with up to $6.0 \cdot 10^{19}$ Bq of activity and 2.0 MW of thermal release	As per Section 6 of the Atomic Energy Act on 28.11.2003 Immediate enforcement ordered on 28 Oct. 2005 1st amendment on 14 March 2008 2nd amendment on 21 July 2014 The storage licence was revoked through the ruling by the Schleswig Higher Regional Court on 13 June 2013 and the ruling by the Federal Administrative Court on 8 January 2015. Kernkraftwerk Brunsbüttel GmbH & Co. oHG applied for a new licence on 16 Nov. 2015.	Start of building work: 7 Oct. 2003 First storage: 5 Feb. 2006 20 casks have been in storage since the end of 2017. 9 casks were stored on the basis of the storage licence until 2013. 11 casks have been stored since 2017 on the basis of a supervisory order.

Table III.6: External waste storage facilities

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Hauptabteilung Dekontaminationsbetriebe (HDB) Karlsruhe BW	To store non-heat-generating waste from FZK, WAK, ITU, the BW state collection point or to provide a buffer facility for third parties	Handling (conditioning and storage) with radioactive residual substances and nuclear fuel waste with up to total activity of $4.5 \cdot 10^{17}$ Bq	Handling licence according to Section 9 of the Atomic Energy Act dated 25 Nov. 1983, replaced by the licence according to Section 9 of the Atomic Energy Act dated 29 June 2009	Operating since December 1964.
2	Interim Storage facility of the utilities Mitterteich BY	To store waste with negligible heat generation from Bavarian nuclear power plants	40,000 waste receptacles (200-l, 400-l or cast-iron receptacles)	Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 7 July 1982	Operating since July 1987.
3	On-site storage facility at Biblis HE	To store other radioactive substances as part of the combined use of the on-site storage facility	Up to a total activity of $1 \cdot 10^{17}$ Bq	Handling licence according to Section 7 of the Radiation Protection Ordinance (old) dated 13 Dec. 2006	Operating since June 2008.
4	Storage facility for NCS Hanau HE	To store waste generating negligible heat mainly from the nuclear industry	1,250 Konrad containers (KC) and 800 m^2 of storage space	Handling licence according to Section 7 of the Radiation Protection Ordinance dated 11 June 2002 Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 2 April 1982	Operating since October 2002. Operating since 1982.
5	North Storage Facility (ZLN) Rubenow MV	To store operating and decommissioning waste from the Greifswald and Rheinsberg nuclear power plants with storage of large dismantled components	165,000 m^3	Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 20 Feb. 1998	Operating since March 998.
6	Unterweser waste storage facility NI	To store radioactive waste with negligible heat generation from the Unterweser and Stade nuclear power plants	200-l and 400-l drums, concrete receptacles, steel plate containers, concrete containers, cast-iron containers with a total activity of up to $1.85 \cdot 10^{15}$ Bq	Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 24 June 1981, 29 Nov. 1991 and 6 Nov. 1998	Operating since the autumn of 1981.

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
7	Gorleben waste storage facility (drum store) NI	To store radioactive waste with negligible heat generation from nuclear power plants, medicine, research and industry	200-l, 400-l drums, type III concrete receptacles, type I-II cast-iron receptacles, type I-IV containers with a total activity of up to $5 \cdot 10^{18}$ Bq	Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 27 Oct. 1983, 13 Oct.1987 and 13 Sept. 1995	Operating since October 1984.
8	Ahaus waste storage facility NW	To store radioactive waste from nuclear power plants	Konrad receptables, 20' containers and unit parts, total activity restricted in the storage area I to $1 \cdot 10^{17}$ Bq	Handling licence according to Section 7 of the Radiation Protection Ordinance dated 9 Nov. 2009	Operating since July 2010.
9	Rossendorf storage facility (ZLR) SN	To store operating and decommissioning waste from the research site	Total storage volume of 2,770 m^3 (gross)	Handling licence according to Section 3 of the Radiation Protection Ordinance (old) dated 10 Feb. 1999	Operating since February 1999.

Table III.7: Reprocessing plant

No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Karlsruhe (WAK) reprocessing plant, Eggenstein-Leopoldshafen BW	Experimental plant for reprocessing and technology development	0.175 Mg of HM/day; approx. 40 Mg of UO_2/a	Operations at WAK: 1st partial operating licence according to Section 7 of the Atomic Energy Act dated 2 Jan. 1967 Decommissioning of WAK: 1st decommissioning licence, March 1993 23rd decommissioning licence dated 14 Dec. 2011 to dismantle the LAVA High Active Laboratory and the LAVA (hot) cells 24th decommissioning licence dated 28 April 2014 for early manual dismantling work in the VEK 25th decommissioning licence to manually dismantle the media and energy supplies in the VEK dated 26 June 2017 26th decommissioning licence to remotely dismantle the VEK process equipment dated 6 July 2018 Operations at VEK 1st partial operating licence for VEK dated 20 Dec. 2005 (inactive commissioning) 2nd partial operating licence for VEK dated 24 Feb. 2009 (nuclear [hot] commissioning)	The facility operated between 1971 and 1990. During this time, about 200 Mg of nuclear fuels from experimental and power reactors were processed. The decommissioning and dismantling with the aim of achieving a “green field” are at an advanced stage with completion due in 2030. Most of the equipment has been removed from the process building. A Vitrification plant (VEK) for 60 m^3 of HAWC was built and operated until Nov. 2010. The HAWC was completely vitrified. This generated 140 canisters of waste glass (56 Mg), which were placed in 5 CASTOR® HAW 20/28 transport and storage containers. The CASTOR® casks have been stored at EWN GmbH’s North Storage Facility since February 2011. This meets important conditions for dismantling the VEK and the HAWC storage facilities.

Table III.8: Conditioning plants for fuel elements

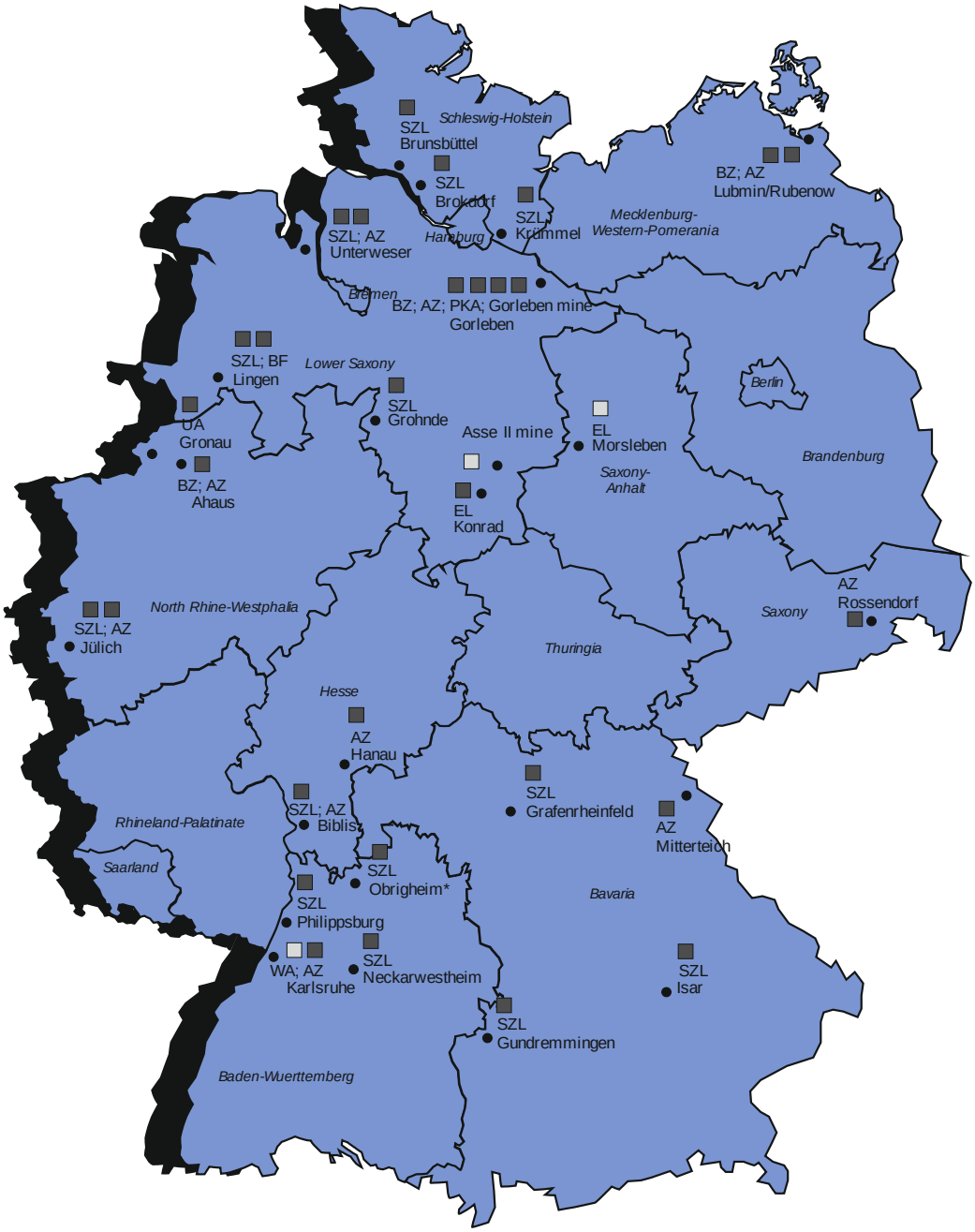
No.	Description of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Pilot conditioning plant (PKA) Gorleben, NI	To repair damaged casks, condition radioactive residual substances and waste (including spent fuel elements, fuel rods and fuel element installation parts) for storage and disposal	Heavy metal quantity applied for: 35 Mg/a Capacity of operational buffer facility: 12 Mg of HM	As per Section 7 of the Atomic Energy Act: 1st partial licence dated 30 Jan. 1990 2nd partial licence dated 21 July 1994 (subsequent condition dated 18 Dec. 2001) 3rd partial licence dated 19 Dec. 2000 (contains the operating licence) Modification licence dated 1 Aug. 2017 (change of licence holder)	According to the 3rd partial licence, usage is initially restricted to repairing damaged storage casks. A subsequent condition to the 2nd partial licence guarantees the readiness to accept a damaged cask at any time.

Table III.9: Disposal and decommissioning projects

No.	Description of the facility and location	Purpose of the facility	Quantities/activity disposed of	Licence	Comments
1	Konrad disposal facility, Salzgitter, NI	To dispose of radioactive waste with negligible heat generation		Application according to Section 9b of the Atomic Energy Act in 1982 (planning approval application) Withdrawal of the application for immediate enforcement in a letter from the BfS dated 17 July 2000. The planning approval decision was granted on 22 May 2002. Once normal appeal procedures against the planning approval decision had been exhausted, it was legally binding from 26 March 2007 and could be implemented. Pending constitutional appeals have not been admitted or accepted for a ruling. The main operating plan was approved by the responsible mining authority on 15 January 2008.	The geological host rock formation is coral oolite (iron ore) beneath a water-impermeable barrier from the Cretaceous period.

No.	Description of the facility and location	Purpose of the facility	Quantities/activity disposed of	Licence	Comments
2	ASSE II mine, Remlingen, NI	Originally: research and development work for disposing of radioactive and chemically toxic waste, disposing of low-level and intermediate-level radioactive waste. Now: decommissioning after prior retrieval of the radioactive waste according to Section 57b of the Atomic Energy Act.	Approx. 125,000 receptacles with low-level and intermediate-level radioactive waste were put into storage between 1967 and 1978.	Licences according to Section 3 of the Radiation Protection Ordinance (old) in the version dated 15 Oct. 1965. Storage licences for nuclear fuels according to Section 6 of the Atomic Energy Act. Licence according to Section 7 of the Radiation Protection Ordinance issued on 8 July 2010 to handle other radioactive substances outside the storage chambers up to 100 times the exemption limit. Licence according to Section 9 of the Atomic Energy Act to handle nuclear fuels and other radioactive substances as part of a fact-finding mission stage 1 dated 21 April 2011. Other licences according to Section 7 of the Radiation Protection Ordinance dated 20 Sept. 2011 to handle enclosed and open radioactive substances (radiation protection laboratory).	The geological host rock formation is rock salt. The BfS became the operator of the Asse II mine on 1 January 2009 – replaced by BGE on 25 April 2017. Since the “Lex Asse” became law in April 2013 (Section 57b of the Atomic Energy Act), the radioactive waste is to be retrieved prior to the prompt decommissioning, if this is technically feasible from a safety point of view.

No.	Description of the facility and location	Purpose of the facility	Quantities/activity disposed of	Licence	Comments
3	Morsleben repository for radioactive waste (ERAM) ST	Originally: to dispose of low-level and intermediate-level radioactive waste, most of which has short-lived radionuclides Now: decommissioning, leaving the waste underground	Disposal of approx. 36,752 m^3 of low-level and intermediate-level radioactive waste in all	22 April 1986: permanent operating licence granted. This was valid until 30 June 2005 according to Section 57a of the Atomic Energy Act; when the Act was amended in 2002, the permanent licence continued without any restrictions with the exception of the regulations for accommodating further radioactive waste or storing it for the purpose of disposal as a planning approval decision. 12 April 2001: declaration by the BfS to forego accepting any further radioactive waste for disposal.	The geology of the disposal areas largely consists of potash and rock salt formations. Putting items into storage was halted on 25 Sept. 1998. An application to convert and keep open the facility was made on 10 July 2003. The process has been suspended since 11 June 2014. Decommissioning was applied for on 9 May 1997. Following the public hearing date in October 2012, BGE is currently performing extensive work to supplement the planning approval documents in line with the recommendations of the German Nuclear Waste Management Commission dated 31 March 2013 and the demands of the experts from the Saxony-Anhalt Ministry for the Environment, Agriculture and Energy (MULE).



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
		□	Under decommissioning

As of 31 December 2018

The application for storage of nuclear fuel was withdrawn on 13.02.2018.
The fuel elements were transported for storage to the SZL Neckarwestheim in 2017.

Fig. III.1: Sites for nuclear supplies and waste management

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